REPORT ON

FOREST RESEARCH

1969

FORESTRY COMMISSION

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FORESTRY COMMISSION

REPORT ON FOREST RESEARCH

for the year ended
March 1969

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CONTENTS

PART II

RESEARCH UNDERTAKEN FOR THE FORESTRY COMMISSION AT UNIVERSITIES AND OTHER INSTITUTIONS

NUTRITION AND FOREST SOILS

FOREST PATHOLOGY

FOREST ENTOMOLOGY AND ZOOLOGY

ENVIRONMENTAL STUDIES

FIRES

Page

APPENDICES

The cover picture, by Frank Thompson, and all the text diagrams and plates are from the Forestry Commission's official Photographic Collection. The maps, which are also Crown copyright, were drawn by Studio Corot, London.

Cover picture: Hybrid larch plantation in the Forest of Dean, Gloucestershire (Compartment 380/1), established in 1918.

INTRODUCTION

By G. D. HOLMES
Director of Research

Jubilee Year 1919–1969

1969 marks the Forestry Commission's Jubilee, and coincidentally the 50th anniversary of the Research Division and the 21st anniversary of the start of publication of our annual Research Reports. A few months after the Forestry Commission was formed in 1919 a Research Branch was set up to tackle practical problems of silviculture, particularly afforestation of bare land and the collection of statistics on tree growth and timber production. At that time, the work was done by a Chief Research Officer and three research officers, one at Oxford and two at Edinburgh, each assisted by a small team of field foresters. At the same time, research on selected pests, diseases, and soil problems relating to forestry was started by the Universities, notably in the Commonwealth Forestry Institute at Oxford, and by other research organisations with the aid of Commission grants. It is hard to over-estimate the value of the work of these early research pioneers in the development of sound forestry practice and the provision of statistics on growth and yield etc., which form the technical basis of forest management as we know it today. The main Research Station at Alice Holt was opened just after the war in 1946, and the present organisation based on two main centres at Alice Holt and Edinburgh was established. Subsequently new research sections were added, notably those covering Seed, Soils, Genetics, Statistics, Library, Publications, Photography, Instrument Workshop, and most recently Physiology.

Although the organisation has evolved and grown in size as forestry has developed over the years, our main objective remains the practical one of improving forestry technology in order to enhance standards of land management and the productivity of our forests and manpower, both in national and private forests. During 50 years, the contributions to practice have been many, but it is true to say that virtually none of the innovations made would have been possible without close co-operation with other research organisations including the universities on the one side, and with forest managers in development and extension work on the other. We are proud of the practical achievements of research in the past, and no effort will be spared in future to ensure that our organisation and programme are in keeping with the industry's requirements and problems.

Advisory Committee on Forest Research

The Committee met in November 1968 and was attended for the first time by Dr. R. L. Mitchell, Director of the Macaulay Institute for Soil Research, who succeeded Dr. A. B. Stewart after his retirement from the Committee in December, 1967. In addition, Professor M. V. Laurie retired as a Committee member in December, 1968. The Report of the 1968 Visiting Group on the Commission's research into forest pests and diseases was approved, and it was agreed that the next Visiting Group be formed in 1970 to examine the work and organisation of our Silviculture, Soils and Ecology Sections. The Committee also discussed the

importance of close consultation between the Forestry Commission and the Natural Environment Research Council in planning future forestry research.

The 1968 Visiting Group

In September, the second Visiting Group (the first having been in 1966 concerned with Seed and Tree improvement work) visited some of our research areas in England, Scotland and Wales to inspect the work of the Entomology and Pathology Sections. The Group members were Dr. W. P. K. Findlay, Assistant Director of the Brewing Industry Research Foundation (Chairman), Dr. S. D. Garrett, F.R.S., of the Botany Department, University of Cambridge, Professor J. L. Harley, F.R.S., of the Department of Botany, University of Sheffield, Dr. N. W. Hussey of the Glasshouse Crops Research Institute, and Dr. C. G. Johnson of Rothamsted Experimental Station. Mr. G. H. Bowers acted as Secretary. The Group reported on the direction, organisation and scientific merit of the work and we are most grateful for the meticulous attention they gave to this task. As with the first Group, we found the independent criticism and the preparatory review of research projects required to be a valuable discipline and opportunity to rethink research objectives.

Natural Environment Research Council

The Commission is represented on the Council's Forestry and Woodlands Research Committee and its Sub-Committee on Research Grants and Training Awards. These contacts are important to ensure close co-ordination of the research of the Forestry Commission and N.E.R.C. funded research at universities, in the Nature Conservancy, and in the future in the new Forest Research Institute proposed by N.E.R.C. at the Edinburgh Centre of Rural Economy. This last development which aims to increase the facilities for long-term basic research, notably in the Genetics and Physiology of forest trees, will probably be located near the Commission's Northern Research Station on the Bush Estate, Edinburgh; this close proximity will greatly assist in integration of the research programmes of the two organisations.

Organisation and Staffing

Work is now proceeding on the new building of the Northern Research Station at the Edinburgh Centre of Rural Economy, with a planned completion date of December, 1969. This will provide the long-needed accommodation and facilities for our existing staff at Edinburgh, and improve the research and advisory service in the North. The location is excellent, with other research organisations of Government and the University located on the same estate. A Chief Research Officer (North) has been appointed to take charge of the Station, which will include staff from all the main research Sections of the Division. The organisation has been re-cast (see p. 182) and the two Chief Research Officers given functional responsibilities for the work of their allotted Sections throughout the country.

The Research Programme and Report

The Report outlines progress on the major research projects of both the Research and Management Services Divisions. Innovations include a subject index and short abstracts of newly published papers. Also, a fuller report than

formerly is included on the joint programme of research with the Forest Products Research Laboratory, because of the growing importance of this programme. The Project Register introduced last year was revised, with some reduction in the number of projects and provision for statements of resource allocation by projects. This has proved a key document, both in management and for the exchange of information internally and with other organisations.

Communications and Information

Advisory and extension work in Commission and private forestry remains a vital part of our activity both in disseminating information and identifying research problems. A substantial effort was devoted to improving these links with forest managers by personal visits, demonstrations, courses, publications etc. Two research refresher courses were held for forest officers, and close contacts were maintained with the Timber Growers Organisation and the Scottish Woodland Owners Association. The Library and Information Services at Alice Holt showed an increase in use of some 60 per cent by outside enquirers.

Conferences

The Annual Research Conference held at Alice Holt in October was attended by the Director General, and guests included Dr. Don McLean, Director of the Petawawa Research Station, Ontario, Dr. D. A. Gill, who is the Deputy Director of the Water Research Association, Mr. T. A. Oxley, Director of the Forest Products Research Laboratory, and Mr. J. N. R. Jeffers, Director of the Nature Conservancy's Research Station at Merlewood.

Members of staff attended 16 scientific meetings and conferences in this country. Elsewhere, D. T. Seal gave a paper at the Annual Conference of the Canadian Institute of Forestry at St. Johns, Newfoundland; A. Whayman attended the Plenary Session of the FAO/ECE/ILO Joint Committee on Forest Working Techniques and Training of Forest Workers, held in Poland; D. Bevan and Miss J. M. Davies visited Moscow to attend the 13th International Congress of Entomology; D. A. Burdekin and B. J. W. Greig took part in the I.U.F.R.O. 3rd International Conference on *Fomes annosus*, in Denmark; and A. J. Grayson attended the 5th Session of the FAO Study Group on Methods and Organisation of Forest Work, held in Geneva.

Visitors

We were pleased to receive more than 700 visitors to Alice Holt, including 151 from more than 25 overseas countries. Our many distinguished visitors from overseas included the Organisation Committee of I.U.F.R.O., composed of Professor I. Samset of Norway, Professor A. de Philippis of Italy, Dr. F. Richard of Switzerland, and Dr. D. R. Redmond of Canada; a Tunisian Parliamentary Delegation arranged by the International Parliamentary Union; a large party of Swiss Forest Officers from Canton Vaud (Lausanne); members of the 1st International Congress of Plant Pathology; and a party of Foresters and Students from Gembloux, Belgium.

We were also honoured by a visit of an all-party Parliamentary Delegation from the House of Commons, including the Earl of Dalkeith, M.P., Mr. J. Parker, M.P., Mr. Peter Jackson, M.P. and Mr. Bert Hazell, M.P., and by parties representing the Commonwealth Forestry Institute, the Association of

British Tree Surgeons and Arborists, the Association of Professional Foresters, the Universities of Aberdeen, Bangor, Oxford and Southampton, and each of the Commission's Forester Training Schools.

Staff Visits Abroad

R. Lines went on a Nuffield Fellowship tour from May to December to study research organisation in Canada, Japan, Australia and New Zealand.

D. G. Pyatt visited the Forestry Division of the Northern Ireland Ministry of Agriculture in April and May to discuss soil survey techniques.

D. T. Seal visited Ontario in September and October to see developments in container planting by the Ontario Department of Lands and Forests.

In September, A. A. Rowan made a tour of various organisations in Sweden, arranged by the Logging Research Foundation, Stockholm, to examine work study techniques, harvesting systems and machinery developments.

Staff Changes

J. R. Thom resigned as Director of Research in March 1968 to take up an assignment with FAO in Guyana, and was succeeded by G. D. Holmes who returned to the Division after five years in the North Wales Conservancy. B. W. Holtam was appointed from Harvesting and Marketing Division to the new post of Chief Research Officer (North) on promotion to Conservator. D. R. Johnston returned to Alice Holt from East England Conservancy as Deputy Director of Management Services heading the Planning and Economics Branch. I. D. J. Phillips, formerly lecturer in Botany at the University College of Wales, Aberystwyth, was appointed head of the Physiology Section in Edinburgh. G. H. Bowers came to Alice Holt as Administration and Finance Officer from South-west England Conservancy in place of Mr. C. Ridley, who returned to Audit Branch at Basingstoke. A. J. Grayson was promoted to Assistant Conservator in his post as Senior Economist.

The following transfers were made within the Commission:

J. A. Spencer (Assistant Conservator), Planning and Economics to Forest Management Division, Basingstoke; A. A. Rowan, Work Study to Harvesting and Marketing Division, London, on promotion to Assistant Conservator; D. Y. M. Robertson, Planning and Economics to North-east England Conservancy, on promotion to Assistant Conservator; J. A. Atterson (District Officer), Silviculture (North), to North Scotland Conservancy; N. Dannatt (District Officer), Work Study to West Scotland Conservancy; D. G. Pyatt (District Officer), Planning and Economics to Soils (Edinburgh). (He is at present on a year's Sabbatical leave at Aberdeen University.). J. T. Stoakley (District Officer), Entomology Section to North Scotland Conservancy; D. E. W. Blandford (Technical Works Grade B, Mech.), South-west England Conservancy to Work Study, as Communications Officer; W. O. Wittering (Senior Executive Officer, Work Study) transferred from Olney, Bedfordshire, to Alice Holt; L. W. Thomas (Executive Officer), General Services Section to Silviculture (South); D. T. Baker, Seed Section to Finance Division, London, on promotion to Executive Officer.

Departures from the Commission included M. Nimmo (District Officer, Silviculture South) who retired after over forty years' service in research. He was a most practical all-round naturalist and silviculturist with great breadth of knowledge and experience of applied research, having been particularly

concerned with problems in the Forest of Dean, East Anglia and the Chalk downlands and heathlands of the South, and he worked closely with many famous names including the late M. C. Rayner, E. M. Crowther, H. M. Steven and W. R. Day. His counsel will be missed and we wish him well in retirement.

We also regret that E. S. B. Chapman (District Officer, Work Study) had to retire on medical grounds.

District Officer J. Laurie-Muir left Work Study for a post in South Africa.

Head Forester A. S. Gardiner resigned to take up a post with the Nature Conservancy at Merlewood, Lancashire.

R. G. Harris (Silviculture, South) joined the Agricultural Research Council on promotion to Higher Executive Officer.

Staff newly appointed or transferred in during the year were:

K. A. Longman (Senior Scientific Officer, Genetics); D. B. Redfern (Senior Scientific Officer, Pathology); J. S. Oakley (District Officer, Work Study); D. B. Paterson and L. M. Simpson (District Officers, Planning and Economics); T. M. Scott (District Officer, Entomology); J. M. Mackenzie (District Officer, Silviculture, North); Miss S. B. Page (Executive Officer, General Services), who returned to Alice Holt from Industrial Establishments, Basingstoke; E. R. Adams (Assistant Experimental Officer, Planning and Economics); R. Carnell (Assistant Experimental Officer, Soils) and J. F. Varley (Assistant Experimental Officer, Statistics).

Appointments and Awards

R. M. Brown (Silviculture South) succeeded J. T. Stoakley as Secretary of Section K. Forestry of the British Association for the Advancement of Science.

C. I. Carter was awarded an M.Sc., degree of London University, for his thesis on the taxonomy and biology of the *Adelgidae* in Britain.

H. M. P. Stocks, Research Worker Grade 1, of Tulliallan Nursery, Fife, was awarded the B.E.M. in the 1968 Birthday Honours List.

In Memoriam

We regret to record the deaths of two distinguished colleagues.

M. V. Edwards, O.B.E., who retired in 1966, died in February 1969. He joined Silviculture (North) in Edinburgh in 1947 from the Burma Forest Service. He later headed the Section and made major contributions to knowledge, especially in the field of provenance research.

W. G. Gray, B.E.M., who retired in 1967, died in December 1968. He joined Research Branch in 1922 and had charge of Kennington Research Nursery, Oxford, from 1925 until his retirement. He was one of the Commission's pioneers and much that is good in our present nursery practice has its origins in his work and influence.

REVIEW OF THE YEAR'S WORK

By D. H. PHILLIPS
Chief Research Officer (South)

PART I
RESEARCH DIVISION

Forest Tree Seed

Because the quality of seed has been much improved, and better nursery techniques are in use, less seed is now needed than formerly, and both the register of seed sources and the stock held in the central seed store continue to be reduced. The stock of most sorts of seed is sufficient for the next three years, but supplies of Hybrid larch and of genetically superior seed of other species are still insufficient and efforts will be made to build them up.

The home conifer seed crop this year was not a good one, though that of Sitka spruce was the best for a long time. Imports of seed were mainly of Sitka spruce, Grand fir, and Noble fir, and Red oak (Table 1, p. 23).

Only a little time could be devoted to research, but some work was done on the best conditions of temperature and relative humidity for cone drying, on the production of graded seed (which is likely to be more and more in demand in the future) and on seed testing methods. Other work is being done on the rapid determination of seed origins, so that provenance of imported seed can be checked quickly when necessary.

Production of Planting Stock

Work in this field is designed to produce in as short a time as possible a good uniform stock suitable for planting. The main studies were on fertilisers, particularly the less soluble ones giving a slow release of nutrient, but there was also an increase in the amount of time spent on the production of special types of planting stock in containers of various kinds.

At three centres, a total of ten species was tested in continued experiments on the effect of late fertiliser top dressings. The foliar content of nitrogen was markedly raised by the dressings in all species except Corsican pine, though late applications of N appeared to increase the susceptibility of Sitka spruce to damage by frost. In most cases there was no clear relationship between late top-dressings and foliar levels of potassium. Some of the seedlings given late top-dressings were transplanted and it was found that differences due to the treatment were negligible in the following season.

In experiments comparing the slow-release fertiliser "Enmag" with potassium metaphosphate and potassium superphosphate, the former failed to supply enough nitrogen to carry the plants adequately through the season. Formalised casein, another material providing a slowly soluble source of nitrogen, was also tried, but did not give very promising results.

In tests on the effects of "Enmag" and "Kay-nitro" used repeatedly on seed-beds and transplant lines, there was no evidence that plants were damaged through increasing levels of P and K applied in the fertiliser. In further work done to investigate possible ill effects from repeated application of "Enmag" with potassium as KCl or K_2SO_4, no "scorch" had appeared on the plants after three years of application. There was a rapid build-up in the soils of available

Mg, even after one year, but toxic levels were not reached (Table 4, p. 33). Another trial with "Enmag", made up in two granule sizes, confirmed earlier findings, that seedling height was greater after application of small than after large granules. Experiments in which "Enmag" fertiliser treatment was combined with partial soil sterilization did not support the suggestion that the effectiveness of the fertiliser was increased in sterilized soils. Trials were also carried out with "Enmag" specially formulated in combination with other nitrogenous materials to see whether the former slowed down nitrogen release in the latter, but the results were not encouraging.

A preliminary trial was made with seed mounted between sheets of absorbent paper. Paper-mounted seed can be evenly and precisely spaced, which could assist mechanisation, and may produce a more uniform crop with more usable seedlings per unit area than does seed sown in the usual way directly in the soil. Several spacings were tested, and in this experiment most usable seedlings were produced per unit number of viable seeds at the wider spacings used (Table 5, p. 34).

Dazomet is of possible interest as a soil sterilant because it is made up in granules and so is easily worked into the soil, and it has some herbicidal as well as pesticidal properties. It was tested as a herbicide at a number of nurseries. In experiments in southern England some damage (apparently related to waterlogging) occurred to plants in some trials, and it appeared that the cost both of the material and its application was such that its use could be justified only on the heavier, more weed-ridden nurseries where soil sterilization may also increase seedling numbers and growth. In trials in Scotland, dazomet gave better weed control than did formaldehyde, the standard soil sterilant with which it was compared. Effects on growth of the plants were inconsistent, but some further work seems justified.

More work was done on the production of container plants in plastic tubes and "Nisula" bales. The "tubed" seedlings (Plates 13 to 15) were raised in glasshouses or polythene structures, and to get satisfactory growth it was found necessary to provide good ventilation, for which large extractor fans were used. The best results were obtained when the plants were grown in mixtures of peat and sand and in John Innes compost, with a seed cover depth of about 3 mm. Various fertiliser regimes were tried, including both base and later top-dressings. No regime emerged as markedly the best, but very high rates of basal dressing depressed germination and top-dressings of urea and ammonium sulphate damaged the plants.

Most of the experiments were done with Lodgepole pine and Sitka spruce, which respectively produced from 70–80 and 60–75 per cent usable seedlings. Some preliminary trials were also made with Grand fir, but results were poor, with low germination and later death of many of the few seedlings produced.

Plants of Lodgepole and Corsican pine, Sitka and Norway spruce, Douglas fir, Western hemlock and Grand fir were all raised successfully by the Finnish "Nisula" method, in which the plants are grown in fertilised peat rolled up into bales in which the peat and the plants are sandwiched between layers of polythene sheeting (Plate 16).

After three years of tests with seed dressings used to colour seed and so aid in sowing, Lithofar red can be recommended for use on all species, but particularly on seed of the various species of larch, germination of which is reduced by red lead, the present standard material.

Site Studies and the Role of Minor Species

Site studies are being made in an attempt to classify sites according to their ability to support various groupings of commonly planted conifers. Particular attention has been given to the minor species Western hemlock, Western red cedar, Grand fir and Noble fir in order to assess their future place in British forestry. It is hoped to complete the work on these and to report on them within the next year.

Provenance

A provenance trial with Lodgepole pine in the transplant lines at Newton Nursery (Moray) showed that wide variations between provenances were paralleled by incidence of lammas growth, the Alaskan provenances showing both the shortest growth and negligible lammas.

Results with a collection of provenances of Jack pine (*Pinus banksiana*) planted at two sites in 1961 are at present difficult to interpret as so far, though there are significant differences between provenances, the ranking of the provenances differs widely at the two sites.

A small trial has been planted at three sites to compare eight provenances of *Pinus ponderosa* from Washington and Oregon.

An experiment with 37 provenances of Sitka spruce was planted in Argyll, and further collections of this, our most important species, are being organised.

The International Trial of over 1,000 Norway spruce provenances in single tree plots is now satisfactorily established in Salisbury Forest, as are experiments with a smaller range of provenances in Scotland.

Results after six and ten years with 25 Japanese larch provenances on three sites show that the best growth has been from seed lots collected from middle elevations between 1,680 and 1,830 m (5,500 and 6,000 ft) in Nagano Prefecture, though some seed from the same area and height range gave rather poor results, and it is therefore difficult to specify satisfactorily the most suitable areas for seed supply to Britain.

Results to date are also reported from 16 experiments with 18 provenances of Western hemlock planted in 1961/62. The main result so far has been that in sites without cover, early growth has been largely checked by repeated killing back of shoots each winter. In the critical establishment phase this resulted in total loss of two experiments, and some others in Scotland have been severely damaged and so have few trees surviving. Under these exposed conditions, the northern provenances, from Alaska, Prince Rupert and Queen Charlotte Islands were best, but in sites established under high cover, the northern provenances have shown the poorest growth, and those from the southern part of the range have been best, together with home-collected seed from Inveraray (Tables 6 and 7, pp. 46–48).

A collection of 29 Douglas fir provenances being raised in three nurseries grew well, but considerable damage to the southern origins was caused by autumn and winter cold.

Trials with *Abies alba* are recovering from early frost damage and browsing deer and new trials are planned with *A. grandis* and *A. procera.*

Choice of Species

Work under this head is often broadly ecological and largely concerned with trials of species on various soil types or under special conditions.

In studies on growth problems in pole-stage Sitka spruce, observations were continued at three sites on the effect on increment of defoliation by the Green spruce aphid, *Elatobium abietinum*. Unsprayed plots were compared with others sprayed with malathion. Aphid numbers were low and not very different in sprayed and unsprayed plots, but at two sites increment was greater in the sprayed than in the unsprayed plot. Differences appeared to be related to damage by *E. abietinum* caused in the unsprayed plots in 1967, when a high population of the aphid was present. In the third site, in which aphid levels were low in both years, no differences in increment between sprayed and unsprayed plots could be detected.

Some small trials of species were continued on Scottish "shale bings", the waste heaps from oil shale mining. The most promising species on these inhospitable sites were alder and sycamore and the best results have been with potted plants.

Steps were taken to increase the number of trials with Lodgepole pine and Sitka spruce on high and exposed sites in Scotland and northern England. Experiments on the establishment of sycamore in such areas, set up largely because this tree is of value for shelter, particularly in the Northern Isles, have been carried on for some years but have given inconclusive results and will be discontinued.

As a result of work on poplars, consideration is being given to the release to the nursery trade of *Populus trichocarpa* 'MB', which has consistently shown good resistance to bacterial canker (*Aplanobacterium populi*) since it was first tested in 1952.

On elms, some work was done on propagation from softwood cuttings and on methods of establishing transplanted rooted cuttings in the forest. The Commelin elm, *U.* x *hollandica* 'Commelin', from the Netherlands, continues to show good resistance to Dutch elm disease (*Ceratocystis ulmi*), and could be planted more widely than it is, particularly as an amenity tree. Of the British elms, only Huntingdon elm. *U.* x *hollandica* var. *vegeta*, is fairly resistant to elm disease.

A new *Eucalyptus* trial, with plots of *E. coccifera*, *E. gunnii*. *E. pauciflora*, *E. simmondsii*, *E. urnigera* and *E. mitchelliana*, was established at Glenbranter Forest in Argyll.

Arboriculture

At Kilmun Arboretum in Benmore Forest (Argyll), opportunity given by clearance of areas windblown in the gale of January, 1968, is being taken to enlarge the *Eucalyptus* collection, and some further planting of other trees was also done both at Kilmun and at Crarae Forest Garden, near Inveraray.

At Bedgebury (Kent), the forest plots were enlarged and work in the main arboretum has included the planning of a group of representative species from each of the major temperate tree genera, with instructional labels drawing attention to the most important features used in identification.

At Westonbirt (Gloucestershire), further opening up and planting has been done and a detailed plan made for the development of a large part of Silk Wood as an extension to this famous collection.

A new coloured guide to Westonbirt was published and a short guide to Kilmun Arboretum also became available at the end of the year.

Planting

Trials with the Finn Forester Tree Planter gave promising results on suitable sites, though at present the machine can be used only on land previously ploughed or needing only shallow cultivation, because it can carry out only superficial screefing.

At present the trend in forestry is towards wider plant spacing, which affects the rate of growth of the trees. In a study on the effects of radial growth rates on wood quality of Sitka spruce, the results confirmed that wood density declines with increasing rate of growth. More information is being sought on this because of its importance to management.

Some years ago the results of trials on peat soils showed that six years after planting, trees set out as transplants were considerably taller than others planted out at the same time as 1-year seedlings. The same series of experiments was reassessed this year and it was found that in general the transplants of all species had at least maintained their lead over the seedlings, particularly on the higher sites. It was calculated that in economic terms, the planting of seedlings instead of transplants could lead to a loss of as much as £10 per hectare (£4 per acre) in discounted revenue. This could have a bearing on the use of tubed seedlings, though so far these appear to be capable of better early growth than those from the nursery bed.

Small trials were in fact made with some of these tubed seedlings (which are also discussed in the section on Production of Planting Stock) in the afforestation of poor, exposed land in the north of Scotland. Six of these experiments had been set up in 1967, three on wet heathland on a peaty podsol at Glen Garry Forest (Inverness-shire), and three on deep peats at Naver Forest (Sutherland). Many plants were affected by exposure, which on the podsol showed as some needle and shoot damage and much frost-lifting of the tubes. In spite of this, survival to the end of 1968 was good and growth of Sitka spruce was also quite good, though that of Lodgepole pine was slow. In the experiments on peat, very little frost lift occurred, but frost damaged terminal buds (especially of Sitka spruce) and so reduced growth. In one of these experiments, step planting of Lodgepole pine on single mouldboard ploughing was compared with planting on double mouldboard ploughing without stepping. Survival and height of the step-planted stock was better than that on the unstepped ploughing, probably because of the shelter given by the planting step. Good root growth took place from the tubes into the peat.

Another eleven tubed seedling experiments were planted in 1968, to examine effects of seedling age at planting, date of planting, type of soil mix in the tubes and length of the tube. Growth in these experiments (especially on peat sites) has been generally good, especially among the seedlings planted early in the season, from May to July.

Calculations showed that if tubed seedlings prove satisfactory, their large-scale use could lead to substantial savings in establishment costs. Work in this field is therefore worth expanding, and an increase in the programme has been planned to cover the use of tubed seedlings not only in new afforestation but also in the replanting of felled areas in which this type of stock may be less subject to the post-planting check often experienced with standard nursery plants.

Nutrition of Forest Crops

Many trials are in progress on various peat types, using nitrogenous, phos-

phatic and potassic fertilisers. At present the tree most commonly grown on the difficult upland peats is Lodgepole pine, and if some of these experiments show that with the aid of nitrogenous fertilisers Sitka spruce may be grown instead, the result will be one of high economic importance. It will be some time before we can reach any final conclusions here. Some preliminary results from trials with urea in checked spruce crops, however, have served to emphasize the fact that nitrogen alone has little effect unless phosphate levels are sufficiently high.

On a pole-stage crop of Sitka spruce on a peaty gley soil at Kershope (Cumberland), phosphate alone produced nearly as big an increase in the first two years as NPK—a result similar to that given by Welsh experiments with the same species. It also produced a better response in low than in moderate yield classes. Two pole-stage experiments on Scots pine at Speymouth (Moray) also suggest that higher percentage increases are to be gained from NPK in lower yield classes than in the higher ones.

The original "deficiency garden" at Wareham (Dorset), now entering its tenth year, continues to show symptoms of N, P and K deficiency, with reduced growth in plots without these elements. So far no effects have been detected on plots without calcium or magnesium. Perhaps the most important result of the trial is the demonstration that on this site limitations to the early growth of most of the species tried are in the soil rather than in the climate, and can be remedied—though not necessarily at a profit. The principle of trials to pinpoint limiting factors accurately is being extended. "Deficiency gardens" for demonstration purposes have been established at Eddleston Water (Peeblesshire) and Shin (Sutherland) and similar demonstrations are planned for Inchnacardoch (Inverness-shire) and Minard (Argyll).

Some early pole-stage experiments in England and Wales are now old enough to show the duration of the response to single treatments with phosphate. Some responses, in poorer crops, are lasting more than nine years, others have almost disappeared. More evidence on this important aspect of fertiliser work is needed, in order to assess the likely economic return from treatment.

Forest Weed Control

Further assessments of experiments with chlorthiamid ("Prefix") showed that most tree species may be damaged by this chemical, particularly when high rates are applied late in the season. Of the individual species, Corsican pine and Sitka and Norway spruce were fairly resistant, Scots and Lodgepole pine gave inconsistent results and *Abies* spp., Western hemlock and Douglas fir were quite sensitive. Height growth of surviving trees was generally unaffected.

In experiments with triazines, ametryne failed to give adequate weed control. It was found that atrazine was effective only when applied directly to weed foliage, but it gave good results when used in this way in April. Later in the year, in June and October, results were not so good.

Reassessments of some of the earlier experiments in bracken control with dicamba showed that on infertile sites good control was obtained for up to four seasons from the date of application, though on moist, fertile sites the bracken may recover by the end of the second season. These experiments were in the south. In Scotland it was found that to get effective control in the second season a rate of 4·5 kg/ha (4 lb/acre) was needed, that of 3·4 kg/ha (3 lb/acre) giving acceptable control only for the first year after planting. Addition of paraquat and dalapon did not improve the bracken control.

In all trials dicamba gave good and reliable control in the first season. Damage to trees occurred if planting followed the dicamba treatment too closely, and after spring treatments with the chemical at least eight weeks delay seems necessary before planting can take place.

In 1967, some cases occurred of damage to crops through volatilisation of 2,4,5-T from treated foliage. Trials were therefore made this year with two esters of 2,4,5-T and it was found that the iso-octyl ester, which has a very low volatility, caused less damage than the N-iso-butyl ester generally used in spraying (Table 19, p. 78).

Further experiments on the control of regrowth of rhododendron showed that high concentrations of 2,4,5-T in oil or water gave satisfactory results and also emphasized the importance of spraying while the regrowth is small to keep the costs of application low.

It was found in work on the control of heather (*Calluna vulgaris*) that a combination of a fertiliser treatment with spraying with 2,4-D gave better heather control than treatment with the herbicide alone.

Some analyses were made of foliage of various tree species in plots weeded by hand or with chemicals. In general it was found that levels of nitrogen were higher in the chemically weeded plots (in which weed control was fairly complete) than in those weeded by hand (Table 20, p. 81).

In collaboration with the Water Research Association some work was done on possible contamination of water by phenoxyacetic herbicides and diesel oil. In the trials made, no diesel oil was found in any sample, though 2,4,5-T could be detected during and just after heavy rain.

Soil Moisture, Climate and Tree Growth

The watering experiment at Bramshill Forest (Berkshire and Hampshire) has been repeated and gave substantially the same result, showing that in this sandy soil, when water is applied in excess of field capacity it leaves the base of the profile at about the same rate as it is applied at the surface. Anomalies in soil water pressure detected by air piezameters seem to be due to site characteristics rather than to the experimental watering technique.

Much effort is at present being directed to the design and proving of field systems for the sensing and recording of water levels and oxygen tensions for use in new drainage studies.

Drainage

Drainage experiments on peat suggest that close and moderately deep ploughing gives a major improvement in drainage, almost as great as that produced by closely spaced deep drains (Table 21, p. 87). The benefit from cross drains increases with depth and closeness of spacing, and is likely to increase with time as the additional drainage provided by the initial superficial ploughing system is reduced by the build-up of surface litter. In studies of root systems it was found that on the whole the weight both of roots and of the whole plants increased with the drainage intensity.

At the end of a ten-year study, drains in peat were found to have maintained their depth almost unaltered, so that the drainage benefits from ploughing in peat soils are likely to last at least until the trees close canopy.

It seems possible that on these peat soils the best form of drainage and turfing system for the establishment of forest crops may be some form of "rigg

and furr", in which good drainage is given by closely-spaced, moderately deep drains, the spoil from which is built up between to provide a good rooting medium and suppress weed growth. This may be a practical proposition using modern powered equipment such as the "Oja-Viska" plough.

It is estimated that about 30 per cent of our forest area is on gleys with clay subsoils and these present considerable drainage problems. With a sufficiently powerful tractor effective drainage may be achieved by means of the Parkgate Deep Drainage Plough. In other work it was found that the large Finnish "Lokomo" plough produced exceptionally stable drain profiles which still persisted unchanged after three years, by which time the walls of drains produced in similar soils by the Parkgate Plough and by hydraulic diggers had collapsed and so lost their depth.

Cultivation

In Scotland experiments have shown that deep, complete cultivation of ironpan soils results in marked improvement in crop growth, the improvement being related to the volume of soil disturbed. It is probable that still deeper cultivation will bring a further substantial response in growth and this will be tested in experiments now being established. Experiments have also been laid down to observe the effect of deep complete cultivation on indurated soils (frago-gleys). The response to intensive cultivation on other soils has been less promising but requires further investigation. Foliage analysis of crops on deep complete ploughed ironpan soil at Teindland showed increased nitrogen but also indicated that phosphate is becoming exhausted by the faster growth. Additional phosphate will be required if the rapid growth obtained from the cultivation is to be maintained.

Regeneration

Two small experiments were planted to study artificial regeneration of Sitka spruce and Lodgepole pine on deep peat on a site previously occupied by larch and Lodgepole pine.

Four experiments on peaty and surface-water gleys, previously under windblown and felled Sitka spruce, were assessed ten years after replanting, and it was found that ploughing with a mounted tine plough had not improved survival or growth of the new crop or reduced weed growth.

Experimental sites have been chosen for work on the replacement of Scots pine crops on frago-gleys and ironpan soils by more profitable species.

Investigations on artificial regeneration on the more freely drained soils continued at Thetford Forest, where plots are being established under a pine cover and in clear-felled strips in the forest. Of the few hardwood species in the trials, *Nothofagus obliqua* has grown conspicuously well, though on the poorer sites it has been badly attacked by *Fomes annosus*. In one of the experiments, a severe frost in late May caused moderate damage to Grand fir planted in clear-felled strips and under a cover of less than 250 stems/ha (100 stems/acre) but not where the overwood stocking exceeded 298 stems/ha (120 stems/acre).

Stability of Crops

About 150 oblique colour photographs were taken in an aerial survey by helicopter of five West Scottish forests affected by the windblow of January,

1968. A study of the photographs shows that most of the throw was on windward slopes, slopes oblique to the wind, on ridge tops and in funnel features, with little on leesides.

In tree-pulling investigations in Yorkshire, it was found that on the compacted soils where the trials were made, root distribution reflected thoroughness of ground preparation with the best rooting following complete ploughing. Here, Lodgepole pine appeared to be more prone to windthrow than other species.

Similar studies on a deep peat in Inverness-shire showed that Lodgepole pine had rooted to a depth of over 1·2 m (4 ft), well below the drains.

In Wales, on a site only poorly drained after single-furrow ploughing, Sitka spruce had a particularly restricted root system and was easily pulled over. Further work will be done on these lines to examine the effect of different ploughing methods on the stability of Sitka spruce in wet soils.

Analyses of annual survey data are being made in an attempt to improve the forecasting of likely windthrow damage and extension.

Trials to examine the effect of different types of thinning (including line thinning) on crop stability are being laid down.

Ecology

Much of the time of the small Ecology Section was taken up by preliminary work on some problems of afforestation in parts of the South Wales coalfield area, where exposure, excessive wetness or mineral poverty of the soils and local atmospheric pollution may all be among the possible factors affecting tree growth.

Forest Genetics

Cone and fruit crops were again generally only light to moderate, though good yields were obtained from the older Scots pine seed orchards in East and South-east England and Central Scotland, from Sitka spruce crops in the Moray Firth region and East Aberdeenshire, and from beech in Eastern Scotland.

Most of the effort on Plus tree selection was expended on Sitka spruce and Lodgepole pine. In all, 100 Sitka spruce and 138 Lodgepole pine Plus trees were selected. It was decided to extend the selection of Lodgepole pine to cover some of the relatively young but promising crops of coastal Washington and Oregon provenances widely planted between 1950 and 1954, paying particular attention to vigour and freedom from butt sweep.

The formation of the new National Tree Bank for Sitka spruce at Wauchope (Roxburghshire) is proceeding quickly and already well over half the area is fully stocked. Trials of planting grafts within five months of grafting show promise, and "container-planting" methods were tried in spring 1969. Closely-spaced grafts have been established to form a scion bank from which scionwood will be obtained for producing grafted plants for the first Sitka spruce seed orchards.

Problems of plagiotropic growth and the development of overgrowth of the scionwood above the graft union have slowed down the progress of the Douglas fir seed orchard programme. Current indications, from a 1962 experiment, suggest that grafting on to 0·9 m – 1·5 m (3–5 ft) tall well-established rootstocks on the seed orchard site considerably reduces these hazards but does not eliminate them completely. In Sitka spruce some improvement in the yield of

successful grafts seems attainable by grafting normal scionwood on to vigorously growing 6-month-old seedlings raised in a partially controlled environment, and by adopting "mini-grafting" techniques. The use of the anti-dessicant "S.600" on scionwood shows promise as a means of further increasing the percentage of surviving grafts.

Controlled pollination programmes were carried out at two centres. At Saltoun in Stenton Forest (East Lothian) several coastal provenances of Lodgepole pine were crossed with a variety of inland provenances, and inter-species hybrids were made between Lodgepole pine and three provenances of *Pinus banksiana*. At Roseisle (Moray) a 7 x 7 diallel cross was successfully achieved with Sitka spruce, and the resultant seed will be used for raising plants on which future heritability studies will be made. Trees showing a variety of characters were selected as the parents.

Several Sitka spruce progeny trials were established on a range of sites with the object of comparing the efficiency of square and line plots and for determining the interactions between adjacent plots; the plot sizes ranged from single tree to thirty-six-plant plots.

Forest Pathology

Further work was done on the eradication of infection by *Fomes annosus* from infested areas by the removal of stumps at or after clear-felling. Three methods of extraction were employed, the first using a Volvo BM 840 wheeled tractor with a grapple attachment to remove whole trees with their attached root systems, the second using a tracked Challenger 33 to push out stumps with a grubber blade, and the third again using a Volvo BM 840 tractor, this time to dig out stumps with lifting tongs. Preliminary results suggest that the third method removed most roots, and the first least, but that of the three methods the second was the cheapest. On certain sites on which infestation by *Fomes annosus* is high, and machinery can be used, some treatment of this kind may be necessary in future before replanting can safely be done.

In the past, observations have suggested that Grand fir is very resistant to *F. annosus* butt rot, while Western hemlock is very susceptible, and the relative susceptibility of these species may be an important factor concerning their future use in British forestry. As part of a larger study on minor species organised by the silviculturists, the pathologists therefore made comparative studies from stands of Grand fir and Western hemlock to increase our information on their relative susceptibility to attack by *F. annosus*. Preliminary results from three sites on which the two species could be directly compared supported the previous observations, indicating that in Western hemlock crops, many more trees were infected than in Grand fir stands of a similar age, and that the fungus progressed further up the butt in the former than in the latter (Table 24, p. 108).

In spray trials against needle blight (*Didymascella thujina*) of Western red cedar, "Actidione Ferrated", a new formulation of cycloheximide, was found to be as effective as "Actispray," giving excellent control of the disease. "Actispray" is no longer available, but "Actidione Ferrated" is now on the market, making cycloheximide generally on sale in this country for the first time.

Five poplar clones have now emerged from recent screening tests showing sufficient resistance to bacterial canker (*Aplanobacterium populi*) to warrant further study. *Populus trichocarpa* 'MB', which past tests have shown to be very resistant to canker, is also resistant to the leaf spot caused by *Marssonina*

brunnea. It is a fast-growing tree, suitable for both amenity planting and timber production.

Beech bark disease, usually considered a disease of mature and over-mature trees, has recently been found causing severe damage in pole-stage crops in southern England, and a preliminary investigation has been started in the affected areas. So far, here as elsewhere, the cause seems to be a combined attack by beech coccus and one or more species of *Nectria*.

Entomology

The pupal survey of the Pine looper moth *Bupalus piniarius* showed a trend to more normal conditions over the 1967/68 figures, though the overall forest average indicated a slight increase (Table 25, p. 111). A field trial using crude B.H.C. in oil against the Pine shoot beetle *Tomicus piniperda* in already attacked logs, gave some measure of successful control. Reports from large-scale user trials generally confirmed the effectiveness of whole-plant dipping in Gammacol (a fine emulsion of lindane) against the weevil *Hylobius abietis*, and against bark beetles (*Hylastes* spp.).

A considerable amount of data accumulated in the investigation on the Douglas fir seed wasp *Megastigmus spermotrophus* may prove useful in forecasting the need for spraying. Further work on control of this pest showed that "Malathion gamma B.H.C." had no effective advantage over the use of "Malathion" alone.

Work on increment loss in Sitka spruce due to the Green spruce aphis *Elatobium abietinum* continued, together with studies on host plant susceptibility, by analysis of extracted sap for amino acid components. Infestations of *Adelges laricis* were abundant in 1968, and their possible connection with "larch die-back" is being followed.

The factors affecting growth and survival of young crops are being studied over a period of five years. Two years' work has so far shown that three species of microlepidoptera appear to be particularly common pests in these plantings.

Mammals and Birds

Investigations on the use of "Warfarin" to control grey squirrels were extended from Scotland into England and Wales, and the effectiveness of the method was confirmed. Results of the trials suggested, however, that the fourteen-day baiting period found adequate in Scotland may be inadequate in England and Wales, and may need to be extended there.

The starling roost dispersal technique using an amplified distress call apparatus combined with bird-scaring cartridges was again tested in a number of forests and gave good results in all except one block of 6,000 acres, which appeared to be too large to be effectively covered by one set of apparatus.

The spring-steel fencing technique developed over the past few years has found ready and rapid acceptance by forest staff and is now being further improved by the Work Study and Training Branches of Headquarters.

This year for the first time, the Mammals sub-section organised a very successful course on wildlife management research for Wildlife Foresters.

Statistics

During the year the Section was reorganised to make the best use of the available staff and to improve training facilities. Services to research sections

continued, but much time was taken up with the analysis for the Management Services Division of data from the census of private woodlands, and with calculations of tables of standard times and other work for the Work Study Branch.

Arrangements were made to dispose of the Lector document reader, but increasing use was made of Port-a-punch cards, and other methods of data capture were investigated.

Research Workshop

The workshop made a large range of equipment for research sections and is now developing apparatus for use in the raising of tubed seedlings. It has also provided advice to various sections on the design of equipment they can themselves construct or adapt. In connection with the Forestry Commission's 50th Anniversary celebrations, the workshop staff has been much occupied in the preparation of material for the Forestry Exhibition at the Bush Estate, Edinburgh, and for Open Days being held at the Forest Research Station, Alice Holt.

Photography

Although over 10,000 colour slides were lent out over the year, the calls on this service were less than in the past, probably because Conservancies have been encouraged to build up their own regional collections and so call on the central collection only for special items.

In the field of audio-visual aids, demands for tapes continue to increase. Video Tape Recording equipment has been bought and will be valuable particularly for education and training purposes.

Publications

Eleven new publications were issued through Her Majesty's Stationery Office, and six others revised and reprinted. Twelve new unpriced Research and Development Papers were brought out and twelve other unpriced publications for general public issue were revised and reprinted.

Research Information

Loans made by the Library, to Commission staff and members of the public, greatly increased during the year. The stock of books and periodicals, and also of translations, was considerably enlarged. An 8 mm ciné camera and projector were bought and a library of films on forestry and forest research is being built up for use in lecturing, teaching and demonstrating.

A revised "Keyword Index to Forestry Commission Publications" has been prepared and issued.

MANAGEMENT SERVICES DIVISION

Planning and Economics and Work Study are branches of the Management Services Division of the Headquarters organisation and not of the Research Division, but accounts of their research work and of that of the Harvesting and Marketing Division appear in this *Report*.

Planning and Economics

A country-wide revision of area and yield class information is now being made, partly to convert the data into metric units and partly to bring older information into line with that more recently collected. The emphasis of soil

and site survey work has changed towards preplanting surveys and surveys of sites liable to windthrow, and those where fertilisation is likely to give economic possibilities for increased production.

The analysis of the National Census of Private Woodlands awaits publication. Various publications on soils and soil surveying have been prepared and, in readiness for the change to metric measurement, several metric versions of mensurational tables have been produced.

A simulation model for the Forestry Commission has been developed and programmed for the computer to enable the effects of changed management regimes on resource requirements and output to be studied.

Revenue losses caused by premature felling have been calculated and the results used in deciding which stands should be cut in order to minimise the cost of supplying any given quantity of wood over and above that produced by normal cutting.

A study of vehicle repair costs has made it possible to assess the effect of different replacement dates on overall vehicle expenditure.

Work continued on the preparation of new financial control procedures for the Forestry Commission, and in connection with the classification of the Commission's financial objectives the effect on management of changes in the test rate of discount was examined. It was found that within a fixed budget the effect of a rise in discount rates would be greater on volume harvested.

Results of an investigation into the factors affecting post-war consumption of wood products in the United Kingdom and forecasts to 1980 are being published.

Work Study

The Work Study Branch has now taken over the responsibility for the Commission's Communications Section.

In the field of machinery investigation, special emphasis has been given to the rapid testing of tractors under forest conditions so that guidance can be given to management before purchases are made.

Work on chain saw vibration has been continued and various saws equipped with anti-vibration handles are on test. Some of these show promise. Additionally, the effects of vibration can be reduced by arranging suitable rest periods throughout the day.

Trials were carried out with mechanical weeding equipment, including a grass roller useful in the control of *Calamagrostis* and bracken, and with an effective mistblower primarily for the application of weedkillers.

The approach to machinery research and development, responsibility for which was taken over in 1968, was clarified. Studies may be made of available commercial machines, in order to assess their possible use in forestry. If no suitable machine is available the Branch may design, construct and develop one, either by itself or with the help of a commercial firm. In addition, design criteria for various types of forest machine will constantly be re-examined.

In studies on afforestation, work was begun on the design of a hand-operated tool for the planting of seedlings raised in plastic tubes, and the operation and performance of various fertiliser spreaders were critically examined.

HARVESTING AND MARKETING DIVISION

Timber Utilisation

Work on the comparative rate of drying of Scots and Corsican pine billets

was completed and it was found that Corsican pine dried more slowly than Scots, and in winter it absorbed water so that its moisture content became five per cent higher than it was when "green".

Further work was done on the use of bark in horticulture. Pulverised bark with added nitrogenous fertiliser, or after exposure to anhydrous ammonia, shows promise as a plunge bed medium and for the making of soil-less composts. Mulching discs made from bark bonded with animal glue were made and appear to be worth further investigation.

Fence post trials comparing the durability of wood of various tree species, either untreated or treated with a water-borne preservative or with creosote, were again assessed. In most cases losses among the untreated posts are now high and in all species the treatments have increased survival, creosote giving superior results to those obtained with the water-borne preservative used in these trials (Table 26, p. 134).

The Joint Programme of work on home-grown timber being done with the Ministry of Technology's Forest Products Research Laboratory was reviewed, and it was agreed with the Laboratory that future work would be in three main fields. The first of these lies in the continued investigation of the intrinsic properties of wood of individual species, the second will include storage of round timber, sawmilling and preservation, pulping and drying, and the third will include special projects such as the effects of planting distances on wood properties and the commercial importance of butt rot and butt sweep. Some of the most important results obtained under this programme over the past year are mentioned below.

There is an increasing demand for roundwood for the manufacture of wood-wool/cement building slabs. Wood of some species is less suitable for this purpose than is that of others, and various home-grown conifer and hardwood species were therefore studied from this point of view. All the common conifers proved suitable (though setting times of slabs made from Scots and Corsican pine were longer than for slabs made with other species), but hardwoods were less satisfactory.

Results of sawmilling studies of home-grown Scots and Corsican pine suggested that on sites suitable for both species it would be better in terms of the quality and quantity of sawn timber obtained to plant Corsican rather than Scots pine, though the differences between the timber properties of the two species were slight.

Experiments on the control of blue-stain in pine showed that in Thetford Chase, in East Anglia, appreciable staining occurred only from March or April to August. Staining could be effectively controlled by spraying with a mixture of the insecticide lindane with the fungicide tribromophenol, and in July good results were obtained with the insecticide alone.

Present methods of preservative treatment for use on home-grown poles are unsuitable when applied to some species and can be carried out only after seasoning. Fairly successful results were obtained in experiments with pine, using the Boulton process, which avoids this long seasoning because the unseasoned poles are immersed in hot creosote and the water in the wood is then boiled off under a vacuum. Further work is needed to confirm the results on pine and to extend the studies to other species.

Promising results have also been obtained from work on the preservation of building timbers by the diffusion of boron salts. This method is also applied to

unseasoned timber and so avoids the need to season before as well as after the treatment. Tests showed that disodium octaborate was retained quite well in the wood even after exposure to heavy rain.

PART II

This section contains reports of work undertaken for the Forestry Commission by other organisations.

In an extract taken from the *Report of Rothamsted Experimental Station* for 1968, Miss B. Benzian, Dr. J. Bolton and Mr. S. C. R. Freeman discuss work done at Wareham, Dorset, on the effects of sulphur on the appearance and growth of seedlings of Sitka spruce, radish and lupins. The sulphur treatments improved the colour of the Sitka spruce, which became a darker green than those in untreated plots, but growth of the plants was not increased.

Mr. H. G. Miller and Dr. B. L. Williams, of the *Macaulay Institute for Soil Research, Aberdeen*, report the results of their work on forest soils and tree nutrition. After treatment with ammonium sulphate, Corsican pine on the sand dunes at Culbin Forest, Moray, showed a considerable increase in growth. Basal area increment increased over the whole range of treatments, but height and volume increment declined when more than 168 kg/ha were applied per annum, and net primary production was not much increased by applications above this level either, and fell when 504 kg/ha/p.a. were given. The trees in the treated plots took up increased quantities of phosphorus and potash as well as of nitrogen. By the end of the 3-year study more nitrogen from the fertilisers was concentrated in the crop than in the litter and humus, and this increase in the nitrogen in the trees was paralleled by a rise in the free amino acid content in the tree needles. Studies on peat were made to see how far division of a blanket bog into site types based on topography and ground vegetation with the aid of air photographs could be related to nutrient content of the peat. In general, the nutrient content was fairly closely related to the site type. The site types themselves could be readily related to variations in the vegetation, but as yet the significance of the differences with respect to tree growth remains to be determined.

In another extract from the *Report of Rothamsted Experimental Station* for 1968, Dr. G. A. Salt (with Mr. R. M. Brown of the Forestry Commission) summarises further experiments confirming the markedly depressing effect of the as yet un-named "psychrophilic seed fungus" on emergence of seedlings of Sitka spruce, particularly on the earlier sowings. When seed of other conifers were inoculated with the fungus they suffered much less than did Sitka spruce.

Mr. A. Manap Ahmed and Dr. A. J. Hayes, of the *Department of Forestry and Natural Resources, University of Edinburgh*, report on the third year of their work on *Crumenula sororia*. Their inoculation experiments appear to confirm the fact that this fungus is pathogenic, and causes the cankers on pines on which it produces its small black fructifications. They found that vigorous trees reacted to the fungus and confined infection to quite small areas, but on suppressed trees a wider, more general attack took place. Individual whorls of the tree were most susceptible when nine years old. The spores of the fungus were shed only in warm, moist conditions and germinated only if they came into contact with liquid water. In warm, dry weather the fruit bodies of the fungus quickly dried up, but if moist conditions returned they soon recovered their original size and shape.

Dr. P. G. Biddle, of the *Commonwealth Forestry Institute, University of Oxford,* and at present on a year's leave of absence at the *University of California, Berkeley,* contributes a report on his work on virus diseases of forest trees. Initially the studies were on poplar mosaic virus, which it was found could reduce the specific gravity and strength of the wood. Emphasis has now moved to the investigation of possible virus diseases of conifers. In spruce and pine trees with symptoms like those of virus diseases, virus-like particles have been found, but so far it has not been possible to show that these particles are of virus origin.

Dr. J. F. Longworth, of the *Forest Pathology Unit,* also at the *Commonwealth Forestry Institute, University of Oxford,* summarises work on viruses of insects. An account of the cytoplasmic polyhedrosis virus of the larch sawfly, *Anoplonyx destructor,* is being prepared for publication.

Mr. W. H. Parry, of the *Forestry Department, University of Aberdeen,* reports on work on the Green spruce aphid, *Elatobium abietinum.* A study of the factors affecting survival of the aphids in winter was begun at Countesswells Forest (Aberdeenshire) and it was found that temperature was the main factor governing population size, with low night temperatures resulting in a fall in aphid numbers. Pockets of aphids that survived when air temperatures reached as low as −15°C appeared almost all to have been protected by an insulating layer of snow. Laboratory studies on effects of temperature on aphid survival and reproduction were also started, and work is also being done on the feeding behaviour of the aphids on Sitka and Norway spruce.

From the same *Department,* Dr. Myles Crooke gives an account of his work on Coal tit and Pine looper moth populations in Culbin Forest, Moray. It has now been possible to increase coal tit numbers in some plots by feeding with mixed nuts and it will now be possible to proceed with the original objective of the study, which aims to collect concurrent tit and pine looper population indices from areas differing in the degree of tit predation affecting the pine looper numbers.

Dr. D. H. Mills, of the *Department of Forestry and Natural Resources, University of Edinburgh,* has continued his studies on salmon and trout populations in the Glentress Burn, Peeblesshire. Information on the growth of brown trout in this stream is now almost complete and will be prepared for publication.

During the year, Dr. D. C. Malcolm, of the same *Department,* finished the collection of data for his project dealing with environmental factors and the growth of Sitka spruce. Ninety-six plots have now been sampled in forests distributed to cover relatively distinct climatic regions in four areas in Scotland. The data are being analysed to give information on the site relationships of Sitka spruce in the various regions, and an attempt will be made to use the information on the soil types to produce a profile index of site productivity.

Dr. L. Leyton, Dr. E. R. C. Reynolds and Mr. F. B. Thompson, of the *Department of Forestry, University of Oxford,* discuss work on the interception of rainfall by the forest canopy, dealing particularly with the results of work done over ten years to study the effects of thinning on interception and throughfall.

Mr. A. J. M. Heselden, of the *Joint Fire Research Organisation, Boreham Wood, Hertfordshire,* comments that for further progress in his work on forest and heath fires, emphasis must move from the experimental and theoretical studies now being summarised to the collection of data from wild fires.

PART I

Work carried out by Forestry Commission Research and Development Staff

RESEARCH DIVISION

FOREST TREE SEED

Service

As in all recent years, the central service work for the whole country (including much for private forestry) on seed procurement, extraction, storage, testing and distribution continue to be the main function of the Seed Section and as in previous years research on seed problems took second place.

Register of Seed Sources

The Register was again reduced by several seed stands. Nothing was added in view of the plans in hand for reducing the register still further owing to very large decreases in seed usage during the last ten years.

The main changes in the Register are as follows:

	Number of Stands	*Hectares*	(*Acres*)
Areas lost—Total	8	23·7	(58·5)
Clearfelled	3	19·4	(48)
Reduced in area	1	0·8	(2)
Windblown	4	3·5	(8·5)
Stands Thinned	4	8·3	(20·5)

Seed Procurement (*Table* 1)

At home there was not a very good crop of conifer seed, but it was roughly twice as good as the previous year when only 129 kg (287 lb) were collected. The total of 207 kg (457 lb) as listed in Table 1 consists only of those lots which were extracted by the end of forest year 1969, i.e. 31st March, and at that time there were still over 400 bushels of cones for extraction which should yield additionally about 200 lb of seed. The main species continue to be Scots pine with Sitka spruce (which gave the largest amount of seed for many years back) a close second. Over 50 per cent of the seed collected originated from selected and registered stands. As regards broadleaved species, sessile oak gave a sufficient amount of acorns for the Commission's requirements.

Seed import continued to be necessary and altogether 2,322 kg (5,108 lb) were purchased abroad, of which Sitka spruce, Grand fir, Noble fir and Red oak were the main species.

Seed Extraction

As in previous years, the extraction work was divided between south and north, i.e. Alice Holt and Millbuie (Ross-shire) respectively. In order to econo-

mise on extraction, it is proposed to centralise all work at Alice Holt when the total collection is below 2,000 bushels.

Seed Store

As less seed is now used, reduction of the seed stocks at the central refrigerated store has continued with present total stock standing at about 1,500 lb less than that held last year. With the exception of a chronic shortage of Hybrid larch the stock is sufficient for three years ahead and therefore the main effort during the next season will be concentrated on Hybrid larch and genetically superior seed lots of which the proportion in store continues to be insufficient.

It should be mentioned that the seed store also provides a storage service for private forestry and the Commonwealth countries, which together account for a yearly turnover of about 500 lb.

Seed Testing (*Table* 2)

During the period under review 650 samples were received for service tests. Seventy of the samples originated from outside Commission sources. As compared with last year there were about 130 samples fewer from the Commission seed stocks and 30 more from the outside sources. The total number of tests decreased by over 600 as compared with last year. This decrease was evenly distributed between research and service work.

TABLE 2

TESTS PERFORMED ON SEED

Kind of test	Service	Research	Total	Total of previous year
Purity	417	—	417	567
Seed size determination	588	15	603	660
Germination	929	195	1,124	1,338
Tetrazolium	25	5	30	23
X-Ray	6	—	6	5
Cutting	14	20	34	3
Moisture content	371	30	401	692
Cone test	—	24	24	18
Total	2,350	289	2,639	3,306

Seed Supply (*Table* 3)

In total the seed usage remained at a level similar to that of last year and private forestry required about 200 lb more conifer seed than the Commission. However, for individual species there were some significant differences, as private forestry required distinctly larger amounts of Scots pine, Norway spruce, European larch and Douglas fir, and smaller amount of Lodgepole pine, Grand fir and Noble fir than did the Commission. However, for both sectors Sitka spruce remained the main species.

The abbreviation letters against Lodgepole pine in Table 3 refer to six groups of provenances which are as follows:

(AL) Alaska
(NC) North Coastal (British Columbia)
(SC) South Coastal (Washington and Oregon, U.S.A.)
(SK) Skeena River Basin, British Columbia
(CI) Central and Northern Interior, British Columbia
(SI) Southern Interior, British Columbia.

Research

As mentioned in the opening paragraph, the execution of the research programme was impaired by the heavy load of service work and a shortage in staff at a supporting level. The current research programme is divided into six groups of projects which embrace the main problems in the service work.

Cone Processing

The importance of the problems involved is directly related to the size of home collections, which at the moment are not increasing as quickly as should be expected. The work is concentrated on optimum regimes of temperature and relative atmospheric humidity during cone drying processes.

Seed Processing

Seed de-winging, cleaning, drying and grading methods are involved. The most acute problem is the development of a safe de-winging machine, which is in its final stage. It is anticipated that very soon the nurseryman will start using graded seed and therefore preparations are being made to meet those requirements.

Seed Testing

The test methods employed in routine work are based on the prescriptions of the International Seed Testing Association Rules. However, for several species these prescriptions are not sufficiently precise and frequently several methods of testing are tried. By this means, evidence is being accumulated which is assisting in the improvement and standardisation of test methods. Unfortunately, the alternative of detailed experimental work on individual species is impossible at present owing to the weight of other work.

As time passes, the requirements of the modern nurseryman are becoming more sophisticated and he is asking for more and more precise information about the seed germination and dormancy and, therefore, the seed analyst must be aware of this fact and act quickly in order to meet these requirements.

Seed Storage

The Commission refrigerated central seed store has been in operation for ten years, and the vast amount of data accumulated during its use needs to be analysed in the near future. Although the routine storage procedures are soundly based the observations show that some consignments of *Tsuga*, *Thuja* and *Abies* species are not behaving as one would expect and therefore may warrant a special investigation.

Quick Determination of Seed Origin

The development of such a method is meant to serve as a safeguard against false declarations of seed origins from imports. This has occurred many times and caused a great waste of money through the sowing and planting of unsuitable provenances. The preliminary investigations so far confined to a study of seed and seedling morphology of Lodgepole pine are showing promise. This investigation is linked with a similar project in the Silviculture Section where a study is being made of plant characteristics. The techniques likely to be involved here may well require the development of new test methods of a more refined nature.

Interpretation of Test Results

This project is important because it aims directly towards the improvement of seedbed economy through more reliable forecasting of seedling production. The project amounts to the organisation of the feedback of information from the nursery. The results of this investigation should also have some influence on our testing and storage techniques. Unfortunately as yet no progress can be reported.

G. BUSZEWICZ

PRODUCTION OF PLANTING STOCK

In 1968, the main lines of research were again on fertiliser regimes, and in particular on the less soluble "slow-release fertilisers".

However, the amount of work on the production of special types of planting stock, e.g. tubed seedlings and "Nisula" transplants, increased and there were some preliminary experiments on new techniques of handling seed.

The nurseries in which experiments were laid down were:

England: Sugar Hill, Wareham, Dorset
Kennington, Oxford
Headley, Alice Holt, Farnham, Surrey.

Wales: Crumbland, Tintern Forest, between Chepstow and Monmouth

Scotland: Newton, Moray
Tulliallan, Clackmannanshire
Inchnacardoch, Inverness-shire
Benmore, Argyll
Fleet, Kirkcudbrightshire.
Bush, Midlothian.

In addition to the experiments described here, work was undertaken by Miss B. Benzian of the Chemistry Department, and Dr. G. A. Salt of the Pathology Department of Rothamsted Experimental Station (see accounts in Part II, pp. 139 and 147). Also several lots of plants for provenance and species trials were raised.

SEED DRESSINGS

Lithofar red and red lead were again compared as colourant seed dressings to test whether lithofar red was a suitable alternative to red lead. Auramine yellow, which had been tested in the previous two years, was excluded as it had no advantages and it was suspected of having carcinogenic properties. Experiments were carried out at Alice Holt, Kennington and Wareham nurseries on four species at each site.

For the third year running lithofar red performed at least as well as red lead, and rather better on all larch species. As in 1967 red lead dressings affected all three species of larch, which germinated satisfactorily but subsequently many seedlings turned yellow. At the end of the season this yellowing had disappeared, but both the numbers and height of European larch and Japanese larch were reduced compared with lithofar red or no dressing at all. Hybrid larch appeared to have completely recovered.

After three years it is possible to conclude that lithofar red is a suitable alternative to red lead for all species, and that it is a safer dressing for all larch species.

FERTILISERS

Late Season Top-Dressings on Seedbeds

Experiments were repeated for the third year at Alice Holt, Kennington and Wareham in which seedbeds of ten species in all were given late top-dressings of

54 kg/ha (48 lb/acre) of nitrogen (N) in mid-September, or 108 kg/ha (96 lb/acre) of potassium (K) in late-August, or both (NK). All species received a standard fertiliser regime prior to August of 57 kg/ha (51 lb/acre) phosphorus, 108 kg/ha (96 lb/acre) potassium, 36 kg/ha (32 lb/acre) magnesium and 109 kg/ha (98 lb/acre) nitrogen, the nitrogen being applied in two top-dressings in June and July.

The object of the late top-dressings was to raise the concentration of N and K in the seedlings with a view to testing the effect of nutrient concentration on resistance to extreme weather conditions (e.g. frost) and on the growth of seedlings as transplants in the following year.

As in 1966 and 1967, seedlings of nearly all species took up N from such top-dressings. Corsican pine was the least responsive species, differences in foliar concentration being negligible, but in all other species seedlings receiving late top-dressings of N had foliar concentrations 15–20 per cent higher than those which had no such late top-dressings.

These responses were, to some extent, predictable. By the end of the year colour deficiency symptoms were common on plots not receiving late N top-dressings and most species showed a marked colour response to additions of N in September. The period May to September was very much wetter than average at all three nurseries.

Responses to K were much more variable. At Alice Holt and Kennington there was no clear relationship between K levels in the foliage and late top-dressings, but at Wareham Sitka spruce and Norway spruce showed increases in foliar concentrations of K of 10–15 per cent after late top-dressings with K.

There were few unseasonable autumn frosts and little damage was observed. However, Sitka spruce (Washington) grew very late at all nurseries because of the mild wet weather in late summer, and a frost of 10°C (22°F) on 4th November, 1968, damaged a number of seedlings in all plots. A count of damaged seedlings showed that seedlings which had received late top-dressings of N had more than twice as many damaged plants as those which had received no N. Late top-dressings of K appeared to have no effect either way.

Residual Effects of Late Top-Dressings

As in the previous two years, seedlings which had received late top-dressings of N, K, or both in the previous year (1967) were put out in transplant lines to see if these treatments affected growth or resistance to extremes of weather the following year (1968).

Apart from slightly earlier flushing in most species on plants that had received late top-dressings of N, there were no significant differences between treatments. It should also be recorded that there were no severe, unseasonable spring frosts in 1968.

Slow Release Fertilisers

"Enmag" and Potassium Metaphosphate – Nutrition in Seedbeds and Transplants

The series of experiments comparing fertiliser regimes based on "Enmag" (see *Report* for 1968, p. 30), potassium metaphosphate or potassium superphosphate continued for the second year at Alice Holt, Kennington and Wareham.

On seedbeds there were some marked differences between regimes, especially at Kennington and Wareham.

"Enmag", as in previous years, gave most species a better start, but by the end of the season most were showing nitrogen deficiency symptoms. "Enmag" plus late top-dressings of nitrogen and potassium markedly improved colour, but these top-dressings did not affect growth. At Kennington and Wareham all species, except Sitka spruce, were significantly smaller under "Enmag" than under potassium metaphosphate or potassium superphosphate regimes.

In 1967, a season with about average rainfall, there was evidence that the nitrogen in "Enmag" did not carry seedlings of most species through the growing season. 1968 has clearly shown this to be true for very wet summers.

Other fertilisers were tested in the series of trials and there was an interesting contrast between two forms of nitrogen fertiliser—highly soluble "Nitro-chalk" and slowly soluble formalised casein. Formalised casein gave a much slower start at all nurseries, but seedlings of most species picked up later in the season. However, at Kennington and Wareham, although seedlings recovered much of their colour, most species were significantly smaller on formalised casein plots than on plots receiving nitrogen in the form of top-dressings of "Nitro-chalk".

On transplants differences were small and generally of little practical significance. "Enmag" regimes tended to produce slightly more vigorous transplants, although on plots receiving "Enmag" alone many species showed slight nitrogen deficiency symptoms by the end of the season.

Effect of Repeated Use of "Enmag" and "Kay-nitro" on Seedbeds and Transplant Lines

Two long-term experiments tested seedlings in 1968, one at Fleet which started in 1964, and one at Newton which commenced in 1967.

The experiment at Fleet nursery was sown with Scots pine, Lodgepole pine and Japanese larch. Results were basically similar to those given in the 1968 *Report*. Differences in end-of-season numbers were mostly small. Height growth was best in treatments involving "Enmag" application during 1968, or "Kay-nitro" during 1968 following "Enmag" in 1967. Repeated annual use of "Kay-nitro" without any basal fertiliser continued to give results as poor as those in plots which had received no fertiliser for five years. Apart from plots which had received "Kay-nitro" for two or more consecutive seasons, growth tended to improve with increasing rate of application of fertiliser. There was no evidence of any damage to seedlings resulting from the high rates of P and Mg applied in "Enmag".

The more recent experiment at Newton was sown in 1968 with Lodgepole pine, Sitka spruce, Japanese larch and Western hemlock. High rates of "Enmag" or potassic superphosphate tended to reduce seedling numbers in comparison with treatments receiving top-dressing only. Western hemlock numbers also appeared to be reduced by high rates of top-dressing. In contrast to the Fleet experiment, potassic superphosphate with "Kay-nitro" top-dressing gave the best height growth, except in the case of Japanese larch where "Enmag" gave the best results. Plots treated with "Kay-nitro" for two consecutive seasons gave results little better than the unfertilised control plots. In most cases, growth increased with the higher application rates, although there appeared to be some fall-off with the highest rate of "Enmag" (providing 300 kg/ha (270 lb/acre) of nitrogen), particularly with Western hemlock.

At Newton, Tulliallan and Benmore, transplants were tested in long-term experiments (mentioned in the 1968 *Report*) which continued for their second season. Only Lodgepole pine and Sitka spruce could be included in 1968, as stock of the more sensitive species Western hemlock and Grand fir were not available.

For both the species used, differences in end-of-season survival and growth were generally small both between regimes and between rates. At all nurseries the small difference between fertilised and unfertilised plots suggests that residual effects from former fertiliser treatment may still be obscuring any treatment differences. There was slight evidence of better growth with the higher fertiliser levels, implying that even at the very high rates involved (up to three times normal) no damage was being done to the lined-out plants.

Results of a similar experiment established at Fleet nursery in 1968 differed from those of the three older experiments. Both Lodgepole pine and Sitka spruce showed significantly greater height growth with "Enmag" than with potassic superphosphate and "Kay-nitro" top-dressing, and growth increased with increasing rate of application. The difference may be due to the known magnesium-deficient nature of the soil at Fleet.

"*Enmag*" *Particle Size*

In a 1964 trial, "Enmag" particle size was found to have little influence on seedling growth (see *Report* for 1965, p. 65). However, the "Enmag" now produced has a lower proportion of readily soluble nitrogen, and it was decided to repeat on seedbeds at two nurseries the comparison of large (4–6 mm diameter) and small (less than 2 mm diameter) particle sizes at three application rates (supplying nitrogen at 50, 100 and 150 kg/ha or 45, 89 and 134 lb/acre).

At the end of the growing season, Lodgepole pine and Sitka spruce seedling numbers at both Benmore and Fleet nurseries were unaffected by particle size or rate of application. On the other hand, height growth of Lodgepole pine was highly significantly better with the smaller size, and Sitka spruce growth was also better, but not significantly so. Both species showed highly significant height increases with increasing rate of application.

"*Enmag*"—*Sterilization Interaction*

Previous trials have suggested that "Enmag" fertiliser may be more effective in partially sterilized soil, and experiments to test this possibility were carried out at Inchnacardoch, Tulliallan and Fleet nurseries. Normal rates of "Enmag" and of potassic superphosphate with "Kay-nitro" top-dressing were compared with and without formalin sterilization, using Sitka spruce and Japanese larch as test species.

Generally, differences in end-of-season numbers were small and not significant. There were no significant differences due to sterilization and little evidence of any interaction between fertiliser and sterilization. However, at Tulliallan, larch numbers were much lower with "Enmag" than with potassic superphosphate, and "Enmag" also reduced spruce numbers at Inchnacardoch.

Height growth was generally significantly better with sterilization. The size of the response varied between nurseries, as did differences between fertilisers, with sometimes "Enmag" and sometimes potassic superphosphate giving the better plants. At Fleet, there was a highly significant interaction between

fertiliser regime and sterilization, apparently due to a somewhat greater response to sterilization of seedlings fertilised with potassic superphosphate. A reverse tendency was shown at Inchnacardoch and Tulliallan, but in neither case was the interaction significant. The results therefore provide little evidence in support of "Enmag" being more effective in sterilized soil.

Other Nitrogen Fertilisers in Combination with "Enmag"

In 1966, IBDU (isobutylidene diurea) and "Nitroform" (urea formaldehyde) were tried without much success as slow-acting nitrogen fertilisers (see *Report* for 1967, p. 31). With the co-operation of Scottish Agricultural Industries Ltd., further trials of these materials, in mixture with "Enmag", were carried out on seedbeds at Newton and Tulliallan. The materials were mixed with "Enmag" prior to granulation of the latter in order to see if a coating of the relatively insoluble "Enmag" would retard release of their nitrogen. A mixture of "Enmag", ammonium sulphate and ammonium phosphate was also prepared. All three mixtures, applied before sowing, were then compared with "Enmag" applied before sowing and followed by top-dressings of ammonium sulphate, and with potassic superphosphate similarly top-dressed. Three application rates provided 50, 100 and 150 kg/ha (45, 89 and 134 lb/acre) of nitrogen respectively.

At the end of the growing season, Sitka spruce and Douglas fir seedling numbers did not differ significantly between treatments. Height growth of both species at Newton and of spruce at Tulliallan was highly significantly better with normal "Enmag" or potassic superphosphate (both top-dressed with N) than with the other treatments. The two higher application rates resulted in somewhat better growth, but the difference was not significant.

It therefore appears from the results that granulating other nitrogen fertilisers with "Enmag" does not result in any effective reduction in their rate of nitrogen release. No further work is planned in this field.

"Enmag" and Potassium Metaphosphate—"Scorch" on Transplants and Long-term Effects

Experiments testing the danger of damage to transplants from regimes based on "Enmag" with potassium as KCl or K_2SO_4, potassium metaphosphate and potassic superphosphate, continued for a third year at Alice Holt, Crumbland, Kennington and Wareham.

Although Grand fir at Kennington showed "scorch" symptoms on old needles there was no difference between treatments. Noble fir at Wareham survived badly in all plots, but survived slightly better under potassium metaphosphate than under other regimes. Otherwise there were few differences between treatments, and it can be assumed that the wet season did not provide critical soil conditions for "scorch".

Soil samples were taken from all experiments at the end of the year and, in view of the reported increase in pH and soil magnesium levels in Scottish trials (see 1968 *Report*), the results in Table 4 are interesting.

pH appears to be little affected at this stage, although magnesium levels have built up under "Enmag" treatments. Clearly, magnesium levels build up after one year and it remains to be seen whether "Enmag" regimes result in a new equilibrium at a higher, but still non-toxic level.

TABLE 4

SOIL pH AND AVAILABLE MAGNESIUM (p.p.m.) AFTER "ENMAG"

Trials in Southern England – December 1968

Nursery	No. of years expt. has been on same plots	Soil Factor	Regime			
			"Enmag" (Cl)	"Enmag" (SO_4)	Pot. Meta-phosphate	Pot. Super-phosphate
Alice Holt	one	pH	4·2	4·3	4·2	4·2
		Mg (p.p.m.)	42	40	12	7
Kennington	three	pH	5·7	6·0	5·7	5·7
		Mg (p.p.m.)	132	138	54	51

Urea Derivatives

Three urea derivatives were tested in small trials at Newton and Tulliallan. Biuret, biurea and oxamide (supplied by Scottish Agricultural Industries Ltd.) applied basally before sowing were compared with ammonium sulphate applied basally and as two top-dressings in July and August. Three rates of application provided 50, 100 and 150 kg/ha (45, 89 and 134 lb/acre) of nitrogen respectively. All plots received a base dressing of potassic superphosphate at 690 kg/ha (5½ cwt/acre) and were split systematically for Sitka spruce and Douglas fir.

Differences in seedling numbers at the end of the season were inconsistent, but in general oxamide gave the poorest results. Effects on height growth were more clear cut, with ammonium sulphate consistently producing the best seedlings. Results with ammonium sulphate applied before sowing were surprisingly good, but in most cases application as a top-dressing had given the best results. Of the urea derivatives, biuret consistently reduced height growth, while growth with the other two was little better than plots with no nitrogen fertiliser. Differences due to application rate were small.

PAPER-MOUNTED SEED

A preliminary experiment was laid down at Alice Holt in 1968 to test paper-mounted seed as a method of precision placement of seed.

Seeds are precisely mounted between two thin sheets of absorbent tissue paper, crimping together of the two sheets holding the seeds in position. Machines currently available in this country can space the seed in rows 2·5 cm (1 in) apart, or multiples of this distance, by any desired spacing in the rows. For widely spaced rows it clearly becomes more practicable to have single-row strips.

Precision spacing in seedbeds may have a number of advantages. Better and more uniform utilisation of space may allow more seedlings to be raised per unit area and may result in a more uniform crop, both in height and root collar diameter. Precision spacing may enable undercutting techniques to be exploited to better advantage than in the past because it will facilitate more precise root pruning *in situ*, and also weed control.

Corsican pine and Sitka spruce were tested at four densities each, with 2·5 cm (1 in) between the rows and a range of four spacings from 1·9 cm (¾ in) to 4·4 cm (1¾ in) within the rows.

Both species germinated normally, except that Sitka spruce was very slightly delayed in emerging from the paper-mounted plots compared with hand-sown plots. Table 5 shows the results of end-of-season assessments for both species.

TABLE 5

NUMBER OF SEEDLINGS EXPRESSED AS A PERCENTAGE OF VIABLE SEEDS SOWN, MEAN HEIGHT AND MEAN ROOT COLLAR DIAMETER – PAPER-MOUNTED SEED AT ALICE HOLT, 1968.

Species	Assessment	Spacing (cm) in row					
		Hand Sown	1·9	2·5	3·1	3·8	4·4
Sitka spruce	Viable seed per sq. yd.	1,400	1,400	1,048	839	700	—
(germination capacity = 81%)	Seedlings as per cent viable seed	32	71	83	85	85	—
	Mean height cm (in)	5·1(2·0)	4·8(1·9)	4·8(1·9)	5·1(2·0)	4·8(1·9)	—
	Mean root collar diam. mm	1·74	1·73	1·74	1·74	1·71	—
Corsican pine	Viable seed per sq. yd.	964	—	1,204	964	804	688
(germination capacity = 93%)	Seedlings as per cent viable seed	62	—	76	84	93	102
	Mean height cm (in)	4·1(1·6)	—	4·3(1·7)	4·1(1·6)	3·8(1·5)	4·3(1·7)
	Mean root collar diam. mm	2·11	—	2·10	2·17	2·18	2·33

Differences in height and root collar diameter were small except that Corsican pine root collar diameter increased at wider spacing, but the large differences in the number of seedlings per unit number of viable seeds sown was unexpected.

Some of the differences between the hand-sown plots and the paper-sown plots may have been attributed to the absorbent paper presenting a more favourable germinating medium, but the fact that more seedlings were produced per unit number of viable seed at wider spacings is interesting.

It should be pointed out that the performance of hand-sown plots was much poorer than average in this particular experiment.

Experiments are continuing in 1969 to test this technique further.

WEED CONTROL

Simazine on Transplants

Experiments on the long-term effects of simazine, applied annually at 1·12, 2·24, 4·48 and 8·95 kg active ingredient per hectare (1, 2, 4, or 8 lb per acre) to newly lined-out transplants, continued into its seventh year.

Weed control was excellent at both Wareham and Kennington at rates of 2·24 kg (2 lb) and above. There was some simazine damage at Kennington at rates of 4·48 kg (4 lb) and 8·95 kg (8 lb) to birch and Douglas fir, but no damage to other species and no damage from any rate at Wareham.

Soil samples were taken from all plots by Mr. Clay of the Weed Research Organisation early in 1969 for bio-assay for simazine residues and possible chemical analysis. It is hoped to be able to give the results in next year's *Report*.

Dazomet on Seedbeds

The Soil sterilant dazomet is easy to apply compared with formalin or chloropicrin because it is in granular form. Besides the growth responses frequently obtained in seedlings following soil sterilization, it was possible that dazomet would give good weed control because it was reputed to be particularly effective in killing weed seeds in the soil.

Trials in the South

Experiments were laid down at Alice Holt and Kennington nurseries to test its value for weed control in particular.

168 kg/ha (150 lb/acre) or 336 kg/ha (300 lb/acre) were rotovated into depths of 11·5 cm (4·5 in) and 23·0 cm (9·0 in) in October 1967 and January 1968, and the surface sealed either by rolling or by covering with polythene sheeting. Two weeks after the January application all plots were rotovated to allow gases to escape and then six weeks later Norway spruce was sown at Kennington and Sitka spruce at Alice Holt.

At Alice Holt, although seedlings germinated evenly, many subsequently died. Deaths seemed clearly related to rates of dazomet applications, but there were anomalies. Sometimes controls were poorer than plots that had received dazomet and dying seedlings looked very similar to those on poor dazomet plots. Severe waterlogging was recorded in the alleyways round plots during and shortly after germination and the results suggest some interaction between dazomet and waterlogging.

At Kennington, waterlogging also caused a few deaths of Norway spruce in patches. There was no relationship between the affected plots and treatments. On the other hand, seedling height and numbers were slightly better under dazomet treatments than on the controls. This was attributed to soil sterilization by dazomet.

Dazomet gave weed control at both nurseries, but this was scarcely sufficient to pay for the cost of treatment. The most successful weed control was at Kennington where the best treatment, 336 kg/ha (300 lb/acre) rotovated to 23·0 cm (9·0 in) in January and then sheeted, produced an estimated saving in weeding time when compared with the worst control plots of 218 man-hours per year. At present-day labour costs, this is around £100 per year, but the cost of 300 lb. of dazomet and its application would certainly be very close to £100 per acre. Only the heavier, more weedy nurseries now have seedbed

weeding costs of over £100 per acre and it would appear that if dazomet has a place in forest nurseries, it will be only in this type of nursery where soil sterilization may also have beneficial effects on seedling growth and numbers.

Trials in the North

Experiments were carried out at three Scottish nurseries to test the effectiveness of dazomet as a weed killer and as a soil sterilant for Lodgepole pine and Sitka spruce seedlings. Dazomet at 168 and 336 kg/ha (150 and 300 lb/acre) was compared with formalin (38 per cent commercial formaldehyde) at 0·5 l in 5–10 l water/m^2 (0·1 U.K. gal in 1–2 U.K. gal water/yd^2). Applications in late autumn and late winter were compared and the effect of rolling to seal the soil surface after application was also investigated. Control plots were unsterilized, either with or without normal weedkiller spray treatment.

At all three nurseries, timed hand weeding indicated that dazomet had given a degree of weed control similar to that obtained using standard weedkiller sprays, with the higher rate proving slightly more effective than the lower one. Little effective weed control was obtained with formalin, which in one nursery appeared to have actually stimulated weed growth. Seedling numbers at the end of the growing season were usually lowest in the unsterilized control plots with no chemical weed control. Differences between the other treatments were not consistent but there was some indication that formalin tended to depress numbers slightly relative to dazomet, particularly in the case of Sitka spruce. At two of the nurseries (Newton and Fleet) height growth in formalin-treated plots was much superior to that in the dazomet plots, which was in turn considerably better than that in the unsterilized controls. On the other hand at Bush (Midlothian) results with dazomet were slightly better than those with formalin. In general it appeared that the higher rate of dazomet gave slightly better results than the lower rate. The effects of early and late application and rolling were not consistent.

In view of its weed control effect, coupled with at least some degree of beneficial soil sterilization, further trials of dazomet seem justified and it is hoped to carry these out in 1970.

PRODUCTION OF SPECIAL TYPES OF PLANTING STOCK

Tubed Seedlings (See Plates 13 to 15)

Work continued on the development of techniques for the production of tubed seedling stock. Three greenhouses were used for the purpose, two covered with polythene and one with conventional glazing. The former were sited at Inchnacardoch (Inverness-shire) and Tulliallan, and the latter at Newton. Valuable experience was gained in operating polythene houses and it became obvious that one of the most important factors in obtaining satisfactory seedling growth was the provision of adequate ventilation by means of large extractor fans.

As a basis for the trials, the "standard" techniques which proved successful in 1967 were used with only minor modification. Polystyrene tubes 7·5 cm long x 1·3 cm internal diameter (3 in x $\frac{1}{2}$ in) slit down one side, were filled with a mixture of equal parts by volume of horticultural peat and sand to which were added the slow-release compound fertiliser "Enmag" and ground limestone at rates of 1·5 kg/m^3 (1·5 oz/ft^3) and 0·5 kg/m^3 respectively. One seed, dusted

with a thiram seed-dressing, was sown in each tube and covered with a 3 mm ($\frac{1}{8}$ in) layer of medium sand. After sowing, trays of tubes were watered from below and then kept for 7 days at 26·7°C (80°F) before being placed in the greenhouse with day and night temperatures of 21°C and 10°C (70 and 50°F) respectively. Watering was carried out as required and a captan drench applied at weekly intervals during the first month. Using this technique, germination of both Lodgepole pine and Sitka spruce averaged 70 to 80 per cent and 60 to 75 per cent of tubes sown produced a "usable" seedling. Seedling heights at 8 and 12 weeks were 2·5 to 3 cm and 3·5 to 4 cm (1 to 1·2 in and 1·4 to 1·6 in) for pine, and 2 to 2·5 cm and 3·5 to 4 cm (0·8 to 1 in and 1·4 to 1·6 in) for spruce.

Similar experiments on the production of Lodgepole pine and Sitka spruce seedlings were carried out at all three nurseries and in the majority of cases it was possible to re-sow experiments during the second half of the growing season, following the 12-week final assessment of the first sowing. Results of the various groups of experiments are summarised in the following sections. A range of further experiments is planned for 1969, concerned mainly with continued testing of fertiliser regimes and with improving the yield of usable seedlings.

Soil Material for Filling Tubes

Six soil materials were investigated for suitability:

(i) Horticultural granulated peat;

(ii, iii and iv) Mixtures of granulated peat and medium sand in the proportions 2:1, 1:1 ("standard" mix) and 1:2 by volume;

(v) John Innes seed compost mixture (2 parts sterilized soil: 1 part peat; 1 part sand);

(vi) Levington potting compost.

"Enmag" fertiliser and ground limestone were added at rates of 1·5 kg/m^3 (1·5 oz/ft^3) and 0·5 kg/m^3 respectively to all except the Levington compost which already contained fertiliser.

Results from all experiments were very similar and showed that there was little to choose between the three peat/sand mixtures and John Innes seed compost mixture as regards germination, height growth, usability and root development. Pure peat tended to give slightly poorer results while Levington compost proved much inferior to the other soils.

Seed Cover Depth and Time of Application

A comparison was made of five depths of seed cover, namely: 0, 1·6 mm, 3·2 mm, 4·8 mm and 6·4 mm (0, $\frac{1}{16}$ in, $\frac{1}{8}$ in. $\frac{3}{16}$ in and $\frac{1}{4}$ in)—using medium sand. Two times of application were compared—immediately after sowing and after a delay of five days, the latter included because of its successful use in tubed seedling work in Alberta, Canada.

At all the nurseries, assessment of germination, height and usability showed similar results. In general the "standard" depth of 3·2 mm ($\frac{1}{8}$ in) was best for both species, closely followed by 1·6 mm: 4·8 mm usually gave results only slightly inferior to those for 3·2 or 1·6 mm. The deepest cover depth (6·4 mm) depressed germination and growth, while "no cover" gave very poor results, with high losses after germination and frequent abnormal seedling development.

There were no worthwhile differences related to time of application and covering at time of sowing is obviously preferable on grounds of convenience.

Fertiliser Regime

The type of fertiliser regime best suited to tubed seedlings was investigated in two related series of experiments in which a 1:1 mixture of peat and sand was used for filling the tubes. In addition a further experiment compared various peat—"Enmag" composts prepared specially by Scottish Agricultural Industries Ltd.

In the first series, the regimes compared were:

(a) "Enmag" at 1·5 kg/m^3 of soil mix (1½ oz/ft^3) with and without top-dressing with ammonium sulphate solution (12 g/l);

(b) potassic superphosphate (Fison's 48) at 0·75 kg/m^3 of soil mix, top-dressed with solutions of ammonium sulphate (12 g/l), urea (6 g/l) or Fison's FL3P (a general-purpose complete liquid fertiliser—6 ml/l);

(c) Fison's FL3P with no basal fertiliser.

Top-dressings were applied 4, 6 and 8 weeks after sowing. In each case, ground limestone at 0·5 kg/m^3 was added to the peat-sand mix before sowing.

There was some indication that germination was best in the FL3P treatment which had no fertiliser added to the soil mix prior to sowing, but differences between treatments were usually small. As regards height growth and usability, results were not consistent but, "Enmag" without top-dressing, potassic superphosphate with FL3P top-dressing and FL3P alone appeared to give the best results. Many Lodgepole pine seedlings and some Sitka spruce seedlings were killed by urea top-dressing, and ammonium sulphate also damaged some seedlings of both species: both materials therefore appear to be unsuitable for top-dressing such young seedlings.

The second series was concerned primarily with nitrogen nutrition, comparing:

(a) "Enmag" at 1·5 kg/m^3 of soil mix without top-dressing ("standard" treatment);

(b) Top-dressed using ammonium sulphate at 12 g/l, urea at 6 g/l, ammonium nitrate at 9 g/l and "Nitro-chalk" at 12 g/l (in effect ammonium nitrate with some calcium in solution);

(c) "Enmag" at 6 kg/m^3, without top-dressing.

As in the first series, the top-dressings were applied 4, 6 and 8 weeks after sowing.

The high rate of "Enmag" (four times the "standard" rate) consistently depressed germination and gave reduced height growth and usability for both species. In most cases the "standard" rate of "Enmag" without top-dressing gave results equal to or better than those obtained with the best top-dressing treatments. As in the first series many seedlings of pine and some of spruce were killed by urea application, and some seedlings of both species were killed by ammonium sulphate treatment.

In the remaining experiment, various types and rates of "Enmag" fertiliser were compared with potassic superphosphate. One of the main objects was to determine whether or not the degree of potassium solubility in the normal type of "Enmag" ("Enmag" 283) had any harmful effects on seedling growth. The

rates used were 1·5 kg/m^3 of normal "Enmag" (or amounts of the other materials providing similar quantities of N and/or K) and four times and sixteen times the above rate.

The most important factor influencing seedling germination and growth was rate of fertiliser application. Sixteen times the standard rate (24 kg/m^3 "Enmag" 283 or equivalent) gave by far the poorest results and was obviously excessive for the conditions of the experiment. Of the other two rates, the lowest (1·5 kg/m^3) gave better germination of both Lodgepole pine and Sitka spruce, while the intermediate rate (6 kg/m^3) gave slightly better height growth. It is interesting to note the difference between results from this experiment and from the first series described above, in which "Enmag" at 6 kg/m^3 gave much poorer results than "Enmag" at 1·5 kg/m^3; the difference may be due to the use of a peat-sand mixture in the first series as compared with undiluted peat in the present case. As regards type of fertiliser, potassic superphosphate gave poorer results than any of the "Enmag" fertilisers. There was no evidence to suggest that potassium solubility in "Enmag" affects seedling growth.

Tube Length

A comparison was made of 7·5 cm, 10 cm and 12·5 cm (3, 4 and 5 in) tube lengths to determine whether or not any problems would arise if seedlings were grown in tubes longer than the standard 7·5 cm size. Results from the three nurseries were not entirely consistent, but there appeared to be little differences between the 7·5 cm and 10 cm lengths, while the 12·5 cm length tended to give somewhat poorer germination and growth. It is possible that the longest tubes dried out more rapidly than the shorter sizes after watering or, alternatively, that trays of the shorter sizes benefited to some extent from shading by trays of the longest size.

Preliminary Trial of Grand Fir Production in Tubes

In view of the proposed extension of tubed seedling trials to include replanting of felled areas and the potential usefulness of Grand fir on such sites, a preliminary investigation was made of the behaviour of the species when sown in tubes. As was anticipated, the start of germination was much delayed in comparison with Lodgepole pine and Sitka spruce and, once started, proceeded very slowly and irregularly. Approximately 12 per cent of unstratified seed germinated, while seed given cold-wet stratification for two weeks prior to sowing gave negligible germination. A considerable number of the seedlings which germinated subsequently died from what appeared to be fungal damage, despite regular use of a fungicidal drench.

Work will continue in 1969 on this difficult species.

"Nisula" Transplants

Preliminary trials were carried out at Alice Holt and at Inchnacardoch on the use of the Finnish "Nisula" technique for raising balled-rooted transplants. In brief the method involves placing seedlings on bands of fertilised peat laid on a polythene strip which is then rolled up so as to sandwich peat and seedlings between layers of polythene (see Plate 16). The completed rolls are then stood upright on level ground and tended as necessary until the plants are large

enough for forest use—usually in one growing season or less. Rolls are transported intact to the planting site and each tree is then planted complete with the "ball" of peat which adheres to the root system.

The potential advantages of "Nisula" stock are:

(1) reduced planting check and higher survival after planting;

(2) suitability for successful summer planting;

(3) reduction in the period required to produce a desired size of transplant.

During 1968, Lodgepole pine, Corsican pine, Sitka spruce, Norway spruce, Douglas fir, Western hemlock and Grand fir were all raised successfully in rolls and will be tested in the field. The stock produced was satisfactory in shoot size and form, and had an extensive but compact and densely fibrous root system, considerably superior to that of conventional transplant stock.

Nursery trials with various systems based on the "Nisula" method will continue in 1969, along with other methods of mass-producing ball-rooted stock.

R. M. BROWN

A. J. LOW

SITE STUDIES AND THE ROLE OF MINOR SPECIES

Site studies are being made to assess the capability of sites to grow the commonly planted forest species. Sites are likely to be placed first into groups of areas each able to support the same range of species under a given silviculture. A tree will be included in the species list for a given area only if it there achieves a minimum height of 15 metres (50 ft). The major groups of areas will then be subdivided into smaller groups in which the various species within them give the same relative performance. These secondary groupings will be further subdivided into groups of sites in which the most productive species have the same yield class.

The data on site, crop and soils for the first attempt at such a classification have been obtained from approximately 500 sites in England, Scotland and Wales. The sites are mostly in pairs, one of each pair carrying a crop of one or other of the four minor species, Western hemlock, Western red cedar, Grand fir or Noble fir, the other carrying one of the more widely planted species. The data is at present being processed for computation for multiple regression and principal component analysis.

The evaluation of Western hemlock, Western red cedar, Grand fir and Noble fir is being taken further to include an assessment of their likely place in British forestry. In this assessment, the critical factors are (a) relative growth rates, (b) timber properties, and (c) susceptibility to heart rot (*Fomes annosus*). A report on this aspect of the work is expected in the next year.

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PROVENANCE

Lodgepole Pine

The experiment sown in 1967 at Newton Nursery, Moray, which was mentioned last year (*Report* for 1968, p. 65), continued to show highly significant differences in height growth between provenances in the transplant lines. Owing to favourable conditions in the late summer there was much lammas growth on certain provenances (notably those from Washington and Oregon coasts) while those from Alaska had virtually none. Differences between provenances were highly significant for both height and lammas growth, and a co-variance analysis of height and lammas growth showed that these were significantly related.

The selection of fifteen provenances from relatively dry areas and limestone districts sown at Wareham, Dorset, in 1967, grew into very vigorous plants in their second year in the nursery on a poor, acid sand.

New experiments containing twenty-four of these provenances from eight main seed regions are being planted in 1969 at Rumster, Caithness, on an extremely poor bog; at Glengarry, Inverness-shire, on a moderately poor bog and at Strathardle, Perthshire, on a heather moor site. They should extend our knowledge of the growth of Alaskan provenances and enable a comparison to be made of nine lots from the Skeena and Bulkley River valleys of northern British Columbia. Selected provenances will also be planted in the reference collection at the Dalnessie section of Shin, Sutherland, increasing the total represented there to thirty-two seed origins.

Jack Pine

Twenty provenances of Jack pine (*Pinus banksiana*) supplied in 1959 by Mr. Mark Holst, Petawawa Forest Experiment Station, Ontario, from his "All-Range" collection, were planted in 1961 at Inshriach, Inverness-shire, and the Broxa section of Allerston, Yorkshire. Six years after planting there were significant differences in height at both sites, but a surprisingly wide variation in the ranking of provenances. For example, the tallest provenance at Inshriach is from Oconto, Wisconsin, which was only tenth at Broxa, while the tallest one at Broxa (Winter Harbor, Maine) was thirteenth at Inshriach. Comparing the latest assessment with earlier ones shows marked fluctuations in performance, and until some stability is achieved it would be rash to suggest where these trends are leading. A full summary will be prepared when the trees are ten years old.

Pinus ponderosa

Eight provenances covering the main area of this species in Washington and Oregon have been planted out at Cannock, Thetford and Bedgebury, with Corsican pine as control at the first two sites.

Norway and Sitka Spruce

Because Sitka spruce is our most important species, even small improvements in productivity, health and frost resistance are likely to repay the cost of further provenance research. Last year an experiment was planted at Glendaruel,

Argyll, with 37 provenances in small plots, of which 25 were replicated. The seed mostly originated in a collection organised by Dr. J. Burley. It is planned to participate in the new seed collection being gathered by the International Union of Forest Research Organisations. The full range of provenances is unlikely to be available for two years.

A new experiment with twenty-six provenances of Norway spruce was planted at Minard, Argyll. This collection contains the same seed origins planted last year at Halwill, Forest of Dean and Cannock.

The International Trial of 1,100 provenances, planted in Salisbury Forest in April 1968, has survived very well, less than one per cent of the plants having died. Growth is variable, but it is noticeable that those trees which were tall when planted (up to 61 cm, 2 ft) grew much less than those of about 15 cm (6 in), many of which have more than doubled their height. Four hundred of these provenances were successfully established at Drummond Hill, Perthshire, and Minard last year. The two Minard experiments are complementary, as the new experiment has larger plots which will provide data on productivity, while the earlier one covers the whole range of the species.

Japanese Larch

In 1957 Professor W. Langner of Schmalenbeck sent seed of twenty-five provenances, collected by Dr. Iwakawa of the Government Forest Experiment Station in Tokyo, to Britain and a number of other countries. The seed was sown in a replicated nursery experiment at Tulliallan, Fife, and early performance was noted in the *Report* for 1959, p. 50. The small quantity of seed restricted the numbers available for planting, so that it was possible only at Fetteresso, Kincardineshire, to have the full twenty-five provenances. At Broxa, Yorkshire, there are twenty provenances, and at Ystwyth, Cardiganshire, there are fifteen. Plots of a seedlot from a commercial bulk collection from Nagano supplied by the Sanwa Co., are an integral part of the experiment at Broxa and occur as demonstration plots at Fetteresso. A similar seed lot from plantations on the Hokkaido Island in the north of Japan (where it is an exotic) is also included.

At Fetteresso the site is a moderately exposed (244 m, 800 ft) peaty podzol, tine-ploughed before planting. Growth and survival at three years were good, and height differences between provenances were highly significant. Regressions were calculated for third-year height on elevation, mean annual temperature, and annual rainfall at seed source and on the weight of 1,000 seeds and height as a one-plus-one transplant. Site factors at source had little effect on height growth, but there was a significant regression on seed weight and the regression of third-year height on transplant height was so highly significant that it clearly explains most of the variation.

In their fifth year, differences in autumn colour and leaf-fall were given a visual score. Differences between provenances were very highly significant, Rengeyama, 2,180 m (7,150 ft), being the first to shed its leaves. Provenances from less than 1,520 m (5,000 ft) at Fujiyama and Kurokochi stood out as they retained their leaves much longer, but there was no clear relationship of leaf-fall with elevation of seed source, as some high elevation origins were still green when others from the bottom of the elevation range were in an advanced stage of leaf-fall. A parallel assessment carried out at Broxa showed a very similar pattern of leaf-fall.

The following spring, flushing stage was assessed and this also showed very highly significant differences between provenances, though no obvious pattern associated flushing stage with elevation or other characteristics of the parent site. There was also little relationship between the two phenological characters. It seemed possible that the tallest provenances might be those which flushed early and shed their leaves late, thus having a long growing season, but examination of the data did little to confirm this hypothesis. There appeared to be a relationship between twig colour and flushing stage; in general, trees with light-coloured shoots flushed later, but there was considerable variation in twig colour within most provenances. A flushing assessment at Broxa gave very similar results.

Height was assessed at six and ten years and the changes in ranking between these assessments were not very large. The tallest provenances were from the Suwa region of Nagano Prefecture (Reizan, Yatsugatake) and from the lower slopes of Mount Fuji. All the tallest provenances came from an elevation between 1,680 m and 1,830 m (5,500 ft and 6,000 ft). The poorest provenances were from places on the periphery of the natural range or else from very high elevations.

The extent to which early performance reflects later height growth is of some interest, as it is often necessary to take provenance decisions on early results. With these larch provenances, if one compares their rank as one-year seedlings with that after ten years in the forest there are some notable changes. The Reizan lot advanced from eleventh place to first, while Nishidake fell from second to eleventh. Two of the Mount Fuji provenances had poor nursery heights but advanced in rank steadily at each later assessment.

The Broxa site was a typical *Calluna* moor at 168 m (550 ft) elevation, with an ironpan soil and patches of local bad drainage. It was ploughed with an "R.L.R." plough. After the first growing season the trees were taller at Broxa than at Fetteresso, chiefly because the plants supplied to Broxa were twice as big as those at Fetteresso. There was a partial check at Broxa and at three years the Fetteresso trees were taller. As this might have been caused by phosphate deficiency, the experiment was top-dressed with ground mineral phosphate in 1963. There is no doubt that the site is less uniform at Broxa, and after six years the level of significance of the differences between provenances in height was lower than at Fetteresso. The trees were then taller at Broxa and this difference increased at the tenth year. Both at six and ten years there is a broad general agreement between the heights of the different provenances at the two sites, though there are some unexplained anomalies: Mizunoto and Akanagi were the tallest origins at Broxa, but only sixteenth and twentieth in rank at Fetteresso.

The commercial collection from Nagano grew nearly as fast as the best from the natural stands at both sites. The Hokkaido origin (whose original provenance farther south in Japan is unknown) was taller than any others; this may be partly due to its larger size at planting (as 1+ 1 + 1's), the lead being maintained at all later assessments. On general principles, the selection exercised by growing a crop at a higher latitude than its source, and then collecting from the best-adapted individuals, is likely to be beneficial and a small nursery test is being carried out with further Hokkaido seedlots. Apart from the general conclusion that the best provenances are from mid-elevations in the Suwa region of Nagano, it is difficult to specify the most suitable areas for seed supply to Britain, as provenances at similar elevations and located close to the successful ones have given rather poor results in these experiments.

Western Hemlock

In 1959 a collection of eighteen provenances was obtained and sown at three nurseries (Benmore, Argyll; Fleet, Kirkcudbrightshire; and Wareham, Dorset). Early performance was noted in the *Reports* for 1961 and 1962. At this date, as some success had been obtained in planting this species in a series of species trials on bare ground in the North, the risk of early failure was accepted and so of twelve experiments planted in the north in 1961 and 1962, all but one were without overhead cover (see Table 6). They were mostly arranged in pairs with a favourable and an exacting site in each region.

In the south, this trial was planted on seven sites. These included an open moor high in North Wales and a sheltered valley in Somerset, both without high cover, and sites under high cover varying from a steep slope with high rainfall, under larch in mid-Wales, to shallow sands on a dry site under Scots pine in Thetford.

Two of the northern experiments have been written off because cold, drying east winds in 1963 killed almost every plant, after excellent early survival. This same exceptional winter was responsible for extensive damage at many other sites and one can only speculate on what might have been the result with less severe conditions during the establishment phase. Experiments at Glenerrochty, Glenclova and Naver have been repeatedly damaged by blasting winds in winter, and results for Glenerrochty are not reported here.

The results of a height assessment on the sixteen remaining sites are given in Table 6, at six years after planting for thirteen of the sites, five years for one and seven years for two sites. The mean height of the tallest provenance is given for six years at all sites to enable comparisons to be made among them all. The mean height of each provenance at each site is expressed as a percentage of that of the tallest at the same site and these percentages are also ranked.

Many of the northern trials have scarcely emerged from check, whilst those on better sites or under shelter have been growing steadily for several years, so that the position may well change greatly in the next few years. As it is, some valuable indications are shown which may not be so visible at a later stage. The results seem at first to have no simple pattern, but if the growth of the five most variable provenances is examined a consistent pattern emerges. The provenances Juneau, Masset and Enumclaw rank very high in Sites 1 to 8 and Site 10, and very low in the other seven (Table 7).

The provenance from Leaburg, Oregon and the lot originating at Inveraray, Argyll, however, rank very low on Sites 1 to 8 and Site 10 and near the top on the other seven. The sites can therefore be divided into two groups according to the growth of any of these five provenances. The sites in Group 1 are those in the north and in Wales with no high cover and those in Group 2 are all the sites with high cover, together with Brendon, which has no cover but is in the warm south-west.

More broadly, if we confine our attention to provenances ranking in the first, second and third positions, among the nine sites in Group 1, the six highest ranking provenances, occupying 43 of the possible 54 top positions, are from the Queen Charlotte Islands or to the north of them, and from high-altitude Enumclaw. In contrast, at the seven sites in Group 2 none of these provenances is anywhere within the first six.

The Juneau provenance was so outstanding at Loch Goil that the next was only 67 per cent of its height; whereas on other sites the shortest provenance

TABLE 6

MEAN HEIGHT AS A PERCENTAGE OF THE TALLEST PROVENANCE AND RANK OF WESTERN HEMLOCK AT SIX YEARS ON SIXTEEN SITES

	Lat. (°N) Alt. (m)	Rainfall mm		Site of Experiment (North to South) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Juneau Alaska	58½ <150	2,100	% of tallest	97	60	82	100	100	90	99	95	71	90	76	64	59	82	65	74
			Rank	2	4	5	1	1	7	2	3	17	3	13	17	18	17	18	17
Prince Rupert N.B.C.	54½ <150	2,500	% of tallest	100	77	100	82	54	77	92	100	78	84	71	77	70	84	70	67
			Rank	1	5	1	4	5	18	3	1	10	6	16	13	15=	15	16	18
Terrace N.B.C.	54½ <150	1,300	% of tallest	76	62	68	72	56	82	83	90	80	87	73	76	75	84	70	81
			Rank	5	9	13	5	3	14	11	5=	8=	5	15	14	14	14	15	14
Masset Q.C.I.	54 <150	1,400	% of tallest	77	83	79	88	67	100	100	93	75	93	74	82	69	93	80	85
			Rank	4	3	7	3	2	1	1	4	15	2	14	11	17	7	11	11
Skidegate Q.C.I.	53½ +600	1,500	% of tallest	54	74	93	63	48	90	81	72	84	*100*	81	85	83	93	77	81
			Rank	6=	7	2	8	6	8	12	13=	7	1	9	7	10=	8	13	13
Shuswap Lake Cent. B.C.	51 +900	700	% of tallest	—	75	—	56	46	77	—	84	80	77	68	82	83	83	77	87
			Rank	—	6	—	11	9	17	—	9=	8=	10	18	12	10=	16	12	9
Courtenay Vancouver I.	49½ <150	600–1,000	% of tallest	49	100	77	67	48	88	90	83	86	73	86	83	86	97	89	95
			Rank	10	1	8=	6=	7	9	4=	11	5	12	7	9	9	3	8	2
Alberni Vancouver I.	49½ <150	1,700	% of tallest	54	65	80	46	46	93	85	67	75	79	88	76	88	95	86	88
			Rank	6=	8	6	17	8	4	7	16	14	7	5=	15	6=	5	9=	7
Ladysmith Vancouver I.	49 <150	600–1,000	% of tallest	48	96	72	48	45	84	84	70	90	66	70	93	88	98	92	91
			Rank	11	2	10=	16	10=	12	10	15	3	17	17	3	6=	2	4	6
Sooke Vancouver I.	48½ <150	600–1,000	% of tallest	44	46	69	67	42	82	88	86	85	68	96	98	88	95	100	87
			Rank	12	13	12	6=	15	15	6	8	6	15=	3	2	6=	6	*1*	8
Camano I. N. Washington	48 <150	480	% of tallest	39	54	56	49	40	85	76	64	77	68	85	100	95	93	99	100
			Rank	14	11	16	15	17	11	13	18	11	15=	8	*1*	3	9	2	1
Forks N. Washington	48 <150	2,900	% of tallest	50	40	72	58	45	83	85	84	77	73	88	82	78	95	91	82
			Rank	9	18	10=	10	10=	13	9	9=	12	11	5=	10	13	4	5	12
Enumclaw Washington	47 +1,300	1,200	% of tallest	88	60	88	96	56	92	90	87	75	89	79	64	82	90	68	76
			Rank	3	10	3	2	4	6	4=	7	16	4	10	18	12	11	17	16
Randle S. Washington	46½ +500	1,580	% of tallest	51	54	60	62	45	95	85	96	88	79	78	89	91	89	90	93
			Rank	8	12	14	9	10=	3	8	2	4	8	12	4	4	10	7	4
Cascadia Oregon	44½ 300	1,580	% of tallest	37	44	57	52	37	86	68	67	76	68	89	86	90	89	90	95
			Rank	16	14	15	14	18	10	15	16=	13	14	4	6	5	12	6	3

	Lat. (°N) Alt.[5] (m)	Rainfall mm		Site of Experiment (North to South) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Leaburg Oregon	44 500	1,450	% of tallest Rank	43 13	42 16	85 4	56 12	41 16	79 16	68 16	74 12	94 2	78 9	100 1	83 8	100 1	89 13	86 9=	86 10
Avondale Co. Wicklow	53 100	1,270	% of tallest Rank	35 17	40 17	77 8=	53 13	44 13	92 5	65 17	72 13=	50 18	69 13	78 11	71 16	70 15=	78 18	72 14	75 15
Inveraray Argyll	56 50	2,160	% of tallest Rank	38 15	43 15	49 17	46 18	43 14	97 2	69 14	90 5	100 1	66 18	97 2	88 5	98 2	100 1	94 3	93 5
Tallest (m)				0·75	0·88	1·35	0·62	1·06	1·77	0·87	0·74	2·81	1·38	3·02	1·98	2·84	3·5[1]	4·0[2]	3·3[2]
(ft)				2·46	2·88	4·47	2·03	3·49	5·82	2·84	2·42	9·20	4·53	9·91	6·50	9·32	11·5	13·1	10·8
Significance				***	***	***	—	***	***	***	***	***	—	—	***	—	***	—	—

[1,2] Estimates, for comparisons of sites from 5 yr and 7 yr data respectively.

	Site	*County*	*Lat. °N*	*Alt. m*	*Alt. ft*	*Rainfall mm*	*Cover*
1.	Naver	Sutherland	58½	100	300	1,190	—
2.	Strathardle	Perthshire	56½	200	650	1,070	—
3.	Faskally	Perthshire	56½	200	650	960	—
4.	Glenclova	Angus	56½	400	1,300	1,500	—
5.	Loch Goil	Argyll	56	170	500	2,800	—
6.	Benmore	Argyll	56	75	250	1,400	—
7.	Laurieston	Kirkcudbrightshire	55	230	750	1,350	—
8.	Gisburn	Yorkshire	54½	230	750	840	—
9.	Wykeham, Allerston Forest	Yorkshire	54½	190	625	815	+
10.	Clocaenog	Denbighshire	53	440	1,450	1,100	—
11.	Rheidol	Cardiganshire	52½	230	750	2,000	+
12.	Thetford	Norfolk	52½	40	130	610	+
13.	Brecon	Brecon	52	380	1,250	1,150	+
14.	Brendon	Somerset	51	140	460	1,200	—
15.	New Forest	Hampshire	51	80	260	900	+
16.	Lulworth	Dorset	50½	100	325	900	+

was usually about 65 per cent of the tallest and several were within 90 per cent or more. Loch Goil is the site with highest rainfall, but Juneau has a lower rainfall than Prince Rupert, the provenance from which here grew to only 54 per cent of the height of the plants in the Juneau plots.

TABLE 7

WESTERN HEMLOCK: SITE RANKINGS OF THE FIVE MOST VARIABLE PROVENANCES

Provenance	Sites (North to South)															
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	9	*10*	11	12	13	14	15	16
Juneau	*2*	*4*	*5*	*1*	*1*	*7*	*2*	*3*	17	*3*	13	17	18	17	18	17
Masset	*4*	*3*	*7*	*3*	*2*	*1*	*1*	*4*	15	*2*	14	11	17	*7*	11	11
Enumclaw	*3*	10	*3*	*2*	*4*	*6*	*4*	*7*	16	*4*	10	18	12	11	17	16
Leaburg	13	16	*4*	12	16	16	16	12	*2*	9	*1*	8	*1*	13	9	10
Inveraray	15	15	17	18	14	*2*	14	*5*	*1*	18	*2*	*5*	*2*	*1*	*3*	5
Area	S	S	S	S	S	S	S	NE	NE	W	W	EE	W	SW	SE	SE
Cover	—	—	—	—	—	—	—	—	+	—	+	+	+	—	+	+

Area: S Scotland
NE Northern England
W Wales
EE Eastern England
SW South-west England
SE South and South-east England.
Cover: — absent
\+ present.

The effects of high cover and southerly situation are somewhat confounded in this experiment, but there are indications that lack of cover has a greater effect in the north than in the south. Benmore (without cover) fits Group 1, where northern provenances are well ahead of southern, although the site is fairly sheltered and on the mild west coast. However, Brendon in the south, also without cover, is firmly in Group 2. Wykeham, slightly further north than Clocaenog, but a much less exposed site, has high cover and fits in Group 2, whereas Clocaenog, an open site, is well in Group 1.

That the altitude of the site may have an influence here is shown by the growth of the Inveraray provenance. This was the tallest of all at Wykeham (cover: 190 m, 625 ft altitude) and at Brendon (no cover: 140 m, 460 ft) and second at Benmore (no cover: 75 m, 250 ft), but shortest of all at Clocaenog (no cover: 440 m, 1,450 ft) and Glenclova (no cover: 400 m, 1,300 ft). Rainfall seems to be important only in the case of Camano Island provenance, from a very dry region, and this is not consistent, being outweighed by other factors on northern sites. Camano Island plots rank low on all sites in Scotland and northern England regardless of rainfall, but are the best of all in the two areas of highest evaporation/rainfall ratios—Thetford and Lulworth, especially on the shallowest soil at Thetford. It is also very good at one high-elevation, low-evaporation site, at Brecon.

It is too early to choose provenances for wider use from the evidence here, but indications at this stage are that for exposed sites in northern areas a choice should be made from the northern and high-altitude provenances from Juneau, Prince Rupert and Masset, while for sites with overhead cover or in the more southerly parts of the country the southern, low-altitude provenances from Leaburg and Camano Island, together with the home-collected seed from Inveraray, should be used. A good all-round provenance from the middle of the range is that from Courtenay, Vancouver Island. The other provenances at present show no special promise.

Douglas Fir

Twenty-nine provenances acquired through the International Union of Forest Research Organisations (I.U.F.R.O.) to sample hitherto unknown regions and to test different sources from known regions of promise, were sown last year. Cold easterly winds over a long period since January have caused browning and some top-dieback among the seedlings in the south. This is well correlated with provenance, and is confined to those provenances from South Oregon and from California. At Newton and Tulliallan nurseries frost damage affected the same provenances but it began in late autumn. In the Brookings, Oregon, provenance a quarter of the trees were unfit to line out. Collections made for I.U.F.R.O. during 1968 have filled in several gaps in the earlier collection and thirteen more provenances have been ordered.

Silver Firs

The *Abies alba* trial at Radnor has recovered from the frost damage of three years ago much more rapidly than had been expected. Browsing by deer has restricted growth in the Scottish experiments. The small-scale trials with *A. grandis* and the larger-scale sampling of the range of *A. concolor* var. *lowiana*, including the overlap or transition area between the two, will all become valuable supplements to a larger experiment. Through I.U.F.R.O. a large number of samples from most parts of the range of *A. grandis* are being acquired. *A. procera*, with a much more restricted range, will also be tested more intensively.

R. LINES

A. F. MITCHELL

CHOICE OF SPECIES

TRIALS OF SPECIES ON GLEYS

Growth Problems in Pole-Stage Sitka Spruce

Control measures and assessments continued in the three experiments that were established in 1967—at the Forest of Deer (Aberdeenshire), Rosarie Forest (Banffshire) and Fetteresso Forest (Kincardineshire)—to study the influence of defoliation by the Green spruce aphis *Elatobium abietinum* on the increment of pole-stage Sitka spruce crops.

At all three sites aphis populations remained at a very low level throughout the growing season, with no appreciable difference in numbers between sprayed and unsprayed plots. Despite this, assessment at the end of the 1968 growing season in the Deer and Rosarie experiments revealed that basal area increment in the sprayed plots had been considerably higher than that in the unsprayed plots. At Deer, the average difference in favour of the sprayed plots was 0·54 m^2/ha (1·9 ft^2 qg/acre) or 16 per cent of the increment in the unsprayed plots, while at Rosarie the difference reached the very high figure of 0·68 m^2/ha (2·3 ft^2 qg/acre) or 36·6 per cent. There seems little doubt that these differences in increment resulted from the *Elatobium* damage sustained in the unsprayed plots during 1967, when high population levels were recorded. Foliage retention at the end of the 1968 growing season was visibly better in the sprayed plots, which could readily be picked out by their denser canopies from the unsprayed surrounds and control plots. In addition, average crown depth was greater in the sprayed plots. Somewhat surprisingly, the differences in foliage retention and crown depth were twice as large at Deer as at Rosarie.

At Fetteresso, which did not suffer to any marked extent from *Elatobium* damage during 1967, there were no differences in increment or foliage retention between sprayed and unsprayed plots.

A. J. LOW

TRIALS OF SPECIES ON FREELY DRAINED SITES

No new trials were planted out, but some failed plots of rare and tender species were replanted with other rare but less tender species. The collection of Mexican species at Plym Forest in Devon have grown exceptionally well and the more general experiment there is now well established with some very vigorous plots.

A number of experiments now twenty to thirty years old, but showing little of value, will be assessed finally and closed.

TRIALS OF SPECIES ON OTHER SOILS

Industrial Waste Sites

In 1967 and 1968 small-scale trials of Lodgepole pine, Hybrid larch, Common alder and hawthorn were made on behalf of the Livingston New Town Development Authorities, in the Central Lowlands of Scotland. Plants directly notched or in pots were planted in three successive years on three different aspects of one "shale bing" complex, none of which had a cover of ground

vegetation. (Shale bings are high mounds of burnt-out oil shale, remaining from the now discontinued shale oil industry, which heated the deep-mined minerals in retorts to drive out oil.)

Chemical analysis of this burnt-out shale gave pH values between 7·5 and 8·9 with traces of free lime. Phosphorus and potassium levels were less extreme, but water soluble sulphate (of which normal soil contains about 0·003 per cent) ranged from 1·8 per cent to 5 per cent rising to 7·6 per cent in deep raw shale.

Lodgepole pine foliage was analysed in 1968 and although N, P, K and Mg levels were low in spite of complete fertilisation, sulphur levels were not unduly high.

Potted plants have been generally superior in survival and health but no marked differences have resulted from different planting season. Alder and sycamore are the most promising species. The survival and condition of plants on the three blocks have differed very widely, partly due to climatic factors and partly to variation in the "bing" material.

Contact was maintained with the National Coal Board especially to review problems of tree planting on open-cast and other difficult sites. Trials to test methods of improving the quality of semi-mature trees and large "standards" presently being raised in special orchards established by the Board were considered. A number of notable restoration schemes currently being undertaken by local authorities, as well as studies being carried out on industrial sites by university departments, also came under review, and in several cases special plants were supplied and advice given on choice of species and planting methods.

Chalk Downland

A review of methods of planting and cultivating beech on Chalk downland has recently been undertaken and it is likely that a small-scale investigation will be started to study some of the outstanding problems revealed.

S. A. NEUSTEIN

J. JOBLING

TRIALS ON HIGH AND EXPOSED SITES

Scotland and Northern England

Two representative peatland areas totalling 3·2 ha (8 acres) have been acquired on North Uist, an island in the exposed Outer Hebrides, and on them various provenances of Lodgepole pine and Sitka spruce, pure and in mixture, will be compared with one another. An adjacent experiment comparing a range of nutritional inputs will guide future nutrition of the main experiment. Chemical analyses of peat show these areas to be broadly similar to the well-documented Lon Mor Experimental Area (Inverness-shire).

A similar trial is proposed in the Weardale Beat of Hamsterley Forest (Co. Durham), where two plots ranging in elevation between 579 m (1,900 ft) and 655 m (2,150 ft) have been demarcated. Here the plantability of approximately 283 ha (700 acres) above the current limit is to be tested.

Following discussions with Conservancy and Acquisition staffs, it appears that there is now a reasonable cover of trial plantations in all the more obvious regions of potential expansion with the exception of the Grampians. A site has been selected at Queen's Forest near Aviemore, Inverness-shire, rising to 608 m

(2,000 ft) to determine whether high inputs in terms of complete cultivation and nutrition could raise the plantable line on the Grampians, which is now at the elevation of the trials planted by Professor M. L. Anderson in 1929.

A considerable number of high elevation pilot trials has been planted since 1946 by northern Conservances and recorded by Research Division (so-called SM 82 plantation). Their condition was briefly summarized in the *Report* for 1965 and one important, though rather unsatisfactory conclusion was that ground vegetation (especially the relative abundance of *Calluna*) outweighed any elevational effect. Rather than wait indefinitely for trees to overcome prolonged check, approximately thirty-five of the plantations have been assessed and NPK fertilisers prescribed where appropriate to alleviate check and PK deficiencies.

A series of five experiments planted on acid grassland in 1963 and 1965 comparing standard and "luxury" establishment methods for sycamore has been concluded. The object was to determine whether the post-planting check so common with this species could be overcome, thereby providing a guaranteed procedure for use, particularly in the Northern Isles where this species is much appreciated for shelter. The "luxury" treatment included pit-planting, added lime(stone), farmyard manure and complete fertilisation plus mulching. The treatments were replicated six times at each site but the results are inexplicably inconclusive. At one forest (Kirroughtree, Kirkcudbrightshire) all the trees with "luxury" treatment made immediate and rapid growth while all normally-established plants died back and were shorter after six years in the field than at planting. However, this result was not repeated at any other forest where, at best, some gain in survival was recorded with occasional, marginal gain in growth. It has been decided that further work on this project is not justified.

S. A. NEUSTEIN

Wales

Tatter flags and anemometers have been maintained at five sites in Wales. Data covering a five-year period are now available and it has therefore been decided to remove the instruments from most of the sites. Work is to continue at Radnor Forest and to a lesser extent at Mynydd Du.

The species trial at Beddgelert Forest planted in 1929 in the form of a Latin Square continues to provide interesting information on the relative performance of various species at high elevation. Thinning in Series IV, elevation 485–525 m (1,590–1,730 ft) will be carried out during the summer of 1969. Foliar analyses of samples from the experiment suggest that phosphate may be beneficial, and so fertiliser will be applied in Spring 1969.

Use of Pre-Potted Plants

Previous work at high-elevation sites in Wales has shown that young plants are at their most vulnerable stage during the winter following planting. Adverse weather conditions usually cause planting to be delayed until the late spring. Plants taken from cold-store in May have made little growth, particularly root growth, by the end of the growing season. An experiment was established at the Radnor Forest high-elevation site in 1968 to investigate the benefit of pre-potting Sitka spruce transplants and of providing artificial shelter. The treatments used were: "Pre-potting" in February of one-plus-one transplants in black whale-hide pots (of 105 mm = 4¼ inch diameter) with Levington No. 2

Compost and "Sheltering" with 40 cm (16 in) circular screens of clear reinforced plastic. All plants were given 85 g (3 ozs) of 1:2:1 NPK fertiliser when planted in late May. The pre-potted plants were planted without removing the pots, but these had completely disintegrated within two to three weeks of planting.

Results obtained at the end of the first growing season are given in Table 8. Spare plants were excavated from the surround of the experiment and the measurements given in Table 9 indicate the increased size of the pre-potted plants. Photographs of representative samples of these plants are shown in Plates 2 and 3.

TABLE 8

RADNOR EXPERIMENT 37A
Pre-Potting and Shelter; Results after One Growing Season.

Treatment	Total height cm (ft)	Length of Lammas growth, cm (ft)	Number of side shoots
Pre-potted	39·6 (1·30)	6·0 (0·20)	4·3
Pre-potted and Sheltered	48·2 (1·58)	11·6 (0·38)	8·2
Planted from cold-store	29·3 (0·98)	2·4 (0·08)	0·7
Cold-store and Sheltered	31·4 (1·03)	2·4 (0·08)	1·0
Least significant difference (at 1 per cent)	4·2 (0·138)	2·2 (0·073)	1·90

TABLE 9

INCREASED SIZE OF PRE-PLOTTED PLANTS

Measurements made	Sitka spruce 1 + 1 planted out in late May	
	Direct from cold-store	Pre-potted in February
Initial height, cm (in)	15·25 (6·00)	15·85 (6·24)
After one growing season:		
Total height, cm (in)	25·00 (9·84)	34·25 (13·48)
Root collar diam, cm (in)	0·50 (0·19)	0·75 (0·29)
Oven dry weight, g (oz):		
Shoot	4·7 (0·17)	13·4 (0·47)
Root	1·5 (0·05)	4·5 (0·16)
Total	6·2 (0·22)	17·9 (0·63)

Although a full assessment after the first winter has not yet been made, the larger potted plants do not appear to have suffered from the severe weather conditions experienced at Radnor.

The substantial benefits resulting from pre-potting can perhaps be attributed to a number of factors. As the plants were kept in lowland conditions before planting they had a growing season at least two months longer than the cold-stored plants. This is likely to be of importance when the normal growing season is about 175 days (six months) at 610 m (2,000 ft) elevation (Howe,

1961). Also the balanced fertiliser in the potting compost was available to the plants as soon as root growth started. The nursery root system no doubt continued to function after planting.

Although the cost of pre-potting as carried out in this instance may be prohibitive for normal establishment work the results of this experiment indicate the possible gains from careful plant handling. Further trials using pre-potted transplants and seedlings are currently being carried out at high-elevation sites in Wales. In addition, trials of other forms of specialised planting stock are being carried out in other areas.

REFERENCE

HOWE, G. MELVYN (1961). Climatic sub-regions of Wales. *Forestry* **34** (1), 75–81.

J. EVERARD

BASAL BOWING OF SOUTH COASTAL LODGEPOLE PINE

This defect of the fastest-growing exposure-resistant provenances continues to cause concern. In recent years repeated references to it have been made in *Reports* and for clarity these are summarized below.

(a) Phosphate, given either in delayed applications at standard rates or in minute doses at planting time, has been tested and found generally unsuccessful in overcoming the problem.

(b) A hormone growth inhibitor (B-9) at a wide range of levels has proved unsuccessful.

(c) Nine other planting and nutritional treatments have been compared in three experiments in 1966 but the trees have not yet reached the susceptible height. The expectation of success with any of these is not high.

(d) Tubed planting stock has been planted on testing sites in the hope that it will lead to less root damage at planting and maintain a better root/shoot ratio and so reduce basal bowing. The trees are not yet tall enough to be susceptible.

(e) Assistance has been given to two post-graduate studies of conversion-loss and compression wood in older South Coastal Lodgepole pine.

(f) Provenance trials suggest that South Coastal Lodgepole pine is at least 20 per cent more productive in volume than straighter, inland provenances which are alternatives on relatively sheltered sites. On exposed sites the alternative North Coastal provenances compare even less favourably with South Coastal for volume production. It can, therefore, be more profitable to plant South Coastal Lodgepole pine and accept increased loss on conversion due to basal bow than to plant alternative provenances.

(g) A partial evaluation of this project has been completed and has emphasised its economic importance. A survey of extent and degree of basal bow and its correlation with exposure has been planned.

ATMOSPHERIC POLLUTION

Proposals to establish new industries in Ross and Cromarty have involved a consideration of potential atmospheric pollution hazards. Close contact is being

maintained with the appropriate divisions of the Scottish Development Department and other interested bodies.

The monitoring of sulphur dioxide levels around the Westfield gasworks (Fife) by means of lead dioxide candles has been terminated after nine years. Final analysis of data in relation to wind direction and SO_2 emission is in hand.

MEASUREMENT OF EXPOSURE BY EXPOSURE FLAGS

The centralised production and assessment of tatter flags by Research staff at Kielder Forest is proceeding satisfactorily. More than two hundred flags are currently exposed. Analysis of wind records from a sample of meteorological stations shows that there is considerable variation in windiness between years and between stations, and this emphasizes the need to treat results as relative within a given period and site. It is hoped that by analysing past data it may be possible to confine exposure of flags to the winter months and thereby effect worthwhile economies.

S. A. NEUSTEIN

TRIALS OF SPECIES WITH SPECIAL CULTURAL AND SITE REQUIREMENTS

Poplars

Varietal Studies

The closure of uninformative trials has continued during the year and work has been confined to the measurement at a few selected sites of the faster-growing commercial cultivars and of trial clones of potential commercial importance. *Populus trichocarpa* 'MB' remains one of the best clones under trial, partly because it has consistently shown good resistance to bacterial canker since it was first included in disease tests in 1952, and its release to the nursery trade in the near future is presently being considered. Measurements recently carried out in the earliest-planted plots suggest that its production will usually be rather better than that of clones of *P.* x *euramericana* currently cultivated for timber. Data from a 15-year-old plot at Flaxley, Forest of Dean, and from the Forestry Commission Management Tables for Poplar Yield Class 120, are given in Table 10 for comparison.

TABLE 10

Populus trichocarpa 'MB' – FLAXLEY, FOREST OF DEAN, HEIGHT, GIRTH AND VOLUME AT 15 YEARS.

Clone	No. of trees per hectare (acre)	Mean ht m (ft)	Mean breast height diam cm (girth, in)	Basal area per hectare m^2 (ft^2 qg)	Volume per hectare over bark m^3 (h ft per acre)	Av. vol. per tree m^3 (h ft)
Populus trichocarpa 'MB'	298 (120)	22·8 (74·8)	26·1 (32·3)	16·6 (56·98)	163·9 (1841)	0·55 (14·6)
Populus x *euramericana* (Yield Class 120)	185 (75)	19·3 (63·5)	28·3 (35·0)	12·0 (41·0)	90·9 (1020)	0·49 (13·6)

The data for *P. trichocarpa* 'MB' are based on trees planted 5·5 m (18 ft) apart, and those for *P.* x *euramericana* in the Management Tables on trees 7·3 m (24 ft) apart.

The clonal collection housed in the Populetum and in the varietal collection remained unchanged during the year. Nearly 320 clones have been planted in the Populetum, though not all are established, and the varietal collection contains near 500 clones.

Silvicultural Studies

The long-term experiments on pruning, spacing in plantations and cultivation of poplar with an understorey continued to be maintained and assessed. The experiment at Cannock Chase (Staffordshire), in which the effects on vigour of different pruning intensities are being compared, again confirmed that annual pruning restricted to the lowest whorl hinders radial growth least of any treatment.

In the spacing experiment at Lynn Forest (Norfolk), in which the production of veneer log timber at four different stockings is being studied, substantial wind damage occurred in early autumn. Damage was largely confined to stem breakage at a height of 6 to 8 m (20 to 26 ft), though it was unrelated to any previous high pruning treatment. The greatest damage occurred in plots with trees initially at a spacing of 4·3 m (14·0 ft) which had just been thinned. The variety in this case, *P.* 'Serotina', is not prone to stem breakage, but a few other poplars producing large leaves, such a *P. generosa*, have this reputation.

Elms

Varietal Studies

Further selections of English elm, *Ulmus procera*, were made during the year, particularly to study methods of propagation from softwood cuttings. So far this elm has proved the most difficult to raise in large quantity, by any method, and it is intended to compare the rooting ability of material of a number of different origins. No further selections are being made of other species or hybrids, except of Dutch elm, *U* x *hollandica* var. *hollandica*, which merits further study on account of its high timber quality and ability to grow well in woodland and to reproduce freely from sucker growth.

The Commelin elm, *U* x *hollandica* v. 'Commelin', an artificial hybrid introduced from Holland in 1954, continues to show good resistance to elm disease (*Ceratocystis ulmi*) in trials and its use on a wider scale, particularly for ornament, appears to be well justified. Of the British elms examined only Huntingdon elm, *U* x *hollandica* var. *vegeta*, several selections of which have been rigorously tested during the past few years, is fairly resistant.

Silvicultural Studies

Work has been confined mainly to methods of establishing transplanted rooted cuttings in the forest. Though well-grown stock usually survives well and grows quickly after planting out, it tends in the first two or three years to be unstable and, especially on wet soils, windblow of quite vigorous trees can occur with attendant staking problems. The effects on stability of deep planting, and of cutting back the main stem to the root collar, are presently being studied at Alice Holt Forest and at Lynn Forest (Norfolk). Preliminary results suggest that survival is not affected by either treatment, but no useful information is available yet on treatment effects on stability. Attempts to improve root development of softwood cuttings were undertaken during the year at Alice Holt and

Kennington Nurseries, but no useful progress can be reported. Cuttings normally develop roots only from the calloused basal portion and treatments to stimulate root growth from other parts of the cutting have so far not been successful.

Eucalyptus

A new Eucalyptus trial was established in Glenbranter (Loch Eck) Forest (Argyll) in order to study under forest conditions the growth and yield of some of the hardier species currently showing promise in the Kilmun Arboretum collection. 100-plant plots of E. *coccifera* (2 origins), E. *gunnii*, E. *pauciflora*, E. *simmondsii* and E. *urnigera* were planted, together with a smaller plot of E. *mitchelliana*. The site chosen is on a steep, relatively fertile slope which formerly carried a crop of Norway spruce, and should provide conditions suitable for studying the potential of the various species.

Leyland Cypress

Work continued in the nursery to improve the rooting of cuttings in heated frames. The benefits of bottom heat were again demonstrated but automatic mist irrigation, thought to aid cutting survival, actually depressed the rate of rooting compared with periodic hand watering.

J. JOBLING

A. J. LOW

ARBORICULTURE

Arboreta and Forest Plots

At Kilmun Arboretum, near Dunoon (Argyll), clearance of trees windblown in January 1968 has now been almost completed and it is planned to replant most of the windblown plots during 1969. The opportunity is being taken to expand the *Eucalyptus* collection by using one of the larger windblown areas for new plots of various species. New groups planted during 1968 included *Larix griffithii*, *Pseudotsuga flahaultii*, *Abies vejari*, *Cupressus sempervirens* and *Sciadopitys verticillata*. The Short Guide to the arboretum mentioned in the 1968 *Report* was scheduled for publication in June 1969. (Now available as *Kilmun Arboretum and Forest Plots*, H.M.S.O. 2s.)

Pending completion of an access road, little progress was made in clearing windblown plots at Crarae Arboretum, near Minard Forest, Argyll. Groups of *Abies procera*, *Alnus incana*, *Nothofagus dombeyi* and *N. procera* were planted during 1968.

At Bedgebury in Kent further clearance of rhododendron scrub-layer has improved the areas south of Marshall's Lake and below Yew Bank. The slope below the car park has been planned by the Committee to contain a vista and to combine landscaping with the addition of many species. The path from the car park is being planted with representative species from each of the main genera, to be fully labelled for instructional purposes.

In the Bedgebury Forest Plots, new plots of *Alnus glutinosa*, *A. cordata* and *A. rubra* were planted and eight plots of provenances of *Pinus ponderosa*.

At Westonbirt in Gloucestershire a comprehensive plan for the development of a large area of Silk Wood has been drawn up, with advice from the Advisory Committee, and work is starting on the clearance of the main ride system. Part of the Waste has been further opened up and underplanted with many new species, including a collection from Mexico. The opening of a large clearing in Wigmore has been completed. This will contain additions to the collections of *Betula* and *Sorbus*. The encroaching sides of Morley Ride have been cleared from the specimen trees and shrubs.

The Advisory Committee has been re-formed as a Consultative Committee. The new coloured guide was published in August (*Westonbirt in Colour*, H.M.S.O. 2s.).

A check-list of species represented and their top heights is being prepared.

Arboricultural Records

The register of size and location of specimen trees now includes more than 28,000 trees of 952 species.

A. F. MITCHELL

A. J. LOW

PLANTING

Planting Methods

Assistance has again been given to Work Study Branch in the assessment of survival and growth of trees planted by various hand methods. Differences between methods were not great, though in one experiment trees planted on stepped turfs were more stable and larger than those planted on top of the ridge.

Mechanisation

With the very helpful co-operation of the British agent for the firm concerned, trials have been carried out with a new planting machine, the Finn Forester Tree Planter. This was first demonstrated on a clearfelled pine site at Thetford Forest, where an appraisal carried out by Work Study Branch justified purchase. As the machine is capable of only superficial screefing, its scope lies either on sites not requiring deeper cultivation or on sites already ploughed.

Feasibility trials on completely ploughed and conventionally ploughed heathland were carried out at Aultmore Forest (Banffshire) and on spaced-furrow ploughing at Kielder. On complete ploughing, planting rates well in excess of 1,000 plants per hour were achieved with good survival and the machine should readily find a place whenever this degree of cultivation becomes prevalent (see *Report* for 1967, pp. 43–44). Spaced-furrow ploughing provides peculiar difficulties and it has been planned, in co-operation with Work Study Branch and the importer, to modify the machine to cope with this type of ground preparation.

Spacing

A study of the effects of radial growth rate on wood quality of Sitka spruce was carried out by the Forest Products Research Laboratory, using material from the 32-year-old spacing experiment at Durris Forest (Kincardineshire). The findings suggest that wood density declines with increasing growth rate and since spacing affects vigour, wood from trees grown at different spacings can therefore be expected to differ in density.

The importance of this in relation to management practice has still to be determined, but in view of the present trend towards wider plant spacing an early assessment of the probable consequences seems highly desirable. To provide part of this information a comprehensive study has begun on wood properties of Sitka spruce as influenced by initial spacing and subsequent thinning practice. The initial work for this will be carried out in a spacing experiment at the Forest of Ae (Dumfriesshire), planted at four spacings in 1935 and 1936 and subjected to two distinct thinning regimes.

Use of Seedlings

Farquhar (*Report* for 1965, pp. 154–168) reported on experiments in which one-year seedlings and transplants (mainly one year plus one year) of five common species were planted for comparison at Glen Trool Forest (Kirkcudbrightshire) on sites with varying depths of peat. He found that at six years after planting the trees raised from seedlings were between half and three-quarters the

height of those raised from transplants. To find out whether the seedlings would even out this difference when properly established an assessment was made at 10 years of age.

The results were analysed as before by depth of peat, elevation, vegetation type and species. They show that, with two exceptions, transplants of all species on all vegetation types maintained, and in most cases increased, their lead over seedlings between the sixth and tenth years. Transplants generally increased their lead to a greater extent on the higher than on the lower elevations. However, the lead of transplants in height should be considered both in absolute terms (usually 15–30 cm (6–12 in), with a maximum of 100 cm (40 in) for Norway spruce) and also in relation to total tree heights. Of the 41 comparisons of seedling and transplant heights at six years and ten years, 35 showed a reduction in the relative advantage of the transplants. In other words, although the actual differences increase the relative differences decreased.

Calculations of the economic effects of using seedlings show that if the displacement in height growth persists, the delay of about one year results in a loss of about £7·4 per hectare (£3 per acre) of discounted revenue for Yield Class 120. Alternatively, if the depression in growth by using seedlings is regarded as a crop of lower Yield Class with the same rotation length, then there is a loss of about £10 per hectare (£4 per acre) in discounted revenue. Although there is no intention of using one-year seedlings today, these results could be relevant to the investigation on tubed seedlings, though initial results suggest these are capable of quite rapid early growth.

S. A. NEUSTEIN
G. G. M. TAYLOR
R. LINES

Forest Use of Tubed Planting Stock

As noted in the 1968 *Report*, experimental work began in 1967 on the use of tubed seedlings in the afforestation of poor, exposed land in the north of Scotland. Six small experiments, three on wet heathland at Glen Garry Forest (Inverness-shire) and three on deep peat at Naver Forest (Sutherland), were planted with 8–12-week-old Lodgepole pine and Sitka spruce seedlings between August and October of that year. Both sites suffered from considerable wind exposure.

During 1968 these experiments were assessed for seedling survival after the first winter, and for survival and height at the end of the first full growing season after planting. Detailed comparisons of the various treatments involved are not justified because nursery problems during 1967 made it difficult to ensure consistency in quality of the seedlings used in the experiments. Taken as a whole, however, the experiments provided very valuable preliminary information on early survival and growth of tubed seedlings on the two sites, and on some of the major factors likely to influence performance of such stock.

On the tine-ploughed peaty podsol site at Glen Garry, overall survival after the first winter was 93 per cent in all three experiments (excluding seedlings treated with two animal repellents, "Aaprotect" and "Curb", which proved to have toxic effects on such young stock. Most of the planting was done with spruce seedlings, but where comparison was possible there was little difference between spruce and pine. Many seedlings showed some signs of winter exposure damage (dead needles and occasional dead shoot tips). Almost 80 per cent of

the seedlings had been affected to some extent by frost-lift and 30 per cent had had their tubes lifted more than half-way out of the soil. In a few extreme cases the tube had been lifted completely out of the soil and left lying on the surface. It was noted that frost-lift was less pronounced where the tubes had penetrated at planting to the peaty layer below the mineral soil in the plough ridge, and that it had rarely occurred where the tube was largely or wholly in peat.

At the end of the 1968 growing season (i.e. 12–14 months after planting), survival at 80–91 per cent had fallen only slightly since spring and most seedlings appeared healthy with only occasional signs of browsing damage.

Mean heights in Sitka spruce ranged from 3 to 9·5 cm (1¼ to 3¾ in) with individual plant heights of 10 cm (4 in) or over occurring fairly frequently. The lowest values were found for October-planted seedlings, which had barely increased in height since planting. Lodgepole pine, planted in September only, had a mean height of 5 cm (2 in). At time of planting the mean height of both species was 2·5–3 cm (1–1¼ in).

On deep peat at Naver Forest, the overall survival after the first winter was 86–88 per cent in two experiments planted in August on double mouldboard ploughing. Signs of exposure damage were reported, particularly on Sitka spruce, which frequently had the terminal bud damaged. In the third experiment, planted in September with Lodgepole pine only and designed to compare growth on single mouldboard ploughing with stepped planting and on double mouldboard ploughing without stepping, survival on the former was 100 per cent and on the latter only 18 per cent with survivors showing signs of exposure damage. This difference is almost certainly attributable to the shelter provided by the planting step on the single mouldboard ridges, but it is surprising that the survival on the double mouldboard ploughing was so much lower than that in the other two experiments also planted on double mouldboard ploughing only one month earlier. Only occasional signs of slight frost-lift were found, in contrast to the severe frost-lift on mineral soil at Glen Garry.

At the end of the 1968 growing season (i.e. 13–14 months after planting), survival was unchanged and most plants appeared healthy. In the two August-planted experiments, both pine and spruce had a mean height of only 5 cm (2 in). Particularly in the case of the spruce this low figure was probably a reflection of the winter shoot damage, which had caused many seedlings to become bushy and multileadered. In the third experiment the mean height of Lodgepole pine step-planted on single mouldboard ploughing was 9 cm (3½ in), with individual tree heights ranging up to 21 cm (8¼ in), as compared with 5 cm (2 in) for the survivors on unstepped double mouldboard ploughing. This superiority of height growth provides further evidence of the value of the shelter provide by the planting step on this exposed site.

In one experiment at Naver the roots of a sample of seedlings were excavated 13 months after planting and it was found that both Lodgepole pine and Sitka spruce seedlings were developing vigorous, well-balanced root systems, with maximum root lengths of up to 16 cm (6¼ in) in the peat outside the tubes. There was little sign of any tendency for roots to remain in the vicinity of the tubes and the general appearance of root development augured well for future growth and stability of the young trees.

During 1968 a further 11 tubed seedling experiments were planted. Most of these were situated at the Glen Garry and Naver sites first used in 1967, and at a new deep peat site in Tighnabruaich Forest (Argyll). Single experiments were

also planted on peat sites at Rumster Forest (Caithness), Shin Forest (Sutherland) and Selm Muir (Midlothian). The most important factors under test in these experiments are:

(1) Seedling age at planting and date of planting, with 8 and 12-week-old seedlings planted at 4-week intervals from May to October;

(2) Nature of soil mix used for filling the tubes;

(3) Length of tube.

Early indications are that growth in these experiments will be distinctly better than in the 1967 series, particularly with seedlings planted in the first half of the growing season, a period which could not be investigated in 1967. On the peat sites, seedlings planted between May and July had frequently grown 8 cm (3 in) or more by the end of the growing season, with Sitka spruce somewhat better than Lodgepole pine. Growth on the podsol site at Glen Garry was slower, but was reasonable in view of the dry summer experienced there. Reports of animal browsing, primarily by hares and black game, were more frequent than in 1967, but in only one case, at Selm Muir, was the damage serious.

On the assumption that tubed seedlings will prove to be a satisfactory type of planting stock, a costings exercise was carried out in which it was estimated that the large-scale use of tubed seedlings in North Scotland Conservancy alone could lead to annual savings of up to £40,000 in establishment costs. This was based on the assumption of a future annual planting programme of 4,800 ha (12,000 acres) of which 70 per cent would be on peat and so, on present knowledge, suitable for use of tubed seedlings. The savings would arise in part from a considerable reduction in nursery costs and in part from a very marked reduction in planting costs. The assumed programme could be undertaken by a considerably smaller labour force than that existing at present. Alternatively, if the present size of labour force were maintained then a much increased planting programme could be carried out in the Conservancy.

An expanded experimental programme is planned for 1969 on sites similar to those used in 1968, with the aim of further investigating the use of tubed seedlings for afforestation purposes. It is also proposed to initiate work at Glenbranter (Argyll), Kielder (Northumberland) and Allerston (Yorkshire) on the use of tubed stock for replanting felled areas. Use of tubed seedlings in such circumstances may help to avoid or reduce the period of post-planting check which has often been experienced with normal planting stock.

A. J. LOW

NUTRITION OF FOREST CROPS

Manuring of Crops on Deep Peat (Project 346)

After five growing seasons, Lodgepole pine at Racks Moss, Mabie Forest, Dumfriesshire (*Report* for 1967, p. 49) is beginning to show responses to different rates of potassic superphosphate applied at planting and as later top-dressings. The rates of fertiliser applied so far (after nine years the second and third treatments will have had the same total amount of P and K as the first) and some of the results are shown in Table 11. The heaviest rate continues to show rapid height growth, as does the control treatment which is 564 kg/ha (504 lb/ac); this is encouraging, since the latter is the standard recommended for planting on such sites. The lowest original rate has responded to the top-dressing in 1967 and is now growing faster than the middle rate. The contrast between the last two treatments is also of interest, showing the beneficial effect of early potassium dressings.

In the top-dressing experiment on Lodgepole pine/Sitka spruce mixtures at Arecleoch Forest, Ayrshire (*Reports* for 1966, p. 32; 1967, p. 49) in which different rates of potassic superphosphate and potassium metaphosphate are compared, the best growth is still being achieved by the middle and high rates of potassic superphosphate which supply 77 kg P + 94 kg K/ha (69 lb P + 84 lb K/acre) and twice these amounts. However, although P and K levels in the foliage are still adequate after five growing seasons, growth is falling off and this coincides with falling nitrogen levels in the foliage. This trend is especially noticeable with Sitka spruce and is probably due to competition from the heather, which will be sprayed in order to observe the duration of the response to the PK fertilisers.

The difference between the effects of potassic superphosphate and potassium metaphosphate on foliage nitrogen concentrations has been commented on in previous *Reports*: another nitrogen effect, the stimulation by deep plough ridges, was mentioned last year (*Report* for 1968, pp. 42–44). Some results from an experiment at Clocaenog Forest comparing the two fertiliser forms suggest that the difference in foliage nitrogen is less in trees adjacent to the deep ridges (Table 12).

In an experiment at Eddleston Forest on the season of application of compound fertilisers some interesting trends are being indicated. PK and NPK compound fertilisers have been applied at two-monthly intervals during 1966/67 and 1967/68 to Lodgepole pine (Sooke provenance) planted in 1959. Figure 1 indicates the annual shoot growth during the first and second growing seasons after fertiliser application. Rates of application were: P, 49 kg/ha = 44 lb/ac.; K, 94 kg/ha = 84 lb/ac.; and N, in the NPK treatment, 113 kg/ha = 101 lb/ac. There are no untreated controls in this experiment, but the histogram includes as a guide the mean 1967 and 1968 growth in the adjacent untreated crop. It can be seen that autumn or late winter/early spring applications could give as good, possibly better, growth than the standard May application. However, it should be noted that the May and July applications have the first growing season as the year of application and this accounts in part for the lower growths shown in the histogram. More substantial growth is expected from these treatments in later growing seasons. This is indicated in Table 13 which shows the needle weights and nitrogen concentrations in NPK treated plots. When com-

TABLE 11

TOP HEIGHT, HEIGHT INCREMENT AND FOLIAGE ANALYSIS FOR LODGEPOLE PINE FIVE YEARS AFTER PLANTING (EXPERIMENT MABIE 5 P.64)

Treatment kg/ha		Top height (m)	Ht. increment (cm)		Foliage analysis			
P	K		1967	1968	Needle wt (mg)	% oven dry weight		
						N	P	K
88	168	2·89	74	87	15·2	1·27	·148	·72
22	42	2·60	63	66	10·4	1·08	·108	·40
5·5 + 11	10·5 + 21	2·36	47	69	14·3	1·13	·142	·49
44	84 (control)	2·74	65	80	13·2	1·17	·137	·57
44	—	2·53	64	73	12·8	1·06	·123	·31

pared with the shoot growth histogram, the low first season needle weights for July and November have resulted in poorer growth in the following season. However, the variable second season figures indicate that an evening-up process may follow.

TABLE 12

NITROGEN CONCENTRATION IN SITKA SPRUCE NEEDLES WITH FORMS OF FERTILISER AND SIZE OF PLOUGH RIDGE

N per cent oven-dry weight

Fertiliser form	Shallow ridge	Deep ridge
Potassic Superphosphate	1·46	2·05
Potassium Metaphosphate	1·20	1·94

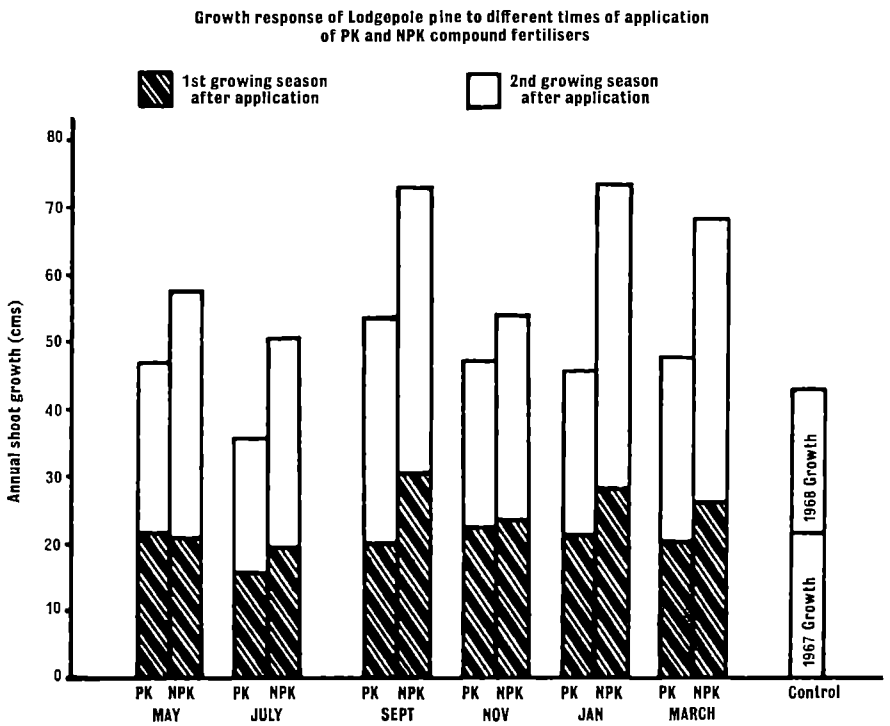

Figure 1: Growth response of Lodgepole pine to different times of application of PK and NPK fertilisers. Eddleston Water Forest, Peeblesshire.

TABLE 13

NEEDLE WEIGHT AND FOLIAR N CONTENT OF LODGEPOLE PINE IN THE FIRST AND SECOND GROWING SEASONS AFTER NPK FERTILISER APPLICATION (EXPERIMENT 6/66 EDDLESTON WATER FOREST)

Month of application	May	July	Sept.	Nov.	Jan.	March
Needle wt. (mg)						
1st growing season	15·7	14·2	15·9	14·2	17·9	15·8
2nd growing season	13·1	17·2	13·3	9·0	9·0	12·3
N content (% O.D.W.)						
1st growing season	1·77	1·77	1·72	1·78	1·79	1·84
2nd growing season	1·53	1·60	1·46	1·35	1·45	1·56

In the light of these preliminary results, further experiments will be laid down to test whether the application time for K and N fertilisers can be spread over a longer period than currently recommended.

Several experiments have been laid down over the past two years to test the effect of repeated applications of nitrogen on Sitka spruce on deep acid peat. Nitrogen in the form of prilled urea will be applied annually and periodically to determine whether spruce can be grown more economically than pine over a whole rotation. This can be classed as luxury treatment and will provide useful data for the top end of the input scale.

Initial responses to the 1967 aerial top-dressing at Achray Forest, Stirlingshire, indicate that unless P levels are adequate, urea application alone will have little effect on checked or semi-checked spruce.

In the new "deficiency garden" at Eddleston Water Forest, planted in 1967, it was noticed that in the plots receiving no potash many Sitka spruce trees were showing what could be an initial K deficiency symptom, namely lack of terminal bud development, although needle colour was normal; the same symptom has been observed at Wareham (see below). Also plots in which phosphate alone was absent showed no better growth than the plots which had received no fertilisers at all. This shows the early value of these demonstration areas. Another "deficiency garden" was established at Shin Forest, Sutherland, and a further two smaller areas are to be established next year in Inchnacardoch Forest, Inverness-shire, and Minard Forest, Argyll, to demonstrate major nutrient deficiency symptoms to Conservancy staff.

Nutrition of Tree Crops on Gleys with Clay or Rock Subsoils (Project 347)

After only the second growing season after fertiliser application, a pole-stage nutrition experiment at Kershope Forest, Cumberland, is showing some responses. Sitka spruce, planted in 1940/41, growing on a peaty gley site, was top-dressed in 1967 with phosphate alone, supplying 57 kg P/ha (50 lb P/acre) and two levels of a compound NPK fertiliser supplying 134 kg N, 56 kg P and 112 kg K per hectare (120 lb N, 50 lb P, 100 lb K per acre) at Rate 1, and twice these quantities at Rate 2. There are seven blocks in the experiment and they support crops of different yield classes ranging from Y.C. 80 to Y.C. 160. Table 14 shows the basal area response by yield classes and suggests that the lower yield classes have responded more than the higher, that phosphate alone

TABLE 14

BASAL AREA INCREMENT OF SITKA SPRUCE IN EXPERIMENT 12/67, KERSHOPE FOREST IN 1968

Current Annual Increment (CAI) as m^2/ha and *ft^2 qg/acre*

Treatment	Control	Phosphate		NPK (Rate 1)		NPK (Rate 2)	
	CAI	CAI	% increase over control	CAI	% increase over control	CAI	% increase over control
YC. 80–100	1·58 *5·4*	2·22 *7·6*	41	2·46 *8·4*	56	2·16 *7·4*	37
YC. 120	1·61 *5·5*	2·13 *7·3*	33	1·84 *6·3*	15	1·81 *6·2*	13
YC. 160	1·31 *4·5*	1·46 *5·0*	11	1·49 *5·1*	13	1·31 *4·5*	0
Mean of exp. blocks	1·55 *5·3*	2·07 *7·1*	34	2·13 *7·3*	38	1·93 *6·6*	24

(Increase of the means is significant at 1 per cent)

applied to a previously unfertilised crop produces initially nearly as big a response as a compound NPK fertiliser, and that the higher NPK rate is less effective than the lower rate.

This basal area response to P alone is especially interesting because foliage analysis showed that the P levels of the control plots were fairly high (mean 0·213 per cent of dry weight). Not only has there been a P uptake, but also a slight increase in N and striking increase in K concentration, as a result of top-dressing with phosphate. This overall improvement may explain how such a striking basal area response to P alone has been possible. Further work on P and PK nutrition on peaty gley soils will be undertaken in 1969.

The trees in the "deficiency garden" at Wareham Forest, Dorset, still continue to grow well (see *Report* for 1968, p. 51) and Plates 9 to 12 show the contrasts between annual NPK manuring with full weed control for the first five years compared with phosphatic fertiliser at planting. (The soil is, in fact, classified as a heath podsol with gleying below the humus-iron layer; since the impeded drainage is a marked feature, it has been included in this project.) Figure 2 also shows the height growth in the main treatments up to the end of 1967. There is a marked effect of omitting P (though the growth appears better than it really is, as there has been some spread either of fertiliser or of roots at the edges of the "minus P" plots) and the trees without N or K are on average smaller than the three other treatments. The figure does not show the marked effect of exposure in increasing K deficiency (least apparent for Scots pine); in the more sheltered replicate the three pines seem least affected by K deficiency. The figures suggest that on average the plots without calcium or magnesium are as good as the completely fertilised (NPKCaMg) plots and it seems clear that little has been lost so far by omitting these nutrients; there is, however, no test of plots without both and since magnesium deficiency symptoms have been observed in some years, effects on growth might be expected in time.

The Genetics Section have scored the plots for stem straightness and crown form and have observed that Sitka spruce and Douglas fir show a tendency to fork in the –K plots, which may be due to bud death or greater susceptibility to wind and bird damage. Western hemlock shows a tendency to bush in the –K plots. There is also a suggestion that Scots pine is coning more heavily in plots with copper (not shown in the figure) either as a spray or as a tack driven into each stem.

It must, of course, be emphasised that the treatments used in this demonstration are not intended to be practical ones for use in the forest. What they have done, in addition to fulfilling the original objective of showing what nutrient deficiencies look like, is to galvanise us into thinking much harder about the real limits to crop production; at this site and up to this age the limiting factors clearly stem from the soil and not from the climate and it is therefore technically possible to put them right.

Nutrition of Tree Crops on Ironpan Soils (Project 349)

Two fertiliser/herbicide trials were laid down at Clashindarroch Forest, Aberdeenshire, on mixed pine and spruce crops in which the Sitka spruce had gone into check. The check of spruce in heather is a very wide-spread problem in East Scotland and elsewhere. Further work is in hand for 1969 including the study of heather regrowth and subsequent tree growth under different pre-

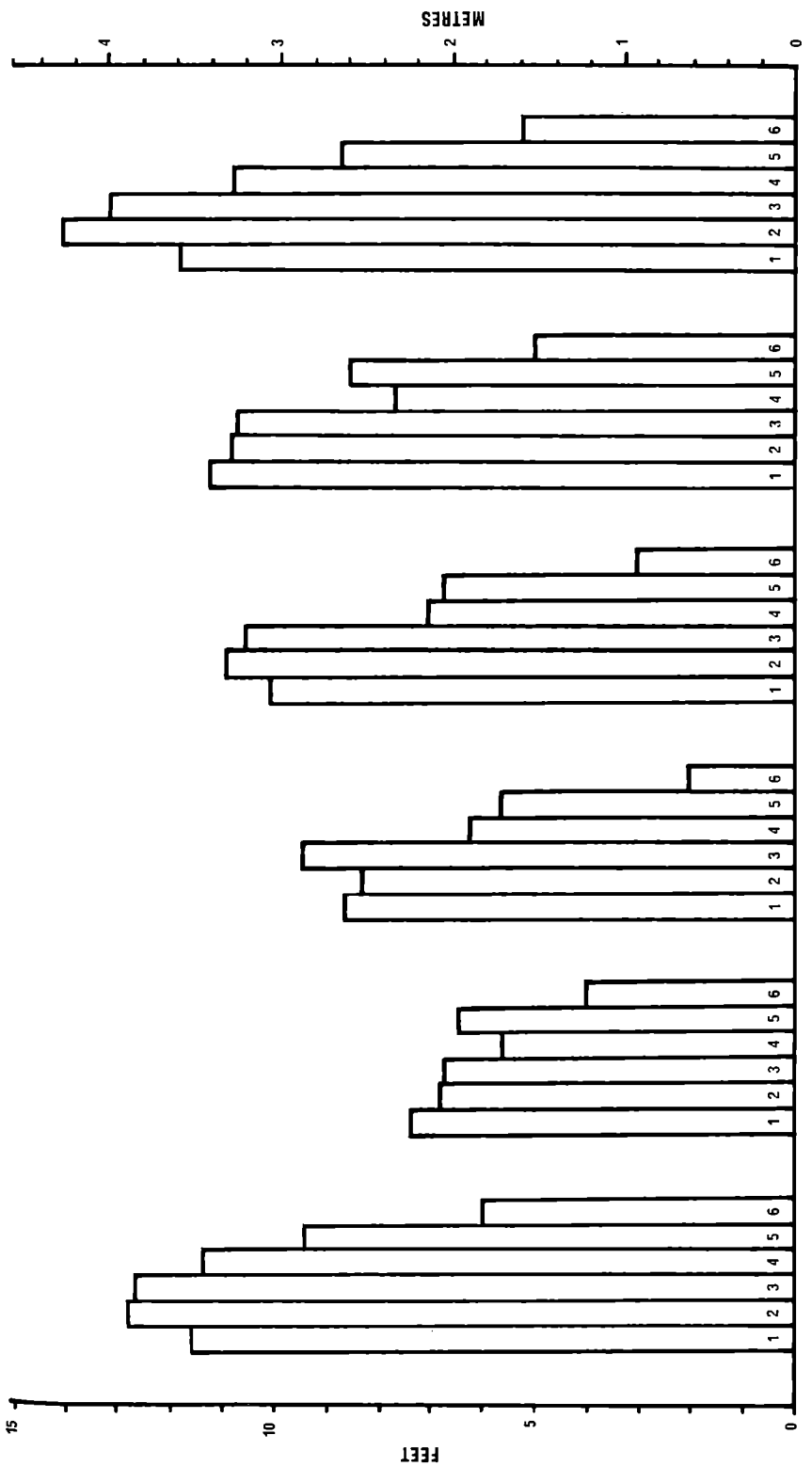

Figure 2: The effect of annual treatment with complete fertiliser and the omission of each nutrient, after eight years (six years for Corsican pine). Wareham Forest, Dorset.

Order of columns, left to right: 1, Complete fertiliser (N P K Ca Mg); 2, minus Ca; 3, minus Mg; 4, minus K; 5 minus N; 6 minus P.

ploughing treatments, namely burning, herbicides and swiping, and also observations of the effect of different application times of herbicide/fertiliser treatments.

Nutrition of Tree Crops on Freely Drained Soils (Project 350)

Work on this project in Scotland is confined to post-establishment manuring. In the 1967 *Report*, p. 50, results from an experiment at Speymouth indicate that on humus iron podsols and podsolised brown earths significant basal area responses by Scots pine result after applying a compound NPK fertiliser. Initial results from another experiment at Speymouth on Scots pine of a higher yield class (Y.C. 100) show that a basal area response is still obtained although not so great as the lower yield class (Y.C. 60) of the first experiment. Table 15 illustrates this, as well as indicating that the higher fertiliser input does not appreciably add to the basal area response.

TABLE 15

BASAL AREA RESPONSE OF POLE STAGE SCOTS PINE, SPEYMOUTH FOREST

Treatment kg nutrients/ha *lb/acre*			Yield Class 60		Yield Class 100	
N	P	K	BA increment for 1st two years m^2/ha *ft^2 qg/acre*	% increase over control	BA increment for 1st two years m^2/ha *ft^2 qg/acre*	% increase over control
0	0	0	1·49 *5·1*	—	2·12 *7·2*	—
134 *120*	56 *50*	112 *100*	1·96 *6·7*	31	2·60 *8·9*	24
268 *240*	112 *100*	224 *200*	2·05 *7·0*	37	2·60 *8·9*	24

Further to this current series of pole-stage nutrition experiments using a compound NPK fertiliser, a new series is to be started in 1969 in which N and P fertilisers will be applied singly and in combination to the potentially higher yielding species, namely Sitka and Norway spruces and Douglas fir of varying yield classes. Experiments to be located in the North Scotland Conservancy will be in the higher yield classes 160–220, in the Great Glen area, to test for response to pre-felling fertilising treatments, and, in conjunction with Conservancy staff, to value any responses using local timber prices. An indication of the possibilities of responses from the higher yield classes of Sitka spruce is noted from an experiment laid out this year at Ae Forest, Dumfriesshire. Here there has been an increase in foliage N concentration after one growing season following an NPK fertiliser treatment. The crop is Sitka spruce, Yield Class 180, planted in 1947, growing on a brown earth soil. It remains to be seen, however, whether there will be a corresponding basal area increase next season.

Persistence of Fertiliser Effects in Established Crops

The length of time for which a single application of fertiliser produces increased increment is very important in deciding whether treatment will be

profitable. We know from work in other countries that nitrogen responses in established crops generally last from four to eight years, and our own experience with phosphorus on young crops suggests that long-lasting improvements are obtained when deficiencies are severe. However, we do not know with any certainty if increased increment due to phosphorus in older and more vigorous crops will be so persistent. The series of 2^5 experiments on pole-stage stands laid down in 1959 (*Reports* for 1962, p. 29; 1965, p. 25; 1967, p. 51; 1968, p. 50) tells us something about this important question. Figure 3 shows the course of the response to fertiliser for four species; five of the responses are to phosphorus, the sixth is to nitrogen.

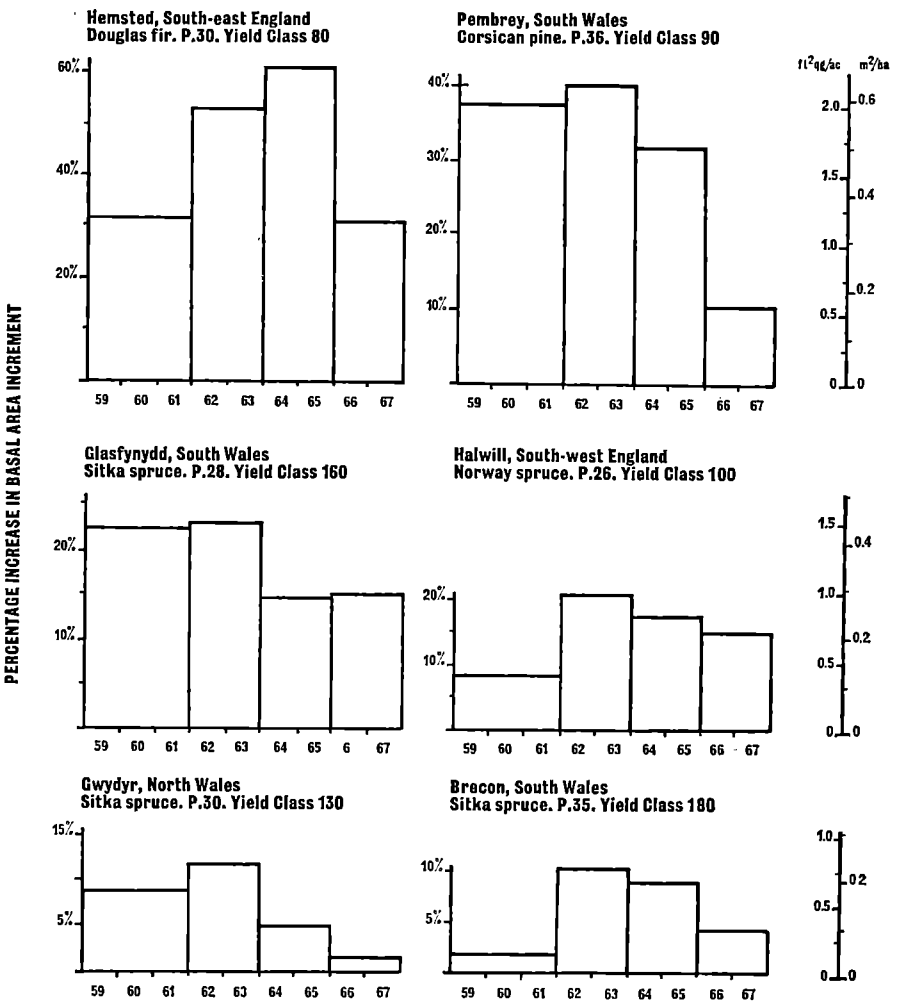

Figure 3: Response of pole-stage crops to fertilisers. Percentage increase in basal area increment due to nitrogen (Pembrey only) at 167 kg N/ha (150 lb/acre) or phosphorus (all other sites) at 94 kg P/ha (88 lb/acre), applied in 1959. The square foot and square metre scales are approximate (see text), and percentage scales vary for each plot.

Note: Douglas fir Yield Class 80 is an estimate, the lowest recognised Yield Class being 120.

The increases have been presented primarily as a percentage of the plots without phosphorus (or nitrogen) and in every experiment, except Gwydyr, the increase is significant for at least one measurement period at $p = 0{\cdot}05$. In an attempt to indicate the absolute basal area responses the histograms have been drawn so that the vertical scale corresponds to the mean increase in increment over the nine years. This means that the value for any measurement period is not exact, as the increment has varied widely during the nine years; for example, the last period, 1966–67, seems to have produced better growth at Pembrey, Gwydyr and Hemsted than the preceding seven years.

It will be seen that the nitrogen response has declined rapidly, and that in two experiments the phosphorus response has virtually disappeared by the end of the ninth year, while in three there is the possibility of further useful increases. Two of the crops showing persistent responses are rather low yield classes of Douglas fir and Norway spruce, and in the two trials where the response has gone the crops are more vigorous.

It would be logical if the short-lived responses were in the better crops and the persistent ones in the poorer; however, the Sitka spruce crop at Glasfynydd has a Yield Class of 160 and is the second best crop in the series. The next assessment at the end of 1969 may define more precisely the end of the response period.

The policy now is to allow the effects to run out and to apply new treatments to those experiments which are not affected by windblow. The main weakness of the 2^5 design is that it gives no indication of the best rate of an effective fertiliser, so where only one treatment has been effective (in all the trials except Halwill) the experiments will be converted to 2 x 4 factorials, that is, the effective nutrient will be reapplied at four rates, but balanced so that residual effects and interactions can be detected. The Pembrey trial has been so converted, the treatments being nitrogen at 84, 168 and 256 kg N/ha (75, 150 and 225 lb N/acre).

Permanent Foliage Sampling Plots

The 1968 foliage analysis data from the permanent sampling plots in Scotland and North England are given in Table 16. Comparing the 1967 data, the Lodgepole pine values are all down in 1968, as are those for the well grown Sitka spruce except for the K level which is greater and has, in fact, increased every year since the plots were started in 1964. The K value also has risen in the partially checked spruce, as have the Mg and needle weight values, although the P value is slightly down.

Analysis of Soils and Foliage

Mineral Soils

A very large programme of analysis (by our standards) was completed for the Minor Species project (see p. 41). The determinations included pH, texture, total phosphorus and loss on ignition. Routine determinations of texture and pH were done as usual for the Planning and Economics Site Survey Officer.

Peat Soils

No determinations are done by Forestry Commission staff, but the contract arrangements this year included some Welsh peats. Somewhat surprisingly the analyses closely resembled those from Scottish peats of the same type, and the reason for better nitrogen uptake in trees on Welsh peats is still unsolved.

TABLE 16

FOLIAGE ANALYSES FROM PERMANENT SAMPLING SITES

Species	Needle wt. (mg oven-dry)	% oven-dry wt.					N:P:K (ratio)
		N	P	K	Ca	Mg	
Sitka spruce (growing well)	*6·8* 5·9–7·6	*1·42* 1·10–1·70	*0·20* 0·16–0·28	*1·33* 1·02–1·81	*0·29* 0·18–0·36	*0·13* 0·10–0·16	7¼:1:6¾
Sitka spruce (in partial check)	*5·8* 4·3–7·1	*1·09* 0·77–1·69	*0·14* 0·08–0·19	*0·89* 0·60–1·26	*0·36* 0·29–0·46	*0·13* 0·10–0·15	8 :1:6½
Lodgepole pine (Washington Coastal Provenance)	*14·6* 8·5–18·8	*1·36* 0·99–1·55	*0·15* 0·10–0·20	*0·50* 0·35–0·73	*0·12* 0·06–0·20	*0·09* 0·07–0·12	9 :1:3¼

Figures in italics are the mean values obtained, and the figures below these are the ranges.

Foliage

Over 3,000 foliage and vegetation samples came in during the autumn and winter, but the purchase of a larger drying oven meant that the preparation of samples was completed more rapidly than usual and analysis started earlier, so that the work was virtually completed by the end of March.

W. O. BINNS

J. M. MACKENZIE

FOREST WEED CONTROL

CHEMICAL CONTROL OF SPECIFIC WEED POPULATIONS

Herbaceous Weed Control

Chlorthiamid ("Prefix")

No new experiment testing chlorthiamid was laid down in 1968, but many of the experiments started since 1964 were re-assessed to check the extent of damage to tree crops.

This review showed that most species can be damaged by chlorthiamid; the higher the rate and the later into the growing season application is made, the greater the risk of damage. There were, however, definite differences in resistance between species. Corsican pine, Sitka spruce and Norway spruce were fairly resistant to chlorthiamid at rates of 3·4 kg and 5·0 kg active ingredient per hectare (3 and 4 lb per acre), but *Abies* spp., Western hemlock and Douglas fir were quite sensitive and it would be clearly unwise to use chlorthiamid on these species.

Some species, previously reported as resistant (*Report* for 1967, pp. 72–73), showed inconsistencies. Amongst these were Scots pine and Lodgepole pine.

Only rarely was the height growth of surviving trees affected. Whether this is because chlorthiamid either kills a tree outright or allows it to grow normally, or whether experiments were not sufficiently precise to pick up differences, is not known. A new series of experiments is being laid down in 1969 specifically designed to test for effects on height growth of chlorthiamid applications.

Triazines

Following the successful preliminary experiment with atrazine and ametryne in 1967 (see last year's *Report*), both herbicides were tested further at two forests in 1968.

Post-planting applications of atrazine and ametryne at 1·4 kg/ha (1·25 lb per acre) or 2·8 kg/ha (2·5 lb per acre), and mixtures of 1·4 kg/ha of each herbicide with paraquat at the rate of 1·1 kg/ha (1 lb per acre = $\frac{1}{2}$ U.K. gal of "Gramoxone"), were compared with standard applications of paraquat and with hand-weeding. Applications were made in April, June and October, 1968.

At both forests, ametryne failed to provide adequate weed control and compared poorly with paraquat.

At Friston Forest (Sussex) the April applications of atrazine gave excellent weed control which persisted rather better than applications of paraquat at the same date, but June applications were not as successful. The full effect of October applications will not be known until mid-1969, but the visual indications are that atrazine will not give good control when applied at this date. Mixing atrazine with paraquat gave no advantage at any date.

Table 17 shows the effect of April and June applications of these chemicals on time subsequently spent to the end of the season on hand-weeding.

At Thetford Forest results with atrazine were poor. The site had been screef-ploughed with a Tolne plough and at the time of both April and June applications there was little weed foliage as a target. *Holcus mollis* subsequently invaded the plots mainly by spreading in from the untreated strips, but there was also germination of weeds in plots.

TABLE 17

EFFECT OF TREATMENT WITH ATRAZINE AND PARAQUAT ON SUBSEQUENT HAND-WEEDING, 1969
WEEDING TIMES PER PLOT (16·72 m^2 – 20 yd^2)

Total for 1968 – Friston Forest — Seconds

Date of application	Atrazine		Atrazine/paraquat	Paraquat	
	1·4 kg/ha	2·8 kg/ha	1·4 atra. + 1·1 par. kg/ha	1·1 kg/ha	2·2 kg/ha
April	95	42	127	168	177
June	132	53	0	0	0

The results suggest, therefore, that atrazine is more effective in the spring than later in the growing season and that it must be applied to the weed foliage. No damage was observed on tree crops. Trials are continuing in 1969.

Bracken Control with Dicamba

Re-assessments of 1965 and 1967 Experiments in the South

These experiments were re-assessed during 1968 to discover how persistent bracken control was following applications of dicamba.

The results suggest that excellent control is obtained for periods up to four growing seasons from the date of application at rates of 4·5 kg/ha (4 lb/acre) and 9·0 kg/ha (8 lb/acre) on infertile sites, but that on fertile, moist forest sites, the bracken may substantially recover by the end of the second season. Control is invariably good in the first season at rates of 3·4 kg/ha (3 lb/acre) and 4·5 kg/ha (4 lb/acre).

No damage has been recorded to crops where these were planted during the winter following spring applications of dicamba. Cold storage was used to keep plants dormant and to enable them to be planted out at intervals of from 0 to 8 weeks after spring applications of dicamba in one series of 1967 experiments. The results suggested that most species would require this interval to be at least eight weeks at the soil temperatures prevailing in spring and early summer.

1967 Experiments in Scotland

Preliminary results from the experiments laid down in 1967 in Scotland indicate that in the second growing season after application a rate of 4·5 kg/ha (4 lb/acre) of dicamba is more effective in reducing height and cover than the lower rate of 3·4 kg/ha (3 lb/acre), although this lower rate may produce an acceptable bracken population for the first year after planting. Persistence of control is vitally important as the cost of materials will have to save from three to six hand-weedings to be profitable. For this reason next year's bracken regrowth will be watched with interest. Application at low volume by mist-blower appears to be a more practical method than at medium volume by knapsack sprayer.

A further trial was laid down in 1968 at Dalbeattie Forest (Kirkcudbrightshire) to test the effectiveness of dicamba in mixture with dalapon or paraquat in controlling a bracken/grass vegetation. The heavier rate of dicamba at 4·5 kg/ha (4 lb/acre) or 3·4 kg/ha (3 lb/acre) has given greater control of bracken

by the end of the first growing season. The addition of paraquat or dalapon did not give any additional control of the bracken. Paraquat killed practically all other vegetation, but by late summer grass was reinvading some plots. Dalapon on the other hand appears to have had little effect on the grass growth.

1967/8 Experiments in the South

Generally, dicamba has given good and reliable control in the first season after application. It is desirable, therefore, to see if advantage can be taken of this control.

A series of experiments was laid down at three sites in the winter of 1967/1968 to see if winter applications of dicamba (1) provided good control of bracken, and (2) damaged the subsequently planted crop. 4·5 kg/ha (4 lb/acre) or 6·7 kg/ha (6 lb/acre) were applied in December 1967 and January and February 1968.

At the end of 1968 bracken control was excellent, percentage ground covers of bracken at all sites varying from 0 to 10 per cent on treated plots compared with 46 to 93 per cent on hand-weeded controls.

Damage to the crop varied with the date of application (see Table 18). Obviously, residues of dicamba take much longer to break down at winter soil temperatures than at the spring and summer temperatures, but the health scores for the December application date are not much worse than the controls.

TABLE 18

MEAN HEALTH SCORE OF TREES IN JULY/AUGUST 1968 AFTER WINTER APPLICATIONS OF DICAMBA

Health score: 1 = healthy to 5 = dead

Site	Species	Rate kg/ha	Rate (lb/ac)	Month of application Dec.	Jan.	Feb.	Control	S.E.	Statistical Comparison between
St. Leonards Forest	Scots pine	4·48 6·71	(4) (6)	1·8 1·8	1·7 2·3	2·1 2·7	1·6	0·23	Control and treatment NS. Rates* Dates*
Rogate Forest	Western hemlock	4·48 6·71	(4) (6)	2·6 3·1	3·2 4·0	3·7 3·9	2·3	0·15	Control and treatment *** Rates** Dates ***
Rogate Forest	Norway spruce	4·48 6·71	(4) (6)	2·0 2·2	2·2 2·6	2·3 2·5	1·4	0·12	Control and treatment *** Rates * Dates NS

Notes: *, **, ***: differences significant at 5,1 and 0·1 per cent levels respectively.
NS: differences not significant.

Experiments commenced in the autumn of 1968 to test October, November and December applications of dicamba, but it is too soon to tell how effective these are.

Woody Weed Control

Low Volatile Esters of 2,4,5-T

Several instances of crop damage due to volatilisation in warm weather of 2,4,5-T from treated foliage were recorded in 1967, and two experiments were laid down in 1968 to assess the merits of using esters of very low volatility in testing circumstances.

At Alice Holt Forest (Hampshire) small plots 2·74 m² (3 yd²) were surrounded by 1 m (1 yd) high fencing made of closely spaced nursery laths, and the inside bottom 30·5 cm (12 in) sprayed with 2,4,5-T in diesel oil solutions to simulate a basal bark treatment of 50 UK gal of spray solution per acre. The esters and concentrations tested were N-iso-butyl ester (the normal ester) and iso-octyl ester (of very low volatility) at 6·8 kg (15 lb) or 13·6 kg (30 lb) in 455 litres (100 UK gal). Plots were treated at two dates, in May and June, the actual spraying days being adjusted to try to catch warm weather (at least over 18°C). Potted Japanese larch were plunged into the plots after the spraying.

End-of-season assessments (Table 19) showed that the use of the iso-octyl ester had reduced damage considerably.

In the second experiment at Chiddingfold Forest (Surrey), N-iso-butyl esters and iso-octyl esters of 2,4,5-T were applied to 1 yd² patches round young Corsican pine using an "Arbogard" at rates of 1·7 kg/ha (1·5 lb/acre) and 2·4 kg/ha (3·0 lb/acre) in 337 litres/ha (30 UK gal/acre), again at two dates adjusted to coincide with warm weather in May and June.

TABLE 19

SCORES FOR DAMAGE TO JAPANESE LARCH DUE TO VOLATILISATION OF 2,4,5-T AT ALICE HOLT, 1968

Damage score: 1 = normal to 5 = severe

Date of Spraying	Assessment	Treatment					
		No spray	Oil only	N-iso butyl		Iso-octyl	
				6·8 kg (15 lb)	13·6 kg (30 lb)	6·8 kg (15 lb)	13·6 kg (30 lb)
May	Needle recurving	1·1	1·0	2·2	2·8	1·3	1·1
	Needle browning	1·9	2·1	2·2	2·7	2·1	2·0
	Stem distortion	1·0	1·0	2·0	2·1	1·0	1·0
June	Needle recurving	1·1	1·0	2·6	3·0	1·1	1·7
	Needle browning	1·9	2·0	2·0	2·1	1·8	2·0
	Stem distortion	1·0	1·0	2·0	2·2	1·0	1·3

The end-of-season scores for damage again showed that the iso-octyl ester of 2,4,5-T caused less damage than the n-iso-butyl, but differences were so small that it would appear unnecessary to use low volatile esters in weedings by this method.

Temperatures well over 18°C were recorded during and following both spraying dates in both these experiments. Temperatures of 23°C were recorded following the May application.

Tree-Injection of Herbicides

Following reports from North America of good control from direct injections of 2,4,5-T and 2,4-D into broadleaved weed species, and some promising results from Conservancy trials in Northamptonshire, a series of trials was laid down in the Autumn of 1968 and the winter and early spring of 1969 to test:

(1) The susceptibility of various species of 2,4,5-T applied by injection.

(2) The effect of spacing of injections and quantity of herbicide per injection on efficiency of kill.

(3) The effectiveness of various herbicides, 2,4,5-T, 2,4-D, ammonium sulphamate and sodium chlorate, were tested, and others may follow.

(4) The importance of method of injection, i.e. injection into wide horizontal cuts (which have a girdling effect also) compared with injection into small circular holes.

It is too early to give any results for these trials. Earlier preliminary trials have suggested that injection of 0·5 ml of undiluted unformulated 2,4,5-T (1 kg/l = 10 lb/UK gal acid equivalent) at 5 to 7½ cm (2 to 3 in) centred round the stem circumference about 30 cm (12 in) from the ground will kill all but the most resistant tree species. At winter temperatures unformulated 2,4,5-T normally requires diluting with the same quantity of diesel oil to make the liquid run.

Rhododendron Control

Results of experiments between 1964 and 1968 have been published elsewhere (Aldhous and Hendrie, 1966), and also referred to in the 1967 and 1968 *Reports*.

A series of four experiments were started late 1967 and 1968 to confirm that 2,4,5-T can kill regrowth of rhododendron and laurel below 1·2 m (4 ft) in height, either sprayed in water or oil, and also to test on nearby crop trees the effect of the high rates of 2,4,5-T required.

6·8 kg (15 lb) or 9·1 kg (20 lb) acid equivalent of 2,4,5-T in 455 l (100 UK gal) of diesel oil, and 9·1 kg (20 lb) or 11·3 kg (25 lb) acid equivalent 2,4,5-T in 455 l (100 UK gal) of water were applied in December, 1967, and March, June and September 1968 to 2 to 3-year-old rhododendron regrowth so that all aerial parts were thoroughly wetted.

By the end of 1968 the regrowth and stools at all sites were mostly dead following all treatments (except for the September 1968 applications which had not had time to act). Rates of spray solution applied varied from 455 l (100 UK gal) where regrowth was small to 1137 l (250 UK gal) where regrowth was lush and tall, *all volumes expressed per acre of rhododendron.*

Damage to crops from December and September sprays was small, and more or less confined to cases where isolated trees had been directly hit by spray. Damage following the June applications was worst, but few trees were killed and damage was mostly confined to twisting and distortion of needles and shoots.

Provided fairly high concentrations of 2,4,5-T are used and all aerial parts of rhododendron regrowth are thoroughly wetted, it is clear that 2,4,5-T in oil or in water can give satisfactory control. Obviously, the smaller the regrowth, the cheaper the operation will be.

Control of Heather (Calluna vulgaris)

Recent assessments of experiments laid down between 1956 and 1960, testing the value of fertilisers, herbicides and combinations of both treatments on the control of heather and the release of crops from check, have shown that a combination of fertilisers and herbicides frequently gives a better kill of heather than herbicides alone.

Such effects were observed at four sites, two in North Wales, at Tarenig and Aeron Forests, and two in South-West England at Wareham. Fertilisers were

applied mainly as phosphates, sometimes with potassium also, in the spring and early summer, and the heather was subsequently controlled in the late summer, using 2,4-D.

It is thought that when fertilisers are added before the herbicide applications, the heather responds with more vigorous growth, and so becomes more susceptible to 2,4-D. This technique may be particularly valuable when attempting to kill tall, leggy heather on infertile sites.

It is worth recording that in a northern underplanting experiment, where 2,4-D was used to control odd clumps of heather, a markedly better kill was obtained under an overwood of Scots pine than is often the case on open ground. Unfortunately the underplanted species (Douglas fir and Grand fir) were also more susceptible to the chemicals and suffered considerable damage.

INDIRECT NUTRITIONAL EFFECTS OF HERBICIDES

The direct effects of weeds on nutrition in the forest are not fully understood, and foresters still argue about the effect of weed growth on the availability of water and nutrients and on degree of frost risk (not to mention on pests and diseases).

The series of trials in England and Wales started in 1965 has been showing some effects of chemical weed control on needle colour for the last two years, and the effects on nitrogen concentration are now showing up. Table 20 shows the means of the nitrogen concentrations in plots with chemical and hand-weeding, averaged over all other treatments.

The differences are consistent for all species in the plots established in the open; in the Thetford plots, established under light shade, weed growth is less vigorous and the effects might be expected to be smaller. However, the impression of improved nitrogen nutrition as a result of fairly complete weed control is clear and the next assessment in 1970 should show if these effects are reflected in improved growth.

It is interesting that most sites were ploughed before planting and vegetation took one or two years to reinvade the site. Vegetation also varied, being mixtures of various proportions of grass and heather (*Calluna vulgaris*) (Brendon, Clocaenog and Thetford) and mainly grass (Thetford), but in all cases was rather sparse compared with the thick mats of vegetation normally accused of checking growth.

SIDE EFFECTS OF CHEMICALS

Basal Bark Applications of 2,4,5-T in Diesel Oil and Water Supplies

Water Authorities are particularly concerned about pollution of water supplies from the phenoxyacetic group of herbicides and many petroleum oils (especially diesel oil) because of their ability to create objectionable tastes and odours at very low concentrations in water.

In collaboration with the Water Research Association, water samples were taken from a stream collecting all drainage water from a small surface water catchment area of 27·6 ha (68·1 acres) at Friston Forest, Wilmington Block (Sussex), on which basal bark/cut stump applications of a solution made of 6·8 kg (15 lb) acid equivalent 2,4,5-T in 445 l (100 UK gal) diesel oil were being made.

TABLE 20

FOLIAGE CONCENTRATIONS OF NITROGEN FOLLOWING WEEDING

Treatment	Species and Site										
	Scots pine		Corsican pine		Lodgepole pine	Monterey pine	Sitka spruce		Douglas fir	Western hemlock	
	Wareham	Thetford	Wareham	Thetford	Clocaenog	Wareham	Brendon	Clocaenog	Thetford	Wareham	Thetford
Hand-weeded	1·57	1·98	1·21	1·48	1·70	1·80	1·71	2·07	1·69	1·21	1·80
Herbicides	1·67	1·89	1·34	1·56	1·80	1·87	2·12	2·38	1·88	1·33	1·87

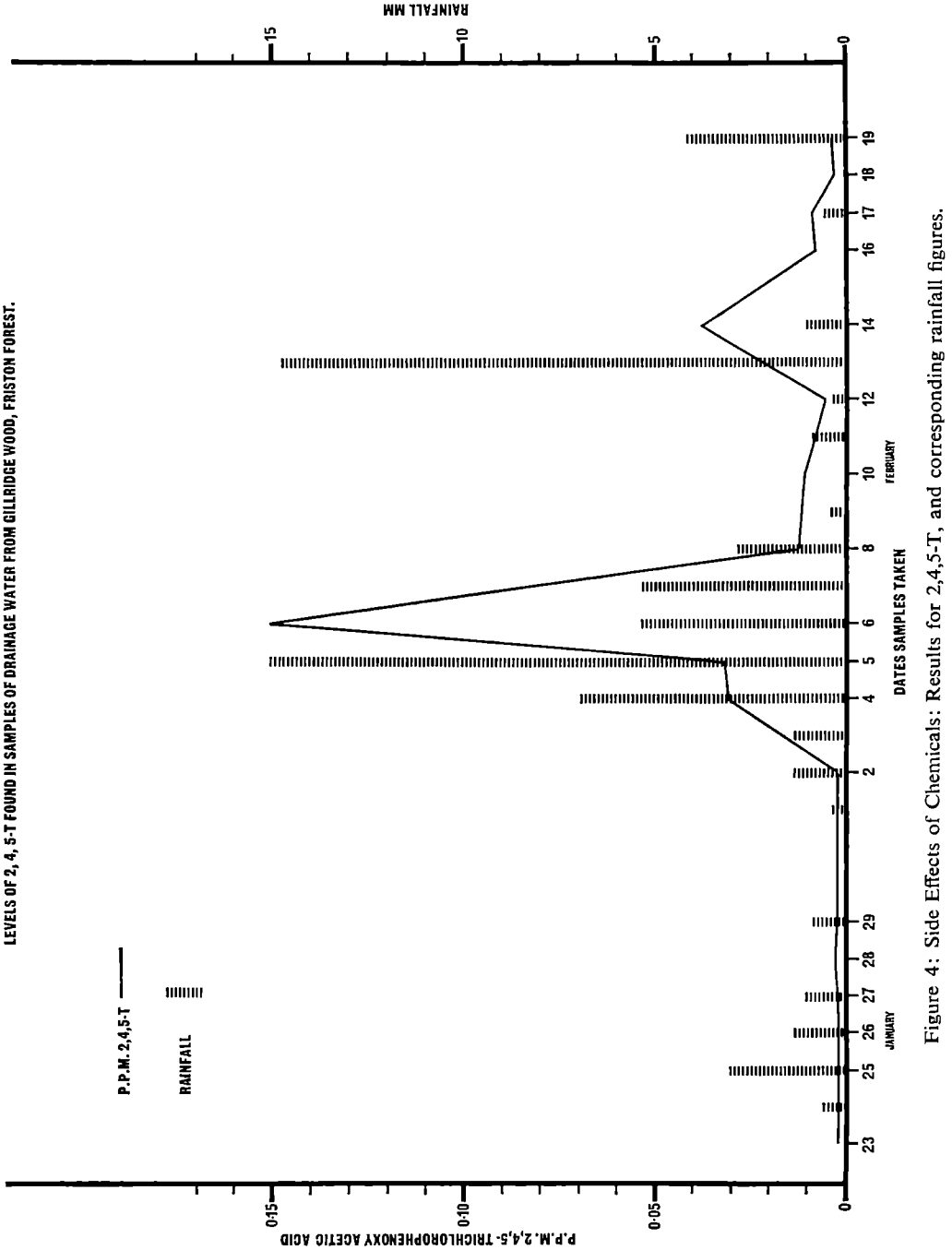

Figure 4: Side Effects of Chemicals: Results for 2,4,5-T, and corresponding rainfall figures.

24·9 acres of the catchment were treated between 22nd January, 1967, and 28th February, 1967, the spraying programme being frequently halted through bad weather. In all, 2864 l (630 UK gal) of diesel oil and 43·0 kg (94·5 lb) of 2,4,5-T were applied. Samples were taken at intervals from just before spraying until 2nd March, 1967, and analysed at the Water Research Association for contamination. Determination of the concentration of 2,4,5-T in water samples was by gas chromatography, and diesel oil by odour panels (still more sensitive than any chemical method).

No diesel oil was detected in any sample.

Figure 4 shows the results for 2,4,5-T (which was detected as free acid in the samples) and the corresponding rainfall figures for the same period.

The association of high concentrations of 2,4,5-T in water samples taken during and just after very high rainfall is quite striking, and this suggests that amount of rainfall and associated surface drainage could be a major factor in influencing contamination of water supplies from basal bark applications.

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REFERENCE

Aldhous, J. R., and Hendrie, R. (1966). Control of *Rhododendron ponticum* in forest plantations. *Proc. Br. Weed Control Conf.* **8**, 1966, pp. 160–166.

SOIL MOISTURE, CLIMATE AND TREE GROWTH

Soil Moisture Studies

Bramshill Forest (Hants)

The water-balance studies carried out since 1962 in adjacent stands of Corsican pine and Douglas fir are being prepared for publication. Professor A. J. Rutter and Mr. P. Robins of Imperial College, London University, are continuing canopy transpiration and rainfall interception measurements; to aid their studies, water storage and moisture block resistance records are being maintained for the coming year.

Rendlesham (Aldewood Forest), Suffolk, and Burley (New Forest), Hants

The results of the water-balance studies on these woodland sites are being worked up and will be reported in due course. The routine observations are complete.

Deep Percolation in Sandy Soils

In our last *Report* we mentioned a simple method of investigating the deep percolation characteristics of soils as a factor in water balance studies. In Bramshill Forest in March 1968 a neutron moisture gauge was again used to follow changes in soil moisture storage after heavy watering at a time when Eo values are low.

The soil round a selected neutron access tube in the Corsican pine and Douglas fir stand was saturated by watering an area 120 cm (4 ft) square. The rate was 5 cm (2 in) per day for five days and the area was covered between each watering to exclude any natural accession of water. In the present experiment neutron counts were taken prior to and during the period of watering in order to observe the onset of through percolation.

The results agree closely with those previously reported, as the sustained losses by percolation were small and similar to the seasonal Eo values. They also confirmed the hypothesis that water appears to leave the base of the profile at a similar rate to its infiltration at the surface.

In an attempt to throw more light on the processes of infiltration and percolation, an air piezometer was installed adjacent to each access tube. These piezometers comprised 4·45 cm ($1\frac{3}{4}$ in) outside diameter aluminium tubes of 1·6 mm ($\frac{1}{16}$ in) wall thickness inserted to a depth of 150 cm (59 in) and were intended to penetrate a zone of relatively fine texture. These tubes were capped at the surface and connected to water manometers.

The piezometer in the Corsican pine stand showed little or no change in pressure over the watering cycle, while significant pressure changes were observed in the Douglas fir stand. During the watering period the pore pressure decreased compared to atmospheric pressure reaching a value of 12·5 cm (4·95 in) of water, eventually reaching 3·9 cm (1·57 in) of water. Twenty-four hours after the last application of water the reading rose to 15·5 cm (6·10 in) above atmospheric pressure. The level then fell till on the fifth day after watering it was only 4·1 cm (1·61 in) above atmospheric. The piezometer was then read

at weekly intervals with the cover removed and the pore pressures fluctuated from 30 cm (11·80 in) below atmospheric to 12 cm (4·7 in) above atmospheric pressure following rain.

Because of this wide variation under natural conditions the anomalous pressures cannot be due solely to the artificially high infiltration rates, as under the same conditions no change was observed on the Corsican pine site. These pressures are, therefore, functions of the site and cannot be considered as artefacts of the experiment.

Drainage Studies

Halwill Forest, Devon

The records of several years' study of drainage effects on these silty-clay surface water gleys are being examined. To gain information on the response of borehole levels and tensiometers to dry periods following heavy rain, a series of daily readings has been carried out at a time of low evaporation losses. It is worth recording that both the long-term weekly borehole level records and the daily readings in January-March 1969, show considerable beneficial effects of the mole-ploughing nearly seven years after treatment. It is intended to close the routine weekly recording in April 1969, and to start again when the Sitka spruce, now 1·5 to 2·5 m (5 to 8 ft) tall, have closed canopy; this will probably be about 1975, as annual leader increments at present are between 60 and 90 cm (2 to 3 ft).

Bernwood Forest, Oxfordshire

Some results from this long-term forest drainage experiment on heavy clay were reported in 1961 (*Report* for 1960, p. 137). Some of the species plots have now closed canopy, but others have yielded little useful information. In a new experiment plan now in operation, attention is being directed to an examination of responses to drainage in high-yielding species such as Corsican pine, Douglas fir, and Grand fir. It is intended to start the borehole readings again in 1970.

Instrumentation

Soil Air and Water

We need two new instrument systems for intensified work on waterlogged soils in relation to artificial drainage: one for the electrical measurement of water levels in small boreholes, tanks and notch flow-gauge systems, and the other for the measurement of soil oxygen potentials.

Though some reasonably-priced field recording equipment is available, e.g. for automatic weather stations, as far as we are aware no cheap and simple water-level transducer has been developed. Accordingly we are investigating several schemes for possible practical use.

Various authors have described electrode systems for oxygen measurement designed for a particular field of application. Some are very small with such a low output that the associated equipment becomes elaborate, while others are based on large numbers of machined parts, or appear to be fragile or readily put out of adjustment. We have designed (but not yet adequately tested) a

simple, robust and inexpensive device which should be no less serviceable than existing forms of electrode. This should enable us to proceed to the more difficult problems of sampling soil solutions and emplacing the measuring system *in situ*.

Garnier Gauge Records

These records, formerly placed in this section of the *Report*, will this year be found in Table 23, p. 99.

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DRAINAGE

Drainage of Deep Peat

The drainage experiment on deep peat at Achray Forest (Stirlingshire) (Achray 3 P.65), has been the subject of intensive studies during the year. A series of boreholes to measure water levels in the peat has been installed, and frequent assessments have shown substantial differences between treatments.

The results are presented in Table 21.

TABLE 21

MEAN WATER LEVELS AT DIFFERENT TIMES OF THE YEAR, RESULTING FROM VARIOUS FORMS OF PLOUGHING AND DRAINAGE
EXPT. ARCHRAY 3 P.65

Mean Water Levels Below Ground Surface in cm (in)

Treatment	November 1967 – April 1968	May 1968 – July 1968	August 1969 – October 1968	November 1968 – January 1969
O – Control	5·3 (2·1)	17·3 (6·8)	11·2 (4·4)	6·3 (2·5)
DS/O	16·3 (6·4)	33·5 (13·2)	24·6 (9·7)	15·5 (6·1)
D/O	22·8 (9·0)	36·6 (14·4)	27·9 (11·0)	19·3 (7·6)
S/100/2	10·2 (4·0)	26·7 (10·5)	19·0 (7·5)	10·7 (4·2)
S/100/4	11·4 (4·5)	27·7 (10·9)	21·1 (8·3)	11·9 (4·7)
S/50/2	15·0 (5·9)	32·5 (12·8)	23·1 (9·1)	14·2 (5·6)
S/50/4	15·7 (6·2)	31·2 (12·3)	25·4 (10·0)	15·7 (6·2)
S/25/2	21·6 (8·5)	39·1 (15·4)	27·4 (10·8)	18·0 (7·1)
S/25/4	24·9 (9·8)	39·4 (15·5)	32·0 (12·6)	22·9 (9·0)

Notes

Treatments

O = Control, no ploughing, no drainage. For the remainder, the prefix indicates the form of ploughing; the first figures the spacing of cross-drains where present, in feet (1 ft = 0·304 m), the suffix the depth of cross-drains in feet.

D = Deep ploughing with single mouldboard turfing plough, furrows at 1·8 m (6 ft) intervals and approximately 38 cm (15 in) in depth.

S = Shallow ploughing with double mouldboard turfing plough, furrows at 3·4 m (11 ft) intervals and approximately 18 cm (7 in) in depth.

DS/O = Deep and shallow ploughing combined, with two furrows of shallow double mouldboard ploughing and one furrow of deep single mouldboard ploughing in parallel, with no cross-drains.

Depth of single mouldboard furrows in this case about 45 cm (18 in) and spaced at intervals of about 6·7 m (22 ft).

Sampling

There are 4 replications of each treatment, with 3 boreholes per treatment plot; each plot exceeds 0·4 ha (1 acre) in size. During the period November 1967 to April 1968, the water levels were recorded on six occasions at intervals of about one month. From May 1968 onwards water levels have been recorded at frequent intervals, on 19 occasions during May to July, on 23 occasions during August to October, and on 21 occasions during the last period. Treatment differences were found to be highly significant on every occasion so far analysed.

The most important point suggested by these data is that close and moderately deep ploughing confers a major drainage benefit, which is only surpassed by deep drains at very close spacing. The data also illustrate the progressive benefit obtained from cross-drains with closer spacing and greater depth. As the superficial ploughing system becomes less effective owing to the accretion of surface litter, the benefit conferred by the cross-drains, which will be maintained, is expected to become more important. The "DS/O" treatment (see *Notes* to Table 21) demonstrates that on flat peat bogs of this type, drainage channels can be parallel with the superficial ploughing and still exert their influence upon the water levels.

A second study was concerned with the development of the root systems after three growing seasons. The results show considerable increases in root weight and in density of rooting, which appear to be correlated with the intensity of drainage and with the initial volume of turf provided as a planting site. Some representative examples of root systems are illustrated in Plates 4 to 8.

At this stage there has been little root penetration of the undisturbed peat, the roots being mainly confined to the turf ridges and markedly oriented along the lines of ploughing. In all, 108 complete root systems were excavated and fresh weights were obtained for the root system and for the aerial part of each tree. Root/shoot ratios were found to be relatively constant, irrespective of site treatment or size of tree, with a mean value of 0·357. The mean total plant weights in grammes are given in Table 22, which may be compared with the water level data presented in Table 21.

TABLE 22

MEAN TOTAL PLANT WEIGHTS (g) ON VARIOUS DRAINAGE TREATMENTS
ACHRAY 3 P.65

Treatment	DS/O	D/O*	S/100/2	S/100/4	S/50/2	S/50/4	S/25/2*	S/25/4*
Mean plant weight g	683	1,563	518	612	798	603	843	1,505

Note. *These treatments are illustrated in Plates 5, 6 and 8.

In the same experiment foliage analysis after four growing seasons was carried out, to check on the result of aerial application of phosphate and potassium during the summer of 1968. These data confirm the rapid uptake of these nutrients, but also reinforce the conclusion suggested by the plant weight data presented in Table 22 that the rate of growth is correlated with drainage intensity, since needle weight and nitrogen content were found to be markedly greater in the D/O and S/25/4 plots than in those given any other treatment.

A series of experiments designed to measure changes in the shape and depth of ploughing on peat has been closed after ten years of study. The reason for closure was the declining accuracy of assessment due to the re-growth of vegetation. In this series there were five experiments on shallow peat with depths ranging from 23 to 46 cm (9 to 18 in), and four experiments on deep peat with peat depths exceeding 76 cm (30 in). The studies included a comparison of single mouldboard and double mouldboard ploughing, with planted and unplanted treatments. These experiments show that after an initial period of rapid shrinkage immediately following ploughing, the depth of the plough furrows has

remained essentially unaltered. The drainage benefit resulting from ploughing on peat soils can therefore be expected to last until canopy closure, and may persist for much longer. The plough ridges showed a steady decrease in height, amounting to some 6·3 cm (2·5 in) on shallow double mouldboard ploughing, and 7·6 to 10 cm (3 to 4 in) on deeper single mouldboard ploughing over the ten-year period. There was little difference between planted and unplanted treatments.

These results have given rise to some speculation with regard to the optimum form of drainage and turfing system for the establishment of forest crops on deep peat. Present knowledge suggests that early growth is markedly influenced by the volume of aerated turf presented as a rooting medium, but that by the third or fourth growing season, the total volume of drained peat available begins to exert an over-riding influence. It is clear that very intensive drainage is required to produce major changes in the water levels of the site. These considerations suggest that a form of "rigg and furr" might be beneficial. In such a system, closely spaced drains of moderate depth would provide good drainage, while the drain spoil mounded between the drains would form a good planting medium. Such a system would have the advantage of providing conditions for a better distribution of the root systems than the present form of narrow turf ridge and would also provide for maximum suppression of competing vegetation, which might enable Sitka spruce to be grown without the risk of heather, *Calluna*, check.

Achievement of such a system on a field scale presents problems, but a form of rotary ditcher has been used to produce this effect experimentally and the development of tree growth will be observed.

Drainage of Gleys with Clay Subsoils

Recent studies in conjunction with the Soil Survey Section of the Planning and Economics Branch indicate that these soils are the most common problem type encountered in British forestry, and are estimated to form some 30 per cent of the total forest area. Much attention has been devoted by the Research Division, by the Work Study Branch and by Conservancies, towards improving techniques for securing adequate drainage in such soils. On afforestation sites the Parkgate Deep Draining Plough has been found to be a cheap and efficient tool, providing adequate tractor motive power is employed. The use of this plough has also been extended successfully to deal with inadequately drained crops in the early thicket stage. Crops up to 4·6 m (15 ft) in height have been tackled with good results without prior rack cutting.

Parallel developments have been made by the Work Study Branch using the much heavier Finnish "Lokomo" plough, and some interesting observations made on the stability of the drain profiles produced may be noted here. At Kielder Forest (Northumberland) some of the earliest drains prepared by this plough are now three years old and appear to be very stable compared with more conventional drain profiles in such soils. In this case the profile is almost semi-circular in cross-section and there has been little deformation or loss of depth during the period of study. Conventional drain profiles prepared by the Parkgate plough or by hydraulic diggers on similar soils show considerable and rapid collapse of the drain sides with a consequent loss of depth.

The experiment at Orlestone Forest (Kent) has now been established for five years and was assessed during the year. Three species, Corsican pine, Douglas

fir and Red alder (*Alnus rubra*) were used and three drain depths and three drain spacings are being compared. As yet there are no significant differences in height growth between the various treatments except that the closest drain spacing, 9 m (10 yd), has resulted in better growth of Douglas fir. Borehole data from this experiment, which is situated on a heavy clay soil (but in an area of relatively low rainfall and with a growing-season moisture deficit), suggest that a depth of 0·6 m (2 ft) may be adequate for drains on this site, and that drains 0·9 m (3 ft) in depth are so far having little additional effect.

The accumulation of borehole data continues in the series of drainage experiments in Sitka spruce crops of varying age, referred to last year (*Report* for 1968). In general, the pattern of behaviour of water levels established soon after draining does not appear to alter greatly during the three years following drainage. On the peaty soils in Wales, local soil differences have tended to mask treatment responses, but it is hoped that this problem will be overcome by the increased numbers of boreholes now installed.

The more intensive drain spacings have shown a continued improvement at Halwill Forest (Devon) as well as at Orlestone Forest (Kent) mentioned above. At Halwill the drains 0·9 m (3 ft) in depth have produced markedly better results than the drains 0·6 m (2 ft) in depth.

It is generally reported that drain side deformation and fall-in is very much greater in drains dug to more than 0·9 m (3 ft), than in drains of the same shape dug less deep. The problem of choosing the right drain shape and drain gradient to minimise maintenance requirements is to be investigated by a series of experiments, commencing in the autumn of 1969 in North Wales.

Drainage of Gleys with Indurated Subsoils

The importance of relict periglacial indurated horizons as a factor contributing to the instability of forest crops, was recognised by Fitzpatrick (1958). The frequent occurrence of such horizons, giving rise to severe superficial gleying in many Scottish forests, has only recently been appreciated. It is now believed that a very large area, exceeding 200,000 acres in total extent, is affected by problems of this type.

Such soils present a double problem for adequate site amelioration. The primary limiting factor is inadequate drainage, but intensive cultivation may also be necessary to relieve compaction if adequate rooting conditions are to be ensured. Experimental study of the problems involved is now in hand, and a new experiment is being established at Montreathmont Forest (Angus). In this experiment the site was cleared, following early windthrow of Scots pine at a top height of only 13·7 m (45 ft). It is concerned with the interaction between various intensities of both drainage and cultivation and will be planted in the spring of 1969.

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CULTIVATION

Cultivation of Ironpan Soils

The benefits of deep, complete cultivation on ironpan soils have been considerable on a number of sites in Scotland (see *Reports* for 1967, p. 44; 1968, p. 40). Recent results from a 20-year-old experiment at Teindland Forest (Moray) confirm the conclusion that the early rate of growth on such soils is correlated with the volume of soil disturbance.

Experiments elsewhere, however, have tended to give less satisfactory results and height growth has not shown such large differences following various ploughing treatments. At Haldon Forest (Devon) an experiment sited on impoverished Eocene sands and gravels has not as yet shown any significant benefits from complete ploughing. At Taliesin Forest (Cardiganshire) complete ploughing has produced the best height growth with Sitka spruce, but the differences between the various treatments are variable and small.

At both of these sites the undisturbed soil is much less compacted and impoverished than on the upland heaths in north-east Scotland. At Taliesin the soil is variable and in parts of the experiment area could be classed as an intergrade with upland brown earths, rather than a fully developed ironpan soil. The absence of a marked benefit from complete ploughing might also be ascribed to the less intensive form of cultivation used in these experiments as compared with those in the north.

In order to clarify the position and to examine the possible response to increased intensities of cultivation, a number of new experiments will be established. At Towy Forest (Brecon) one of this series has been ploughed for planting in the spring of 1969, the site lying upon ironpan and intergrade soils. The ploughing treatments to be tested are: double mouldboard turf ploughing to a depth of 25 cm (10 in): spaced single furrow tine ploughing to a depth of 50 cm (20 in): complete tine ploughing to a depth of 50 cm (20 in); and complete tine ploughing to a depth of 50 cm (20 in) preceded by deep subsoiling to 75 cm (30 in) at intervals of 1m (39 in). To examine the proposition that complete breakage of the pan will obviate the need for drainage, the cultivation treatments have been factorially combined with drainage of varying intensity. The drain spacings used are 15 m, 30 m and 60 m (16½, 33 and 66 yd).

At Teindland Forest (Moray) a similar experiment is being established, but in this case omitting the drainage comparison and concentrating attention upon various forms and intensities of deep, complete cultivation. Recent foliage analysis data from Experiment 81 at Teindland (*Report* for 1967, p. 44) suggest that the enhanced growth due to deep, complete ploughing has been brought about by increased nitrogen mobilisation. The data also suggest that the initial phosphate application has been exhausted in the faster growing plots and additional application will be required to maintain the original impetus due to the ploughing.

G. G. M. TAYLOR

J. E. EVERARD

REGENERATION

ARTIFICIAL REGENERATION

On Deep Peat

Two small experiments have been planted to study artificial regeneration on deep peat. As there are few crops of suitable age elsewhere, the trials have been sited in old closed experimental plots of larch and Lodgepole pine at Inchnacardoch Forest (Inverness-shire). Both experiments compare notch and turf replanting to confirm the evidence from work on peaty gleys that the former is adequate. In addition, the growth of Sitka spruce will be compared with that of Lodgepole pine and the rate of re-invasion of vegetation following removal of the previous larch and Lodgepole pine will also be studied.

On Gley Soils

Among the earliest regeneration experiments were four on peaty and surface water-gleys, in which various species were compared on windthrown and felled Sitka spruce sites. These sites, which had a complete cover of grasses, were at the Forests of Ae (Dumfriesshire) and Newcastleton (Roxburghshire) (see *Report* for 1958). A main object was to investigate the practicability and value of ploughing with a mounted tine plough under the prevailing conditions, by assessing response in terms of plant survival, weeding needs and growth. These experiments have been assessed at ten years. No worthwhile gain in survival, weeding reduction or growth of the new crop has resulted from tine ploughing.

On Frago-gleys and Ironpan Soils

Many sites on frago-gleys and ironpan soils are planted with Scots pine the average growth potential of which is Yield Class 80, and work is therefore needed on the possibility of replacing these crops by others of more profitable species. Sites have been selected in East Scotland for experiments to this end, but owing to the glutted timber market consequent on the gale of January 1968, felling has had to be deferred.

On Freely Drained Soils

Underplanting of Pine

At Thetford, in a replanting experiment begun in 1964 on three contrasting soil types, in which 18 species were planted below a Scots pine overwood of about 495 stems per hectare (200 stems per acre), growth on the most fertile site (deep acid sand) has continued to be satisfactory and has permitted the removal of the overwood in early winter in plots of ten species. Because of the greater risk of frost damage to certain susceptible species, namely Western hemlock, Western red cedar, Atlas cedar (*Cedrus atlantica*) and five fir (*Abies*) species including Grand fir, the overwood in plots of these has been retained at least for a further year. At the two other, less fertile sites (complex Methwold/Workington soil type and thin soil over chalk) no overwood removal has yet been done because of the slower growth of the underplanted species. At all

three sites *Nothofagus obliqua*, one of only three hardwood species in the experiment, has proved to be particularly vigorous and merits consideration for wider use at Thetford; but on both the poorer sites it has been badly attacked by *Fomes annosus* and the range of conditions in which it may safely be planted is probably limited. Western hemlock, Hybrid larch, Leyland cypress and Douglas fir, though much less vigorous, are, overall, still the fastest growing species in the experiment.

In the related experiment planted in 1967 on two sites (deep acid sand and a complex soil type) in which the establishment of Corsican pine and Grand fir is being examined in clearfelled strips and under different densities of overwood cover, a ground frost (–6°C) on 19th May provided useful evidence of the sensitivity of Grand fir to injury by unseasonably low temperatures. None of the pine was damaged but the fir, which had just begun to flush, suffered moderate injury to lateral shoots, notably in clearfelled strips and under cover where the overwood density was less than 250 stems per hectare (100 stems per acre). Where the overwood stocking was greater than 298 stems per hectare (120 stems per acre) no damage occurred. None of the trees suffered permanent injury, but if the frost had been a few days later the leading buds, which on 19th May had scarcely begun to open, might have been killed, leading to stem bends and forking.

A review of regeneration work at Thetford is currently being prepared for publication.

Underplanting of Larch

Both southern experiments, planted in 1963 at Radnor Forest and at Michaelston, Coed Morgannwg (Glamorgan), are virtually established, though occasional slow growing plots again had to be weeded in mid-summer. At Michaelston, bramble proved to be the main problem, notably in plots of Grand fir, Norway spruce and *Abies alba*. There was no clear relationship between weeding times and amount of overhead shade. Light meter measurements were undertaken in August in both experiments.

In the youngest experiment in this series, planted at Allerston (Yorkshire) in 1967, survival of Grand fir was unaccountably low, irrespective of overwood or cultivation treatment. Heavy snowfall in December 1968 caused considerable damage to Scots pine, Lodgepole pine and Japanese larch especially where under an overwood.

Soil Erosion Following Clearfelling of Spruce

The steep clearfelled plots at Benmore Forest (Argyll) in which soil movement has been monitored since 1966 (*Reports* for 1967, p. 59; 1968, p. 57) are now soon to be abandoned owing to the moss cover which invaded while other vegetation was excluded chemically. Total, oven-dry weight of trapped material leaving the site ranged from 159 kg per ha (142 lb/acre) in the plot from which slash had been cleared to 237 kg per ha (212 lb/acre) where it had been retained. The trapped material was divided into floatable and denser fractions. Less than half the trapped material fell into the denser fraction. Even allowing for a considerable amount of experimental error, the hazard of erosion on this fairly extreme site does not appear to warrant further investigation.

NATURAL REGENERATION

Estimates of Seedfall

The two Sitka spruce seed trapping experiments at Newcastleton (Roxburgh-shire) and Farigaig (Inverness-shire) referred to in last year's *Report* were concluded. Total number of seed trapped over the period (October-June) was 30·1 million per hectare (12·5 acre) at Newcastleton, and 1·2 million per hectare (0·5 acre) at Farigaig. The proportion of sound seed, assessed by X-ray photography, was 23 per cent and 70 per cent respectively.

The greatest fall of seed at Newcastleton was during February and March (as in a previous experiment at Glenbranter). The Farigaig stand shed a quarter of its sound seed in October, thus suggesting that it would be advisable to collect cones as soon as possible after ripening or at least not later than December. There was no marked tendency for unsound seed to be shed before sound seed.

Natural Regeneration of Sitka Spruce

Monitoring of growth and survival of natural regeneration at the Forest of Ae continues. There was a large crop of germinants in 1968 (equivalent to 150,000 per hectare or 60,000 per acre) which by November had diminished by 21 per cent, mainly due to drought in the litter layer, beyond which the roots did not penetrate. The southern half of the small clearings in which regeneration is being studied started with more seedlings than the northern half, but survival was not obviously affected by position within the clearing. Germinants under surrounding cover had markedly lower first-year survival.

S. A. NEUSTEIN

J. JOBLING

STABILITY OF CROPS

Behaviour of Trees and Crops under Wind Stress

Windblow Survey: The Gale of January, 1968

An aerial survey, foreshadowed in last year's *Report*, to make a particular study of the correlation of windthrow incidence with topography, was made by helicopter in the five forests of Knapdale, Glenbranter, Loch Eck, Benmore and Ardgartan in West Scotland. The helicopter was not adapted for vertical photography, but about 150 oblique colour photographs were taken in a total flying time of three and a half hours.

Most of the damage was one-directional windthrow, with little windbreak at less than 10 per cent, and the location of damage could be fairly readily attributed to topographic and assumed soil factors. The latter will be more closely examined when clearance has been completed.

Subsequent analysis of colour transparencies generally endorsed the classification of Hutte (1967). Forty-five per cent of occurrences were on windward slopes and slopes oblique to the wind, and 16 per cent of occurrences were located on ridge tops and the same proportion in funnel features. There was very little damage on leesides—a category which Hutte regards as an important one. In addition, starting and stopping points were recorded (e.g. roads, rides, change of speciesi and crop height). Only in half of the damaged areas could starting and stoppng features be recognised, which is to some extent a reflection of the irregularity of the windflow.

The value of an aerial view for general management purposes was most impressive, and in particular the distribution of retarded crops was most obvious.

Staff from Aberdeen University Forestry Department completed a valuable survey of damage at Glendevon Forest (Perthshire) which reinforced the topographic correlations obtained elsewhere.

At Carron Valley Forest (Stirlingshire) damage was particularly extensive. Windthrow of uniform shallow-rooted spruce crops in this smoother topography indicates the likely catastrophic damage if such a severe gale occurred in the Scottish border region. Correlation of damage with specific topographic features was less valid than correlation with elevational zonation—the system of windthrow prediction now in use in these conditions.

A publication is proposed describing the effects of this particular gale. It will include meteorological, silvicultural, production and marketing aspects. Guidance for restocking gale damaged areas was widely circulated in a Research and Development Paper (Neustein, 1968).

S. A. NEUSTEIN

Site Factors in Relation to Stability and Growth

Tree Pulling Investigations

The bulk of this year's effort has been directed to a very rapid and therefore somewhat superficial investigation into the rooting of various minor species. This has been undertaken as part of the Minor Species investigation currently being carried out by Research Division. The species covered have been Grand

fir, Noble fir, Western hemlock and Red cedar, and at all sites a major species (where possible Sitka spruce) has also been studied to provide a basis for comparison.

The methods being employed are those described by Fraser and Gardiner (1967). A series of studies has been carried out to determine the effect of a wide range of soil conditions upon the stability of the major conifer species, with an emphasis upon Lodgepole pine.

Initial work at Allerston Forest (Yorkshire) has shown that the strongly compacted mineral soils of these upland heaths restrict the root development of all the principal conifer species. Early results suggest, however, that Lodgepole pine may be slightly more prone to early windthrow under these conditions than most other species. The distribution of roots is clearly correlated with the form of ground preparation, with complete ploughing providing the most uniform distribution.

In a study of Lodgepole pine on deep peat, carried out at Inchnacardoch Forest (Inverness-shire) in a crop planted in 1935, six trees out of a sample of eight broke before they could be pulled over. Excavation showed that healthy roots had exploited the peat to a depth of over 1·2 m (4 ft). The site had been well drained at planting, but drain depths were never more than 60 cm (24 in). The stand was unthinned and sufficient additional moisture may have been removed from the soil by its dense canopy to permit this deep root penetration. It is too early to judge if rooting of this order can be expected on all deep peat sites with Lodgepole pine, but the result is encouraging.

Tree pulling has been carried out in two of the drainage experiments on Sitka spruce sites in the south. The data collected will serve as an assessment of root form prior to drainage and it is hoped that further trees will be pulled over throughout the rotation to investigate the response of rooting to the various treatments. It is interesting to record that trees pulled over at the Crychan (Brecon) drainage experiment had a particularly low resistance to overthrow. This, no doubt, can be attributed to the restricted root system which has developed on poorly drained single furrow ploughing. Tree pulling studies are to be undertaken during 1969 to investigate the effect of different ploughing methods on the stability of Sitka spruce on wet land.

It is likely that tree pulling, perhaps with a simplified method, will be used increasingly as a form of assessment in various types of experiment, particularly in the fields of drainage and cultivation.

J. E. EVERARD

G. G. M. TAYLOR

Prediction of Windthrow

Records of Windthrow

The national survey of windthrow, using notification cards, has been maintained. The work involved in recording the damage caused by the January 1968 gale was underestimated and a large number of forests have still to be covered. It is hoped that the backlog of this work can be done at Alice Holt from maps and compartment records.

Prediction of Windthrow

A common and perhaps predictable form of damage is the type which occurs annually in the extensive spruce crops of the Scottish Borders. Annual surveys

of damage in several forests indicate that new clearings are numerous but mostly below 0·60 ha (1·5 acre) in area. The height of crops in relation to soils and elevation at which new damage begins is the basis of the susceptibility rating now used by local management. However, the great bulk of damage is due to extension of clearings, and so analysis of annual re-surveys is currently in hand to attempt to make short-term forecasts of the amount of extension to be expected from a given distribution of clearings. The manager's ability to programme his production will be greatly enhanced if extension under these circumstances is even approximately predictable.

S. A. NEUSTEIN

J. E. EVERARD

Preventive and Remedial Measures

Thinning Studies

The current policy expressed in the Kielder Forest (Northumberland) Working Plan assumes that crops in the most windthrow-susceptible zone will remain stable longer if unthinned. One small experiment (see *Report* for 1967) compares the stability of crops subjected to a range of thinning treatments, but it was felt that a wide range of sites and crops should be examined. The first of a series of experiments comparing the stability of crops thinned normally (at Management Table intensity), line-thinned and unthinned has been established at Kielder. Concurrently, the accuracy of the original susceptibility classification and the rate of extension of windthrow will be assessed.

A similar series of experiments is to be carried out in Wales and South West England on sites classified by the Soil Survey Section of the Planning and Economics Branch as being susceptible to windthrow.

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ECOLOGY

Tree Growth in the Forests of the South Wales Coalfield

Forestry Commission land in the South Wales Coalfield amounts to nearly 30,000 hectares (75,000 acres), with a considerable programme of new planting. By no means all of the older plantations—now 40–45 years old in some forests—are showing a satisfactory rate of growth and it was decided early in 1968, following discussions between South Wales Conservancy and Research Division staffs, to make a thorough survey of the performance of the main species against the ecological background. Some reconnaissance was done in 1968 and systematic survey, which is expected to continue for several years, will begin in 1969.

Sitka spruce, to which the general climate of South Wales appears well suited, is the main species and attention will be largely focused on it. But there are substantial areas of Norway spruce, Corsican and Scots pines and Japanese larch. Some of these, as well as a few other conifers, which so far have not been widely planted in the forests, may have an important place in certain environments less suited to Sitka spruce; the collection of data is accordingly by no means restricted to that leading species.

Generally the area is characterised by a long growing season, strong winds and local industrial pollution—all of these properties strongly influenced by a deeply dissected topography. Altitude ranges from near sea level to about 600 m (1,970 ft) and many of the valleys open to south or south-west towards the coast. Soil drainage, though no restriction in the early plantations on the steep valley slopes, is important on the flatter uplands where recent afforestation is being carried out. Mineral poverty of the soils derived from the Pennant Series of sandstone rocks seems to be a general feature.

There is no present intention of a special investigation of the air pollution factor, but it is hoped that current and future work by scientists of the University Colleges of Wales will illuminate this aspect of our problem. Such work is highly specialised and a fair assessment of the bearing of SO_2, or other pollutants, on the performance of trees 30 to 40 years old demands an evaluation of environmental changes due to the creation of new sources of pollution, the abolition of old ones, or the measures taken by some industrial proprietors to minimise the effect of phytotoxic effluents.

The Weather of the Year 1968

Monthly values of the main climatic elements for Alice Holt Lodge, Hampshire (115 m, 378 ft) are given in Table 23 for the year 1968. As these figures indicate, the summer in the south and east of Britain was dull and rather wet throughout: excepting only 1958 and 1954, it was the dullest year—and the dullest summer—since records here began twenty years ago. Nearly 600 mm rain (more than 60 per cent of the year's total) fell during the six months from April to September, an exceptionally wet month in which 114 mm (4·2 in) fell in two days on 14th–15th; severe flooding was caused then in many parts of the Thames catchment. In marked contrast, the north and west of Britain, and more especially Ireland, enjoyed excess summer sunshine and warmth and long periods without rain. Perhaps forestry suffered least in a summer which proved so disappointing in those parts where most people live and work.

TABLE 23

MONTHLY WEATHER RECORDS, ALICE HOLT LODGE, HAMPSHIRE, FOR THE YEAR 1968

Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Yearly means	Yearly totals	April–September means	April–September totals
Air temperature screen °C																
Mean daily maximum	6·4	4·9	10·2	12·5	14·8	19·4	19·6	19·1	17·9	15·5	8·7	4·6	12·8		17·2	
Mean daily minimum	0·8	−1·0	3·0	2·8	5·4	10·3	10·7	11·8	10·3	9·8	3·7	0·2	5·7		8·55	
Monthly extreme grass minimum	−13·3	−8·3	−6·1	−8·9	−2·8	1·7	0·6	3·3	1·7	0	−7·2	−10·6				
Soil temperature (°C) at 9 hrs																
Mean at:																
10 cm (4 inches) under bare soil	3·2	1·4	4·4	7·6	11·4	16·4	17·4	19·0	13·6	11·2	5·9	2·7	9·5			
20 cm (8 ,,) ,, ,, ,,	3·7	2·5	4·8	7·6	10·8	15·7	16·9	19·1	14·1	12·6	6·9	3·6	9·8			
60 cm (2 feet) under short grass	4·9	4·3	5·6	8·4	11·4	15·4	17·1	19·9	15·8	13·9	9·6	6·2	11·0			
Precipitation (mm)	56	42	27	69	83·5	80·5	100	72	192·5	93	63	99·3		977·8		597·5
Number of days with rain (·2 mm or more)	20	11	12	15	15	16	10	17	21	20	15	13		185		94
Lysimeter (Garnier Gauge) A	−2·8	9·6	33·0	43·9	43·2	65·7	107·8	68·8					see text note			
Evaporation losses (mm) B	4·6	15·0	37·6	57·9	59·0	71·1	132·3	94·5								
Total hours bright sunshine	47	80	148·6	182	175	182	152	120·5	129	71	48	35·4		1,370·5		941
Mean daily run of wind (miles)	82·3	70	105	68·1	57·1	68·3	45·2	51·7	66·8	56·9	62·2	44·6				

The destructive gale of mid-January 1968 in the Clyde-Forth region of Scotland was mentioned in last year's *Report*. Apart from flooding in the south, the only other unusual occurrence was the dropping of massive hailstones during the passage of a cold front in early July. Damage to young trees was caused in a swathe extending from South Wales to Yorkshire.

The winter of 1968–69 was also abnormal, inasmuch as a mild January was both preceded and followed by two rather cold months; with an unusual prevalence of winds from east or north-east, spring will be later than those of recent years.

Throughout 1968 some doubt was felt about the accuracy of the Garnier lysimeter data; there was difficulty in maintaining a strong grass sward and some evidence of unrecorded loss of water below ground from one gauge. Accordingly, readings were interrupted at the end of August and the installation was thoroughly overhauled; the new lay-out was ready for resumption of records by January 1st, 1969.

J. M. B. BROWN

FOREST GENETICS

Seed Crops

The 1968 cone and fruit crops ranged from light to moderate. Scots pine cropped well in the seed orchards of Central Perthshire, Wiltshire and East Anglia; in contrast, most of the Corsican pine and Lodgepole pine seed stands produced only light crops—even on the most favourable sites for flowering. Scattered but light cone crops of Sitka spruce were reported throughout Wales, with good crops locally further north, and in east-Aberdeenshire in particular. Douglas fir crops were generally poor, although moderately good crops were noted locally in central Perthshire and around the Beauly Firth. The oak mast was good in southern Britain, but generally poor elsewhere. In contrast, the beech mast was very heavy in northern districts and particularly in eastern parts of Scotland from the Moray Firth southwards to Berwickshire.

Survey of Plus Trees

The search for Plus trees continued; most of the effort was directed at Lodgepole pine and Sitka spruce. A further 138 Lodgepole pine and 100 Sitka spruce Plus trees were selected.

Most of the old and middle-aged crops of Lodgepole pine were surveyed during the period 1960–1964, and only recently has it been possible to make selections in the relatively young but promising crops of coastal Washington and Oregon provenances which were extensively planted in the 1950–1954 period. The main criteria for selection were vigour and relative freedom from butt-sweep, which is the commonest defect in coastal provenances. Variants with a combination of these attributes were found to occur on a wide variety of sites and in the proportion of approximately one tree in four thousand. Plantations were surveyed in Wales and in north, north-east, west and south-west Scotland.

Sitka spruce surveys were restricted to forests in the Great Glen, Inverness-shire, and south-west England. The first phase of the Sitka spruce Plus tree survey programme, which until now has been concentrated on the older pre-1940 plantations, should be completed by 1971. After a short interval the surveys will be resumed in post-1945 plantations which were established on more difficult sites but which benefited from improved draining, cultivation and fertiliser practices. It is highly probable that the Plus trees selected from each of these two planting eras will show distinctly different genetic differences; these will only become evident from progeny-tests.

In January 1968, the gale which devastated several forests in west Scotland either uprooted or snapped thirty-one out of ninety-four Sitka spruce Plus trees in the Cowal district of Argyll. All the fallen or damaged trees were found with some difficulty and scionwood was collected and successfully grafted in the late spring. Unfortunately timber core-samples could not be obtained for routine laboratory wood quality-tests. The examination of 12 mm cores from Sitka spruce Plus trees is continuing at the Forest Products Research Laboratory and investigations have now been made on cores from 314 trees; cores from a further 189 trees are currently being examined.

Vegetative Propagation

Douglas Fir

Pot-grown Douglas fir grafts frequently adopt a plagiotropic habit of growth, i.e. a strong tendency to horizontal rather than vertical development, after planting in seed orchards. Furthermore, the survival rate of pot-grown plants is usually low and sporadic deaths continue to occur over a period of several years as a result of a breakdown in the water-conducting tissues in the region of the graft union; the causes are unknown. Deaths can be anticipated by observing the development of a swelling or "overgrowth" of scion tissues above the point of grafting, coupled with a general yellowing of the scion foliage.

In 1962 it was believed that a solution to both problems might be obtained by grafting Douglas fir scionwood near the top of well-established, 0·9 m–1·5 m (3–5 ft) tall, rootstocks and by leaving many of the rootstock branches unpruned to act as "feeders" for the root system. An experiment was conducted at Clanna, in the Forest of Dean, in which forty-eight clones were grafted on paired 3-year-old rootstocks previously selected for good vigour and health. In all, 829 grafts were made using a side-veneer grafting method and at a point 0·6–0·9 m (2–3 ft) above ground level. After two growing-seasons 93 per cent of the grafts survived and most of the plants showed good apical dominance; the rootstock branches were lightly pruned to prevent competition with the developing scion. The paired grafts were singled in May 1965 to leave the best individuals selected for vigour and for quality of the graft union. After four growing-seasons 87 per cent of the original positions were occupied by live plants and at this stage only a small number of grafts showed any signs of "overgrowth". Survival was 83 per cent after six growing-seasons and 78 per cent in autumn 1968, thus suggesting that the effects of delayed incompatibility continue. Plate 17 illustrates the form of a selection of these grafted plants in spring 1969.

There is no clear evidence to indicate that incompatibility is directly associated with clonal differences. Thirty-six of the forty-eight clones still have a survival rate of over 75 per cent. In the remaining twelve clones the heaviest losses occurred during the first three years following grafting, and surviving individuals of half these clones are above average for quality of graft union and overall vigour. After the initial losses, which were confined to relatively few clones, subsequent deaths have been fairly uniformly distributed between all the clones represented.

Sitka Spruce

The current practice for propagating Sitka spruce Plus trees, for use in seed orchards and tree banks, is by grafting scions under glass on to potted 3- or 4-year-old rootstocks using a side-veneer technique. Recent grafting success has been in the order of 40–50 per cent. Trials with large well-established rootstocks on the orchard sites have not given better results (see *Report* for 1968) and it was, therefore, considered worthwhile to investigate the possibilities of using very young and vigorous seedling stocks raised in a controlled environment for "mini-grafting" trials.

Six-month-old, 10–15 cm (4–6 in) tall seedlings which had been raised in the growth-rooms at Grizedale were used for a small trial in 1968. A proportion of the sturdiest seedlings were grafted, using soft-tissue material from other actively

growing seedlings; these were unsuccessful. Later grafts were made using 1-year-old wood from four 30-year-old trees. Small medical scalpels were used for cutting because of the delicacy of the operation and the fragile nature of the rootstocks. Three types of grafting method were attempted; side-veneer; cleft; and an unorthodox "hybrid" between a bud- and side-veneer. Due to the very lush and weak condition of the material, top-working was almost impossible and therefore all the grafts were made at a point near the rootstock collar. Seventy-two grafts were made on the day after scion collection; these gave 38 per cent success with the side-veneer; 30 per cent with the cleft and 5 per cent with the "bud-veneer". The second batch of forty-six grafts, which were made twelve days later and using the same source of scion material, gave 48 per cent success with the side-veneer and 4 per cent with the cleft; no "bud-veneer" grafts were attempted.

At the beginning of July, a further fifty-five grafts were made using softwood scions from actively growing transplants. "S.600" anti-dessicant was sprayed on a proportion of the scionwood twenty-four hours before removing the scions from the stock plant; a further proportion of the scionwood was sprayed with "S.600" after grafting. Although only a limited number of grafts were treated, the results from treating the scions with "S.600" before grafting are encouraging. After grafting, all the plants were kept in the growth-rooms for at least three months. The initial growth of the scions was very fast and a union was rapidly formed between rootstock and scion; subsequent growth has not been spectacular but from the general appearance of the plants at present it seems reasonable to expect satisfactory growth during 1969.

In a trial of grafting using one-year-old seedling rootstocks raised under glass at Alice Holt and using normal scionwood, a 56 per cent survival was obtained compared with 35 per cent survival for normal grafting on 3-year-old rootstocks.

The Formation of Tree Banks

The establishment of a National Tree Bank for Sitka spruce began in 1966 at Wauchope, Roxburghshire. This bank will accommodate 550 clones and already 331 clones have been established. Each clone is represented by six ramets spaced at 2·4 m (8 ft) within lines and 9·6 m (30 ft) between lines. Spring planting is the common practice but limited trials using 6-month-old potted grafts planted in July directly from the glasshouse have been quite successful. Currently "container-planting" methods are being investigated during the spring and summer periods.

Planting in the Wauchope section of the National Tree Bank should be completed by the end of 1971 after which it will continue at Glenalmond (Ledmore Forest), Perthshire. A small "scion bank" has also been established at Wauchope; this will provide a source of inexpensive scions when grafting to produce plants for the first seed orchards. The grafts in the "scion bank" are spaced at 1 m x 1 m (3¼ ft x 3¼ ft); whole plants will be used to yield the necessary scionwood. Since the "scion bank" will have a short life, plans are in hand to replace it with a collection of grafted Plus trees which will be sited at the new propagation centre to be built as an adjunct to the Northern Research Station at Bush, Midlothian, in 1969. This collection will be contained in a polythene-clad house where the plants will be pruned at regular intervals to provide an abundant source of scionwood.

Controlled Pollination

Lodgepole Pine Inter-provenance Crossings

In Britain Lodgepole pine provenances from the coastal belt of Oregon and Washington grow vigorously but tend to develop heavy branches, broad crowns and frequent stem bends which are often associated with butt-sweep; more northerly coastal provenances from British Columbia and Alaska, which grow more slowly, have a better stem form and branching habit, but the same tendency to develop broad crowns. Inland provenance from British Columbia generally produce trees with straight stems, narrow crowns and finer branches. A within-species hybrid, combining the vigour of the coastal provenances and the desirable stem and branch form of the inland ones would have obvious merit in British forest practice. For this reason a variety of artificial crosses was made within a selection of distinctive trees of coastal and inland origin growing in the Saltoun (Stenton Forest), East Lothian, collection of provenances. The programme duplicated, in part, the work which was referred to in the *Report* for 1961, but which yielded few seeds as a result of faulty pollination techniques. In all, eleven intra-specific crosses were made in 1968, three of which were between "coastal" provenances and the remainder between "coastal" and "inland" provenances.

Inter-Species Crosses

The Canadian Jack pine, *Pinus banksiana*, and Lodgepole pine have been successfully hybridised artificially by several workers; natural hybrids occur in north-east British Columbia and Western Alberta. Artificial hybrids previously produced in Britain developed characters which were intermediate between the two parent sources and with no suggestion of hybrid vigour (heterosis). No attempt has yet been made to hybridise one species with different and widely separated provenances of the other species; such crosses could give indications of the possibilities of the potential for obtaining heterosis. For this reason artificial crosses were made at Saltoun between a Queen Charlotte Island, British Columbia, provenance of Lodgepole pine (a far westerly source) used as the mother parent, with provenances of *P. banksiana* from Saskatchewan (western), Wisconsin (south-central) and Maine (south-eastern) parts of its range, as fathers.

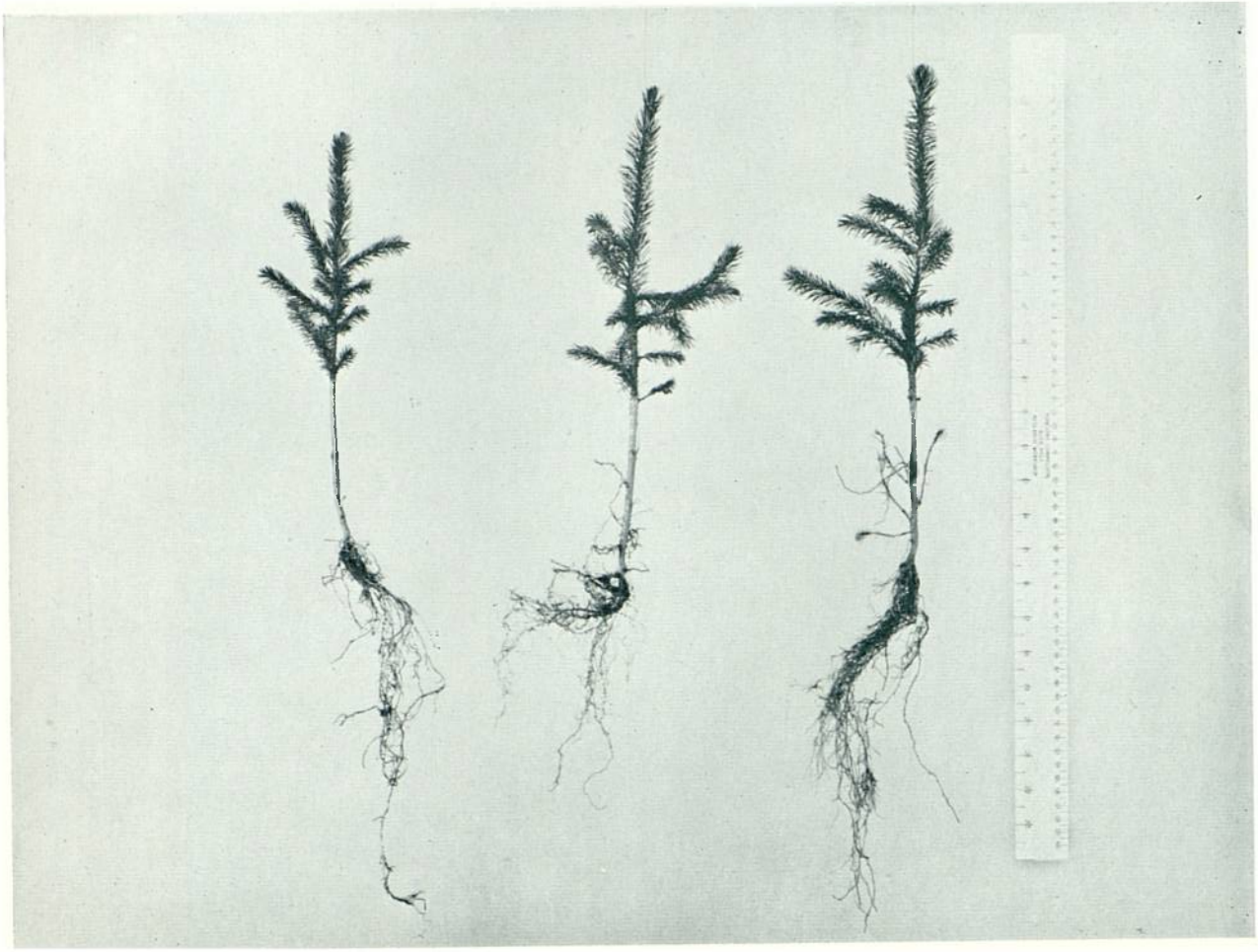
Sitka Spruce Diallel Cross

For the basis of future heritability studies on Sitka spruce a 7 x 7 diallel crossing programme (one in which each of 7 trees were used as both mother and father parents—and including self-pollinations—to provide a total of 49 crosses in all) was accomplished on seven 32-year-old parent trees selected for variability in form and habit of growth, and growing in Roseisle Forest, Moray. Female flowers were isolated twelve days before pollination using 46 cm x 23 cm (18 in x 9 in) "Terylene bags"; freshly collected pollen was used.

Losses of flowers caused by abrasion inside the bags were low. The mean seed yields ranged from 20 full seeds per cone for the "selfs" to 63 full seeds per cone for the out-crosses; open-pollinated checks yielded 140 seeds per cone.

PLATE 1: Forest Pathology (p. 107)

Experimental removal of pine stumps infected by *Fomes annosus* using the Volvo BM 840 tractor with lifting tongs. Thetford Chase, East Anglia.



PLATES 2 AND 3:

Planting methods for exposed situations. (Choice of Species, p. 53).

Sitka spruce transplants, aged one plus one year, planted in late May 1968, on an exposed site at Radnor Forest, and lifted in October of the same year. Reproduced at about one-third actual size.

PLATE 2 (*left*)

Planted direct from cold store.

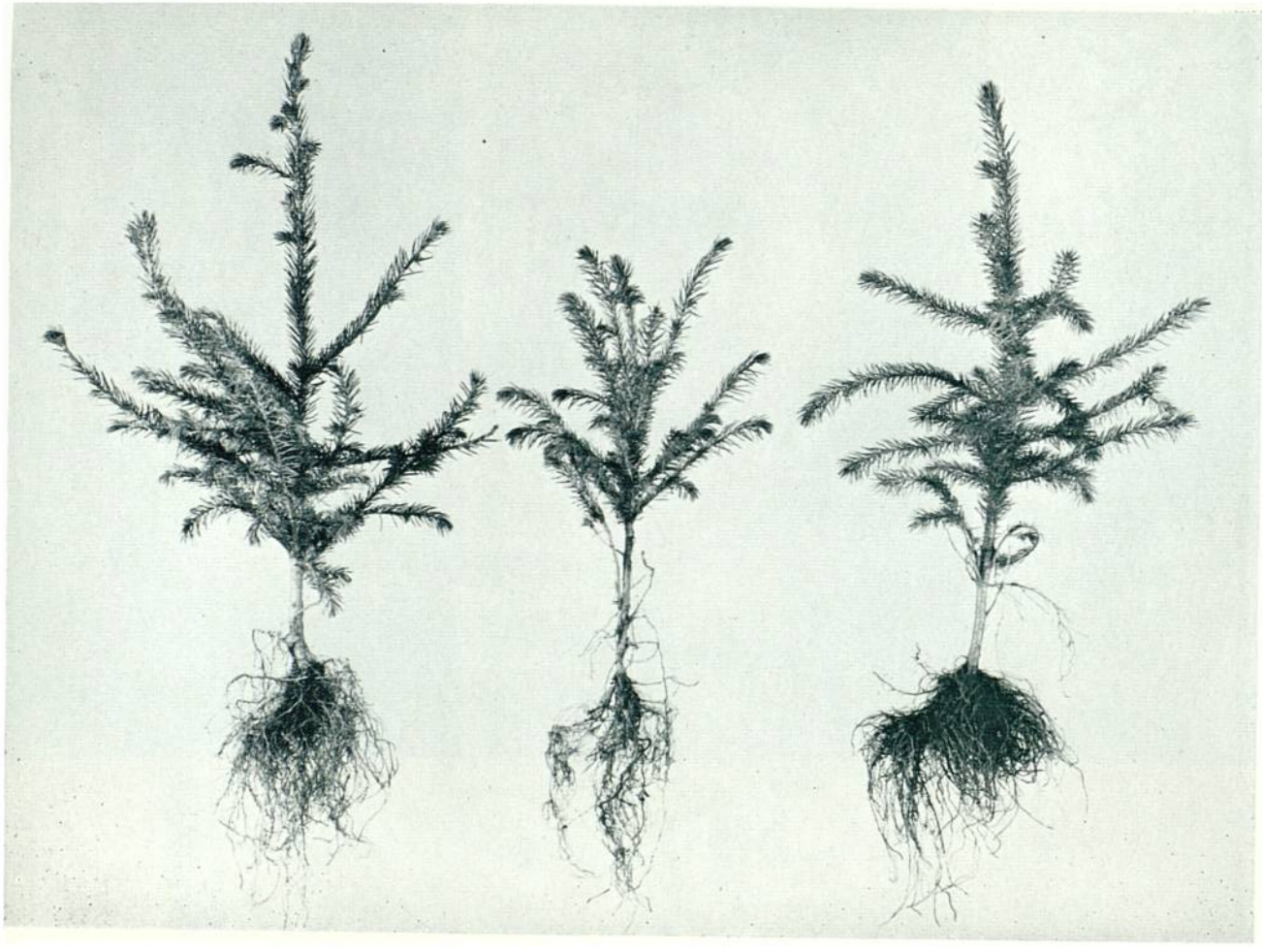
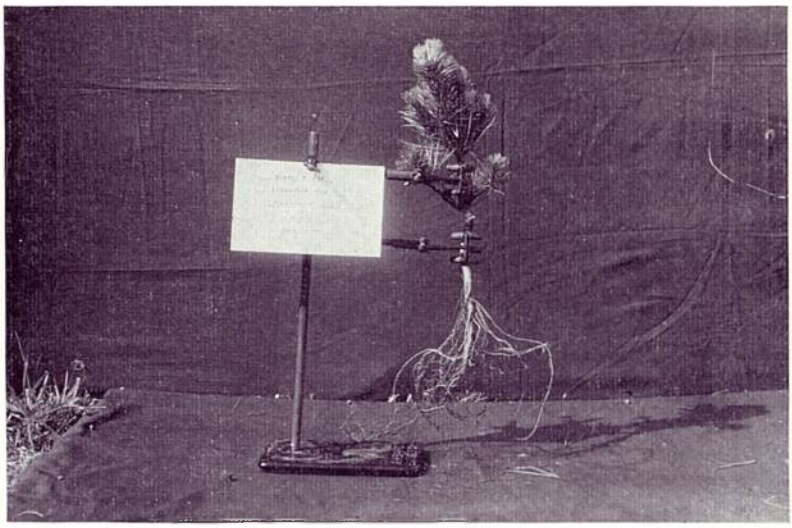


PLATE 3:
Potted in 105 mm (4¼ inch) black whale-hide pots, in Levington No. 2 compost in February 1968. Planted without removal from the pots.



(*Plate 4*) (*Glenamoy tunnel*)

PLATES 4 to 8: Drainage (p. 88)
Experiment No. Achray 3 P65. Root studies. The effect on root form and vigour resulting from differing sizes of turf ridge and varying intensities of drainage.

PLATE 4: (*Above*)
Glenamoy Tunnel ploughing, producing very thin turf ridge. Cross-drains 0·9 m (3 ft) deep at 15 m (50 ft) spacing. *Drainage effect poor.* (Treatment U/50/3).

PLATES 6, 7 AND 8 – (*facing page*)
DOUBLE MOULDBOARD PLOUGHING GIVING THIN TURF RIDGES.

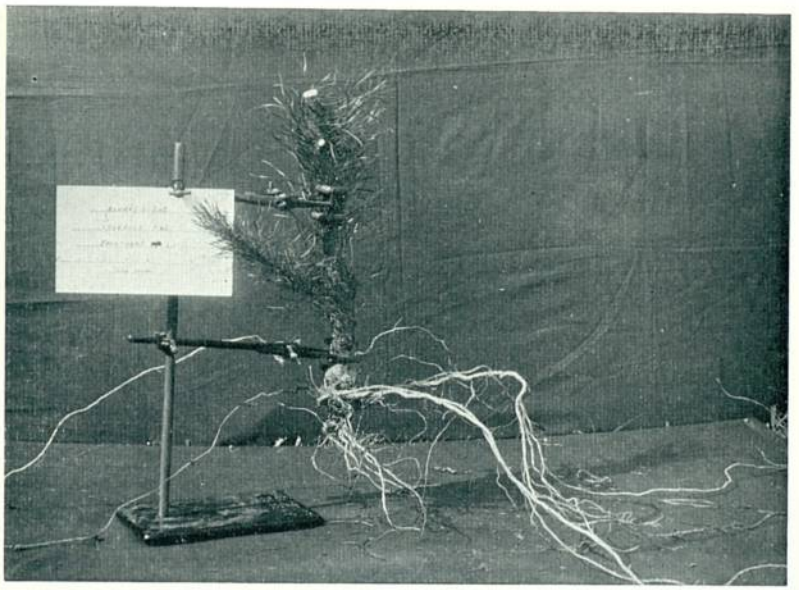
PLATE 6: Cross-drains 0·6 m (2 ft) deep at 15 m (50 ft) spacing. *Drainage effect poor.* (Treatment S/25/2).

PLATE 7: With deep single mouldboard furrows at 6·7 m (22 ft) spacing. *Drainage effect moderately good.* (Treatment 75/0).

PLATE 8: With cross-drains 1·2 m (4 ft) deep at 7·6 m (25 ft) spacing. *Drainage effect very good.* (Treatment S/25/4).

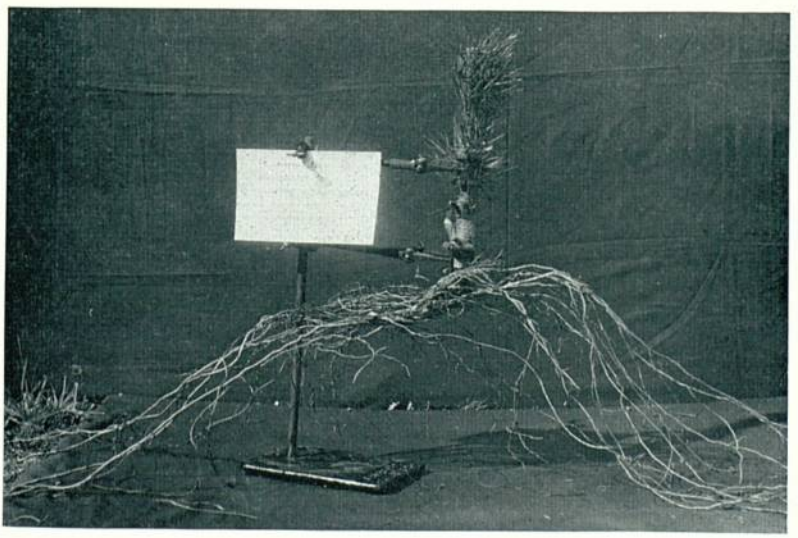
PLATE 5: (*Below*)
Single mouldboard ploughing giving thick turf ridges, *with good drainage effect* due to close spacing of deep furrows. (Treatment D/O).

(*Plate 5*)
(*Single mouldboard*)



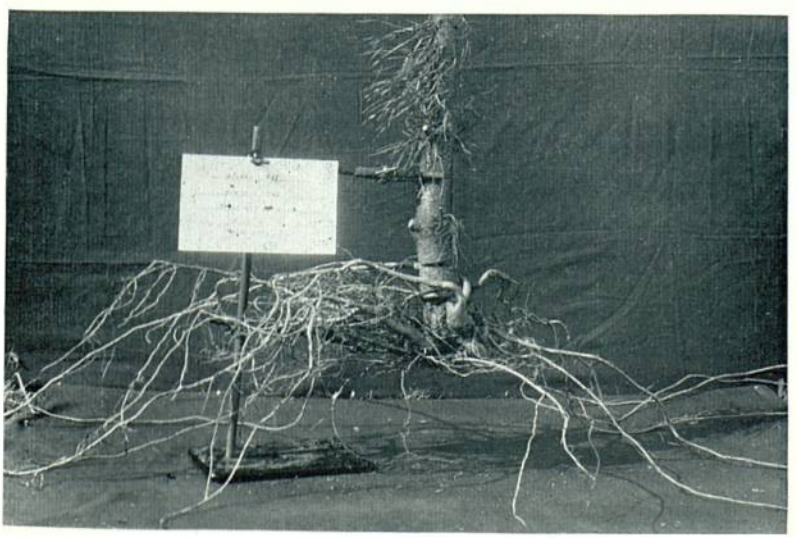
(*Plate 6*)

(*Double mouldboard, shallow cross-drains at 15 metres.*)



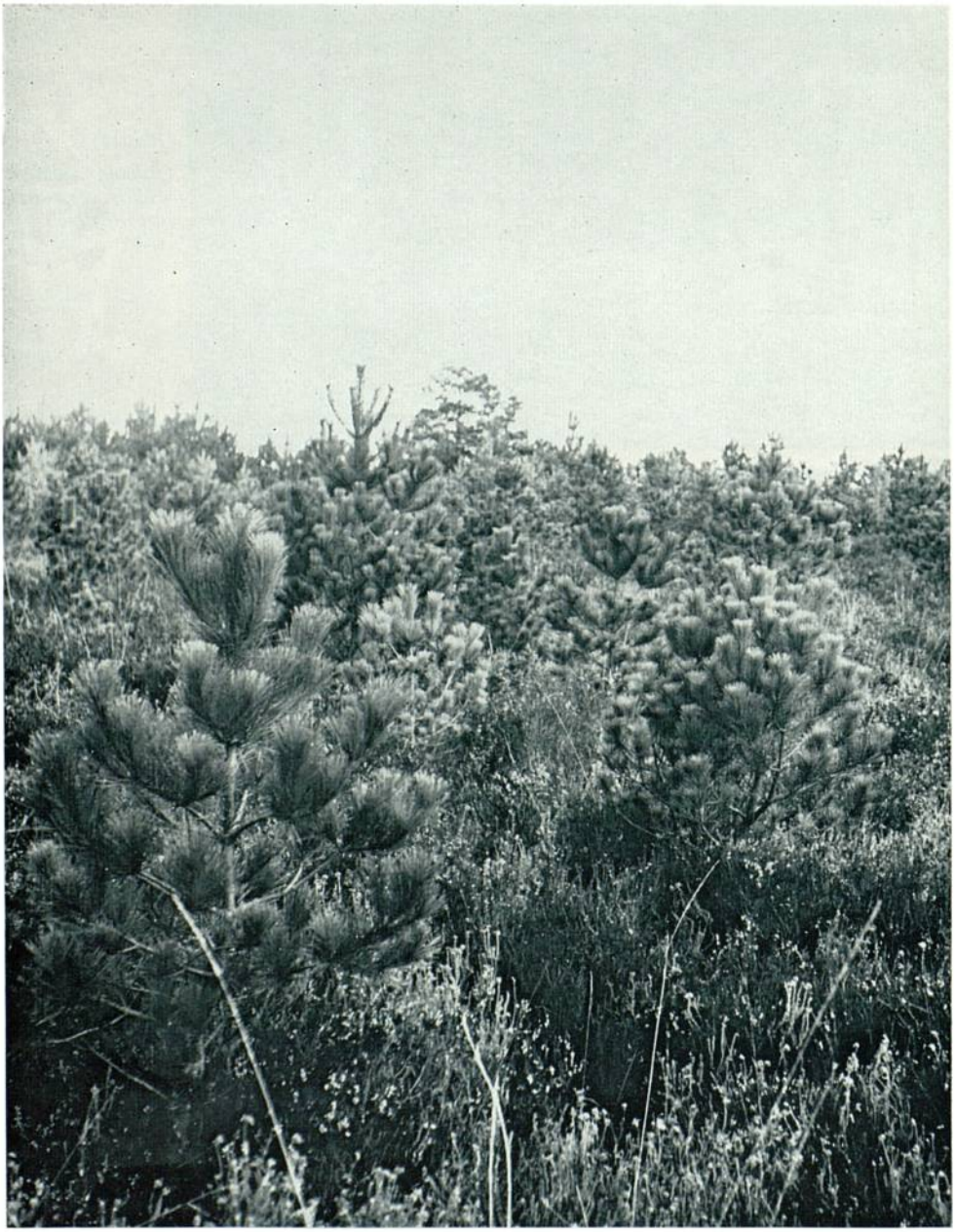
(*Plate 7*)

(*Double mouldboard, deep furrows at 6·7 metres.*)



(*Plate 8*)

(*Double mouldboard, deep cross-drains at 7·6 metres.*)



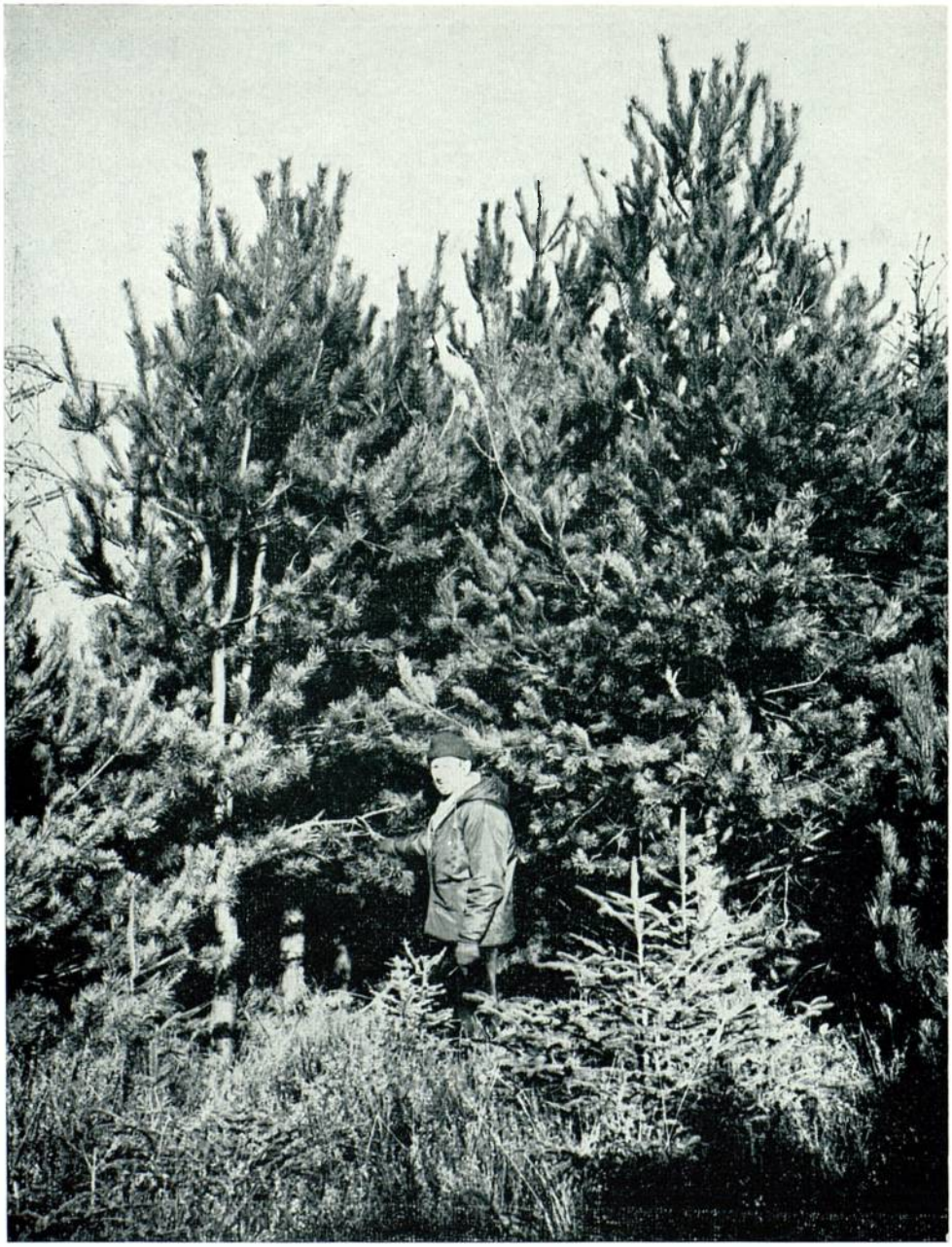
PLATES 9 TO 12: Nutrition of Forest Crops (p. 68)[11]

Tree growth in adjacent plots at Wareham Forest, Dorset, under the normal forest regime, and with annual fertilisation plus complete weed control for five years. (*Continues overleaf*).

PLATE 9: (*Above*)

Corsican pine nine years after planting, treated once only with phosphatic fertiliser.

PLATE 10: Corsican pine seven years after planting, treated annually with NPK fertiliser, and with complete weed control for five years.



PLATES 9 TO 12: Nutrition of Forest Crops (p. 68)

Tree growth in adjacent plots at Wareham Forest, Dorset, under the normal forest regime and with annual fertilisation plus complete weed control for five years. (*Continued from previous pages*).

PLATE 11: (*Above*)
Scots pine nine years after planting, treatment as for Plate 10.

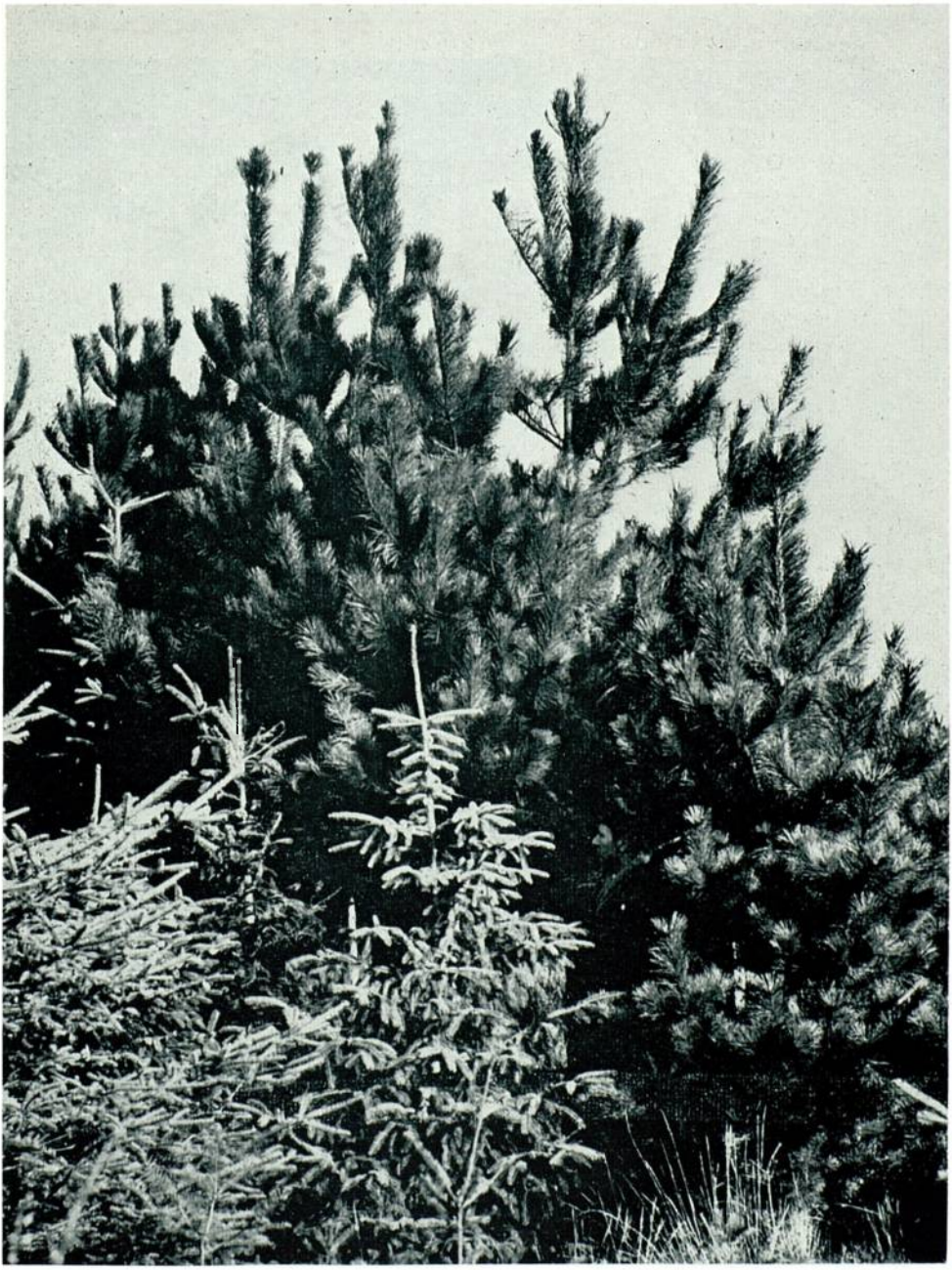


PLATE 12: Monterey pine nine years after planting, treatment as for Plate 10.

PLATES 13 TO 16: Production of Planting Stock (pp. 36–40). (*Continues overleaf*).

PLATE 13 (*left*): Polythene-covered greenhouse, 40 ft long x 20 ft wide, used for tubed seedling research at Tulliallan Nursery. Note outlet for ventilation fan.

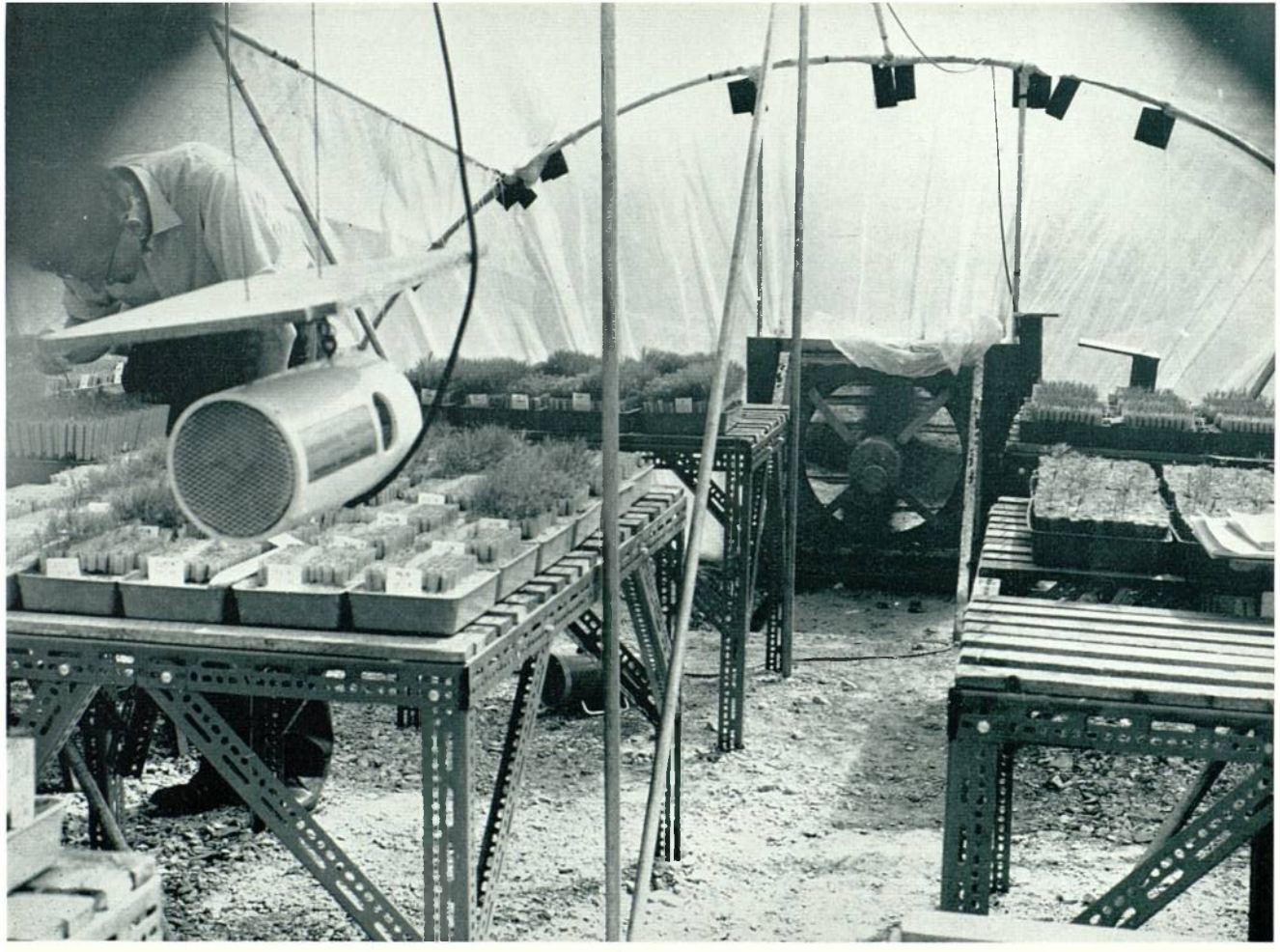


PLATE 14: Interior view of polythene greenhouse at Tulliallan Nursery. Note tubular steel framework, ventilating fan and aspirated thermostat.

PLATE 15: (*Above*)
8-week-old Lodgepole pine tubed seedling, ready for planting. Actual size.

PLATE 16:
"Nisula" Transplant Roll. One-year seedlings inserted in a peat/polythene roll, and allowed to grow for a further year before planting in the forest. The technique provides stock capable of being planted well outside the normal planting season.

PLATE 17:
Forest Genetics (p. 102)
Douglas fir clonal seed orchard at Clanna, Forest of Dean, seven years after grafting. The position of each graft union can be seen at the division between the dense growth of the rootstock foliage (after trimming) and the more open growth of the scion.

PLATE 18:
Work Study (p. 128)

The Massey-Ferguson "Treever", a four-wheel drive frame-steered tractor/trailer/crane combination undergoing trials at Kielder Forest (Northumberland) early in 1969

PLATE 19: Work Study (p. 129).

A Cooper Pegler Vermorel tractor-mounted mistblower spraying a clear-felled area at Hazelborough Forest (Northamptonshire) against woody-weed growth prior to re-planting.

Progeny Trials

The programme of routine progeny-testing Plus trees continued during 1968 and was supplemented by a series of plot-size and plot-shape experiments. Earlier statistical work on progeny tests has been mainly concerned with the experimental design and layouts and has to some extent ignored the problems, some of them economic, associated with the size and shape of the treatment plots. In order to evaluate some of the problems of differing plot sizes and shapes, a series of experiments using seven, half-sib families, derived from open-pollinated Sitka spruce Plus trees and an imported "control" were planted at five forest sites, namely: Aultmore, Banffshire; Farigaig, Inverness-shire; Kershope, Roxburghshire; Laurieston, Kirkcudbrightshire; and Towy, Cardiganshire during 1968. These experiments compare ten different sizes and shapes of plots including 1, 4, 16, 25 and 36-plant square plots and 4, 8, 12 and 16-plant line plots. The various plots are randomised throughout the layout.

R. FAULKNER

R. B. HERBERT

A. M. FLETCHER

FOREST PATHOLOGY

Death and Decay Caused by Fomes annosus

Three major aspects of the control of *Fomes annosus* (Fr.) Cooke have been studied during the year.

Deaths on Alkaline Sites

The first of these is the control of the disease on infested alkaline sites at or after clear felling and before a new crop is planted. It is on these sites, of which a major part of Thetford Chase in East Anglia is the prime example, that *F. annosus* causes death of pine crops throughout the rotation. The use of *Peniophora gigantea* for stump protection over the last ten years has largely prevented the further entry of *F. annosus* during thinning operations. However, many stands had one or more thinnings before stump protection was introduced and the fungus has slowly been spreading from one tree to its neighbour via their root systems. This has meant that there has been a gradual build-up of infection underground which, after clear felling, is a potential source of infection for the subsequent crop.

An experiment was laid down in 1956 to test the effects of various treatments which might reduce the level of infection underground prior to the planting of a subsequent pine crop. Further experiments were laid down in 1961. Preliminary results of these experiments were quoted in the *Report* for 1966 and consideration of the commercial application of the successful treatments has been undertaken during the current year.

The following three treatments showed a reduction in the level of killing in the subsequent crop:

Removal of stumps after clear felling.

4–6 years' delay before replanting.

Treatment of stumps with *Peniophora gigantea.*

The most effective treatment was the removal of stumps after clear felling and this reduced the level of killing from over 50 per cent to about 20 per cent in the subsequent crop after 12 years.

Another experiment in the series on this aspect of the problem, including the three treatments mentioned above and various combinations of them, was laid down during 1968 in Thetford Chase. This experiment was planned to provide further evidence for the choice of a suitable treatment, and was laid out on a sufficiently large scale to allow techniques of stump removal to be costed. Costing studies were undertaken by the Work Study Section, who have costed three different methods of removing stumps, while the Pathology Section has studied the efficiency of these methods for removing roots and stumps from the soil. The methods used were:

(1) Pushing over and extraction of whole trees with root systems attached (instead of normal clear felling) using the Volvo BM 840 tractor with a grapple attachment.

(2) Pushing out stumps after normal clear felling using a Challenger 33 with a grubber blade.

(3) Digging out stumps after normal clear felling using the Volvo BM 840 tractor with lifting tongs (see Plate 1).
(The Volvo is a wheeled tractor and the Challenger 33 is a tracked vehicle.)

Final results of these studies are not yet available but preliminary results indicate that Method 3 removes most roots and Method 1 least. Preliminary results of costings indicate that Method 2 may be the cheapest. The financial costs and benefits of stump removal are at present being studied and it is clear that serious consideration should be given to the practical use of this technique for reducing the level of infection by *F. annosus* after clear felling on heavily infested alkaline sites.

Butt Rot

On the majority of acid mineral sites in this country butt rot is a potential problem and the use of a resistant species must be considered at least for replanting on heavily infested sites.

One species in particular, Grand fir, has been recognised on the basis of mainly observational evidence as a potentially butt rot resistant species. Douglas fir is considered a moderately resistant species on similar evidence.

However, there has been insufficient evidence to give a firm recommendation on the use of Grand fir as a butt rot resistant species. The implementation of a Minor Species Survey by the Silviculture (South) Section has given the opportunity to obtain more information on the relative resistance of four minor species, Grand fir, Western hemlock, Western red cedar and Noble fir, to butt rot caused by *F. annosus*. In this investigation, each minor species was paired with a major species growing close by.

The Pathology Section's part in this survey was planned in two stages.

The first stage was to examine a large number of Pressler increment borings taken from those stands in the survey which were either on sites with a previous conifer crop or were more than 30 years old. Twenty borings were taken at random in each stand and a total number of 3,950 borings were examined under the microscope for the presence of the conidia of *F. annosus*.

It was hoped that some indication of the relative susceptibility of both minor and major species might be gained from these observations. However, though the results of the first stage of the study showed which of the minor species stands were infected, the fungus was revealed in only a relatively small number of these stands and realistic comparisons between minor species could not be made. The second stage of the study has involved a detailed investigation of selected infected stands in order to determine the number of infected trees in the stand, and also the extent of the infection within individual trees.

So far, the investigation has been concentrated on two species, Grand fir and Western hemlock, as the relative resistance or susceptibility of these may be important factors in determining their future use.

Preliminary results indicate that there are differences in both the percentage of the crop infected and the extent of the infection within the stem. The results shown in Table 24 are those obtained on three sites where the two species can be directly compared.

These results confirm previous field observations that infection by *F. annosus* is more common and more extensive in Western hemlock than it is in Grand fir. Further confirmation of these results is being sought at other sites.

TABLE 24

COMPARISON BETWEEN WESTERN HEMLOCK AND GRAND FIR

Age of crop	Western hemlock		Grand fir	
	Percentage infected	Maximum height of *F. annosus* in stem	Percentage infected	Maximum height of *F. annosus* in stem
20 years	15	1·2m (3·5ft)	0	0
35 years	14	4m (12ft)	0	0
40 years	50	3·5m (10·5ft)	8	2m (6ft)

In due course the butt rot study will be extended to other species. At this stage is it important to decide which species can be recommended for planting on heavily infested butt rot sites.

Biological Control

Two fungi able to decay Sitka spruce wood under laboratory conditions have been included in a stump treatment experiment on Sitka spruce stumps. The two fungi do not produce spores when grown on culture media in the laboratory and a macerated mycelium was used for inoculation. Basidiospores of *F. annosus* were included in the inoculum in order to determine the competitive ability of the two fungi against *F. annosus* in the stump tissues.

Laboratory studies have included investigations into the best method of preparing the mycelial macerate prior to inoculation.

Armillaria mellea

The long-term experiment on the invasion of Norway spruce stumps by the Honey fungus, *Armillaria mellea*, was again sampled during the year (see *Report* for 1968). Eighteen months after felling, *A. mellea* was colonising the majority of the stumps. Invasion of the wood tissues was just beginning.

An experiment was laid down to test the effects of mechanical destruction of large oak stumps infected with *A. mellea*. A machine was used which breaks down the stump into small chips. Observations will be made to determine whether *A. mellea* continues to grow in or on the chipped residue of the stump. The area which the stump had occupied has been replanted with Corsican pine and subsequent deaths will be recorded. Control plots surrounding intact oak stumps were also established.

Needle Blight of Western Red Cedar caused by Didymascella thujina

A spray trial was laid down at Ferndown Nursery (Hampshire) to confirm last year's preliminary findings that a new formulation of cycloheximide "Actidione Ferrated" was as effective as "Actispray" at controlling this disease. "Actidione Ferrated" was sprayed at 85 and 170 ppm at 1,100 l per ha (100 UK gal/acre) and gave a similar degree of control to "Actispray" applied at the same rates of application. No symptoms of phytotoxicity were observed in either case.

"Actidione Ferrated" has now been cleared through the Pesticides Safety Precautions Scheme and is available commercially in this country.

Bacterial Canker of Poplar caused by Aplanobacterium populi

Routine screening of poplar clones for resistance to bacterial canker has continued and the results of the first planting in this series are now available. The following five out of thirty-nine clones tested have shown sufficient resistance to warrant further study:

(1) *Populus trichocarpa* 'C'	(*P. trichocarpa*)
(2) 'Regenerata H'	(*P.* × *euramericana*)
(3) 'Vert de Garonne'	(*P. nigra*)
(4) 'V 234'	(*P. trichocarpa*)
(5) 'V 24'	(*P. trichocarpa*)

In rigorous past screening tests of promising clones, *P. trichocarpa* 'MB' has proved very resistant to bacterial canker. It is also resistant to *Marssonina brunnea*, the cause of an important leaf disease, and is being considered for release to the nursery trade for use as a fast-growing amenity tree and for rapid timber production.

Top Dying of Norway Spruce

Growth measurements were made on the Norway spruce plants from the greenhouse experiment which was set up during the winter of 1967–68 (see *Report* for 1968). Those plants which had been placed in the warm compartment of the greenhouse at a minimum temperature of 4·5°C (40°F) by night and 10°C (50°F) by day flushed a fortnight earlier than the plants in the cold compartment. The average shoot length of plants from the warm and cold compartments was similar by the end of the growing season.

A further experiment was set up during the winter of 1968–69 where the temperature in the warm compartment was set to a minimum of 4·5°C (40°F) by night and 12·5°C (55°F) by day.

Beech Bark Disease

In Britain this disease was thought to be of little importance except in mature or over-mature beech. However, during the past twelve months two serious outbreaks have been reported in pole stage crops in Queen Elizabeth Forest (Hampshire and Sussex) and Savernake Forest (Wiltshire and Berkshire).

An investigation into this disease has therefore been started. From preliminary observations, the previously held theory that drought was an important factor appears untenable and a combination of the Beech coccus insect and fungi of the genus *Nectria* appears to be causally involved. This combination of causal agents has been found on *Fagus grandifolia* in North America and on *F. sylvatica* in Denmark.

Advisory Work

A total of 492 enquiries were dealt with during the year, 179 from Commission staff and 313 from others. Three hundred and eighty-three of these enquiries were dealt with at Alice Holt and 109 by Pathology staff in Scotland. A hundred and forty-three visits were paid in connection with enquiries.

Identified parasitic disorders accounted for 173 enquiries, the most frequent parasites being *Armillaria mellea* and *Didymascella thujina*. Elm disease (*Cerato-*

cystis ulmi) appeared to be on the increase, but there was a striking decline in damage to Weeping willows by the fungus *Marssonina salicicola*, which causes leaf-spot, shoot-canker and dieback. *Cristulariella depraedans*, a fungus previously unrecorded by us, caused spectacular damage to sycamore leaves in places in the south. *Phytophthora cinnamomi*, which causes root rot on a wide range of plant species, was found associated with death of roots of Douglas fir seedlings in their second year.

The most common non-parasitic disorder was frost damage, the weather in May being mostly cold. Summer was generally much finer in the north than in the south, and drought crack in conifers was reported in Scotland. In July, hail caused exceptionally severe damage to trees in several localities ranging from Devon to Yorkshire. Winter was remarkable for the change from exceptionally mild weather in January to very cold weather in February and by the end of March cold injury to evergreen foliage was becoming apparent.

General

As mentioned elsewhere in this *Report*, a Visiting Group inspected the work of the Section during September 1968.

Dr. D. B. Redfern joined the Section in September 1968 and has started investigations into selected aspects of two important forest pathogens, *Armillaria mellea* and *Fomes annosus*.

Mr. N. A. Byrom of Brunel University worked in the Section for six months on the chemical control of *Didymascella thujina* on Western red cedar and on top dying of Norway spruce.

The third meeting of the British Forest Pathology Working Group was held in East Scotland in April 1968. Field excursions were arranged by Mr. J. S. Murray and his colleagues at Aberdeen University. A number of diseases including *Peridermium pini* (resin top of pine) and *Hypodermella sulcigena* (a leaf cast of Corsican pine) were studied in the forest.

During the year a revised edition of the leaflet on larch canker and dieback was prepared.

D. A. BURDEKIN

FOREST ENTOMOLOGY

Pine Looper Moth, Bupalus piniarius

The pupal survey carried out in the winter 1968–69 presents a most interesting set of data for comparison with the previous year. The general small increase reported in the 1967/68 survey shows a reverse trend to more normal conditions in 1968/69.

Of the four high populations noted in 1967/68, one has returned to low density and may now be ignored, one shows a large increase and two, at first glance at least, appear merely to have maintained their order of magnitude. On closer inspection of the last two cases, however, it will be noted that although the data for "highest compartment mean" are roughly the same, or show a slight decrease, those for the overall forest average show an increase. This population behaviour is remarkably similar to that found in the years immediately prior to the 1963 Cannock infestation. The figures for the two years are given in Table 25.

TABLE 25

BUPALUS SURVEY, 1967/68 AND 1968/69

Pupae per square yard

Forest	Overall forest mean		Highest compartment mean	
	1967/68	1968/69	1967/68	1968/69
Sherwood	5·2	5·5	12·8	9·6
Cannock Chase	5·0	7·6	20·4	18·8
Tentsmuir	3·0	4·9	6·0	26·4

Note: The difference between the above square yard values and their square metre conversions are too small to have practical significance.

Pine Shoot Beetle—Tomicus piniperda

Control

A field trial, based on previous experimental work, was carried out to test the effectiveness of post-attack treatment by spraying stacks of 200–300 ft^3 with crude B.H.C. at ·05 per cent in diesel oil. The dosage rate was based on the following formula:

$$\text{Solution in gallons} = \frac{\textit{Surface area of stack in } ft^2}{70}$$

This reduced dosage, and using a mistblower brought the cost of spraying down to approximately ½d per cubic foot. Beetle attack was low, but analysis of breeding and emergence assessments showed that the treatment was effective.

A small-scale experiment was designed to test the effectiveness of BHC emulsion in oil and in water at three concentrations (0, 0·5, 0·75) as a protectant against *Tomicus piniperda* attacks. These treatments were applied at the rate of

1 UK gallon to 100 square yards of bark surface using a mistblower. All treatments were found to be successful.

Control of the Large Pine Weevil, Hylobius abietis, and the Bark Beetle, Hylastes spp.

An experiment was started in March 1967 on two sites at Thetford, to test the control of *Hylastes* obtained by dipping whole plants in 1·6 per cent "Gammacol" (a water-based fine suspension of lindane), and to check the effectiveness of this treatment against *Hylobius*. The assessment carried out in the first season of growth, 1967, showed that very effective control of *Hylastes* was obtained. This was also the case for *Hylobius*, with the exception of one site where a large number of treated plants suffered light damage. The summer and autumn assessments of 1968 showed very satisfactory control of both *Hylobius* and *Hylastes*. Reports from large-scale user trials generally confirm the effectiveness of the treatment.

In order to test further the effectiveness of "Gammacol" in wetter conditions than obtained at Thetford, and also to check its performance on spruce, trials including a range of insecticides are being carried out at Kielder.

Douglas Fir Seed Wasp, Megastigmus spermotrophus

Seed trapping, which has been carried out in five seed stands since 1964, was continued during the year. A considerable amount of data has now been accumulated supporting the previously reported association between low percentage infestations and good seed crops. In addition, this information which includes time of seed-fall, total seed-fall, and number of potentially and actually sound seeds, may prove useful in forecasting the need for spraying. An interesting feature of 1968 was that the seed stands in the western and northern areas, which had an unusually dry and warm spring and summer, bore bumper crops.

An experiment was carried out at Lyminge Forest, South-east England, to test and compare the reduction of infestation obtained by three repeated applications of "Malathion" and a "Malathion/gamma B.H.C." mixture during the period of oviposition. This was a repetition of a similar experiment spoilt by bad weather the previous year. Both treatments gave good control but there was no significant difference between them, tending to confirm the suspicion from an earlier experiment that the strongly fumigant action of B.H.C. is not effective against the insect under forest conditions.

Green Spruce Aphid, Elatobium abietinum

Host Plant Susceptibility

Extracted xylem sap samples from Sitka spruce have continued to be qualitatively analysed for amino-acid components. Throughout the growing season of 1968 samples were taken at weekly intervals from selected sites in order to record seasonal changes and to find any variations that may occur. A greater number of amino-acids was found in two-year-old wood than any older wood. From a range of identifiable compounds to be found in March, only a few were detectable by May and June, but this was followed by a recovery in variety in late July and August.

Flight

The flight period during 1968, as measured by a suction trap at Alice Holt, followed a similar pattern to that recorded during 1966 and 1967 but the numbers caught were much higher. The first alatae were captured on the 9th May and the last on the 16th June; 90 per cent of the individuals trapped occurred between 24th May and 4th June. Such an assessment of the aerial population can give a standard measure of the dispersal phase of this pest in any locality which could then be linked with damage; critical timing of chemical control operations for a locality could also be established. (See also pp. 50 and 152).

Studies on Adelgids

Investigations into life-cycle patterns and the phenology of the various morphs has been continued and will provide a more accurate basis for control operations in nurseries, seed orchards and arboreta. Infestations of *Adelges laricis* were particularly abundant in 1968 and severe needle and shoot damage occurred throughout England. The significance of the feeding activity on larch and the coincidence of heavy populations with the disorder long known as "larch die-back" is being followed.

Factors Affecting Growth and Survival of Young Crops

Two projects dealing with the subject were started during the year and are planned to run for five years. The first deals entirely with new plantings in Scotland, and aims to monitor the first five years of progress in a sample of plantations established in the year of inclusion in the project. The second is an investigation into the effects of fertiliser application and certain silvicultural measures upon insects in young crops. Here the main aim is to record the relative incidence of insect species in treated and untreated plots with a view to correlating the data with growth performance.

The two projects have common ground in that the plants examined in both often have a similar set of debilitatory or mortality factors operating on them. Particularly common pest species have been three microlepidoptera, *Clepsis senecionana*, *Philedonides prodromana* and *Argyrotaenia pulchellana*. Hares, blackgame, deer and frost are also recorded as causing significant damage.

Enquiries

There were 30 written enquiries in the south and 23 in the north from Forestry Commission, and 95 in the south and 8 in the north from private sources during the year.

General

In September 1968 the work of the Section was inspected by a Visiting Group.

D. BEVAN

MAMMALS AND BIRDS

Grey Squirrels

Investigations of methods of grey squirrel control are made in liaison with the Infestation Control Laboratory of the Ministry of Agriculture, Fisheries and Food.

Trials of "Warfarin" poison against grey squirrels were carried out during the period April–July 1968 using the technique developed in the Scottish trials (1958–65). Whole-grain wheat bait was presented in tunnel-entrance ground-hoppers for fourteen days. The bait was coated with "Warfarin" at concentrations either of 0·025 per cent or 0·005 per cent.

Both squirrel and small rodent populations in the experimental areas were trapped, marked and released before poisoning. Trap rounds were repeated after the poison had been picked up. The animals caught were killed and examined for symptoms of "Warfarin" poisoning.

The results showed that squirrels and small rodents in the vicinity of poison hoppers were killed by "Warfarin" at both 0·025 per cent and 0·005 per cent concentrations. Only one animal trapped after poisoning failed to show poison symptoms, and this was a small juvenile squirrel which may have left the nest just after the poison was removed from the area. The numbers of unmarked animals found dead or trapped with poison symptoms suggest that poisoning is more effective than cage-trapping. However, the results also suggested that the fourteen-day poisoning period found adequate in Scotland will need extending for squirrel populations in England and Wales.

A tree-hopper with a flap-door to prevent small rodents and birds having access to the poison bait has been developed for the trials in 1969.

The experimental work on protection of a vulnerable crop in non-isolated woodland by cage-trapping in and around it, before and during the damage season, has been completed and is being written up.

Deer

Work on methods of aging deer and of assessing bone marrow changes as an indicator of condition has been postponed pending the acquisition of laboratory facilities in 1969.

The tagging of red deer calves in Galloway, South Scotland, has continued; 33 calves were marked in 1968 to bring the total to 122. Of these, 33 are known to have been culled or died. One stag yearling, with the hind, was shot approximately twelve miles from its birthplace. One seventeen-month old hind was carrying a stag embryo when shot.

Preliminary results of the application of basic slag, nitro-chalk and an NPK fertiliser to natural wet heath vegetation in Galloway showed that the N, P and K percentages of vegetation in all treated plots were higher than in the control plots fifteen months after the application of the fertilisers. No gross inter-treatment differences are apparent in the oven-dry weights of the vegetation samples from the plots. No marked grazing preferences by red deer or wild goats have been observed.

A freeze-marking technique, originally developed for permanent identification of cattle, is being given preliminary trials on roe deer. This involves apply-

ing local intense cold to the skin to destroy the pigment-producing cells of the hair follicles so that subsequent hair growth is white. Some difficulty has been experienced in clipping the dense, coarse winter coat of roe sufficiently close to the skin.

Starling Roost Dispersal

The starling roost dispersal technique described in the last *Report* (1968) has now been tested on six winter roosts and one summer roost. The areas involved were Wilsey Down Forest, Cornwall (1967, 1968); Kesteven Forest, Lincolnshire (1967, 1968); Bowland Forest, Lancashire (1968); St. Gwynno Forest, Glamorgan (1968); Sherwood Forest, Nottinghamshire (1969).

The summer roost at Bowland Forest was dispersed in four evenings, as were the winter roosts at Wilsey Down and Kesteven in 1967 and at Sherwood. At Wilsey Down and Kesteven the roosts re-formed in winter 1968, but at each place it took only two evenings to move the roosts for the second time. This suggested that a proportion of the birds had experienced the first dispersal and left the area more readily on the second occasion.

The only roost not successfully dispersed was at St. Gwynno. The chief factor in the failure to break up the roost here appeared to be the physical impossibility of transporting the distress call apparatus from one end of the 2,428 ha (6,000-acre) block to the other as rapidly as the birds could fly across it during the brief period of dusk. It is hoped that this problem on large forest blocks can be overcome by using two or three amplified distress call sets to cover different areas of the forest.

Chemical Repellants

No untested repellants were available for trials in the 1968/69 season. The Dutch repellant, Aaprotect, was given further trials against severe roe deer browsing on Norway spruce in Cranborne Chase Forest, Wiltshire. Instead of completely covering all aerial parts of the trees by spraying, the leading shoots only were treated. All untreated leaders had been browsed two months after the trial began; approximately a third of the treated leaders had been damaged three months after the beginning of the trial. While damage is markedly reduced by such treatment, it seems likely that the slow accumulation of damage will still reach economic proportions in one or two seasons where browsing is a severe hazard to young plantations.

Fencing

An investigation of the advantages and disadvantages of different wire netting specifications is being made. This is linked to a study of the different specifications of spring steel fencing required for various protection problems. In particular, the problem of matching woodwork to wire and netting specifications to obtain the same length of life from all components is being investigated. Comparisons are also being made of the decay rates of fencing materials in polluted and non-polluted air conditions.

Damage

The investigation of the effects of damage by various mammals and birds has been concentrated on the susceptibility of the four minor tree species at

present being specially studied by the silviculturists (see Site Studies and the Role of Minor Species, p. 41), and on an extensive damage survey in the Galloway region of South Scotland.

Squirrel Questionnaire

The annual questionnaire for red and grey squirrels for the year ending September 1968 showed little change in the distribution of either species. Damage by both species was slightly less extensive than in the two previous years.

JUDITH J. ROWE

STATISTICS

General

The Statistics Section has continued to act as a service section whose main functions are:

(a) to advise on statistical methods in the conduct and analysis of experiments and surveys,

(b) to analyse and assist in the interpretation of the resulting data, and

(c) in support of these functions, to provide a programming, data preparation and computing service.

During the year under review much attention has been paid to the organizational aspects of the work. This has been necessary because of the many staff changes which have taken place over the last eighteen months. We are now, it is hoped, in a period of consolidation, in which it will be possible to devote considerable time to staff training, both in-job and by means of external courses. Practically all the junior technical staff are in fact following external part-time courses. By arrangement with universities the Section accepted four students for six-month industrial training periods and, it is believed, both sides have found the contact stimulating and useful. The major staffing difficulty has been our inability to fill the vacancy of Statistician in the north, but Dr. D. R. Causton is to take up this post in May 1969 and, though other vacancies are still unfilled, the staffing situation should then be much improved.

The new Statistics building at Alice Holt is now nearing completion and final plans for the transfer of staff and equipment have been made. Occupation is scheduled for early May 1969.

Projects

In the face of these factors the Section's own research and development activities have had less emphasis than the routine service work and the exploration of applications of multivariate analyses made in recent years has diminished.

The main part of the computing service to the Management Services Division has been devoted to the analysis of data from the census of private woodlands. A suite of programmes dealing with the volume data from the census has been written and the final tabulations should be completed soon. Intensive efforts have enabled the calculation of the long-term forecasts of production, for each Forestry Commission working-plan area, to be completed on time. Work is now underway to develop a suitable system for producing forecasts based on metric data.

A new series of standard-time tables has been calculated for the Work Study Branch, based on work study field investigations on thinning and felling in coniferous crops in which the snedding has been carried out with a chain-saw. A start has been made on the establishment of a structure for a comprehensive data-bank for work study data to be accessed by computer.

A critical review of the projected work load for the Lector document reader showed that although it had been used with some success for processing the Census of Woodlands data, the difficulties of integrating it into the data collection systems used by the Forestry Commission made it less attractive than

originally thought. Rather than allow it to be grossly underused once the census work was completed, it was decided to arrange for it to be sold in the spring of 1969. Apart from the census work it was used during the year on very small projects such as the fire and accident reports, and a few research and work study projects with varying success.

In contrast, the use of Port-a-punch cards has expanded, and standard 80-column punched cards have begun to find application through the use of the card-to-tape converter. Trials of other methods of data-capture, particularly with audio-tape recorders have continued.

Mention should be made of the Section's indebtedness to Mr. W. G. Batchelor of the Cement and Concrete Association, who made available to the Forestry Commission a very useful program package which allows the Incremental Graph Plotter to be used by autocode programs. This has made it very much easier to use the plotter which until this time had had a very restricted use. The C. and C.A. have also made available their modification of the Sirius autocode compiler which generally allows autocode programs to run appreciably faster.

The study for the computing configuration to replace the present Sirius machines was brought to a stage when an "operational requirement" could be specified.

Statistics Section Papers

The following Statistics Section Papers have been prepared:

No. 146. Portable, magnetic-tape encoders for computer data.

No. 147. Data processing in forestry with the aid of Lector.

Enquiries about this series should please be made to Statistics Section at Alice Holt.

R. S. HOWELL

D. H. STEWART

D. K. LINDLEY

RESEARCH WORKSHOP

Work Completed

During the year several special instruments and items of experimental equipment have been completed and are now in use by the research sections. Full details of the results obtained with this equipment are usually given by these sections upon completion of the project. Such items include a fence reeling unit (made for the Mammals Section) which allows three rolls of high tensile wire to be run out at any time; a temperature gradient chamber (made for the Entomology Section) in which five separate chambers are kept at different temperatures ranging from –20°C to +5°C; and a chain saw test rig (made for the Safety and Training section of Headquarters), with which prototype leg guards can be tested. A preliminary survey of a tree shaking machine for use in cone collection was begun last year by the workshop and has now been completed. Work on this equipment is continuing as a joint project by the Research Division and the Work Study Branch of the Management Services Division.

Current Work

Equipment is being made for the Silviculturist, North, to simplify the hand-filling of tubes for the production of tubed seedlings (p. 37). This apparatus includes vacuum seeders, sand applicators, loading units and a filling/packing bench. Trials with such equipment will assist in the design of a fully automatic unit should the project be economically successful.

There is a requirement for a light portable high seat for deer observation. A simple design is under way so that a high seat can be constructed by field staff using elementary hand tools. Three versions are being considered, made from

(1) galvanized steel,

(2) aluminium alloy, and

(3) fibre glass.

The economic merits of all three materials will be compared.

Exhibition and Engraving

The Forestry Commission's 50th anniversary celebration exhibitions to be held in June 1969, at both the Bush Estate, Midlothian, and Alice Holt have placed an extra load upon the workshop in the design and manufacture of special exhibits and engraving notices for displays and nature trails, etc. Over 7,000 engraved plastic labels were produced this year and, with the need for good informative signs increasing, the workshop has considered other methods of producing labels. Three processes have been studied:

(a) polyester encapsulation,

(b) etched aluminium, and

(c) printing on plastic.

Samples of all three processes are being field tested. The polyester encapsulation, subject to satisfactory useful life, is more economic than engraving for

larger notices. This process has been recommended for use with nature trails and walks where a five-year-life is acceptable, although the notices may well last longer than this.

Metric Conversion

The changeover to the metric system of measurement has provided an opportunity to rationalise the systems at present in use in silvicultural research and to standardise on a basic set of equipment. Several different experimental scales and height rods have been made and tried in the field. The basic kit will include:

$\frac{1}{2}$ metre scale graduated in 2 cm classes,

2 metre scale graduated in 2 cm classes and 10 cm classes,

$1\frac{1}{2}$ metre height rods in sets of 8.

The commercial scales should be available by July or August 1969.

Advisory

The workshop service to the sections includes advice on the design of equipment that they can manufacture or adapt themselves. The three 40-ft towers erected by the Silviculturist, South, the squirrel feeding boxes for the Mammals Section and the temperature chambers of the Silviculturist, North, are examples of this work carried out during the year.

R. E. STICKLAND

PHOTOGRAPHY

Photographic Collection

Ten thousand, three hundred and seventy slides were loaned for various purposes. This was again a reduction on the previous year and it looks as if the creation of local slide collections, which we have actively encouraged, is now beginning to have its effect. It has long been our view that each Conservancy should have a basic selection of slides of a regional nature and only draw on the Central Reference Collection for more specialised items. Not only would this substantially reduce the amount of "handling" but also the risk of damage or loss of valuable transparencies in transit.

Use of monochrome prints rose to 1,996 and it is anticipated that next year will also show a marked rise owing to the increase in published material in connection with the Commission's Jubilee. This was just beginning to affect the service aspects of the work as the year ended.

Three hundred and thirty loans of cinematograph films were made.

The problems of indexing and retrieving material in the Collection remain. During the year under review the subject was dealt with as an O & M exercise, and the resulting report is being considered. If agreement on methods is reached, rearrangement of the Collection will start during the winter of 1969/70. This could cause some inconvenience to borrowers.

Audio-Visual Aids

Video Tape Recording equipment was purchased during the year. We are still at the "working-up" stage, but it is already clear that, as was anticipated, the equipment is going to be particularly valuable for education and training purposes.

The build-up of the sound library has been slower than was originally planned. This was due entirely to diversion of staff time owing to the present difficulties in retrieving material from the Collection. Nonetheless, the demand for tapes is increasing and they seem to have found a particular use at shows and exhibitions, either as background or, synchronised with projected visual material, as an integral part of specific displays.

Work is being done in collaboration with the Research Workshop on the prototype of a device for presenting a form of audio-visual quiz. This should be in use during the coming show season.

General

Though initially the demands were slow in coming in, the last two months have seen the Section committed almost entirely to work for the various Jubilee exhibitions and shows.

I. A. ANDERSON

PUBLICATIONS

The following eleven new priced publications were issued through Her Majesty's Stationery Office during the course of the year; previous issues are shown in Sectional List No. 31, available free of charge from the Publications Officer or Her Majesty's Stationery Office.

Reports

Forty-eighth Annual Report of the Forestry Commissioners, 1967 (HC 311. Session 1967–68). (10s. 0d.)

Report on Forest Research for the year ended March, 1968 (20s. 0d.).

Forest Records

No. 65. Butterflies in Woodlands, by T. C. Robinson (3s.).

No. 66. Blackgame, by C. E. Palmar (3s.).

No. 67. Effect of Fertilizer and Density Pretreatment on Spruce Seedling Survival and Growth, by T. I. W. Bell (4s).

No. 68. Pulpwood Supply and the Paper Industry by J. A. Dickson and P. J. Dixon. Report of a Conference on 12th June, 1968. (5s.)

Booklets

No. 20. Know Your Broadleaves, by H. L. Edlin (15s.).

No. 21. Public Recreation in National Forests, by W. E. S. Mutch. (9s.).

No. 22. Forestry in the Weald, by C. A. J. Barrington (3s. 6d.).

No. 24. Forestry in the British Scene, by I. A. Anderson and R. F. Wood. (10s. 0d.).

Guide

Westonbirt in Colour, by A. F. Mitchell (2s.).

In addition six priced publications sold by Her Majesty's Stationery Office were reprinted after varying degrees of revision.

Twelve unpriced Research and Development papers were produced, mainly for internal circulation. The titles are included in Appendix II, p. 174.

Twelve unpriced publications for general public issue were revised and reprinted during the year.

H. L. EDLIN

RESEARCH INFORMATION

Annual Research Conference

A major event in the Research Division's calendar, this year's Conference started on Tuesday 15th and finished at mid-day on Friday 18th October, 1968. The Research Information Section was responsible for preparing, organising and servicing. Over 70 people attended, including staff from Headquarters and Conservancies, as well as three Directors of other Research Stations and other distinguished guests.

With the prospect of a new research station opening at Edinburgh in the near future, the opportunity was taken to look more closely at ourselves, and the four topics considered by ten discussion groups were devoted to problems of administration and organisation.

The Director General addressed the conference on Forestry Commission policy and the Director of Research spoke on forest research policy and objectives.

The Research Conference, as it has now evolved, provides an invaluable occasion for open and profitable discussion and for a greater awareness of developments in all aspects of research. It improves communications, stimulates thought and fosters a good morale. The contribution of the Section's staff towards the preparation of literature in advance, during and afterwards, and to the general smooth running of a particularly successful conference, gives come cause for satisfaction.

Library

Use of the Library facilities greatly increased during the year. The total number of loans to Commission staff and members of the public was up by 66 per cent on last year and items requested from other libraries increased by 54 per cent. The number of British and overseas periodicals taken rose by 16 per cent. In all, we acquired 179 books, loaned out 2,275 publications and requested 666 items from other libraries. Thirty-six translations were completed during the year and 275 periodicals taken.

A stocktake of the library's contents was carried out during the year and a revised catalogue, in subject order, will appear soon.

In 1966 we noted the purchase of a Microfilm Reader and a complete set of the Commonwealth Forestry Bureau's card index on microfilm covering the years 1951–64. This year we purchased the second instalment covering the period up to 1968, which gives us a further 100,000 references.

As an adjunct to our written information and to help with visitors and lectures, we acquired an 8 mm ciné film projector and camera to enable us to build up a library of 8 mm films. To date we have fifteen 4-minute films covering subjects such as grafting techniques and vole control methods. This particular medium is cheap, easy to use, quick to prepare and has proved valuable not only for demonstration purposes but also as a basis for discussion and analysis.

Information Services

A trial "Keyword Index to Forestry Commission Publications" was tested amongst Conservancy and Headquarters staff during the year, and the results

obtained from the questionnaire sent out after six months were highly encouraging. The Index is being enlarged to cover other forestry publications and is being duplicated for issue to staff.

Each week a note is made of articles of general interest appearing in publications put on display in the Library Reading Room and is circulated amongst Headquarters and Research staff. This "screening" service is being developed and now, quarterly, field staff receive a similar note drawing their attention to articles appearing each quarter in those journals that they are likely to take themselves.

Liaison

It is frequently difficult, when dealing with a foreign language article, to judge whether the subject matter is worth the increasing cost of translation. We have recently arranged with two large technical libraries for the provision of a "linguistic aid" service.

Annual Research Report

The Report on Forest Research, which is progressed by Mr. S. H. Sharpley of this Section, was produced even earlier than the previous year and was available in time for our annual conference.

O. N. BLATCHFORD

MANAGEMENT SERVICES DIVISION

Planning and Economics and Work Study are branches of the Management Services Division and not of the Research Division, but a statement is included in the Research Report to cover the research and development aspects of their work.

D. R. JOHNSTON

PLANNING AND ECONOMICS

Planning

During the past year traditional working plan survey work has been halted temporarily to enable a country-wide revision of area and yield class data to be made. This has been done first to convert the data to metric units and secondly to bring earlier data into line with that collected during more recent and more comprehensive surveys. This re-survey should be completed before 1970 when topographic survey work will be resumed. Soil and site survey developments include the completion of work on 111,250 ha (275,000 acres) and a change in emphasis towards pre-planting surveys, surveys of windthrow-susceptible sites and surveys of sites where fertilisation offers economic possibilities for increasing production. A short guide to soil groups has been prepared and considerable progress has been made with the Manual for Forest Soil Survey in Upland Areas. Two regional forest soil guides (for North and Mid-Wales and for the Moray Firth regions) are soon to be published. The National Census of Private Woodlands area analysis has been completed and is awaiting publication. The Mensuration Section has produced several metric versions of tables and is reviewing measurement conventions so as to take full advantage of the change to metric measurement. Yield tables have been constructed for unthinned crops of most species. Some 50 permanent sample plots were lost in the gale of 15th January, 1968, including the replicated thinning experiment in Scots pine at Edensmuir.

R. T. BRADLEY

Economics

Resource Use

In any business, whatever the length of the production cycle, it is important to consider the consequences of future programmes of work on the labour and finance needed to carry them out. A computer program has been written which enables such studies to be made for the Forestry Commission. Timber output, net cash flows, labour and materials and machinery input in future years are calculated on a variety of assumptions as to scale of planting, road making and harvesting, variations in cutting practice, changes in labour productivity and wages, changes in machinery and materials use and cost, and change in timber price.

The simulations of a large number of feasible combinations of future circumstances can be used to identify situations which appear critical, and thus to provide management with an early warning system as a result of which policies and programmes may be adjusted. A particularly important assumption in the analysis is that of the rate of increase of labour productivity. In recent years

labour productivity, in the sense of output per worker-year, has risen substantially faster than in the 1950s, partly because of changes in job specifications, partly because of changes in technique (such as the use of herbicides in the control of vegetation and the increasing use of machines in general), partly because of improved worker skills and partly because of improvements in organisation of operations in the field and a more critical review of the work to be done. The new data provide a key to the sort of assumptions about labour productivity increase which may be realistic for a period of rather rapid technological change.

A study has been made of the repair costs of certain categories of vehicles used in forest management, harvesting and road building, in order to assess optimum replacement ages and the sensitivity of economic life to expected repair costs in particular years. The study has in general confirmed existing guides on the appropriate lives for different categories. This work also makes it possible to determine the consequences of different replacement dates on the expenditure on repairs and new machines, net of resale value of old ones, for specific categories of machine.

Calculations have been made of the likely returns on investments in the existing Forestry Commission estate and in extensions to it as part of the current review of the method of financing the Commission. The results have emphasised the important effect on financial flows and capital value in a long-term enterprise like forestry of changes in assumptions on inflation and on the rate of interest charged.

Control Procedures

Work has continued, in collaboration with staff from the Conservancies and from other Headquarters Divisions, on the preparation of new financial control procedures for the Forestry Commission. This work embraces a whole range of subjects from the definition and the communication of Commission strategy, and the preparation of a corporate plan for the whole Commission (in which work the simulation program already described is an important aid), to the definition of responsibilities of different levels of management and the establishment of a revised system of appraisal, budgeting and control of operations.

Work on the control of harvesting and marketing has led to the study of methods of forecasting the product out-turn of roundwood products in complex situations where product specifications overlap, and where quality may be an important consideration. A forecasting method designed for hand calculation has not been entirely successful in trials; but an alternative method utilising a simple dynamic programming algorithm is feasible where computing facilities are available. This method is capable of optimising the product out-turn of individual trees and it should be possible using a sampling procedure to extend the method so as to estimate the optimum product out-turn for a forest.

Forest Management Studies

The opportunity costs of premature felling have been studied. These costs are equivalent to the premia on normal prices obtainable for the particular tree sizes and standing volumes which would be required to make it as profitable to cut early as to retain stands to the most profitable age given normal prices. The

results make possible a rational allocation of stands of differing species, age and yield class to clear felling in order to meet a temporary extra requirement of roundwood.

In connection with the clarification of the Commission's financial objectives, explorations have been made of the effect on management of changes in the test rate of discount. This is the discount rate adopted in the computation of net discounted revenue which is used as the financial criterion of success. The study shows that within a fixed budget, the extent of change in practice implied by a rise in discount rate would be most marked on volume harvested. For example, a rise in the discount rate from $3\frac{1}{2}$ to 5 per cent would require rotations to be shortened by 5 years or so, and the effect of a rise from $3\frac{1}{2}$ to $6\frac{1}{2}$ per cent would be to reduce rotations by about 10 to 15 years. The balance of investments in crop establishment and improvement would not however be radically altered. This follows from the fact that, within the range of investments open to an enterprise like the Forestry Commission, there is only a limited range of opportunity for investing in operations which are automatically favoured by a high discount rate. Such operations are essentially ones promising a rapid pay-off and their number, at any rate under current technological and economic conditions, is strictly limited.

Wood Consumption Study

A study of the factors influencing the post-war consumption of wood products in the United Kingdom has been completed and is being published as a Forest Record. Change in consumption and imports of wood products, both in volume of wood used in their manufacture and in value at constant prices, can be easily accounted for in terms of changes in national income and change in the value of stocks and work-in-progress in the economy as a whole. While most of the growth in consumption has been associated with rising real output, some has occurred because of the fall in real price (that is the price of wood products relative to the general level of prices in the economy) which has occurred since 1951. Although the price fall may be viewed as unfortunate for forestry in this country as well as producers abroad, the British consumer has gained greatly in terms of a larger consumption of wood products. Forecasts based on analyses covering the period 1955 to 1967 suggest that by 1975 the volume of United Kingdom consumption in terms of roundwood requirement may rise some 320 million hoppus feet overbark over the 1966 level. Because of rising home production the extra volume of imports may be expected to be rather less at 285 million hoppus feet. The value at 1958 prices of wood products consumed will rise faster than the volume of roundwood used in their manufacture, owing to a continued rise in the degree of processing incorporated into wood products.

Research Projects

In conjunction with Research Division work is being carried out on the determination of the most promising projects for future research and development. This work will involve an assessment of the use of technological forecasting methods in project selection and the exploration of project evaluation techniques under conditions of uncertainty. Even with a relatively unsophisticated approach, however, it is possible to indicate the wide range of prospective return from different lines of development within a given field of research activity.

A. J. GRAYSON

WORK STUDY

ORGANISATION

During the year the Branch assumed responsibility for the Communications section. This adds to the seven regional and three special purpose teams already in full operation.

The formulation of work study programmes through the medium of project plans and their progressing is now rapidly developing. This is considered very necessary in view of the diversity of work study investigations and close liaison required with other Divisions, Branches and outside interests.

MACHINERY INVESTIGATIONS

General

Major emphasis has been laid on testing new tractors under field conditions, the aim being to carry out relatively short, sharp trials. These are designed in the first instance as an aid to management to help them determine whether a particular machine is worthy of serious consideration for purchase. Examples are the Unimog 411, Mitsubishi F.T. 2E, "Highland Skidder" and Massey Ferguson "Treever" (see Plate 18).

Cable Cranes

Work has continued on developments of the Skyline and many are now in operation. Provisional standard times have been prepared and issued. Further study is in hand in order to make these definitive.

Chain Saw Snedding

Provisional standard time-tables are now available for the snedding of both Norway and Sitka spruce and Scots and Corsican pine.

Work on chain saw vibration has been continued jointly with Education and Training Branch, the National Institute of Agricultural Engineers, manufacturers and medical men. It has been shown that anti-vibration handles may be expected to reduce the amplitude of vibration by about 75 per cent. Various models are on test and some show distinct promise. Investigations continue as a high priority. It is clear that vibration effects are reduced by laying aside the vibrating equipment for regular periods throughout the day and we have suggested ten minutes in each hour: this more or less coincides with the need for refuelling chain saws when they are used intensively, as for snedding. The importance of maintaining whole body warmth has also been stressed by our medical advisers.

Weeding Equipment

Mechanical

Successful trials of the Work Study Weeding machine were completed. This is basically a rear-mounted, tractor-powered rotary brush cutter with a variable cutting width effective between 5 and 7 feet. This was mounted on an M.F.

Vinyard tractor with a track width of only 4 feet. These trials have established the need for a front-mounted scrub cutting/weeding machine. Such a machine, hydraulically operated, is now being constructed.

A grass roller of variable weight pulled by an M.F. 135 tractor has demonstrated its worth in controlling *Calamagrostis* sedge and bracken. A more advanced model is to be built for trials in 1969.

Chemical

Trials have been carried out of a Cooper Pegler "Vermorel" tractor-mounted mistblower (see Plate 19) in three situations:

(i) Foliage spraying with 2,4,5-T in water.

(ii) Spraying of cut stumps with 2,4,5-T in diesel oil.

(iii) Spraying with 2,4,5-T in water on brambles under a crop of pine prior to thinning.

These trials have demonstrated the effectiveness of the machine and the considerable cost savings that can result.

A preliminary trial of tree injectors has shown the value of this method for killing standing scrub and pointed the way to further work.

LIAISON WITH INDUSTRY

The Branch now has a direct link with industry through the medium of joint working groups. There are three groups with representatives from Harvesting and Marketing Division, Work Study and the firms concerned. The groups discuss problems pertinent to the supply of timber to the particular firm and decide what course any particular study will take. An overall major aim is to increase productivity. Problems such as the provision of pulpwood in the length, rather than by the piece, and investigations into the use of "lower landing" systems in order to speed-up delivery, are typical of matters investigated.

MACHINERY RESEARCH AND DEVELOPMENT

Responsibilities for machinery research and development were allocated to the Branch early in 1968. That year was a formative one but in 1969 the approach to this work has been clarified and defined.

There are three main lines of approach:

(1) The examination of machines in production or about to go into production. The first task is to make estimates of suitability and feasibility. If these prove that the machine may have a future in forestry the machine is purchased or hired for field trials and reports circulated as a guide to management. Examples are the four machines mentioned earlier in this report.

(2) The design, construction and development of a machine by the Branch. This is carried out when there is shown to be a need which a production machine cannot fulfil. Usual feasibility studies are, of course, carried out. An example of this type is the front-mounted weeding machine.

(3) In more complex cases machinery is designed with the help of outside firms. Current examples are a hydrostatic forest tractor and hydraulic winches.

In addition to these three methods a continuous project is that of investigating the design criteria for varying types of forest machine. A considerable number of tests have been carried out using a strain-gauge dynamometer and Rustrac Recorder to determine the drawbar pulls of ploughs and tractors under varying conditions. Results may enable us to achieve more suitable design for ploughs and ploughing tractors in the future. Similarly very exact measurements can be made of the vertical and horizontal components of the strain in a winch tower, so allowing the most economic form of construction whilst maintaining safety standards.

AFFORESTATION

Planting

Further studies have been carried out, using both the semi-circular spade and traditional methods on various types of ploughed land resulting from different ploughing methods, including single mould-board, double mould-board and complete ploughing. Some guidance will soon be available on probable rates of output.

Work commenced on the design of a hand-operated tool for the planting of the planting of tubed seedlings.

Successful trials were concluded using the Finn Forester Planting Machine at Thetford. They have pointed the way to further modifications which may possibly lead to the satisfactory use of this type of machine on ploughed ground.

Ploughing

More studies have been carried out in order to refine earlier work. Analysis of all the data has yet to be completed.

Fertilising

A critical examination has been made of the erratic distribution pattern produced by various types of spreader. The pattern is improved when granulated fertilisers are used.

Some work has been carried out on the use of a Vicon spreader attached to the front of a ploughing tractor. First indications are that spreading and ploughing simultaneously can be successfully carried out at a reasonable cost.

INFORMATION

Routine liaison has been maintained with the F.A.O./E.C.E./I.L.O., in particular with the Study Group on Mechanisation of Forest Work.

Papers issued by the Branch

Reduced Intensity Brashing in Sitka spruce.

The Metsa Viska Fertiliser Distributor in Northern Ireland.

The Riklea Measurement System.

Chainsaw Utilisation when Pulpwood Cutting.

The Finn Forester Planting Machine.

Evaluation of Articulated Lorries.

First Trials of the Crychan Minor Double Drum Winch.

Massey Ferguson "Robur" Timber Carrier Trials.

The Parkgate Deep Draining Plough.

Report on Trial of Unimog 411.

The Tree Length Harvesting System using the Holder A.20 Tractor.

Trial of Mitsubishi F.T. 2E. Tractor.

Report on Trial of "Highland Skidder" Tractor.

Enquiries regarding any of these papers should be directed to the Work Study Branch at Alice Holt.

L. C. TROUP

HARVESTING AND MARKETING DIVISION

TIMBER UTILISATION DEVELOPMENT

Measurements of the Rate of Drying and of the Solid Content of Stacked Roundwood at Thetford

This project was completed during the year and the results prepared for circulation as a Forest Record.

Before being close-piled in the yard for drying, 2m (6 ft 6 in) Scots and Corsican pine billets were barked and sorted into diameter classes as follows:

1. Class A. 130 mm (5 in) to 200 mm ($7\frac{3}{4}$ in)
2. Class B. 110 mm ($4\frac{1}{4}$ in) to 150 mm (6 in)
3. Class C. 90 mm ($3\frac{1}{2}$ in) to 120 mm ($4\frac{3}{4}$ in)

the overlap between classes being due to the electronic method of sorting.

It was observed that there was a substantial difference between the rates of drying between the two species, especially in the larger diameter classes. Not only did Corsican pine dry more slowly than Scots pine, but during the period November to February it actually absorbed water to achieve a moisture content in the region of 5 per cent above its initial "green" weight. In both species the rate of drying of the small diameter classes was the most rapid.

With the exception of the "edge and top effect" the position of the billet within the stack had no noticeable influence on the rate of drying. It was found that while no loss in volume of the stack could be attributed to shrinkage of the individual billets, apparent losses due to the "settling down" of billets can occur in transit on lorries. This "settling down" can bring about a reduction of up to 7 per cent in the height of a stack after a journey of 320 kilometres (200 miles), which results in increase in the solid/stacked volume ratio of roughly $2\frac{1}{2}$ per cent.

Use of Bark in Horticulture

Following the unsuccessful attempts to compost bark at Thetford by adding nitrogenous fertilisers, development work has been undertaken on the possible use of fresh bark as a substitute for peat in horticulture.

Bark from the Cambio machine at Brandon Central Depot near Thetford has been effectively used as a plunge medium (sand, sedge peat, or vermiculite is normally used for this purpose) at two garden centres. It was reported that it was warmer than other media, but it was felt that the addition of a small quantity of a nitrogenous fertiliser was desirable, when watering the plunged crops, to preclude the depletion of this element during the microbiological breakdown of bark.

If bark is pulverised its use is extended considerably. Not only does it make a tidier plunge bed medium and a more uniform mulch, but it can also be used in place of peat for soil-less composts, provided, of course, that an appropriate quantity of nitrogenous fertiliser is added. Small-scale experiments have shown that horticultural crops can be grown successfully on a mixture of silver sand and bark if appropriate nutrients are added.

A market survey was undertaken in Norfolk in which 56 commercial growers were interviewed and some of them were supplied with samples of pulverised bark to conduct their own trials. Of those visited 57 per cent thought that the texture of the bark, which had passed through a $\frac{5}{8}$-inch screen, was about right, 9 per cent would have preferred finer material and 9 per cent would have preferred it to have been coarser. Twenty-three per cent thought that there might be possibilities for retailing the product.

The main disadvantage in using bark for horticultural purposes is that it is almost always essential to add nitrogen to the growth medium. However, one possible way of overcoming this is to expose the bark to anhydrous ammonia which it freely absorbs to form a stable product. Fresh Scots pine and Corsican pine barks have a nitrogen content of about 0·30 per cent (of the oven dry weight) and a pH of about 4·5. Ammoniated bark of these species, on the other hand, has a nitrogen content of about 3·6 per cent and a pH exceeding 6·0.

A small quantity of ammoniated bark was prepared at the Forest Products Research Laboratory and used for germination trials. The results have indicated that it might be slightly phytotoxic during the winter months when the seedling is less able to make use of the ammonium. This toxicity might perhaps preclude the use of ammoniated bark in soil-less composts, but is not expected to affect its usefulness for mulches or for "digging-in". Furthermore it is possible that partially ammoniated bark would prove suitable for use in soil-less composts.

The possibility of making slotted discs to place round the base of established crops was investigated at two centres. At the Forest Products Research Laboratory attempts were made to use sodium silicate (the cheapest commercial adhesive) as the bonding medium for the bark, but without success. A further attempt was made using a hot press with no adhesive, but it was found that temperatures of 150° Celsius and pressures of 6,895 kilonewtons per square metre (1,000 lbf/in^2) were required to produce a stable block. Such high temperatures and pressures are unlikely to be economic for the manufacture of a low-cost product.

At the Gelatine and Glue Research Association mulching discs were prepared from bark using an animal adhesive. Initially, prolific development of surface moulds was troublesome but it was found that this could be inhibited by the addition of a trace of cupric oxide. While animal adhesives are more costly than the synthetic types, they have two possible advantages for mulching discs. First they are not water-stable and could be expected to breakdown and offer less resistance to penetration by rain, and secondly they have a high nitrogen content which might help to correct the adverse carbon/nitrogen ratio of the bark.

Fence Post Trials

The annual assessments were carried out on the nine sites in Scotland which were set up in 1957, and on the eleven sites in England and Wales which were established one year later.

In Scotland only 4 per cent of the untreated birch posts and 30 per cent of the untreated Sitka spruce posts have survived. Of the posts which were treated with a waterborne preservative (of a type no longer marketed for use in contact with the ground in this country) 66 per cent of the birch and 73 per cent of the Sitka spruce posts remain. Only one creosoted birch post (= 0·7 per cent), and none of the creosoted Sitka spruce, have so far failed.

In England and Wales the service given by Scots pine is being compared with that of various locally grown hardwoods (except at Rosemaund Farm in Herefordshire where a number of different species of hardwood and softwood are under observation). The results to date are given in Table 26.

TABLE 26

RESULTS OF FENCE POST TRIALS: ENGLAND AND WALES

Percentages of Post Remaining

Species	No. of sites (out of 11)	Treatments			
		Untreated	Waterborne preservative	Creosote	Charring
Scots pine	11	6	89	100	—
European larch	1	75	93	100	—
Japanese larch	1	44	100	100	—
Ash	2	Nil	12	78	Nil
Birch	5	20	88	100	—
Elm	2	6	22	94	—
Oak	1	Nil	56	100	—
Sweet chestnut	1	75	93	100	62
Sycamore	2	12	81	93	—

Additionally, results are available from a further three sites set up in 1963, in which the service of untreated Scots pine and Douglas fir is being compared with similar posts which have been treated with an improved waterborne preservative (which is recommended for use in contact with the ground). So far 4 per cent of the untreated Douglas fir and 8 per cent of the untreated Scots pine posts have failed; there have been no failures in the treated posts in this series.

J. R. AARON

THE JOINT PROGRAMME ON HOME-GROWN TIMBER

An extensive review of the Joint Programme of Work on home-grown timber carried out by the Ministry of Technology's Forest Products Research Laboratory and by the Forest Commission was undertaken in the light of the Commission's need for further information on the properties of home-grown wood, and it has been agreed with the Laboratory that future work in the Joint Programme should be carried out in three main fields. The first of these will be the continued investigation of the intrinsic properties of the wood of individual species with special stress on "plus" trees (as selected by the geneticists), and it is to include a particular study of the nature and extent of the variability and inter-relationships of those properties. The second field will include a study of the problems involved in the storage of round timber, the improvement of sawmilling and preservation techniques, and further study of the pulping and drying of home-grown wood; and the third field will cover special projects such as the effect of planting distances on the effect of wood properties, the economic importance of butt rot, an appraisal of the commercial consequence of butt sweep, and the possible application of machine stress grading to home-grown wood.

Below is an account of the work done under the Joint Programme, contributed by Mr. T. Harding, of the Forest Products Research Laboratory, who acts as Secretary to the Home Grown Timber Research Committee, which controls these investigations.

General Investigations on Home-Grown Timber

Norway Spruce—Variation within the Tree

Anatomical studies have been carried out on two trees from each of two sites to determine the range and pattern of variation of several timber characteristics within the tree. The characteristics studied were growth rate, specific gravity, fibre length, spiral grain, compression wood and chemical composition.

The analysis demonstrated the possibility of accounting for significant proportions of the variability of selected wood characteristics in individual trees in terms of year of growth and height in the tree. Proportions of the variation accounted for in terms of these variables were high for growth rate, specific gravity and fibre length, intermediate for spiral grain and most chemical properties, and low for compression wood.

Wood Study of Sitka Spruce from Wykeham and Bush Provenance Plots

Provenances having differences in duration of extension growth might be expected to produce different proportions of early wood and late wood, with a consequent effect on the density of their wood. Samples have been examined of provenance material having different periods of extension growth and this study will contribute to a better understanding of the pattern of wood formation in a ring, the variability of early wood density and the influence of early and late wood amounts on overall density. In addition, ranking of the provenances for wood density, volume production and weight of wood substance will be obtained.

The Suitability of Certain Home-Grown Softwood Species for the Manufacture of Woodwool-Cement Building Slabs

The widening application and increasing use of woodwool/cement building slabs is making greater demands for round wood of suitable species. In order that home-grown timber should make its proper contribution to the increasing demand, investigations were carried out on the suitability of a wider range of softwood species than has hitherto been accepted for this purpose.

Certain species of timber contain substances which delay or even inhibit the setting of Portland cement. The following species were examined for their suitability from the point of view of cement setting: Norway spruce, Sitka spruce, Douglas fir, Western hemlock, Corsican pine, Scots pine, Grand fir and Lodgepole pine.

These all gave satisfactory results, although setting times were longer with Scots and Corsican pine.

Among the home-grown hardwoods, oak, beech, hornbeam, sycamore and ash were also examined. In all cases it was shown that these were less suitable for woodwool/cement production than were the softwoods examined.

As a final stage to this project, it is hoped that, in co-operation with a woodwool/cement manufacturing firm, it will be possible to correlate the results obtained at the Laboratory with those obtained in commercial practice.

The Sawmilling of Home-Grown Scots and Corsican Pines

In some areas in Britain, both Corsican and Scots pine can be grown satisfactorily and the choice as to which of these species should be planted depends, not only on the silvicultural factors involved in the establishment and growth of trees, but also on the properties and quantities of wood obtained from trees of all marketable sizes in relation to market needs and prices.

It is likely that sawmills will continue to provide a market for home-grown material, and a detailed comparison has been made of the outturn of graded, sawn timber from representative sample logs of each of these two species.

Among the conclusions reached on the results obtained *from the particular consignments of logs supplied for this investigation*, it is evident that it would be better, in terms of the quality and quantity of the sawn material, to plant Corsican pine rather than Scots pine in those areas which will accept both species.

A parallel investigation was carried out, using the material from the sawmilling project, to make a comparative study of the timber of home-grown Scots and Corsican pines.

This study demonstrated that, *for the limited material examined*, there is very little difference in timber properties between these species.

Examination of Pruned Logs from Windblown Material

The hurricane in Scotland in January 1968 resulted in approximately 38 million hoppus feet (overbark) of windblown timber. Various sites were affected on which pruning experiments had been carried out over a number of years. Of particular interest was a pruning experiment at Edensmuir Forest (Fife), in which a stand of Scots pine had been given two replications of each of six treatments.

Windblown material from this site has been sent to the Laboratory for conversion and grading of the sawn outturn, with the object of providing more precise information about the value of pruning.

Blue-Stain Experiments at Thetford

Experiments up to 1962 established that end treatment was relatively ineffective, compared with whole-log treatment, in controlling staining. They also emphasised the importance of preventing bark beetle attack.

Subsequent experiments, intended to establish the comparative effectiveness of different preparations, were inconclusive and in 1966 a long-term experiment was set up in which trees were felled at monthly intervals. Treated billets and untreated controls were stored for three months in ground contact in a forest ride and then examined for staining after cross-cutting.

The results of this show that, in Thetford Chase, appreciable staining of the wood occurred only from March or April to August, although staining of the log ends was never entirely absent even during the winter months.

Staining was most effectively controlled by the combined lindane/tribromophenol treatment. Application of this from April to August should, in practice, lead to a substantial reduction in log staining. However, in July and, perhaps, August a considerable measure of control should be achieved by treatment with lindane alone.

A continuation experiment was initiated to confirm the level of infection occurring in the forest during the period from the end of February to the end of September, using only untreated control logs.

The Preservation of Poles—The Possible Use of the Boulton Process, particularly for Pine Poles

The greater proportion of poles used in this country are of imported Scots pine (*Pinus sylvestris*), known in the timber trade as redwood. Home-grown timbers, including Scots pine, larch, Douglas fir and spruce are also accepted as being suitable (British Standard 1990) although they suffer certain disadvantages. For example, the home-grown Scots pine contains a considerably greater proportion of sapwood compared with the imported redwood, particularly when grown in England, and so takes longer to season. With current drying practices this increases the risk of decay before the poles are ready for preservative treatment. The other home-grown timbers mentioned are more difficult than redwood to treat satisfactorily.

Investigations are in progress to examine the practicability of drying and seasoning home-grown Scots pine poles using the Boulton Process, thus avoiding a long seasoning period. By this process, unseasoned timber is immersed in hot creosote and the water in the wood boiled off under vacuum. Impregnation with creosote accompanies the drying.

Although work to date has been restricted to Scots pine, the process could have a wider application in the pole-treating industry and might also be suitable for other home-grown timbers as well as for imported redwood.

Fairly successful drying and creosoting have been achieved, mainly with poles stored for a time in log ponds before processing, although net retentions of creosote have generally been higher than at present specified in British Standard 913. However, as yet there are insufficient data to say whether or not the process would be suitable for all Scots pine, wherever grown in the United Kingdom. Neither is it possible at this stage to lay down any standard processing schedule which could be adopted in practice and which would ensure complete sapwood penetration with a moderate net retention of creosote.

Preservation of Home-Grown Timbers by Diffusion

The development of the preservation treatment by diffusion of boron salts into unseasoned (freshly-felled) timber has given the home timber industry the opportunity of treating timber of any species to standards which are acceptable for building carcassing or interior use without the need to season twice. Work which is being carried out at the Forest Products Research Laboratory to determine the rate of leaching of boron salts from treated timber which is used out-of-doors, but not in contact with the ground, will help to assess whether boron diffusion treatment is suitable for such uses.

A report has been prepared on the effect of moisture content on the rate of diffusion of disodium octaborate into Sitka spruce and Scots pine. Relationships have been obtained which show the times taken for a loading of not less than 0·2 per cent boric acid equivalent to reach the centre of 4-inch by 2-inch material, at various moisture contents between 40 and 200 per cent.

Work has continued on the loss of disodium octaborate by leaching from treated timber exposed out-of-doors. Results so far on Scots pine sapwood and

heartwood have shown that, after exposure to 12 inches of rainfall, loss from the lateral surfaces is confined to the outer $\frac{1}{4}$ inch layer of timber but, since there is a large quantity of preservative in this layer, the losses are not serious.

Further tests have been set up to determine the losses from end-grain surfaces. Preliminary indications, after exposure to 6 inches of rainfall, are that significant losses from the end-grain occur to a greater depth than from lateral surfaces, extending to a depth of about 1 inch.

T. HARDING

Forest Products Research Laboratory

PART II

Research Undertaken for the Forestry Commission at Universities and other Institutions

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NUTRITION AND FOREST SOILS

NUTRITION EXPERIMENTS IN FOREST NURSERIES

By BLANCHE BENZIAN, J. BOLTON and S. C. R. FREEMAN

Rothamsted Experimental Station, Harpenden, Herts

Extract from *Rothamsted Report* for 1968

Sulphur

Sulphur is an essential nutrient, required by plants in about the same weight as phosphorus. Coal, oil and unpurified natural gas contain much S and in most industrial countries burning these fuels puts enough sulphur in the air and rain to provide for crops; sulphur is also supplied by sulphates used as fertilisers (e.g. calcium sulphate in ordinary superphosphate). The cleaning of combustion gases to make the air purer, and the change to more concentrated fertilisers that contain little or no S, increase the possibility of responses to sulphur. What we think are the first effects in England of applying sulphur to soil in field experiments were obtained with conifer seedlings and radishes at Wareham, Dorset.

Sitka Spruce

In 1965 Sitka spruce (*Picea sitchensis*) seedlings grown in very acid soil (pH in 0·01 *M* $CaCl_2$ 3·3–3·5) at Wareham gave height responses to graded additions of calcium sulphate (*Rothamsted Report* for 1965, p. 62), which were attributed to calcium acting as a nutrient. In the same experiment, improvement in seedling colour also closely followed the amounts of calcium sulphate given, and it was suspected that the pale green of the untreated seedlings was associated with sulphur deficiency. Later results from several small trials with Sitka spruce seedlings testing calcium sulphate, sodium sulphate and calcium carbonate, showed that calcium improved growth but not colour, whereas sulphur improved colour but not growth.

In 1967, healthy green seedlings grown with potassic superphosphate (a mixture of 90 per cent single and 10 per cent triple superphosphate plus KCl) supplying 14 g S/m^2 contained 0·18 per cent sulphur in needle dry matter, whereas needles from pale plants on plots with sulphur-free fertilisers contained 0·09 per cent sulphur; needles from plots with similar fertilisers but with 14 g S/m^2 contained between 0·10 and 0·16 per cent when S was supplied as sodium sulphate and 0·16 per cent S when calcium sulphate was given. This agrees fairly well with the values of $<$0·13 per cent S given by Ingestad as indicating deficiency and 0·13–0·18 per cent S as an intermediate range for Norway spruce (*Picea abies*) grown in solution culture (*Meddn St. Skogsforsk Inst.* (1962), 51 No. 7, 150 pp). The only published reference to sulphur deficiency

in conifers in Britain seems to be the transient yellowing of Corsican Pine (*Pinus nigra* var. *calabrica*) observed by Binns and Keay on "no sulphur" plots on the Culbin sand dunes in Scotland (*Rep. For. Res., Lond.*, 1962, p. 87).

To elucidate further the effects of S and Ca, Sitka spruce seedlings treated with Ca- and S-free fertilisers (consisting of magnesium ammonium phosphate, potassium metaphosphate and top-dressings of either urea or ammonium nitrate) were compared with those given additional calcium carbonate, sodium sulphate, calcium sulphate ($CaSO_4.\frac{1}{2}H_20$), or flowers of sulphur (pure S). The sulphur concentrations in seedling needles (Table 27) agreed well with earlier results and ran parallel to the colour scores, except that the slight improvement from sodium sulphate was not reflected in larger percentage S. Heights of seedlings at the end of the season confirmed the vigour scores, which showed that calcium (whether applied as calcium carbonate or as calcium sulphate) but not sulphur in any form, improved growth. (Benzian, Bolton and Freeman).

TABLE 27

EFFECT OF SULPHUR AND CALCIUM ON SITKA SPRUCE SEEDLINGS, WAREHAM, 1968

Treatments	Applied (g/m²)		August			End-of-season	
	Ca	S	Colour score*	Vigour score	% S (needles)	Height (cm)	pH ($CaCl_2$)
None	—	—	2·4	2·1	0·092	9·2	3·2
$CaCO_3$	24	—	2·0	2·8	0·082	9·9	3·5
Na_2SO_4	—	19	3·3	1·8	0·096	9·2	3·2
$CaSO_4.\frac{1}{2}H_2O$	24	19	4·2	3·0	0·170	10·3	3·3
Sulphur†	—	19	5·0	2·2	0·196	7·0	3·1
			Standard errors		± 0·0048	± 0·15	± 0·03

*Largest value = darkest green.
†As flowers of sulphur.

Many seedlings on plots treated with flowers of sulphur and a few seedlings on those with calcium sulphate (all with basal ammonium nitrate) had the characteristic tip-burn symptoms of copper deficiency. The tops of these plants contained only about 1 ppm Cu (in dry matter) whereas symptom-free seedling tops on calcium sulphate plots contained 3 ppm. These values agree fairly well with those of Benzian and Warren (*Nature, Lond.* (1956) **178**,864). (Benzian, with Hill, Biochemistry Department, Rothamsted).

Radish and Lupin

These species were expected to need more sulphur than Sitka spruce, and were used as test crops in two small trials at Wareham in 1968 on plots exhausted by fifteen years of continuous cropping without fertilisers. Sulphur-free basal NPKMg fertilisers were used. Table 28 shows that 19 g/m² of elemental sulphur increased dry matter yields of the first radish crop (planted in mid-May and harvested 6 weeks after) by about 14 per cent. This seems to be the first statistically significant yield response by any crop in the United Kingdom to sulphur applied in the field. Plants from the untreated plot con-

tained only 0·22 per cent S, much less than is usual in brassicae. A second radish crop grew badly on the plots given sulphur, possibly because the sandy soil had become very acid. However, a third crop planted in mid-August after liming, also yielded less dry matter on the sulphur-treated than on untreated plots; the radishes from this planting on the untreated plots contained more sulphur than those of the first planting on treated plots, showing that some sulphur had become available to the plants during the summer either from rain, the atmosphere or by mineralisation of organic-S.

TABLE 28

SULPHUR AND YIELDS AND COMPOSITION OF RADISHES AND LUPINS

S applied g/m²	Radish				Lupin	
	1st crop		3rd crop			
	Yield*	%S	Yield*	%S	Yield*	%S
0	202	0·22	191	0·76	519	0·22
19	231	0·73	145	0·96	386	0·45
Standard errors	± 4·1	± 0·046	± 8·6	± 0·060	± 34·4	± 0·022

*Yields as g dry matter/m²

Yellow lupins planted in May and harvested in late August yielded less on the sulphur-treated than on the untreated plots, again possibly because of acidity (soil pH measured in water was 4·1 in treated and 4·7 in untreated plots after cropping). (Bolton and Benzian.)

RESEARCH ON FOREST SOILS AND TREE NUTRITION

By H. G. MILLER and B. L. WILLIAMS

Macaulay Institute for Soil Research, Aberdeen

Work continues to be concentrated on various aspects of nitrogen nutrition. A new experiment has been laid out in pole-stage Scots pine growing on sand dunes to compare the effect of various forms of nitrogen fertilisers, combined factorially with applications of phosphorus and lime, on both tree growth and the immobolisation of nitrogen in the humus layer.

Tree Nutrition

Investigations described previously (*Reports* for 1965 to 1968) into the effect of nitrogen fertiliser on both tree growth and the distribution and movement of nutrients in a pole-stage crop (standing volume of 190 m^3 per ha) of Corsican pine at Culbin Forest, Moray, have now been largely completed. This crop was intensively sampled in February 1964, following which various rates of ammonium sulphate were applied over three years. Each treatment was subsequently resampled in February 1967. During the interval between samplings regular assessments were made of the weight of litter dropped by the trees and of the release of nutrients from the crop both in litter and by recretion (crown leaching) into rainwater.

By 1967 the weight of the tree crop in the different treatments ranged from 150,000 to 180,000 kg per ha, of which the stems accounted for about 60 per cent and the roots for 20 per cent. (The values given in previous *Reports* differ slightly from these owing to an error that was incurred in earlier calculations of the weight of lateral roots). The proportion of the crop weight represented by foliage, however, increased with treatment, rising from 5 per cent in the untreated control plots to 8 per cent in the two heaviest treatments. As a result of this increase in weight of photosynthetic tissue there were marked differences in tree growth between treatments, as can be seen from Table 29.

In Table 29 the values for net primary production represent the increased weight of the tree crop, including root systems, between February 1964 and February 1967 plus the weight of litter-fall over this period. However, no allowance has been made for root death and wastage.

The parameters of basal area, height and timber volume show markedly differing patterns of response to the fertiliser treatments, although the response in terms of volume fairly closely parallels the pattern of change in net primary production. In fact, stem tissues account for relatively little of the total net primary production, as low as 14 per cent in the control trees as against 42 per cent directed to foliage, including needle litter. In treatment N_3, on the other hand, not only was the total net primary production more than doubled but the proportion directed to stem formation increased to 30 per cent, with the foliage and needle litter now accounting for only 35 per cent.

The fertiliser applications resulted in a marked rise in the weight of nitrogen in the tree crop, from 195 kg per ha in the control plots to 680 kg per ha in

TABLE 29

EFFECT OF REPEATED APPLICATIONS OF AMMONIUM SULPHATE ON NEEDLE NITROGEN CONCENTRATION AND ON TREE GROWTH

Treatment	Rate of application kg N per ha per annum	Total application 1964–66 kg N per ha	% N in top-whorl foliage at Oct. 1966	Growth; 1964–66 inclusive			
				Basal area m^2 per ha	Top height (100 s.p. ha) m	Volume m^3 per ha	Net primary production Mg (10^6g) per ha
N_0	0	0	0·91	2·80	0·28	18·6	23·1
N_1	84	252	1·57	4·48	0·56	34·5	41·7
N_2	168	504	2·07	5·11	0·73	40·3	44·5
N_3	336	1007	2·26	5·43	0·58	39·8	46·7
N_4	504	1510	2·63	5·79	0·32	36·7	43·1
Standard error			0·13	0·35	0·08	2·9	
Linear trend			***	**	n.s.	*	
Quadratic trend			*	n.s.	**	**	

Notes: n.s. = not significant. Significance at the 5%, 1% and 0·1% levels denoted by one, two and three asterisks respectively.

treatment N_4. Increases with treatment were also recorded for the weights of phosphorus, potassium, magnesium and sodium, whereas the weight of calcium tended to show a slight decrease.

The increased weight of nutrients within the tree crop represents only a proportion of the total uptake, the rest being released both in litter-fall and by recretion into rainwater. Recretion was found to be a fairly minor process in the redistribution of nitrogen and phosphorus, indeed in the lower treatments there was a net absorption of nitrogen from rainwater by the tree foliage. On the other hand, recretion results in high losses of potassium, calcium, magnesium and sodium which, except for calcium, exceeded the quantities released in litter-fall.

Over the three-year period of study mean annual uptake of nitrogen in the control plots was only 16 kg per ha as against a value of 143 kg per ha in treatment N_3, the treatment in which the highest net primary production was recorded. Mean annual uptakes of other elements in these two treatments were, respectively, 4 and 9 kg phosphorus, 19 and 57 kg potassium, 39 and 37 kg calcium, 10 and 11 kg magnesium and 43 and 33 kg sodium. The proportion of the total uptake that was released by the trees over this period tended to decrease with increasing growth rate. For example, in the control plots the quantity of nitrogen released was equivalent to 68 per cent of the weight of this element taken up by the trees, whereas in treatment N_3 it was equivalent to only 13 per cent of the uptake.

Application of ammonium sulphate was found to result in increased concentrations of nitrogen not only in the tree crop but also in the waste organic matter on the forest floor. However, no increases in concentration were detectable in the mineral soil, which in this forest consists of over 99 per cent coarse and fine sand and has an extremely low organic matter content. In treatment N_1 the amount of additional nitrogen found in the ecosystem in 1967 was comparable to the amount known to have been supplied, but at the heavier treatment rates appreciable loss of fertiliser nitrogen had occurred, the recovery amounting to only 75, 55 and 45 per cent of the amount applied in treatments N_2, N_3 and N_4 respectively. The greater part of this nitrogen was located in the tree crop, which accounted for 55 to 70 per cent of the fertiliser nitrogen retained in the ecosystem, the proportion increasing with increasing rate of application.

Thus in all treatments the tree crop acted as a more important store of fertiliser nitrogen than did the litter and humus layers, and this may in part account for the relatively long-lasting effect of nitrogen fertiliser on the growth of coniferous trees (*Report* for 1968). Two-dimensional paper chromatography suggests that appreciable storage occurs as free amino-acids, there being marked differences in the concentration of these between untreated and fertilised trees. Of the amino-acids identified in needle extracts, α-alanine, γ-amino-butyric acid and arginine were present in the greatest amounts, in general agreement with the results obtained by Muir *et al.* (1964) with Scots pine. However, arginine, in particular, was present in very much greater amounts than suggested by these authors and in view of the marked seasonal variation that has been found in the concentration of arginine in fruit trees this matter requires further investigation. Newly fallen litter was also found to contain appreciable amounts of free amino-acids despite the marked reduction in the concentration of nitrogen that occurs in needles prior to abscission.

Studies on Peat

In co-operation with the Peat Section (Department of Pedology) of the Macaulay Institute, and the Research Branch of the Forestry Commission, a study was undertaken to ascertain whether the subdivision of a blanket bog into site types on the basis of topography and ground vegetation, using large-scale aerial photographs, could be related to the nutrient content of the peat. Such a classification carried out on an area of blanket bog in Strath Tirry (Sutherland) produced seven site types and a series of profiles were sampled on a volume basis, in each of these. The nutrient content of the peat (expressed in kg per ha) was found, with certain exceptions, to be fairly closely related to site type. Analysis of the results suggests the presence of two distinct trends, these apparently being related to erosion on the one hand and to "flushing" with mineral-rich ground water on the other. Both processes result in an increased weight of dry peat material per unit volume of fresh peat, and this was found to be the predominant factor controlling nutrient content of the peat, both in the immediate surface horizons and to a depth of 0·5 metres. However, flushing is also associated with high concentrations of nitrogen, phosphorus and potassium, whereas erosion is associated with high concentrations of calcium and magnesium.

Cation-exchange capacity of the fresh peat tended to increase with increased decomposition (humification) of the peat, and was therefore higher in the drier eroded types. However, in these the concentration of exchangeable bases is low and the degree of base saturation is correspondingly low. In the flushed types, on the other hand, although the cation-exchange capacity is low due to the small weight of solid matter per unit volume of fresh peat (high moisture content), the concentration of exchangeable bases is relative higher, increasing with increasing degree of flushing, and so the degree of base saturation is greater than in the eroded types.

The different site types could be readily related to variations in the relative proportions of the main components of the vegetation. However, although the site types showed appreciable differences, the significance of these with respect to tree growth has still to be determined, particularly as management techniques, such as drainage and cultivation, may well have differing effects on the various site types.

Summary

Treatment of Corsican pine growing on sand dunes with ammonium sulphate considerably increased tree growth, but whereas basal area increment continued to increase over the full range of treatments applied, height increment, volume increment and net primary production were depressed at the highest rate of treatment. The treatments resulted in marked increases in uptake by the trees, not only of nitrogen but also of phosphorus and potassium. By the end of the experiment a greater amount of the fertiliser nitrogen was located in the tree crop than in the litter and humus layers, and this increased nitrogen content was accompanied by an increase in the free amino-acid content of the tree foliage. A comparison has been made of the nutrient content of peat from a variety of site types delineated on an area of blanket bog according to features of topography and ground vegetation.

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FOREST PATHOLOGY

CONIFER SEEDLING PATHOLOGY

By G. A. SALT

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Extract from *Rothamsted Report* for 1968

The "Psychrophilic Seed Fungus".

The effect this unnamed endophyte has on the emergence of Sitka spruce and other seedlings was confirmed in 1968 at Wareham and Kennington, using methods previously described (*Report* for 1968, p. 156).

At Wareham, emergence of seedlings from broadcast Sitka spruce within an inch on either side of a line of inoculated seed was decreased by 80 per cent when sown early or late in February, by 30 and 53 per cent where sown early or late in March, and by 28 and 50 per cent where sown in April. The average loss over all six sowing dates was 53 per cent, but only 11 per cent where the seed was treated with thiram. Much of the thiram-treated seed that failed to emerge was sown early in February, so the fungicide was least effective when conditions most favoured infection and when seed lay dormant for two to three months. At Kennington the width of the "bare strip" of killed seeds depended on sowing date. It averaged 8·75, 4·25, 0·5, 1·5, 0·25 and 1·75 inches respectively for the six consecutive sowing dates from early February to late April.

Where other conifer species were inoculated similarly with the same isolate from Sitka spruce seed, they suffered much less than Sitka spruce. The fungus was re-isolated from ungerminated seed of Western hemlock, Lodgepole pine, Japanese larch and Douglas fir but not from Grand fir, Scots pine, Norway spruce and Corsican pine.

BIOLOGY OF THE FUNGUS CRUMENULA SORORIA

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The investigations into the biology of this fungus, which causes stem cankers on Scots, Corsican and Lodgepole pines, has been continued for a third year. Extensive observations on Corsican pine have made it possible to classify the disease symptoms into a number of different stages depending upon the size and extent of cracks, resin production, and the size of the resulting canker. The infection pattern has been found to differ markedly on vigorous trees when compared with suppressed trees. In vigorous trees, infection is localised in relatively small areas and active host defence reactions occur, whereas in suppressed trees a more diffuse generalised infection results.

On Corsican pine nodal cankers always resulted from the invasion of a moribund branch by *Crumenula sororia* and subsequent spread into the main stem, whereas internodal cankers were produced by the direct infection of bark, or else by the infection of a pre-existing bark slit. Tissues most frequently infected include the bark, xylem and medullary rays. The pith is occasionally infected and is often reached via the medullary rays. In severe cases the whole stem at the site of the canker shows a deep black discoloration. Infected wood is flinty, resin-soaked and blackish in appearance and is usually surrounded by a zone of non-pigmented resin-soaked wood cells. Infection appears to promote the proliferation of xylem cells, but lumina size is not affected. Rays are also more numerous in infected as compared with uninfected wood, but the size of the individual rays is significantly smaller.

The influence of physical factors on the frequency of the disease has been further examined, and the previous findings confirmed. Aspect is the most important single factor influencing disease incidence, the majority of cankers occurring on the north and north east sides of the trees. It has been suggested that this increased susceptibility may be due to a number of different factors.

1. In this position liquid water would tend to persist longer, and in addition the relative humidity may be somewhat higher. Both these factors would exert a favourable influence on ascospore germination.
2. Continuous temperature recording has shown that the bark temperature on the N./N.E. sides of the tree remain somewhat cooler in winter than do the remaining aspects.
3. Ascospores have been found to remain viable longer at lower temperatures (5°C) than at somewhat higher temperatures, and the fungus has been found to be capable of slow growth at low temperatures.

The age of the crop as a whole appears to have little effect on the levels of infection, except where these occur on northerly aspects. In these situations infection becomes particularly severe. There is, however, a most marked correlation between whorl age and disease susceptibility. Individual whorls are most susceptible at age nine years, although infections were also found on

5-year-old to 12-year-old material. This confirms the suggestion made in the previous *Report* that annual (or at least periodic) reinfection of the young tissues is essential to maintain the infection.

Although apothecia are generally produced in May and June, in 1968 production was delayed until August and September. This was attributed to the cold weather following the winter of 1967 and 1968. Investigations of spore production and spore discharge were continued, and it has been found that large-scale discharge of ascospores occurs only when the temperature is relatively high (15–20°C) and only then in a near-saturated atmosphere. Low temperatures, very high temperatures and low relative humidities, either alone or in combination, are inhibitory to spore discharge. Under warm dry conditions, the apothecia rapidly assume the desiccated condition. However, application of liquid water for a few minutes or of saturated relative humidity for a few hours was sufficient to restore the apothecia to their original size and shape. Spore discharge could apparently occur over a long period. (This phenomenon implies that the apothecia are adapted to produce spores only when conditions approach the optimum for subsequent germination, thereby attempting perhaps to reduce the waste of ascospores if sub-optimal conditions occur.) Ascospores were found to germinate only if they come into contact with liquid water within 36 hours of being shed, the temperature optimum being 22·5°C. It has also been observed that germination was markedly stimulated by bark and wood extracts of Corsican pine. This may, in part, account for the frequency of infections occurring at the nodes, where water might persist for longer periods.

The laboratory infection experiments have been continued. *Crumenula sororia* has been successfully re-isolated from plants infected eighteen months previously, providing strong evidence for the pathogenicity of *Crumenula sororia*. This phase of the investigation is now in its terminal stages, although it is hoped to extend the studies on *Crumenula sororia* later in 1969 to include extensive survey work on the distribution of the disease. The bulk of the present investigation will be published in due course.

Summary

The investigation of the biology of *Crumenula sororia* has been continued. A number of different stages of development of disease symptoms have been defined, depending upon size and extent of bark cracking, amount of resin production and the size of the resulting canker. The principal infection sites have now been elucidated. There is a marked tissue age susceptibility, tissues nine years old showing the maximum number of infections. The factors influencing spore production and germination have also been studied. Successful re-isolation of *Crumenula sororia* has been carried out from pot plants previously infected with the disease and this provides strong evidence for the pathogenicity of the fungus.

VIRUS DISEASES OF FOREST TREES

By P. G. BIDDLE

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The emphasis of the work on virus diseases has been shifted from the study of poplar mosaic virus to investigation of possible virus diseases of conifers.

The results of the studies on poplar mosaic virus have shown that the virus occurring in Great Britain is homogenous, without strain variation and probably identical to that occurring throughout Europe. The virus can be purified most readily from the herbaceous hosts to which it can be inoculated; *Nicotiana megalosiphon* has proved a particularly suitable alternative host. The best purification method has involved heat clarification of sap, followed by ammonium sulphate precipitation of the virus and final purification by density gradient centrifugation or gel filtration.

The studies on the effects of virus infection on growth of poplar trees have been terminated. These have demonstrated that severe losses in height and diameter growth occur in some clones in the nursery, resulting in approximately 25 per cent loss in dry matter production. Despite these severe losses in the nursery, no significant reduction in diameter increment could be detected on older crops in plantations. The differences in diameter between healthy and virus-infected mature trees could be accounted for by the reductions which occur during the early growth in the nursery. It is suggested that the initial severe effects on infected plants in the nursery may be caused by a reduced rooting ability of infected poplar cuttings.

Studies on the effects of virus infection on the wood properties of poplar have demonstrated that the virus infection can reduce the specific gravity of the wood independently of effects on the growth rate, and also affect the strength additionally to any effects on specific gravity. This is the first known example quantifying effects of virus infection on wood structure. The mechanism associated with these effects on wood properties is not understood, but it is suggested that the virus may be affecting either the chemical composition or packing density of the cell walls.

The investigations into viruses in conifers have shown an association of possible virus symptoms with the occurrence of virus-like particles in the tree. This association is found in Sitka spruce showing needle chlorosis, defoliation and dieback, and in Scots pine showing symptoms of bushy stunt similar to those described by Jančařik and Blattný (1966) in Czechoslovakia. Similar particles to those seen in these species have also been noted in all specimens of *Pinus monticola* which have been investigated (Biddle and Tinsley, 1968).

Further investigations of these particles have been made while on a year's leave of absence at the University of California, Berkeley. These studies throw considerable doubt on the virus nature of the particles, and show the necessity for further research into their chemical nature and pathological effects. The close association of the particles with symptoms in Sitka spruce and Scots pine leads one to believe that they are related to the pathological condition, but their virus origin is not proved.

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FOREST ENTOMOLOGY AND ZOOLOGY

STUDIES ON INSECT VIRUSES

By J. F. LONGWORTH

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Mrs. J. Underwood continued to assist in the following investigations.

Anoplonyx destructor

Further collections of *A. destructor* larvae were made in 1968 from Mortimer Cross (in Mortimer Forest, Shropshire) and the cytoplasmic polyhedrosis virus was again found in the population. Up to 40 per cent of the larvae died in the laboratory from this disease. Like the cytoplasmic polyhedroses of the Lepidoptera, the polyhedra develop only in the cytoplasm of the midgut cells. The polyhedra in *A. destructor* are unusually small, 0.75μ in diameter. These contain many small spherical virus particles, about 50μ in diameter. An account of the development of this virus is being prepared for publication.

Pieris brassicae

Investigations are being made into the antigenic properties of polyhedron protein, virus particles and whole granules of the granulosis virus of *P. brassicae*. This work is an essential preliminary stage before unequivocal serological comparisons can be made between nuclear polyhedroses and granuloses of insects.

Non-occluded Viruses

A new non-occluded virus has been isolated from *Pachymetana* sp., a Lasiocampid pest of *Cupressus* in Uganda. The development and properties of this virus will be compared with a non-occluded virus of *Gonometa podocarpi*, a Lasiocampid pest of *Pinus patula* in Uganda.

RESEARCH ON THE GREEN SPRUCE APHID, ELATOBIUM ABIETINUM

By W. H. PARRY

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Following the study of aphid population levels and needle fall during a peak year in the summer of 1967 at Forest of Deer, Aberdeenshire, and Fetteresso Forest, Kincardineshire (Parry, 1969), further aphid and needle sampling was carried out at Deer from April to October 1968. Throughout the sampling period very few aphids were observed in any plot. Virtually no aphids overwintered on three plots, most being recorded in Plot 9 which was sprayed in 1967 and again in April 1968 with malathion. Following the spraying virtually no aphids were observed until August when isolated individuals were found in plots 4, 5 and 9, possibly following recolonisation by alate aphids from outside the plots. A slow build-up of aphid numbers then took place forming a small potential overwintering population. There was no evidence of needle fall in the absence of the aphids.

During the winter months of 1968–69 a study of the factors governing the survival of aphids in winter was initiated at Countesswells Forest, Aberdeenshire. Sixty marked shoots on Sitka spruce of 4–10 feet high were utilised, of which 30 were as near ground level as possible, the remainder at breast height. Shoots at each level were infested artificially with aphids, the 1967 needles being utilised on 15 shoots, the 1968 needles on the remainder. An attempt at maintaining known aphid densities proved unsuccessful owing to a high initial mortality, despite attempts at acclimatising the insects prior to infestation. The general level of infestation in early November was, therefore, fairly light.

From the results it became evident that temperature was the main factor regulating population size. Up to mid-December a steady rise in the population level occurred in association with maximum day temperatures of 7° to 10°C and a minimum of 2·5° to –4°C. During the latter half of December a drop in the level occurred, in association with temperature maxima of 2° to 5°C and minima of –3° to –6°C. The population level rose again in January with maxima of 5° to 9°C and minima of –2° to –5°C. A final population drop to virtually nil occurred in February, with maximum temperatures of 4° to 6°C and minimum temperatures of –8° to –15°C. Therefore, day temperatures of around 5°C and above, with night temperatures just below freezing, enable the population to increase, while day temperatures below 5°C in conjunction with night temperatures well below freezing result in a fall in aphid numbers, mortality being mainly caused by the low night temperatures.

Small pockets of aphids were able to survive air temperatures as low as –15°C. With the exception of one individual aphid these were all located on the lower shoots which were covered with snow during the periods of severe frost in February. The snow, presumably, acted as an insulator by shielding the aphids from the temperature extremes prevailing at this time.

The results suggested that the rate of increase was greater on 1967 needles than on 1968 needles at both crown levels. There was no evidence of differential population responses between crown levels. No predatory or parasitic activity was observed during the winter months.

Laboratory work on the effects of temperatures on aphid survival and reproduction have been initiated. At 15°C with 75 per cent humidity the results obtained differ substantially from those of Hussey (1952) at identical temperatures. The time from birth to adulthood was 12·4 ± 0·74 days compared with Hussey's 18·4 ± 0·5 days. Adult life was 41 days compared with 31 days, while the total nymphs produced per adult aphid totalled 28·9 compared with 12·1. The preliminary results obtained at 10°C suggest a lengthening in time of the birth to adulthood period. Further experiments at lower temperatures are planned to enable potential and actual values in the field to be related.

A laboratory study of the feeding behaviour of the aphids on Sitka spruce and Norway spruce is now under progress. Initial studies of the choice of site showed that on Sitka spruce the aphids chose the side of the needle bearing most stomata, irrespective of whether these were on the upper or lower surface. On Norway spruce there was no evidence to substantiate a similar distribution of aphids. On both trees aphids were rarely seen feeding near the tip of the needle and were found to feed indiscriminately along the basal four-fifths of the needle. In practically all cases the feeding adults faced the base of the needle with only the odd individual facing the tip.

Observations on feeding adults showed that once the aphids had settled they tended to remain in the same position for long periods—frequently until the needle was within a few days of dropping. Honeydew droplets were produced up to two hours after the initial settling down of the aphid; these were allowed to form as globules on the posterior end of the abdomen before the aphid flicked the droplet off with one hind leg. These droplets frequently travelled over one inch from a half-inch height. This presumably serves to keep the immediate surroundings of each aphid free of drops of honeydew.

By allowing aphids to feed on needles for known periods of time, the behaviour of the feeding aphids is being investigated by sectioning the needles and tracing the salivary sheaths left in the needle by the aphids. Results so far indicate that in both Norway and Sitka spruce entry into the needle is invariably through a stoma. The path of entry through the cortex may be intra- or intercellular and is generally inter-cellular through the endodermis. All stylet sheaths pass around, not through, the xylem. Termination of successful probes always lies in the phloem.

In a two-hour feeding period the number of probes per aphid on Norway spruce greatly exceeds that on Sitka spruce, a mean of about one sheath per aphid being produced on Sitka and about five sheaths per aphid on Norway spruce. Approximately 66 per cent of the sheaths terminate in phloem on Norway spruce and about 30 per cent in Sitka spruce. On Sitka the aphids appear to experience some difficulty in penetrating the endodermis as large depositions of saliva and branching occurs at this point. It is suggested that the Norway spruce is a relatively unsuitable host in that the probing stimulus is easily elicited whilst the feeding stimulus has a high threshold value so that a high "hunger" stimulus is required for feeding to occur. In Sitka, on the other hand, the difficulty experienced in penetrating through the endodermis may lower the "hunger" threshold sufficiently for feeding to continue once the phloem is reached. Further work on this problem is in progress.

The effects of known periods of probing by aphids on the needle is also currently under investigation. The aphids are encapsulated on individual needles using gelatin capsules and taken off after up to 72 hours probing.

Results show that as the probing time increases so the length of time to the formation of the yellow lesions and the fall of the needle decreases (Table 30).

TABLE 30

EFFECT OF APHID FEEDING PERIOD ON FORMATION OF YELLOW BANDING AND NEEDLE FALL OF SITKA SPRUCE

Feeding period (hrs.)	Time to formation of yellow lesion (days)	Percentage of needles showing yellowing	Percentage of those needles which fall	Time to needle fall (days)
18	15·6	39·0	6·2	—
24	10·5	93·3	76·1	35·3
48	10·0	92·9	79·5	27·2
72	9·0	94·7	86·1	23·7

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STUDIES ON TIT AND PINE LOOPER MOTH POPULATIONS AT CULBIN FOREST

By MYLES CROOKE

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The spring 1968 breeding census of Coal tits revealed that there were approximately twice as many pairs in Plot 1 as in Plot 2. It has previously been shown that the provision of nesting boxes in Plot 1 did not increase the breeding density there as compared with the unboxed Plot 2, and the difference in number of breeding pairs in the two plots in 1968 is ascribed, therefore, to the provision of supplementary food in the form of mixed nuts in Plot 1 during the preceding winter from September 1967 until March 1968. During that winter, as was mentioned in the previous report in this series, large flocks of tits were present in the plot, feeding from the twelve tables carrying the nuts. A sufficiently large proportion of these birds apparently remained in the plot to account for the difference in breeding densities recorded. Now that Coal tit populations can be so manipulated as to increase substantially their breeding densities in selected areas it will be possible to achieve the original objective of this study, viz. the collection of concurrent tit and Pine looper, *Bupalus piniarius*, population indices from study areas which differ in terms of the intensity of tit predation acting upon Pine looper numbers.

Feeding has again been supplied for the winter period 1968/69 and plans are in hand to add another pair of plots to the series, and also to commence direct measurement of consumption of different growth stages of *Bupalus* by tits. This latter approach will be aimed at describing Pine looper population trends by preparing survivorship curves or life tables for a number of successive *Bupalus* generations in situations where the intensity of tit predation differs.

Sampling for Pine looper pupae in February 1968 showed that the average number of pupae per square yard was 1·2 in Plot 1 and 1·7 in Plot 2.

FISH POPULATIONS IN FOREST STREAMS

By D. H. MILLS

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The study of the salmon and trout populations in the Glentress Burn, Peebles-shire, has continued during the last year. A total of 5,300 unfed salmon fry were released in the stream in February 1968, but a census of the stream in October 1968 failed to find any salmon fry in the stream, and it is believed that the fry were released at too early a stage in their development. It is planned to release a further 7,000 in April 1969.

A study has been started on the movements, mortality and annual production of brown trout in the upper reaches of this stream. Data on the growth of trout in this stream are almost complete and will be published elsewhere at a later date.

ENVIRONMENTAL STUDIES

ENVIRONMENTAL FACTORS AND THE GROWTH OF SITKA SPRUCE

By D. C. MALCOLM

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The collection of data for this project was completed during the year under report.

The Bin Forest in Aberdeenshire, East Scotland Conservancy, was selected as representative of the conditions in the eastern part of Scotland and as having a sufficiently large range of productivity classes to meet the other constraints on sample selection. Subsequently, Clashindarroch Forest, also in Aberdeenshire, was included for sampling as the elevational range and soil type variation at Bin proved inconveniently small. Twenty-five different plots were sampled from these forests, thus completing the collection of field data in this project.

In all, 96 tenth-acre plots have been sampled. These are distributed between four areas in Scotland to provide a range of yield classes within relatively distinct climatic conditions. The forests sampled have been Glentress (Peeblesshire), Inverliever (Argyll), Glen Garry (Inverness-shire), The Bin and Clashindarroch.

In each plot, top height, five-year intercept and basal area have been measured. Physiographic factors were noted and the vegetation within the plot listed by species. A soil profile was dug in each plot and each horizon sampled for physical and chemical analyses. Four hundred and fifty-two horizon samples have been analysed for a number of plant nutrients and soil moisture characteristics. The resultant data are now being analysed to provide information on the site relationships of Sitka spruce in each of the areas sampled. The field data has been sorted into six different soil types and the variation within these is being investigated, while various methods are being tried to provide a means of integrating horizon characteristics into a profile index of site productivity.

When the analysis of the data has been completed the whole project will be written up and the results published.

HYDROLOGICAL RELATIONS OF FOREST AND MOORLAND VEGETATION

By L. LEYTON, E. R. C. REYNOLDS and F. B. THOMPSON

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It is being increasingly argued that although they may still yield useful quantitative data over limited areas, traditional catchment trials, in so far as they generally fail to explain why particular results are obtained, are insufficient in themselves to provide the knowledge of the phenomena underlying the hydrological aspects of land use. The alternative, the so-called "synthetic" approach, which involves intensive studies of particular phases of the hydrological cycle and emphasizes basic plant/environment relations will, we believe, ultimately lead to a far better understanding of the problem (cf. Reynolds and Leyton, 1968). It is along these lines that much of the research carried out during the last decade or so in Oxford has been planned. The research that has, and is still being conducted, covers many aspects, including studies of tree root distribution and related patterns of water uptake from the soil, the interception of water by forest and moorland vegetation and its evaporation, and the continuous recording of sap flow up tree stems as a quantitative measure of transpiration (Leyton, 1967); more recently, studies have begun on stomatal control of transpiration in different species. However, rather than give a superficial account of all projects in hand, for the present report we have selected work on interception to describe in rather more detail, largely because it is now generally accepted that differences in the amount of interception and in the rate of evaporation of intercepted water may account for much of the difference between one vegetative cover and another on water yields from catchments. Studies in various stands in Bagley Wood, near Oxford (Leyton, Reynolds and Thompson, 1967; Reynolds and Henderson, 1967), have revealed characteristic differences between species in their effect on the amount and distribution of rainfall reaching the forest floor as throughfall and stemflow. In beech stands, mainly because of their relatively high stem flow, there is considerable concentration of rainfall in certain areas of the forest floor; the effect is much less marked in Norway spruce and negligible in larch stands. Thinning of a plantation is another factor that might be expected to influence interception and throughfall, so investigations have been carried out to see how far these quantities were affected by different thinning regimes. It is useful to collect together our results in order to follow the changes over ten years in a pole stage crop.

Measurements were made in a Norway spruce stand, planted in Forest Year 1942, in Bagley Wood subjected to the following treatments (thinnings were always made in late autumn):

(1) In 1963, following a number of years' study of interception, stem flow and throughfall, a uniform D grade thinning was carried out which reduced the true basal area from about 138 to 107 ft^2/acre (= 31 to 24 m^2/ha);

(2) the stand was divided into four plots of equal area and in 1964 two of these plots were thinned to about 82 ft^2/acre (= 19 m^2/ha);

(3) in 1966, these two plots were further thinned to about 75 ft^2/acre (= 17 m^2/ha) and the other two to about 100 ft^2/acre (= 23 m^2/ha). During

the first half of 1967 comparisons of throughfall distribution were made between the two pairs of plots using 10 five-inch rain gauges randomly distributed in each plot;

(4) in 1968, between 20 and 30 per cent of the stems on each plot were removed, reducing basal areas by about one-fifth. Before and after this thinning, measurements of throughfall were made in a similar manner as in 1967. The top height achieved by 1969 was 54·6 ft with 413 and 253 stems per acre (= 1,033 and 633 stems per ha) on the two treatments.

In Table 31 the results are presented in the form of linear regressions, relating Y, the throughfall as a percentage of gross rainfall, to x, the distance of the measuring point from the nearest tree stem.

Until 1969 all these linear regressions were significant at the 5 per cent level of probability, or better, and it follows that apart from stem flow (which in this stand is only of the order of a few percent of the total throughfall), the amount of rainfall reaching the forest floor increases more or less linearly with distance from the tree stem. By 1969 the standard error of the catch of 20 randomized gauges has fallen to 5·7 and 7·0 per cent of the mean for the light and heavy treatments respectively, about half the reported average for the 1959 data (Reynolds and Leyton, 1963). The tree spacing after the most recent thinning is such that random distribution of gauges is inappropriate to demonstrate a significant relationship with position; stratified randomization should be employed. However, the relation remains linear although the thinning to 51 per cent canopy cover and 253 stems/acre (= 633 stems per ha) appears to cause more rain to fall nearer the stems than in gaps under the fine rain conditions of winter. This will be examined more critically when more rain has fallen. The regression coefficients are certainly dependent on the type of rain and possibly the evaporative conditions as well. This appears from relations for different periods during which the gauge positions and canopy dimensions have not changed. Taking this into account, it appears from the data that thinning significantly reduced the rate of increase in throughfall with distance from the stem (the slope of the regressions). This is undoubtedly due to expansion of the tree crowns; following thinning the mean crown radius has approximately doubled since 1959.

Until 1967 at least, the different intensities of thinning do not appear to have had much influence on the throughfall pattern, since neither the constants nor the slopes of the regressions differ significantly from each other and it is possible to combine the data for the two pairs of plots in 1967 and the resulting linear regression remains significant. By the end of 1968 the increase in throughfall with distance from the trunk was less in the heavily thinned plots.

As explained previously (cf. Reynolds and Leyton, 1963), an estimate of total throughfall can be obtained from such linear regressions using a value for the mean distance from the tree stems estimated from many randomly distributed points. Alternatively, as from 1967, this distance can be calculated from the mean area per tree. The estimates of throughfall are shown in Table 31 with earlier data for comparison. It must be stressed that the percentage throughfall is to some degree a unique resultant of the prevailing canopy and climatic conditions, but serves to demonstrate that the difference between treatments is normally significant. Immediately after imposing the differential treatment in 1964, the relative increase in throughfall was almost as great as

TABLE 31

THROUGHFALL DISTRIBUTION IN NORWAY SPRUCE PLANTED IN FOREST YEAR 1942, AT BAGLEY WOOD, OXFORD
Linear regressions of throughfall as % gross rainfall (Y) on distance from tree stems (x cm). L – lightly thinned; H – heavily thinned.

Year	Season (solar)	Treatment	Basal area (m^2/ha)	% Cover	Regression	Mean distance from tree (cm)	% Throughfall (mean with S.E.)
1959	summer, autumn	—	19·5	76	Y = 14 + 0·839x	68	71·6 ± 5·2
1964	spring	—	24·1	—	troughs	83	58·4 ± 3·8
1965	winter	L	24·1	—	,,	83	41·5 ± 3·9
		H	18·8	—	,,	98	50·7 ± 4·0
1967	winter, spring	L	24·8	—	Y = 40 + 0·209x	99	61·0 ± 1·7
		H	17·2	74	Y = 41 + 0·205x	124	65·9 ± 1·6
1968	autumn	L	28·0	89	Y = 11 + 0·531x	99	64·1 ± 3·5
		H	21·3	79	Y = 44 + 0·224x	124	71·9 ± 5·1
1969	spring	L	23·4	85	Y = 45 + 0·126x	116	59·2 ± 4·0
		H	17·5	51	Y = 113 – 0·212x	144	82·5 ± 5·1

the proportional decrease in basal area under heavy thinning. Thereafter the relation with basal area is obscure. From the limited information available, the mean percentage throughfall was inversely related to the percentage cover, although the latter is a subjective estimate. The increase in throughfall was probably not quite as large as the decrease in cover.

As already pointed out, the rate of evaporation of water intercepted by the foliage is of considerable importance in the hydrological cycle and some attention has been given to the meteorological factors influencing it, in particular wind turbulence and the advection of heat energy. A comparative study of wind turbulence has been made over pole stage and five-year-old Scots pine, heather and short grass turf in and around Bramshill Forest, Hampshire, as a preliminary approach to studying the mechanism of heat advection to forest canopies (Bull and Reynolds, 1968).

The field investigations on interception by moorland vegetation (near Hebden Bridge, Yorks) are virtually completed and a computer programme has been devised to deal with the data obtained from the automatic logging instruments used in these studies. In addition to measuring and recording rainfall, throughfall and leaf wetness, a rain detector, sensitive to 0·05 mm, has been designed and installed.

Information on interception by foliage and the duration of wetting is of importance not only to hydrologists, but also to pathologists (Thompson, 1969); attention has also been given to factors governing the wettability of leaf surfaces (Leyton and Armitage, 1968) and to techniques for determining plant surface areas.

It is a pleasure to acknowledge the continued support of the Forestry Commission in providing assistance in the field work through Mr. E. A. S. Ogden.

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FIRES

FIRES IN FOREST AND HEATHLAND FUELS

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The various phases of the experimental and theoretical work in this programme have all been reported and a final summary is now being written.

Comparisons between controlled laboratory experiments and theory and instrumented controlled burns have been partially successful, but for further progress the emphasis will have to be on acquiring more statistical data from wild fires; the physical models of fire spread that have been developed are being used to identify the data that need reporting.

APPENDIX I

Main Experimental Projects and Localities

(*See Maps, page* 190, *for situations*)

SILVICULTURE AND SOILS

PRODUCTION OF PLANTING STOCK

Benmore Nursery, near Dunoon (Argyll)
Bush Nursery, near Edinburgh
Fleet Nursery, Gatehouse of Fleet (Kirkcudbrightshire)
Headley Nursery, Alice Holt Forest (Hampshire and Surrey)
Inchnacardoch Nursery, near Fort Augustus (Inverness-shire)

Kennington Nursery, near Oxford
Newton Nursery, near Elgin (Moray)
Sugar Hill Nursery, Wareham Forest (Dorset)
Tulliallan Nursery, Devilla Forest (Fife and Clackmannanshire)

PROVENANCE EXPERIMENTS

Scots pine:	Black Isle Forest, Findon (Ross-shire) Thetford Chase (Norfolk and Suffolk)
Corsican pine:	Bowland Forest (Lancashire) Brighstone Forest (Isle of Wight) Cotswold Forest (Gloucestershire) South Yorkshire Forest Thetford Chase (Norfolk and Suffolk) Wareham Forest (Dorset)
Lodgepole pine:	Achnashellach Forest (Ross-shire) Allerston Forest, Wykeham (Yorkshire) Black Isle Forest, Millbuie (Ross-shire) Brendon Forest (Somerset) Ceiriog Forest (Denbighshire) Clocaenog Forest (Denbighshire and Merioneth) Forest of Deer (Aberdeenshire) Glen Trool Forest (Kirkcudbrightshire and Ayrshire) New Forest (Hampshire) Shin Forest (Sutherland) Taliesin Forest (Cardiganshire and Montgomeryshire)
Jack pine:	Allerston Forest (Yorkshire)
Sitka spruce:	Clocaenog Forest (Denbighshire and Merioneth) Coed Morgannwg (Glamorgan) Glendaruel Forest (Argyll) Glen Trool Forest (Kirkcudbrightshire and Ayrshire) Kielder Forest (Northumberland) Loch Goil Forest (Argyll) Mynydd Du Forest (Brecon and Herefordshire) Radnor Forest (Radnorshire and Herefordshire) Ratagan Forest (Ross-shire and Inverness-shire) Taliesin Forest (Cardiganshire and Montgomeryshire) Wark Forest (Northumberland) Wilsey Down Forest (Cornwall)

PROVENANCE EXPERIMENTS—contd.

Norway spruce:	The Bin Forest (Aberdeenshire) Brendon Forest (Somerset) Cannock Chase (Staffordshire) Drummond Hill Forest (Perthshire) Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire) Halwill Forest (Devon and Cornwall) Minard Forest (Argyll) Newcastleton Forest (Roxburghshire and Dumfriesshire) Salisbury Forest (Wiltshire)
European and Japanese larches:	Allerston Forest (Yorkshire) Clashindarroch Forest (Aberdeenshire) Coed y Brenin (Merioneth) Drummond Hill Forest (Perthshire) Fetteresso Forest (Kincardineshire) Mortimer Forest (Herefordshire and Shropshire) Plym Forest (Devon) Savernake Forest (Wiltshire and Berkshire) Walcot Forest (Shropshire)
Douglas fir:	Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire) Ferness Forest (Nairnshire) Glentress Forest (Peeblesshire) Land's End Forest, St. Clement (Cornwall) Lynn Forest, Shouldham (Norfolk) Mortimer Forest (Herefordshire and Shropshire) Rheidol Forest (Cardiganshire)
Western hemlock:	Allerston Forest, Wykeham (Yorkshire) Benmore Forest (Argyll) Brecon Forest (Brecon) Brendon Forest (Somerset) Clocaenog Forest (Denbighshire and Merioneth) Loch Goil Forest (Argyll) New Forest (Hampshire) Rheidol Forest (Cardiganshire) Thetford Chase (Norfolk and Suffolk) Wareham Forest (Dorset)
Western red cedar:	Alice Holt Forest (Hampshire and Surrey) Benmore Forest (Argyll) Cannock Chase (Staffordshire) New Forest (Hampshire) Radnor Forest (Radnorshire and Herefordshire) Thetford Chase (Norfolk and Suffolk)
Silver fir, Abies alba:	Drummond Hill Forest (Perthshire) Lael Forest (Ross-shire) Radnor Forest (Radnorshire and Herefordshire) Thetford Chase (Norfolk and Suffolk)
Silver fir, Abies lowiana/concolor:	Brendon Forest (Somerset) Honiton Forest (Devon and Somerset) Mortimer Forest (Herefordshire and Shropshire)

PROVENANCE EXPERIMENTS—contd.

Oak:	Forest of Dean, Penyard (Gloucestershire, Herefordshire and Monmouthshire) Dymock Forest (Gloucestershire and Herefordshire)
Beech:	Queen Elizabeth Forest (Hampshire and Sussex) Savernake Forest (Wiltshire and Berkshire) Wendover Forest (Buckinghamshire)

CHOICE OF SPECIES FOR AFFORESTATION

Species and mixture trials on peat soils:	Achnashellach Forest (Ross-shire) Beddgelert Forest (Caernarvonshire) Eddleston Water Forest (Peeblesshire) Glen Trool Forest (Kirkcudbrightshire and Ayrshire) Inchnacardoch Forest (Inverness-shire) Kielder Forest (Northumberland) Kirroughtree Forest (Kirkcudbrightshire) Naver Forest (Sutherland) Rumster Forest, Watten (Caithness) Shin Forest (Sutherland) Strathy Forest (Sutherland) Wauchope Forest (Roxburghshire)
Species and mixture trials on gley soils:	Forest of Ae (Dumfriesshire) Alice Holt Forest (Hampshire and Surrey) Allerston Forest (Yorkshire) Beddgelert Forest (Caernarvonshire) Black Isle Forest (Ross-shire) Blairadam Forest (Fife and Kinross-shire) Bowland Forest, Gisburn (Yorkshire) Brendon Forest (Somerset) Clocaenog Forest (Denbighshire and Merioneth) Forest of Deer (Aberdeenshire) Drumtochty Forest (Kincardineshire) Elibank and Traquair Forest (Selkirkshire and Peeblesshire) Fetteresso Forest (Kincardineshire) Gwydyr Forest (Caernarvonshire and Denbighshire) Hamsterley Forest (County Durham) Kielder Forest (Northumberland) Land's End Forest (Cornwall) Lennox Forest (Stirlingshire and Dunbartonshire) Loch Ard Forest (Perthshire and Stirlingshire) Rockingham Forest (Northamptonshire) Rosarie Forest (Banffshire and Moray) Taliesin Forest (Cardiganshire and Montgomeryshire) Wilsey Down Forest (Cornwall)
Species and mixtures on ironpan soils:	Allerston Forest (Yorkshire) Clashindarroch Forest (Aberdeenshire) Devilla Forest (Fife and Clackmannanshire) Hambleton Forest (Yorkshire) Newtyle Forest (Moray) Teindland Forest (Moray)
Species and mixtures on freely drained soils:	Alton Forest (Hampshire) Bedgebury Forest (Kent and Sussex) Bodmin Forest (Cornwall) Bradon Forest (Wiltshire) Brechfa Forest (Carmarthenshire)

CHOICE OF SPECIES FOR AFFORESTATION—contd.

	Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
	Exeter Forest (Devon)
	Honiton Forest (Devon and Somerset)
	Hursley Forest (Hampshire)
	Land's End Forest (Cornwall)
	Micheldever Forest (Hampshire)
	Mortimer Forest (Herefordshire and Shropshire)
	New Forest (Hampshire)
	Plym Forest (Devon)
	Thetford Chase (Norfolk and Suffolk)
	Tintern Forest (Monmouthshire)
	Wareham Forest (Dorset)
Trials of species on other soils:	Brighstone Forest (Isle of Wight)
	Chilterns Forest (Buckinghamshire, Oxfordshire and Hertfordshire)
	Cranborne Chase (Dorset and Wiltshire)
	Exeter Forest (Devon)
	Friston Forest (Sussex)
	Queen Elizabeth Forest (Hampshire and Sussex)
Trial plantations on difficult sites:	Beddgelert Forest (Caernarvonshire)
	Borgie Forest (Sutherland)
	Clocaenog Forest (Denbighshire and Merioneth)
	Deudraeth Forest (Merioneth)
	The Garraries (Kirkcudbrightshire)
	Glencoe Forest (Argyll)
	Glen Garry Forest, South Laggan (Inverness-shire)
	Glen Trool Forest (Kirkcudbrightshire and Ayrshire)
	Hafren Forest (Montgomeryshire)
	Hoy Experiments (Orkney Islands)
	Land's End Forest (Cornwall)
	Lewis Experiments, Isle of Lewis (Ross-shire)
	Myherin Forest (Cardiganshire)
	Mynydd Du Forest (Brecon and Monmouthshire)
	Naver Forest (Sutherland)
	The Queen's Forest (Inverness-shire)
	Radnor Forest (Radnorshire and Herefordshire)
	Rumster Forest (Caithness)
	Shetland Experiments (Shetland)
	Shin Forest (Sutherland)
	South Yorkshire Forest
	Strathy Forest (Sutherland)
	Torrachilty Forest (Ross-shire)
Trials of species having specialised cultural requirements:	Alice Holt Forest (Hampshire and Surrey)
	Bagley Wood, St. John's College Estate, near Oxford
	Bedgebury Forest (Kent and Sussex)
	Blandford Forest (Dorset)
	Bradon Forest (Wiltshire)
	Cannock Chase (Staffordshire)
	Chilterns Forest, Wendover (Buckinghamshire)
	Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
	Huntingdon Forest (Huntingdonshire)
	Land's End Forest (Cornwall)
	Lynn Forest (Norfolk)
	Quantock Forest (Somerset)

CHOICE OF SPECIES FOR AFFORESTATION—contd.

Queen Elizabeth Forest (Hampshire and Sussex)
South Yorkshire Forest
Stenton Forest (East Lothian, Midlothian and Berwickshire)
Thetford Chase (Norfolk and Suffolk)
Wareham Forest (Dorset)
Wentwood Forest (Monmouthshire)
Westonbirt (Gloucestershire)
Wynyard Forest (Co. Durham)

ARBORETA

Benmore Forest, Kilmun (Argyll)
Minard Forest, Crarae (Argyll)
National Pinetum, Bedgebury (Kent)
Westonbirt Arboretum (Gloucestershire)

CONTAINER PLANTING

Alice Holt Forest (Hampshire and Surrey)
Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Glen Garry Forest (Inverness-shire)
Gwydyr Forest (Caernarvonshire and Denbighshire)
Naver Forest (Sutherland)

Radnor Forest (Radnorshire and Herefordshire)
Thetford Chase (Norfolk and Suffolk)
Tighnabruaich Forest (Argyll)
Towy Forest (Cardiganshire, Brecon and Carmarthenshire)

NUTRITION

Allerston Forest (Yorkshire)
Arecleoch Forest (Ayrshire)
Clocaenog Forest (Denbighshire and Merioneth)
Culbin Forest (Moray and Nairnshire)
Eddleston Water Forest (Peeblesshire)

Exeter Forest (Devon)
Inchnacardoch Forest (Inverness-shire)
Kielder Forest (Northumberland)
Mabie Forest (Kirkcudbrightshire and Dumfriesshire)
Selm Muir (Midlothian and West Lothian)

Shin Forest (Sutherland)
Speymouth Forest (Moray and Banffshire)
Tarenig Forest (Cardiganshire and Montgomeryshire)
Teindland Forest (Moray)
Towy Forest (Cardiganshire, Brecon and Carmarthenshire)

Wareham Forest (Dorset)
Wilsey Down Forest (Cornwall)

FOREST WEED CONTROL

Abinger Forest (Surrey)
Alice Holt Forest (Hampshire and Surrey)
Alton Forest (Hampshire)
Bedgebury Forest (Kent and Sussex)
Forest of Bere (Hampshire)

Bodmin Forest (Cornwall)
Bramshill Forest (Berkshire and Hampshire)
Chiddingfold Forest (Surrey and Sussex)

FOREST WEED CONTROL—contd:

Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Durris Forest (Aberdeenshire and Kincardineshire)
Exeter Forest (Devon)
Friston Forest (Sussex)
Glentress Forest (Peeblesshire)

Hursley Forest (Hampshire)
Lleyn Forest (Caernarvonshire)
Neroche Forest (Somerset)
New Forest (Hampshire)
Rockingham Forest (Northamptonshire)

Rogate Forest (Sussex)
Taliesin Forest (Cardiganshire and Montgomeryshire)
Thetford Chase (Norfolk and Suffolk)
Wareham Forest (Dorset)

DRAINAGE

Achray Forest (Perthshire)
Forest of Ae (Dumfriesshire)
Allerston Forest (Yorkshire)
Bernwood Forest (Oxfordshire and Buckinghamshire)
Clocaenog Forest (Denbighshire and Merioneth)

Crychan Forest (Brecon and Carmarthenshire)
Hafren Forest (Montgomeryshire)
Halwill Forest (Devon and Cornwall)
Inchnacardoch Forest (Inverness-shire)
Kershope Forest (Cumberland)

Kielder Forest (Northumberland)
Lennox Forest (Stirlingshire and Dunbartonshire)
Naver Forest (Sutherland)
Newcastleton Forest (Roxburghshire and Dumfriesshire)
Orlestone Forest (Kent)

Rumster Forest (Caithness)
Shin Forest (Sutherland)
Towy Forest (Cardiganshire, Brecon and Carmarthenshire)

CULTIVATION

Achnashellach Forest (Ross-shire)
Allerston Forest (Yorkshire)
Black Isle Forest (Ross-shire)
Clashindarroch Forest (Aberdeenshire)
Clocaenog Forest (Denbighshire and Merioneth)

Dornoch Forest (Sutherland)
Exeter Forest (Devon)
Fetteresso Forest (Kincardineshire)
Hallyburton Forest (Angus and Perthshire)
Hambleton Forest (Yorkshire)

Inshriach Forest (Inverness-shire)
Speymouth Forest (Moray and Banffshire)
Taliesin Forest (Cardiganshire and Montgomeryshire)
Teindland Forest (Moray)
Towy Forest (Cardiganshire, Brecon and Carmarthenshire)

REGENERATION, NATURAL AND ARTIFICIAL

Forest of Ae (Dumfriesshire)
Alice Holt Forest (Hampshire and Surrey)

REGENERATION, NATURAL AND ARTIFICIAL—contd.

Allerston Forest (Yorkshire)
Bernwood Forest (Oxfordshire and Buckinghamshire)
The Bin Forest (Aberdeenshire and Banffshire)
Brendon Forest (Somerset)
Coed Morgannwg, Michaelston (Glamorgan)
Cranborne Chase (Dorset and Wiltshire)
Culbin Forest (Moray and Nairnshire)
Culloden Forest (Inverness-shire and Nairnshire)
Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Drumtochty Forest (Kincardineshire)
Glenbranter Forest (Argyll)
Hursley Forest (Hampshire)
Kielder Forest (Northumberland)
Kirkhill Forest (Aberdeenshire)
Lennox Forest (Stirlingshire and Dunbartonshire)
Newcastleton Forest (Roxburghshire and Dumfriesshire)
Portclair Forest (Inverness-shire)
Radnor Forest (Radnorshire and Herefordshire)
Rannoch Forest (Perthshire)
Thetford Chase (Norfolk and Suffolk)

STABILITY OF CROPS

Forest of Ae (Dumfriesshire)
Allerston Forest (Yorkshire)
Clocaenog Forest (Denbighshire and Merioneth)
Crychan Forest (Brecon and Carmarthenshire)
Hamsterley Forest (County Durham)
Kielder Forest (Northumberland)
Newcastleton Forest (Roxburghshire and Dumfriesshire)
Redesdale Forest (Northumberland)
Teindland Forest (Moray)
Wark Forest (Northumberland)
Wauchope Forest, Whitrope (Roxburghshire)

GENETICS

PROPAGATION CENTRES

Alice Holt Forest (Hampshire and Surrey)
Bush Nursery, near Edinburgh
Grizedale Nursery (Lancashire)

TREE BANKS

Alice Holt Forest (Hampshire and Surrey)
Alton Forest (Hampshire)
Bush Nursery, near Edinburgh
Chiddingfold Forest, Witley (Surrey and Sussex)
Newton Nursery, near Elgin (Moray)
Teindland Forest (Moray)
Wauchope Forest (Roxburghshire)

SEED ORCHARDS

Alice Holt Forest (Hampshire and Surrey)
Bradon Forest (Wiltshire)
Craigvinean Forest (Perthshire)
Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Drumtochty Forest (Kincardineshire)
Keillour Forest, Glenalmond (Perthshire)
Lynn Forest (Norfolk)

SEED ORCHARDS—cont.

Newton Nursery, near Elgin (Moray)
Stenton Forest (East Lothian and Berwickshire)
Westonbirt (Gloucestershire)
Whittingehame (East Lothian)

PROGENY TRIALS

Alice Holt Forest (Hampshire and Surrey)
Allerston Forest (Yorkshire)
Ardross Forest (Ross-shire)
Aultmore Forest (Banffshire)
Benmore Forest (Argyll)

Bramshill Forest (Berkshire and Hampshire)
Chillingham Forest (Northumberland)
Clocaenog Forest (Denbighshire and Merioneth)
Coed Sarnau (Radnorshire)
Coed y Brenin (Merioneth)

Craigvinean Forest (Perthshire)
Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Devilla Forest (Fife and Clackmannanshire)
Elchies Forest (Moray)
Farigaig Forest (Inverness-shire)

Glendaruel Forest (Argyll)
Glenlivet Forest (Banffshire)
Gwydyr Forest (Caernarvonshire and Denbighshire)
Inchnacardoch Forest (Inverness-shire)
Kilmichael Forest (Argyll)

Kilmory Forest (Argyll)
Laurieston Forest (Kirkcudbrightshire)
Monaughty Forest (Moray)
Speymouth Forest (Moray and Banffshire)
Stenton Forest (East Lothian, Midlothian and Berwickshire)

Teindland Forest (Moray)
Thetford Chase (Norfolk and Suffolk)
Thornthwaite Forest (Cumberland)
Wauchope Forest (Roxburghshire)
Westonbirt (Gloucestershire)

PATHOLOGY

FOMES ANNOSUS

The Bin Forest (Aberdeenshire and Banffshire)
Bramshill Forest (Berkshire and Hampshire)
Clocaenog Forest (Denbighshire and Merioneth)
Dartmoor Forest (Devon)
Kerry Forest (Montgomeryshire, Shropshire and Radnorshire)

Lael Forest (Ross-shire)
Radnor Forest (Radnorshire and Herefordshire)
Thetford Chase (Norfolk and Suffolk)

ARMILLARIA MELLEA

Alice Holt Forest (Hampshire and Surrey)
Bramshill Forest (Berkshire and Hampshire)
Chiddingfold Forest (Surrey and Sussex)
Westonbirt (Gloucestershire)

POLYPORUS SCHWEINITZII

Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)

CRUMENULA SORORIA ON PINE

Ringwood Forest (Dorset and Hampshire)

ELM DISEASE TRIALS

Alice Holt Forest (Hampshire and Surrey)

BACTERIAL CANKER OF POPLAR

Blandford Forest (Dorset)

TOP DYING OF NORWAY SPRUCE

Coed Morgannwg (Glamorgan)

ENTOMOLOGY

UCE APHID: ELATOBIUM ABIETINUM

Forest of Ae (Dumfriesshire)
Alice Holt Forest (Hampshire and Surrey)
Bramshill Forest (Berkshire and Hampshire)
Dovey Forest (Merioneth and Montgomeryshire)
Inverliever Forest (Argyll)
New Forest (Hampshire)

ADELGES SPP.

Alice Holt Forest (Hampshire and Surrey)

PINE SHOOT BEETLE: TOMICUS PINIPERDA

Bramshill Forest (Berkshire and Hampshire)

BLACK PINE BEETLE: HYLASTES SPP.

Thetford Chase (Norfolk and Suffolk)

LARGE PINE WEEVIL: HYLOBIUS ABIETIS

Kielder Forest (Northumberland)
Thetford Chase (Norfolk and Suffolk)

DOUGLAS FIR SEED WASP: MEGASTIGMUS SPERMOTROPHUS

Brendon Forest (Somerset)
Culloden Forest (Inverness-shire and Nairnshire)
Mortimer Forest (Herefordshire and Shropshire)
New Forest (Hampshire)
Thornthwaite Forest (Cumberland)

LARCH SAWFLY: ANOPLONYX DESTRUCTOR

Drumtochty Forest (Kincardineshire)

PINE LOOPER MOTH: BUPALUS PINIARIUS

Cannock Chase (Staffordshire)

EFFECT OF FERTILISERS

Achray Forest (Perthshire)
Aeron Forest (Cardiganshire)
Arecleoch Forest (Ayrshire)
Brendon Forest (Somerset)

N*

EFFECT OF FERTILISERS—contd.

Cannock Chase (Staffordshire)
Clocaenog Forest (Denbighshire and Merioneth)
Clwyd Forest (Denbighshire and Flintshire)
Coed Morgannwg (Glamorgan)
Dartmoor Forest (Devon)
Eddleston Water Forest (Peeblesshire)
Exeter Forest (Devon)
Halwill Forest (Devon and Cornwall)
Mabie Forest (Kirkcudbrightshire and Dumfriesshire)
Neroche Forest (Somerset)
Selm Muir (Midlothian and West Lothian)
Shin Forest (Sutherland)
Strathy Forest (Sutherland)
Tarenig Forest (Cardiganshire and Montgomeryshire)
Towy Forest (Cardiganshire, Brecon and Carmarthenshire)
Wareham Forest (Dorset)
Wilsey Down Forest (Cornwall)

NEW PLANTING LOSSES

Arecleoch Forest (Ayrshire)
Aultmore Forest (Banffshire)
Craik Forest (Roxburghshire, Selkirkshire and Dumfriesshire)
Glenerrochty Forest (Perthshire)
Glen Garry Forest (Inverness-shire)
Glenorchy Forest (Argyll)
Kirroughtree Forest (Kirkcudbrightshire)
Leanachan Forest (Inverness-shire and Argyll)
Rannoch Forest (Perthshire)
Rumster Forest (Caithness)
Selm Muir (Midlothian and West Lothian)
Shin Forest (Sutherland)
Tornashean Forest (Aberdeenshire)

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:	Black Isle Forest, Findon (Ross-shire) Ebbw Forest (Monmouthshire) Roseisle Forest (Moray) Thetford Chase (Norfolk and Suffolk) Tintern Forest (Monmouthshire)
Corsican pine:	Aldewood Forest (Suffolk)
Sitka spruce	Allerston Forest (Yorkshire) Brecon Forest (Brecon) Clocaenog Forest (Denbighshire and Merioneth) Coed Morgannwg, Rheola (Glamorgan) Gwydyr Forest (Caernarvonshire and Denbighshire)
Norway spruce:	Clocaenog Forest (Denbighshire and Merioneth) Clunes Forest (Inverness-shire) Coed Morgannwg, Rheola (Glamorgan) Glenlivet Forest (Banffshire)

SPACING—contd.

Kerry Forest (Montgomeryshire, Shropshire and Radnorshire)
Monaughty Forest (Moray)

European larch:
Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Fleet Forest (Kirkcudbrightshire)
Mortimer Forest (Herefordshire and Shropshire)
Radnor Forest (Radnorshire and Herefordshire)

Japanese larch:
Brechfa Forest (Carmarthenshire)
Caeo Forest (Carmarthenshire)
Coed Morgannwg, Rheola (Glamorgan)
Crychan Forest (Brecon and Carmarthenshire)
Dalbeattie Forest (Kirkcudbrightshire)
Drumtochty Forest (Kincardineshire)
Ebbw Forest (Monmouthshire)

Douglas fir:
Allerston Forest (Yorkshire)
Brechfa Forest (Carmarthenshire)
Ystwyth Forest (Cardiganshire)

THINNING

Scots pine:
Aldewood Forest (Suffolk)
Black Isle Forest, Millbuie (Ross-shire)*
Cannock Chase (Staffordshire)
Crown Estates, Fochabers, near Speymouth Forest (Moray and Banffshire)
New Forest (Hampshire)
Thetford Chase, Swaffham (Norfolk)
Thetford Chase (Norfolk and Suffolk)

Corsican pine:
Aldewood Forest (Suffolk)
Culbin Forest (Moray and Nairnshire)
New Forest (Hampshire)
Pembrey Forest (Carmarthenshire)
Sherwood Forest (Derbyshire, Yorkshire and Nottinghamshire)*
Thetford Chase, Swaffham (Norfolk)
Thetford Chase (Norfolk and Suffolk)

Sitka spruce:
Forest of Ae (Dumfriesshire)*
Ardgartan Forest (Argyll)
Brendon Forest (Somerset)
Dovey Forest (Merioneth and Montgomeryshire)*
Glen Trool Forest (Kirkcudbrightshire)*

Norway spruce:
Bowmont Forest (Duke of Roxburgh's Estate, Roxburghshire)*
Cairn Edward Forest, Bennan (Kirkcudbrightshire)
Kershope Forest (Cumberland)
Monaughty Forest (Moray)
Tintern Forest (Monmouthshire)

European larch:
Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Murthly Estate (near Strathord Forest, Perthshire)

Japanese larch:
Bodmin Forest (Cornwall)
Brechfa Forest (Carmarthenshire)

THINNING—contd.

	Coed Morgannwg, Rheola (Glamorgan) Drumtochty Forest (Kincardineshire) Glentress Forest (Peeblesshire) Stourhead Estate (Wiltshire)
Douglas fir:	Alice Holt Forest (Hampshire and Surrey)* Gwydyr Forest (Caernarvonshire and Denbighshire) Mynydd Du Forest (Brecon and Monmouthshire) Wensum Forest (Norfolk)
Noble fir:	Dovey Forest (Merioneth and Montgomeryshire)
Picea omorica:	Bedgebury Forest (Kent and Sussex)
Oak:	Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire) Hazelborough Forest (Buckinghamshire and Northamptonshire) Micheldever Forest (Hampshire) Wensum Forest (Norfolk)
Beech:	Hampden Estate (Buckinghamshire) Nettlebed Estate (Buckinghamshire)

UNDERPLANTING

Corsican pine, underplanted with Grand fir:	Thetford Chase (Norfolk and Suffolk)
European larch, underplanted with various species:	Dymock Forest (Gloucestershire and Herefordshire) Exeter Forest (Devon)
Oak, underplanted with Western hemlock:	Micheldever Forest (Hampshire)

MIXTURES

Sitka spruce/Lodgepole pine *Sitka spruce/Japanese larch*	Beddgelert Forest (Caernarvonshire)
Oak/beech:	Tintern Forest (Monmouthshire)

APPENDIX II

Publications by Staff Members

Reprints of many of the papers listed are available on application to the Librarian. Priced publications issued by the Forestry Commission are available from H.M. Stationery Office at addresses shown on back cover.

AARON, J. R. (1968). Use of wood residues in agriculture and horticulture. *Suppl. Timb. Trades J.* April 1968, p.35.

A recent survey of literature has indicated that sawdust, shavings and wood chips can for most crops be used as a mulch or incorporated in the soil with beneficial effects, provided a nitrogenous fertiliser is added.

AARON, J. R. (1968). Timber demonstration building, Farm Buildings Centre, Stoneleigh Park, Kenilworth: A structure of home-grown Douglas fir, hardboard stressed skin roof panels, and hardboard wall panels. *Wood* **33**(5), 15–16.

Describes the supply and preparation of Douglas fir from the Forest of Dean, given by the Forestry Commission for the laminated structures of the timber demonstration building, at the Farm Buildings Centre.

AARON, J. R., and CARTER, K. W. (1968). Forestry in Berlin. *Q. Jl For.* **62**(2), 154–160.

An account of the history, growing stock, protection, utilisation and amenity aspects of the 19,000 acres of woodland managed by the Berlin Forest Service.

ALDHOUS, J. R. (1968). In *Weed control handbook* (British Weed Control Council), 5th ed. Oxford; Blackwell Scientific Publications:

Vol. 1, *chap. 14.* Weed control in forests and forest nurseries.

A chapter setting out the background to forest weed control, emphasising the time scale, general financial circumstances and effect of the crop eventually suppressing most of the original weed species.

Vol. 2, chap. 7. Recommendations for the use of herbicides in forestry.

A chapter giving detailed recommendations. The style is terse, in keeping with the rest of the volume, and is intended for the adviser and any others who can relate the quantities of active ingredient recommended into quantities of any of the formulations currently on the market.

ALDHOUS, J. R. (1968). *Maintenance of fertility in forest nurseries.* Res. Dev. Pap. For. Commn, Lond. **68**.

Prescriptions are given for N, P, K and Mg fertilisers and bulky organics used in forest nursery seedbeds and transplant lines. Recommendations are given for maintaining a suitable pH in the soil and guidance given on the interpretation of the analysis of P, K and Mg in the soil.

ALDHOUS, J. R. (1968). Report on the Pesticides Conference, November 20, 1967 – Countryside in 1970. *Q. Jl For.* **62**(3), 225–232.

The conference was timed to coincide with the publication of the leaflet *Pesticides – a Code of Practice.* The report comments on the leaflet and summarises the thirteen papers that were presented. Three of these gave manufacturers' views, six gave users' ideas and four papers were concerned with conservation.

ALDHOUS, J. R. (1968). Weed control in forest nurseries. *Agriculture* **75**(11), 522–526.

A general paper for an agricultural audience outlining current practice.

BARRINGTON, C. A. (1968). *Forestry in the Weald.* Bookl. For. Commn **22.** (H.M.S.O. 3s. 6d.)

Shows, with photographs, the natural setting of the woodlands of the Weald, discusses their history and economic value, and suggests how they can be preserved both as scenery and as a source of useful timber.

BELL, T. I. W. (1968). *Effect of fertiliser and density pre-treatment on spruce seedling survival and growth.* Forest Rec., Lond. **67.** (H.M.S.O. 4s.)

This Forest Record originated as a thesis accepted by the University of Toronto, and is therefore based on Canadian conditions. Though the enquiries were directed to the survival and growth of seedling trees planted out *in the forest*, the results may be equally valuable in this country as they indicate similar progress for seedlings first transplanted *in the nursery*, as an intermediate stage. Experiments showed that:

1. White spruce seedlings gave the best results in survival and field growth where the heaviest of three fertiliser rates was applied. There was an indication that time of fertiliser application affected survival but differences in results were slight.
2. White spruce seedlings grown at three nursery fertiliser levels and at four densities gave a wide variety of seedling size, both in the nursery and after one simulated field growing season. If 15 cm (5·9 in.) minimum height and 4·5 mm (0·18 in.) minimum diameter are used as the criteria of plantable stock, the heaviest tested fertiliser treatment, applied to stock grown at 1·9 per m^2 (20 per ft^2), the second lowest density gives the best results.

BINNS, W. O. (1969). Water use by tree plantations. *J. Hydrol.* **7**, 109–110.

Brief comments on the paper *Water use by tree plantations* by R. Kitching (1967) in *J. Hydrol.* **5**, 206–213.

BROWN, R. M. (1968). The effect of chlorthiamid on young forest trees. *Proc. Br. Weed Control Conf.* **9**, vol. 2, 975–980.

Experiments in 1964 and 1967 in which chlorthiamid formulated as a 7 per cent granule was applied in planted crops at rates of from 3·4–13·4 kg.a.i./ha (3–12 lb a.i./acre) during March to July were examined for evidence of crop damage.

All species were affected to some degree but differed in their resistance to chlorthiamid damage. Damage was greater at the higher rates and later dates of application. At 4·5–6·7 kg. a.i./ha (4–6 lb a.i./acre) in March to May, Sitka spruce, Norway spruce and Corsican pine were quite resistant, Western hemlock and Douglas fir were moderately sensitive, and all *Abies* species were extremely sensitive. The resistance of Scots pine, larches, beech and oak needs clarification since results were erratic or contradicted previous work.

BROWN, R. M. (1968). Further experiments on the control of bracken in forestry with dicamba. *Proc. Br. Weed Control Conf.* **9**, vol. 2, 981–988.

Assessments in 1968 of experiments in which dicamba was sprayed at 1·1–9 kg a.e./ha (1 to 8 lb a.e./acre) from February to June 1965 showed that control of bracken was still evident three and a half years after application.

The results of experiments in 1967 and 1968, involving pre-planting applications of dicamba at 1·7–6·7 kg a.e./ha (1½ to 6 lb a.e./acre) from December to early June indicate that bracken control is invariably good in the first year provided spraying takes place before full frond development, but varies in subsequent years depending on site factors. Fertility and soil moisture are suggested as being important.

The interval required between application and planting to avoid damage to the crop varies with the season. It is probably about 8 weeks or more in the late spring and summer, but 12 weeks or more during the winter.

The successful use of dicamba for bracken control in forestry depends on exploitation of the first year's control, on vegetational succession and price.

BROWN, R. M. (1968). Recent developments and experience in chemical weed control in forestry. *J. chart. Ld Ag. Soc.* **67** (7), 300–307.

A survey of the latest advances in the use of chemicals for weed control in forestry, with emphasis on the technical usefulness of standard and recently introduced herbicides in all spheres of forest weed control. Machinery and methods of application are not covered.

BURDEKIN, D. A. (1968). Stump treatment against *Fomes annosus*. *Suppl. Timb. Trades J.* October, p. 16.

A brief note on stump treatment against *Fomes annosus* directed to the needs of the private landowner.

BUSZEWICZ, G. (1968). Problems and rewards in processing and storing seed. *Scott. For.* **22**(2), 129–134.

The author describes the Commission's main procedures for procuring, processing and storing seed. The great majority of seed is imported, but lately a lot of work has been done to increase supplies from home sources. The most important work in this respect is the establishment of seed orchards and the creation of a Register of Seed Sources, which lists all the most valuable stands for seed collection purposes. Good facilities for seed processing, testing and storage are having widespread effects on seed economy in nurseries, where it is shown that during the last ten years the annual seed usage was reduced by about 6,800 kg (15,000 lb) of conifer seed for more or less the same planting programme.

CARTER, C. I. (1968). A change in the *Lepidoptera* of Hampstead after four decades. *Proc. S. Lond. ent. nat. Hist. Soc.* 1967 (4), 123–125.

A species list of *Lepidoptera* collected in Hampstead, London, between 1950 and 1958 is contrasted with older records published in 1913 and compared to some extent with the species found during a recent survey of Buckingham Palace Garden.

More than two-thirds of the 149 previously recorded species were not found again, but of the 87 species listed 41 per cent are thought to be new records and indicate a species change. The greater similarity between the records of modern Hampstead and Buckingham Palace Garden and those of 1913 may be an indication that a general ecological change has taken place in London.

A higher percentage of the present-day Hampstead species feed on trees and shrubs than those of Buckingham Palace Garden, but in spite of Hampstead Heath having lost many of its herbaceous plants through human pressure and the many exotic trees that are now established, the proportion of tree and shrub feeding *Lepidoptera* has not appreciably changed.

DICKSON, J. A., and DIXON, P. J. (1969). *Pulpwood supply and the paper industry.* Forest Rec., Lond. **68**. (H.M.S.O. 5s.)

Report of a conference of the British Paper and Board Makers' Association, London, 12th June, 1968, to consider the supplies of pulpwood coming forward, in Britain, up to the end of the century.

EDLIN, H. L. (1968). A modern Sylva or a Discourse of forest trees.

25. Hemlocks, Western red cedar and Incense cedar: *Tsuga, Thuja and Libocedrus genera. Q. Jl For.* **62**(2), 145–154.

26. Subtropical trees: *Eucalyptus* species, Palms, Club palms, Tree ferns, and the Maidenhair tree. *Q. Jl For.* **62**(3), 199–206.

Part of a series dealing popularly with the main tree species.

EDLIN, H. L. (1968). Woodland year: Cones in Autumn. *Q. Jl For.* **62**(4), 284–293.

Describes cones as an aid to identification of softwood trees, with notes on enemies of cones and seeds.

EDLIN, H. L. (1969). Woodland notebook: Bark in Winter. *Q. Jl For.* **63**(1), 21–30.

A general description of the formation, structure and uses of bark.

EDLIN, H. L. (and DARTER, C.). (1968). *Know your broadleaves.* Bookl. For. Commn **20**. (H.M.S.O. 15s.)

A description of the main broadleaved tree species growing in Britain, with drawings and photographs.

FOURT, D. F. (1968). *Sitka spruce, shelter and moisture.* Res. Dev. Pap. For. Commn, Lond. **72**.

Sitka spruce (*Picea sitchensis*) transplants were grown in pots for six months in 1955, with three moisture regimes and three levels of side shelter.

The treatment combining shelter with plentiful soil water supply produced the best growth. However, while height growth declined progressively with restrictions in both shelter and soil water supply, diameter growth was reduced by cutting down water supply, but was independent of side shelter. These results suggest that on sites with an adequate supply of soil water, but where drying winds can induce high transpiration stresses, stands of Sitka spruce should be treated to preserve mutual crown shelter as afforded by the dominant trees. Growth reductions, particularly in height, may follow the exposure of tree crowns to unfamiliar stresses.

GARDINER, A. S. (1968). *The reputation of birch for soil improvement: A literature review.* Res. Dev. Pap. For. Commn, Lond. **67**.

In order to find out how birch has gained a reputation as a soil improver, and to separate observation from hearsay, the author has made a detailed examination of the relevant literature.

This has revealed that the recognition of birch in this role dates back at least to the eighteenth century. Since then, its reputation has grown through the comments, observations and detailed studies of many workers in various European countries. It appears to have arisen in two ways: indirectly by the observation of the behaviour and effect of natural or artificially planted birch – either as a nurse crop or in true mixture – on other species; or, directly from studies of the effect of birch on the forest soil.

The author concludes that apart from the objections of some foresters, who noted its bad influence on the growth of pine in north-east Germany, the case for birch, both as a nurse and as a soil improving species, is a good one.

GRAYSON, A. J. (1967). Planning the cut from forests. *Indian J. agric. Econ.* **22**(4), 146–149.

Technically based formulae for yield calculation are criticised and arguments are put forward for planning the cut after simulation of the effect of different patterns of yield has been studied in terms of the flows of costs and benefits produced by alternative regimes.

GRAYSON, A. J. (1969). *Applications of new mathematical methods to forest planning in Great Britain.* Paper for FAO/ECE/ILO Study Group on methods and organization of forest work, LOG/WP.1/37, Geneva, March 1969.

Examples are given of the use of statistical analysis (mainly using multiple regression), simulation techniques (production forecasting, nursery planning, forecasting future cash flows in aggregate model for the Forestry Commission) and linear programming either directly as aids to management or indirectly by providing the analytical basis for management studies.

GRAYSON, A. J. (1969). *The implications of trends in forest working techniques in the context of the British Forestry Commission.* Paper for FAO/ECE/ILO Study Group on methods and organization of forest work, LOG/WP.1 Conf. Room, Doc. 14. Geneva, March 1969.

In recent years, with the spread of a number of labour-saving techniques and changes in specifications, labour productivity has increased quite rapidly. Assuming a continuing fairly high rate of rise in productivity, there are important effects on labour demand. The incentives for promoting technological change in forestry are great and, while there are important technical and institutional problems to be solved before technological change can be effected, the basic needs in the sphere of long-term or strategic planning are clear. These include technological, economic and social forecasting with the aims of clarifying future operational specifications and matching the demand for labour with its supply as well as possible over future periods.

GRAYSON, A. J. (1969). *Methods of payment: Review of the position in the Forestry Commission of Great Britain.* Paper for FAO/ECE/ILO Study Group on methods and organization of forest work, LOG/WP.1/38, Geneva, March 1969.

The paper discusses the requirement to establish standard times as the basis for piece-work payment. Re-assessment of such times forms a necessary part of the system. Difficulties associated with the transformation of standard times into money rates per unit of output are recognised.

GRAYSON, A. J., and ROUSE, G. D. (1968). *Adjustments of silvicultural and harvesting methods needed for profitable plantation management.* Paper for FAO/ECE/ILO Symposium on mechanization of harvesting of small-sized wood and logging residues, Warsaw, June 1968.

The principal shifts in forest management following the current concern with economics are towards deferring first thinning, cutting more heavily and introducing line thinning in the early thinnings. With wider spacings in new plantations, the higher average tree size at first thinning will make thinning operations more profitable. It is possible that in some situations wide spacing and "no thinning" will give the best economic return.

GREIG, B. J. W. (1969). On drought crack in Grand fir. *Suppl. Timb. Trades J.* March, pp. 26–27.

The incidence of drought crack in Grand fir (*Abies grandis*) stands in Great Britain is low, with major scars present on only about 8 per cent of standing trees. The extent of internal cracks is closely related to these major external scars. Conversion studies have shown that serious loss of produce only occurs from severely scarred trees. While in individual trees losses of 20 per cent or more of the value of the produce may occur, the total losses will be small. It is clear that both the incidence and the effect of drought crack have been over-emphasized in the past.

HERBERT, R. B. (1969). Glasshouse techniques in tree breeding research: A recent application. *Suppl. Timb. Trades J.* March, pp. 22–23, 25.

The paper describes progress to date in the development at Alice Holt of early-test procedures for progenies of Sitka spruce, using glasshouse techniques.

After one growing season, the principal characters of importance in tree breeding, namely, vigour, stem straightness and branching habit, can be measured, but further work is in progress to determine the value of extending the trials over two growing seasons.

It remains to be shown that data on growth characteristics, obtained from progeny trials under glass, can be correlated with those obtained from similar progenies grown in the field, in order that the validity of such trials can be proved. If this is achieved, the testing of the breeding population of Sitka spruce could be greatly accelerated.

HINSON, W. H. (1968). A visit to Finland to see forest drainage on peat. *Scott. For.* **22**(3), 221–227.

The Finnish forest trees are strikingly different in form from the same species in Britain, due apparently to lack of wind and the slow rate of growth. There are big responses to draining and fertilising peat soils, and the swamp types responsive are well recognised. Compared with ours, the peats have better load-bearing properties and greater water conductivity, probably because of the alternate freezing and thawing, and the slow rate of decomposition; this makes it easier to use machines. Caution should be exercised in taking conclusions reached under Finnish conditions and applying them to British peats.

(EDWARDS, R. S., and) HOLMES, G. D. (1968). Studies of airborne salt deposition in some North Wales forests. *Forestry* **41**(2), 155–174.

This investigation used special collectors to measure the deposition of marine salt within the damaged zone of Newborough Forest on the south-west coast of Anglesey. The quantity of salt deposited decreases rapidly with distance from the sea and increases with height above the ground, both these trends being exaggerated by increases in wind speed and much influenced by local shelter, e.g. adjacent sand-dunes or trees. Salt deposition on trees at three sites in North Wales was measured for comparison with salt levels found on the same sites using the special collectors. Correlations between these data were established on two sites and there were considerable differences in salt deposition between sites. It is concluded that a causal relationship probably exists between salt deposition and tree damage at Newborough Forest, and that the levels of salt found in forests more remote from the sea were so much lower that winds of quite exceptional violence would be needed to raise salt there to damaging levels.

HUMMEL, F. C. and GRAYSON, A. J. (1969). The future of wood supplies in Great Britain. In *Pulpwood Supply and the Paper Industry*. Forest Rec., Lond. **68** (H.M.S.O. 5s.)

IVISON, G. H. (1968). *Notes on a work study visit to Hedenlunda, Sweden.* Res. Dev. Pap. For. Commn, Lond. **74**.

A diary of a visit to Hedenlunda, a large country estate in Sweden used as a training establishment by A.N.A. Sweden, a commercial tractor firm forming part of the S.A.A.B. complex. The estate is used for the benefit of representatives, salesmen, owners and drivers of equipment purchased, and for the testing of new machines and equipment.

Much of the machinery used in Swedish forests is based upon farm tractors, but manufacturers are now also producing pure extraction machines. Notes are given on various machines seen in operation, and also on the S.L.A. (Federation for Swedish Forest and Agricultural Employers), which hopes to help increase the country's overall forestry efficiency.

(DARRAH, G. V., DODDS, J. W.,) JOBLING, J., and PENISTAN, M. J. (1968). Woodland elms in Wessex. *Forestry* **41**(2), 131–151.

A study undertaken by the Wessex Silvicultural Group on the growth of elm in woodland disclosed the occurrence of potentially valuable elm stands in many parts of south-west England. The paper discusses some aspects of cultivating elm in woodland, and provisional estimates of volume production are made Much of the information relates to English elm (*Ulmus procera* Salisbury), but other species and hybrids are briefly reviewed. Comments on some current elm problems are included.

LINES, R. (1968). The silviculture of Lodgepole pine. *Scott. For.* **22**(2), 91–108.

The growth of Lodgepole pine (*Pinus contorta*) in relation to seed origin, nutrition and productivity, in comparison with other species and in mixtures is discussed in a framework of visits to a range of experiments and other sites by the Silvicultural Group of the Royal Scottish Forestry Society. The paper also summarises lectures by J. R. Aldhous on the species in North America, on nutrition by J. Atterson and on the mensurational aspects of its production by R. T. Bradley.

Note is made of the use of Lodgepole pine as a "nurse", and also of its defects in this role if the wrong provenance is chosen. It can stand considerable exposure, and comparison of its growth with that of other species shows that on the poorest sites it has few equals. A list of selected papers on Lodgepole pine silviculture in the British Isles is appended.

LOW, A. J. (1968). Tubed seedlings – The trees of tomorrow. *Suppl. Timb. Trades J.* October, pp. 29–30.

Trials of tubed seedlings have begun recently in Britain because of potential advantages such as rapid planting and extension of the planting season. Methods used for raising and planting seedlings are briefly described. On present evidence the technique is most promising for peatland planting.

MITCHELL, A. F. (1968). Trees of the Caucasus.

1. *Gdnrs' Chron.* **163**(25), 12–13.
2. *Gdnrs' Chron.* **163**(26), 16–17.

A very small area of the world has provided us with a disproportionate number of our best trees. Most Caucasian trees are remarkable for their large, shiny and healthy foliage and vigorous growth. Caucasian representatives even of huge, widespread genera like *Quercus* and *Acer* are among the finest of all. There is, after 1760 when the first arrived, a peculiar lack of information on precise dates or people responsible for introduction, not found in plants from any other areas, and continuing until 1900.

MITCHELL, A. F. (1968). Some hybrid trees. *Gdnrs' Chron.* **164**(10), 11–15.

Once nurseries had trees from different continents growing together, intercontinental hybrids began to appear. The main period for the start of this was from 1880. Some are described, like *Catalpa hybrida*. Hybrid vigour is shown in Leyland cypress and Rehder's Wing-nut. Earlier intracontinental hybrids like the Lucombe and Turner's oak are described with their histories.

MITCHELL, A. F. (1968). The larches. *Gdnrs' Chron.* **164**(22), 18–20.

The advantages of larches for gardens are numerous. Vigorous rapid growth, early flowers, bright colour in spring and autumn, attraction to many pretty and useful birds, and suitability for underplanting bulbs are mentioned. Stress is laid on the necessity for the use of small but vigorous plants, two years old at most, for shapely and rapid growth.

MITCHELL, A. F. (1968). Some trees in Hyde Park and Kensington Gardens measured in 1967. *Jl R. hort. Soc.* **93**(5), 214–218.

Some indication of the wealth of good specimens and rare trees is given, followed by a list of dimensions of about one hundred of the best.

MITCHELL, A. F. (1968). The dawn Redwood in Britain. *Suppl. Timb. Trades J.* October, pp. 24–25.

Several specimens are now near or above 50 feet tall. All the tallest and largest known are listed, together with a brief history and observations on conditions for best growth. Of these, soil moisture and some shelter are the most important.

MITCHELL, A. F. (1968). *Westonbirt in colour.*

A new Forestry Commission Guide, with colour photographs, to Westonbirt Arboretum, Gloucestershire. (H.M.S.O. 2s.)

NEUSTEIN, S. A. (1968). *Restocking of windthrown forest.* Res. Dev. Pap. For. Commn, Lond. **75**.

Many woodland managers in Scotland are faced with the problem of replanting following clearance of the timber thrown in the disastrous gale of January 1968.

This paper summarizes the main criteria in selecting the appropriate methods of restocking following an initial diagnosis of the site-based causes of damage. Among the topics dealt with are the size and shape of clearings; the amount of slash clearance required relative to the subsequent drainage and cultivation required by various soil types; the time and method of replanting and the choice of species.

Advice is also given on the protection of replanted stock against insect attack and small mammals.

NEUSTEIN, S. A., and ROWAN, A. A. (1968). *A review of site preparation and planting techniques on peat in the Forestry Commission.* Paper for the Natural Environment Research Council Symposium on Peatland Forestry, Edinburgh, Sept. 1968.

The historical development of turf planting with special reference to ploughing patterns, turf thickness and tree growth is described. The provisional results of recent Work Study comparisons of four planting methods on five types of ploughing are given, their object being to determine whether there were any particular disadvantages in the faster planting methods. It was concluded that the greatest gain in planting rates was achieved with the semi-circular spade on the thick turfs produced by single mouldboard plough, particularly on non-fibrous peat. (Outputs up to 4,000 plants per 8-hour day were reached in comparison with the general level of 2,500–3,000.) Using a filming micro-motion procedure an optimum method was evolved which combines the best features of several individual methods.

Advice is given on the organisation of the work and the factors which influence productivity.

Likely future developments in peatland and afforestation methods are briefly described, e.g. development of a deep double mouldboard plough; "riggs and furrs"; broadcast manure spreaders; powered plough carriages; reversible draining ploughs; and the use of tubed planting stock.

PHILLIPS, I. D. J. (1968). Nitrogen, phosphorus and potassium distribution in relation to apical dominance in dwarf bean (*Phaseolus vulgaris*, c.v. Canadian Wonder). *J. exp. Bot.* **19** (60), 617–627.

The levels and distributions of nitrogen, phosphorus, and potassium were followed in the axillary buds and internodes of dwarf bean plants, subsequent to decapitation and application

of either lanolin or lanolin IAA to the cut surface of the stem. Nitrogen continued to accumulate in decapitated internodes supplied with IAA for at least 15 days, whereas decapitated internodes not treated with auxin showed only a slight accumulation of nitrogen. The lanolin IAA preparation also maintained correlative inhibition of the axillary buds for at least 15 days. However, enhanced accumulation of N, P and K in an IAA-treated internode did not appear to be sufficient to deprive the axillary buds of an adequate supply of these nutrients, for approximate balance sheets showed that more total NPK was accumulated in the internode and axillary buds, taken together, in plants treated with plain lanolin than in those treated with IAA. Furthermore, the total N, P and K content per unit dry weight of the apical 5 mm of axillary buds was higher in the inhibited buds of IAA-treated plants than in the elongating buds of lanolin-treated plants. Nevertheless, in dwarf bean it was found that an adequate nitrogen supply to the roots favoured lateral bud growth. From these results it would appear that this effect of nitrogen is an indirect one, perhaps influencing the production of substances, such as cytokinins, stimulatory to lateral bud growth.

PHILLIPS, I. D. J. (1969). The growth regulators – Part 1. Chemical messengers in plants. *Grower* **71**(6), 311–312.

An introduction to the subject of plant growth hormones, and to a series of articles concerning the use of plant growth regulators in agriculture and horticulture.

RAWLINSON, A. S. (1968). *Log storage and prevention of degrade during storage.* Res. Dev. Pap. For. Commn, Lond. **70.**

Of the various methods of preventing degrade of timber, the simplest, cheapest and most effective, while the tree is fresh and green, is to leave the timber portion of the tree attached to its rootstock.

It is generally agreed in the literature reviewed, that once the timber portion of the tree is severed from its rootstock, water storage is most effective in the prevention of degrade in logs. The logs can be stored either in water, or stacked under water sprinklers.

Other methods of treatment are spraying stacks of logs with insecticides or fungicides, or combinations of the two sprayed simultaneously.

The use of end-sealing compounds is a useful method of reducing end checks and splits.

Costs will vary depending on circumstances and method or treatment used. Following windblow in Denmark in 1967, it was estimated that the probable cost of two years' water storage will be in the region of 9d per hoppus foot and sprinkler systems at 8d and 5d for two years. In Great Britain estimated all-in costs for chemical spraying log stacks against insect attack, principally *Trypodendron lineatum*, will amount to something in the region of 1·0d.–1·5d.

The cost of the methods used to prevent degrade must be considered in relation to probable value of losses from degrade.

ROBINSON, T. C. (1968). *Butterflies in woodlands.* Forest Rec., Lond. **65.** (H.M.S.O. 3s.)

An illustrated description of the haunts, habits, distribution and varieties of the British woodland butterflies, with some thoughts on their future in the changing forests.

STOAKLEY, J. T. (1968). Control of the Pine weevil, *Hylobius abietis* L., and of *Hylastes* species. *Forestry* **41**(2), 182–188.

Dipping the tops of plants, prior to planting, in a 5 per cent oil-based emulsion formulation of DDT has given good control of *Hylobius* but does not control *Hylastes*, and may involve damage due to phytotoxicity in some circumstances. Experimentation with newly introduced water-based formulations of DDT and BHC confirmed earlier findings that there are few significant differences between possible materials. The need to dip whole plants in order to control *Hylastes*, with minimum risk of phytotoxicity, has led to the use of 1·6 per cent water-based BHC on a field trial scale with promising results.

STOAKLEY, J. T., and STICKLAND, R. E. (1968). *Applying sprays to tall trees by ground-operated methods.* Res. Dev. Pap. For. Commn, Lond. **73.**

Ground-operated methods developed and tested to spray insecticides on to crowns of trees 12–30 m (40–100 ft) high are described.

A knapsack mistblower used from a Simon Hydraulic Platform treated rideside trees effectively. In good conditions, trees 24–27 m (80–90 ft) high could be sprayed using a mistblower with a 73 cc motor.

A tractor-mounted mistblower with a special "Coconut" outlet sprayed trees up to 21 m (70 ft) high in light airs only.

A modification of a method described by Grigsby, using a rotating garden sprinkler, gave good results under still conditions. The sprinkler, supported by 6 m (20 ft) of alloy tubing and positioned to spray downwards, was fixed to a tree with the sprinkler 0·6 m (2 ft) above the tip. Insecticide was supplied through a 1·27 cm (½ in.) diameter polythene tube from a trailer-mounted pump. Trees 45 m (50 yd) from the pump were treated satisfactorily. For repeated sprayings, the equipment was left in position and disconnected from the pump.

A trailer-mounted, pneumatically operated, telescopic mast tested as an independent support for the sprinkler unit, was found to be successful for spraying rideside trees.

The merits of the different methods are discussed. The choice depends on the practical considerations and experimental requirements. Tree-supported sprinkler units were found to be the most suitable under the conditions of these tests.

TAYLOR, G. G. M. (1968). Ploughing and planting. *Suppl. Timb. Trades J.* October, pp. 20–21.

The importance of ploughing in British forestry is discussed, with a brief outline of development of the technique. The need to employ the correct technique for particular soil conditions is emphasized and a sub-division of forest ploughs by functional category is suggested.

Some aspects of current research and development are briefly mentioned.

WARDLE, P. A. (1968). *Economic aspects of tree planting on peat.* Paper for the Natural Environment Research Council Symposium on Peatland Forestry, Edinburgh, Sept. 1968.

Exploitation of peatland may only be feasible by practising forestry, but because forestry can be practised, this does not mean that it must be. It is clearly desirable, once the decision to undertake forestry is made, to decide the most profitable intensity at which investment should be carried out. Managers are hampered in this search for the most appropriate intensity by their lack of knowledge of the outcomes of particular treatments. The researcher should overcome his diffidence and indicate his view of the likely results of treatments intermediate between, and also beyond, the range within which he has actually experimented. He should state the range within which the result of a given treatment is expected to lie and indicate the likelihood of outcomes in various positions over the range, as well as the outcome which is regarded as most likely.

In considering the choice of investments in research the following questions should be answered:

(i) Is the subject major, in the sense of affecting activity on a large scale?
(ii) Are large changes expected to result as a consequence of research?
(iii) Is there a reasonable expectation of obtaining a result?
(iv) Will results appear shortly or only after a long time?

WOOD, R. F., and ANDERSON, I. A. (1968). *Forestry in the British scene.* Bookl. For. Commn **24**. (H.M.S.O. 10s.)

A pictorial publication with the minimum of text, illustrating the scale and diversity of forestry in Britain. It aims at encouraging the public and the schools to visit and enjoy the forests.

APPENDIX III

Staff Engaged in Research and Development

As at 31st March, 1969

The main centres for research and development are:

FORESTRY COMMISSION RESEARCH STATION
Alice Holt Lodge,
Wrecclesham,
Farnham, Surrey. Tel. Bentley (Hants) 2255

FORESTRY COMMISSION
Government Buildings,
Bankhead Avenue,
Sighthill,
Edinburgh EH11 4AF. Tel. Craiglockhart 4010.

Some staff engaged in research and development (or controlled by Director Research) are also stationed at:

FORESTRY COMMISSION
25 Savile Row,
London W1X 2AY. Tel. 01 734 0221.

Research on timber and other forest products is not carried out by the Forestry Commission but by the Ministry of Technology's Forest Products Research Laboratory, Princes Risborough (Phone 3101), Aylesbury, Buckinghamshire. The Forestry Commission keeps in close touch with this work, some of which is done jointly by the two organisations.

RESEARCH DIVISION

Director	G. D. Holmes, B.Sc. (*Alice Holt*)
Administration and Finance Officer .	G. H. Bowers (*Alice Holt*)
Director's Secretary. .	Miss O. A. Harman (*Alice Holt*)

Chief Research Officer (South) .	D. H. Phillips, M.Sc., Ph.D., M.I.Biol. (*Alice Holt*)

(With general responsibilities for research in the Southern areas, and with special responsibilities for research in seed, ecology, pathology and entomology, and for seed supply, publications and photographic services.)

SEED (*Alice Holt*)

G. M. Buszewicz, Mgr. Eng., Head of Section
Laboratory: D. C. Wakeman: Mrs. L. S. Elgy, Miss R. E. Crumplin
Seed Store: M. D. Witts (Research Forester): J. C. Ray, T. A. Waddell
Office: Mrs. B. P. Hartley, B.A.: E. R. Parratt

ECOLOGY (*Alice Holt*)

J. M. B. Brown, B.Sc., Dip.For., Head of Section
Research Foresters: B. G. Howland: P. Marsh

PATHOLOGY

Alice Holt

D. A. Burdekin, B.A., Dip.Ag.Sci.,M.I.Biol., Head of Section
D. B. Redfern, B.Sc., Ph.D.
S. A. Batko, For. Eng., D. Eng.
Research Foresters: C. W. T. Young: B. W. J. Greig, J. E. Pratt, R. G. Strouts, P. J. Webb
Laboratory: Mrs. J. M. Lord: Miss S. M. Harvey: Miss A. Trusler
Office: J. G. Jackman: Mrs. B. A. Reynolds (Typist)

Edinburgh

Research Foresters: J. D. Low: M. Cruickshanks

ENTOMOLOGY

Alice Holt

D. Bevan, B.Sc., Head of Section
Miss J. M. Davies, B.Sc.
Miss J. J. Rowe, B.Sc. (Mammals and Birds)
T. M. Scott, B.Sc.
Research Foresters: R. M. Brown, L.I. Biol., L. A. Tee (Mammals): A. R. Barlow,* I. G. Carolan (Mammals, Dundeugh), D. Elgy (Mammals), C. H. Hudson, C. J. King, H. M. Pepper (Mammals), C. Walker

*On unpaid leave at Aberdeen University.

Laboratory: C. I. Carter, M.Sc., M.I.Biol.: N. R. Maslen, T. G. Winter
Office: J. Ellison

Edinburgh
Research Forester: R. C. Kirkland

PHOTOGRAPHY (*Alice Holt*)

I. A. Anderson, F.I.I.P., Head of Section
Mrs. T. K. Evans, F.R.P.S.
Miss H. J. Turner
R. W. Genever
A. W. Coram (Illustrator)
Miss M. Trusler
Office: Mrs. S. C. Cockrem

RESEARCH WORKSHOP (*Alice Holt*)

R. E. Stickland
H. G. W. Bodkin, M. F. Johnston, C. H. Bodkin

PUBLICATIONS (*London*)

H. L. Edlin, B.Sc., Dip.For., Head of Section
P. A. Mayne
Mrs. E. H. Nolan

Chief Research Officer (North) . . . . . B. W. Holtam, B.Sc. (*Edinburgh*)

(With general responsibilities for research in the Northern areas, and with special responsibilities for research in silviculture, soils, genetics and physiology.)

SILVICULTURE (NORTH) (*Edinburgh*)

D. T. Seal, B.Sc., Head of Section
R. Lines, B.Sc.
A. J. Low, B.Sc., Ph.D.
J. M. Mackenzie, B.Sc.
S. A. Neustein, B.Sc.
G. G. M. Taylor, B.Sc.

		Centre
Research Foresters	G. R. Dunbar, J. Howarth, R. D. Wishart	Edinburgh
North Scotland Region	A. Macdonald	Fort Augustus
North Scotland Area	J. B. McNeill, D. C. Coutts, A. A. Green	Fort Augustus
North East Scotland Area	G. Bartlett N. P. Danby, A. McInnes	Mid-Ardross, Ross and Cromarty
Central Scotland Region	J. Farquhar, M.B.E.	Kincardine-on-Forth
Central Scotland Area	E. R. Robson W. G. Paterson, M. Rodgers	Kincardine-on-Forth
East Scotland Area	J. H. Thomson A. L. Sharpe, A. W. F. Watson	Newton, Elgin
South East Scotland Area	D. K. Fraser N. Mackell	Bush Nursery, Roslin, Midlothian
Mearns Area	J. C. Keenleyside J. E. J. White	Drumtochty, Laurencekirk, Kincardine
West Scotland Area	A. R. Mair J. E. Kirby, A. B. Lewis	Kilmun, by Dunoon, Argyll

Research Foresters		*Centre*
South West Scotland Area	E. Baldwin W. Brown, J. D. McNeill	Mabie, Dumfriesshire
North England Region	J. Weatherell	Wykeham, Scarborough
North East England Area	T. C. Booth* K. A. S. Gabriel M. K. Hollingsworth P. Priestley	Wykeham, Scarborough
Borders Area	G. S. Forbes J. D. Lindsay, A. H. Reid, D. L. Willmott	Kielder by Hexham, Northumberland
North West England Area	D. S. Coutts	Grizedale, nr. Hawkshead, Westmorland

SILVICULTURE (SOUTH) (*Alice Holt*)

R. M. G. Semple, B.Sc., Head of Section
J. R. Aldhous, B.A.
R. M. Brown, B.Sc.
J. E. Everard, B.Sc.
A. I. Fraser, B.Sc.**
J. Jobling, B.Sc.
A. F. Mitchell, B.A., B.Agric.(For.)

Office: L. W. Thomas: Miss A. Davidge: Miss E. Burnaby, Miss R. M. Matthews

Research Foresters		*Centre*
South East England Region	R. Hendrie	Alice Holt
South East England Area	G. F. Farrimond I. H. Blackmore, J. B. H. Gardiner, D. W. H. Durrant, P. D. Howard	Alice Holt
Wareham Area	L. A. Howe A. C. Hansford, A. M. Jenkin	Sugar Hill Nursery, Wareham Forest
Bedgebury Area	A. W. Westall A. C. Swinburn	Bedgebury Pinetum
South West England Region	D. A. Cousins	Bristol
South West England Area	K. F. Baker	Exeter
Dean and South Wales Area	F. Thompson A. J. A. Graver, R. M. Keir, M. L. Pearce, F. R. W. Stevens	Dean
Westonbirt Area	E. Leyshon D. J. Rice	Westonbirt Arboretum
North Wales Region	G. Pringle	Betws y Coed
North Wales Area	G. A. Bacon D. Downs, C. W. Webber	Betws y Coed
Mid-Wales Area	D. G. Tugwell P. A. Gregory, C. J. Large	Knighton, Radnor
East England Region	P. W. W. Daborn	Kennington, Nr. Oxford
Kennington Area	F. S. Smith, H. C. Caistor	Kennington, Nr. Oxford

*On unpaid leave at Aberdeen University.

**On Sabbatical leave at Edinburgh University.

Research Foresters		*Centre*
East England Area	R. M. Ure R. E. A. Lewis, K. Mills, D. J. Williams	Santon Downham, Nr. Thetford

SOILS

Alice Holt

W. O. Binns, M.A., B.Sc., Ph.D., Head of Section
W. H. Hinson, B.Sc., Ph.D.
G. P. Moffatt, M.Sc.

Research Foresters: A. E. Coates, D. F. Fourt (L.I.Biol.): T. E. Radford

Laboratory: R. Carnell: Mrs. M. J. Cardrick: Miss S. A. Dabek, E. Darlington Mrs. C. Y. Haggett

Edinburgh

D. G. Pyatt, B.Sc.*

GENETICS

Edinburgh

R. Faulkner, B.Sc., Head of Section
A. M. Fletcher, B.Sc., Ph.D., A.I.W.Sc.
K. A. Longman, B.Sc., Ph.D.

Research Foresters: C. McLean (Bush Nursery, Roslin, Midlothian), M. T. T. Phillips (Newton, Elgin): D. S. Coutts (Grizedale, Lancs.), J. Howarth

Alice Holt

R. B. Herbert, B.Sc., A.I.W.Sc.

Research Foresters: I. J. M. Dawson: R. B. Collins, G. Simkins, G. C. Webb (Westonbirt, Glos.)

Laboratory: Miss L. S. Devereux

Office: F. H. Khawaja

PHYSIOLOGY (*Edinburgh*)

I. D. J. Phillips, B.Sc., Ph.D., Head of Section

STATISTICS

Alice Holt

R. S. Howell, Head of Section
D. H. Stewart, B.Sc., M.I.Biol.
D. K. Lindley, B.Sc., M.F.
J. F. Varley

Assistants: C. A. Thorne: I. D. Mobbs, I. Pollock, M. H. M. Webb (Research Foresters): Mrs. R. J. F. Glynn, Miss E. C. Bridger, Mrs. E. Butler, Miss J. E. Hudson, Mrs. S. D. James (Machine Operators)

Office: Miss A. M. Welch: Mrs. U. Schofield (Typist)

Edinburgh

J. Baird (Research Forester): Miss F. M. K. Farquharson (Machine Operator)

RESEARCH INFORMATION SECTION (*Alice Holt*)

O. N. Blatchford, B.Sc., A.I.Inf.Sc., Head of Section
S. H. Sharpley
F. C. Fraass
Miss L. D. Watson
Mrs. L. D. Birchall (Typist)

---

*On paid leave at Aberdeen University.

ADMINISTRATIVE STAFF

Alice Holt

Deputy Administration and Finance Officer:	W. D. Wardrop
Establishment:	P. H. Hamilton: Mrs. C. Gore, Mrs. D. M. Pearson
Finance:	J. J. Richardson: J. Empson, Miss. G. B. Hayden, A. R. Taggart
General Services:	Miss S. B. Page: B. D. Higgins
Typists:	Miss M. Hopkin: Mrs. J. G. Anderson, Mrs. E. L. Allen, Mrs. B. E. Dickinson, Mrs. V. O. C. Lampard, Mrs. J. Richardson, Mrs. E. A. Walters.
Telephone Operator:	Mrs. E. A. R. Empson
Messengers:	Mrs. M. Butt, Mrs. N. E. C. Anthony
Gardens:	H. Farr
Workshop:	R. H. Butt, R. D. Butt: T. G. Watts

Edinburgh

Office:	P. Hunter: Miss M. E. Grant, T. T. Johnston: G. F. Campbell, Miss J. M. Gray: Mrs. O. E. Jenner, Mrs. B. J. Lyons, Mrs. M. J. Pedder, Mrs. R. J. K. Webber (Typists).

MANAGEMENT SERVICES DIVISION

Director of Management Services . . . J. Q. Williamson, B.Sc. (*London*)

Deputy Director of Management Services . . . . D. R. Johnston, M.A. (*Alice Holt*)

(With special responsibilities for Planning and Economics.)

PLANNING AND ECONOMICS (*Alice Holt*)

D. R. Johnston, M.A., Head of Branch
R. T. Bradley, M.A.
A. J. Grayson, M.A., B.Litt.
G. J. Hamilton, B.Sc.
G. M. L. Locke, B.Sc.
A. M. Mackenzie (*Edinburgh*)
J. F. Morgan, B.Sc.
D. B. Paterson, B.Sc. (*Edinburgh*)
L. M. Simpson, B.Sc.
P. A. Wardle, B.Sc.
E. R. Adams

Foresters: Based on Alice Holt: J. McN. Christie, G. M. Haggett, G. D. Spiller: P. Bond, J. Dickinson, I. C. Embry, E. J. Fletcher, G. G. Green, M. A. Mitchell, R. Q. Oakes, M. D. Whitlock.

Based on Edinburgh: J. Armstrong: A. F. Brown.

Working Plans and Mensuration:

Field Staff (Foresters)—England and Wales

R. F. E. Bartlett, D. D. G. Davies, A. C. Dover: C. R. Alpe, A. Beardsley, D. A. Bell, P. E. Cliffe, M. A. Colley, J. S. Conduit, S. Cooper, M. W. Davies, D. M. Dymond, D. Ellis, P. Green, E. R. Hall, G. E. Harrison, D. R. Hornby, P. Hutchinson, G. J. Jones, E. B. Jury, J. B. Kingsmill, C. E. G. Lawes, G. H. MacGowan, A. C. Miller, D. W. Price, J. J. Pruden, J. L. Read, J. B. Richards, R. J. Rogers, M. B. Scutt, K. G. Shuker, R. N. Smith, W. B. Sturges, F. G. Thurlow, R. C. B. Vines, P. C. Westley, M. R. Wigzell, J. L. Williams.

Field Staff (Foresters)—Scotland

J. Straiton: J. C. Anderson, J. R. Boyd, A. R. Brown, N. C. Bunyan, W. Elger, K. Fryer, A. N. Gordon, P. J. Humphries, C. R. Liversidge, J. Livingstone, P. J. Lodge, L. C. MacCallum, I. D. MacDonald, R. J. A. MacDuff, L. D. Macrae, D. Main, I. M Parrott, J. C. Phillipson, A. A. J. Rees, P. G. Risby, P. L. W. Simon, A. E. Surman, F. G. O. Thom, B. Thompson, J. J. Waddell, G. A. Watson, P. J. Williams.

Soil Survey (Foresters)

J. Davidson, D. A. T. Douglas, A. S. Ford, D. Harrison, J. S. Innes, G. N. Kearns, W. Thomson, F. Webster.

Office:

Mrs. E. Simpson, Miss B. Parfitt: Miss P. A. M. McCunnin.

WORK STUDY (*Alice Holt*)

L. C. Troup, B.Sc., Head of Branch
J. V. St. L. Crosland, B.Sc.
T. W. G. Coulson, B.Sc. (*Langholm*)
A. A. Cuthbert, B.Sc. (*Annan*)
J. A. Drummond, B.Sc. (*Kilmun, Argyll*)
D. M. Hughes, B.Sc. (*Dolgellau*)
J. S. Oakley, B.Sc. (*Inverness*)
A. H. A. Scott, B.Sc. (*Lyndhurst*)
A. R. Sutton, B.Sc. (*Brecon*)
D. H. Wallace, B.Sc. (*Inverness*)
A. Whayman (*Hawick*)
W. O. Wittering

Machinery Research and Development:

R. B. Ross, A.M.I.Mech.E.
K. A. Kernahan
W. S. Mackenzie (*Kielder*)

Roads Research and Development:

K. T. Davidson, B.Sc., A.M.I.H.E. (*Inverness*)

Communications:

D. E. W. Blandford (*Bristol*)

Foresters:

D. J. Morris (*Brecon*), D. M. Percy (*Lyndhurst*), F. B. W. Platt (*Mildenhall, Suffolk*), E. V. Rogers (*Olney, Beds.*): C. E. Allison (*New Forest*)*, St. J. G. D. Bland-Flagg (*Yardley*), R. H. Brown (*Byrness, Northumberland*), J. Campbell (*Fort Augustus*), C. F. Dampney (*Lyndhurst*), P. P. Davis (*Dolgellau*), M. J. Day (*Santon Downham, Suffolk*), P. Featherstone (*Olney, Beds.*), M. J. C. Graham (*Langholm*), J. Grieve (*Kilmun, Argyll*), M. J. R. Ingoldby (*Olney, Beds.*), G. H. Ivison (*Langholm*), P. W. Lansdown (*Lyndhurst*), R. S. MacInnes (*Ae*), T. G. Queen (*Fort Augustus*), A. S. Rawlinson (*Inverness*), R. J. Reid (*Brecon*), I. Richardson (*Dolgellau*), T. R. Sawyer (*Brecon*), G. O. Smith (*Kilmun, Argyll*), B. D. Symes (*Langholm*), W. Trotter (*Kilmun, Argyll*), K. E. Wallis (*Ae*), G. D. Watt (*Fort Augustus*), V. Williams (*Brecon*), P. Wood (*Santon Downham, Suffolk*).

Office: R. D. Duncan: J. M. Littler

HARVESTING AND MARKETING DIVISION

J. R. Aaron, M.A., M.Sc., A.I.W.Sc. (*London*)
J. Meechan (Forester) (*Alice Holt*)

*On secondment to F.A.O., Zambia.

APPENDIX IV

Metric Equivalents of Values used in this Report

The following conversion factors are taken from the basic units of the Système International (S.I.) (British Standard 350: Part 1: 1959). Exact factors are marked with an asterisk.

Length

1 inch (in) = 2·5400 centimetres (cm)*
1 foot (ft) = 0·3048 metres (m)*
1 yard (yd) = 0·9144 metres (m)*
1 chain = 20·1168 metres (m)*
1 mile = 1·609344 kilometres (km)*

Area

1 square inch (in^2) = 6·4516 square centimetres (cm^2)*
1 square foot (ft^2) = 0·09290 square metres (m^2)
1 square foot quarter girth (ft^2 qg) = 0·1183 square metres (m^2)
1 square yard (yd^2) = 0·8361 square metres (m^2)
1 acre = 0·4047 hectares (ha)
1 square mile = 258·9 hectares (ha)

Weight

1 ounce (oz) = 28·35 grammes (g)
1 pound (lb) = 0·45359237 kilogrammes (kg)*
1 hundredweight (cwt) = 0·05080 tonnes (1000 kg) (t)
1 (long) ton = 1·01605 tonnes

Volume

1 gallon (gal) = 4·546 litres (l)
1 bushel = 36·37 litres (l)

Timber Volume

1 hoppus foot (h. ft) (1·273 cubic feet) = 0·03605 cubic metres (m^3)
1 hoppus foot per acre (h. ft/acre) = 0·08905 cubic metres per hectare (m^3/ha

Weight per Unit Area

1 gramme per square yard (g/yd^2) = 11·96 kilogrammes per hectare (kg/ha)
1 pound per acre (lb/acre) = 1·121 kilogrammes per hectare (kg/ha)
1 hundredweight per acre (cwt/acre) = 125·5 kilogrammes per hectare (kg/ha)
1 ton per acre (tons/acre) = 2511 kilogrammes per hectare (kg/ha)

Volume per Unit Area

1 gallon per acre (gal/acre) = 11·23 litres per hectare (l/ha)

Weight/Volume

1 pound per gallon (lb/gal) = 0·09978 kilogrammes per litre (kg/l)
1 ounce per bushel (oz/bushel) = 0·7795 grammes per litre (g/l)

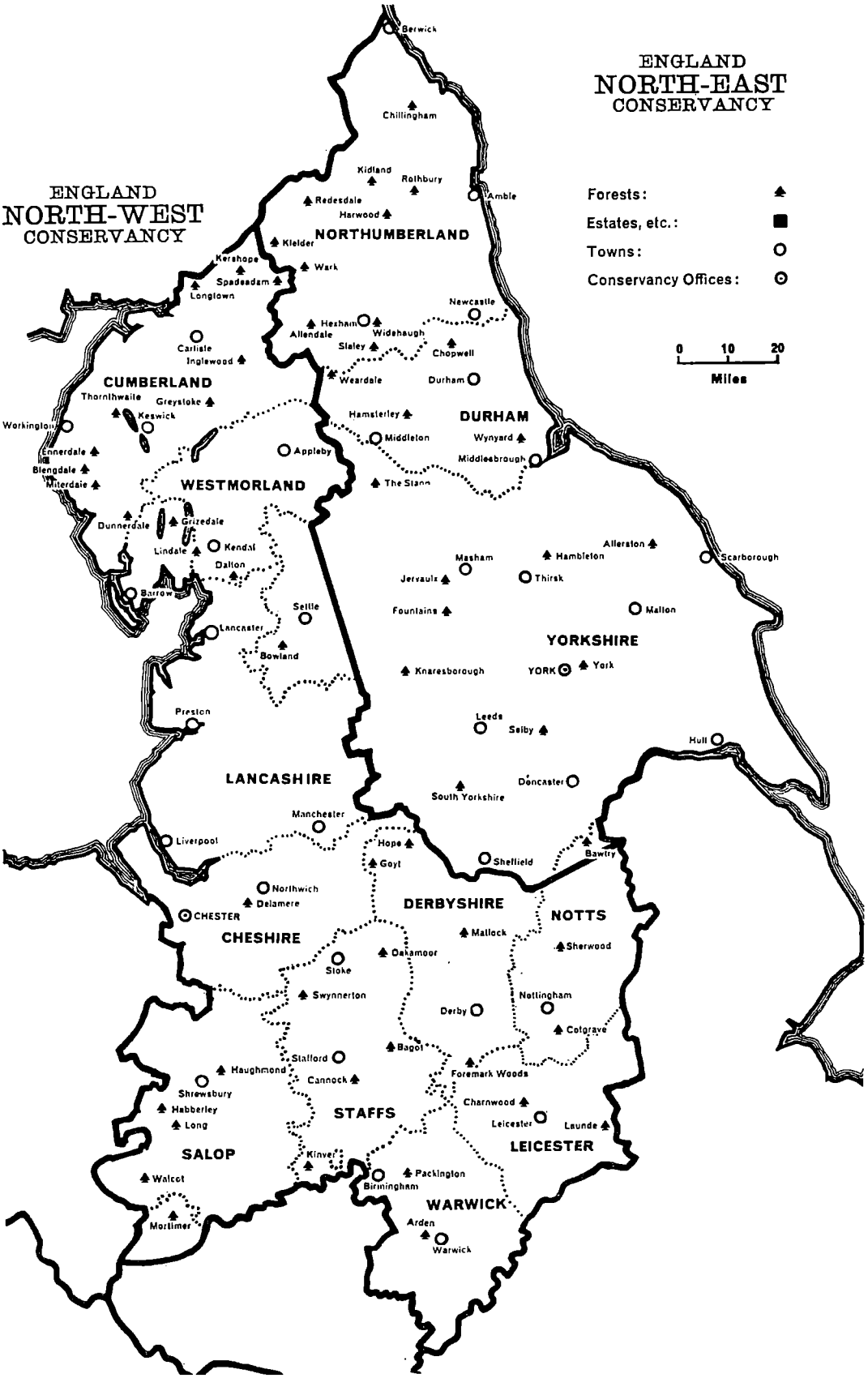
Linear Velocity

1 foot per minute (ft/min) = 0·00508 metres per second (m/sec)*

Note. Forestry Commission Booklet 5. *Conversion Tables for Research Workers in Forestry and Agriculture* (H.M.S.O. 1960, 6s. 6d.) gives a more comprehensive series of equivalents, with reciprocals.

MAPS

Showing situations of Commission Forests and Experimental Projects listed in Appendix I.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NORTH-WEST
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Estates, etc.:
Towns:
Conservancy Offices:
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Kidland
Rothbury
Redesdale
Harwood
Amble
Kielder
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Wark
Spadeadam
Longtown
Newcastle
Hexham
Allendale
Widehaugh
Slaley
Chopwell
Carlisle
Inglewood
Weardale
Durham
CUMBERLAND
Thornthwaite
Greystoke
Keswick
Workington
Hamsterley
DURHAM
Middleton
Wynyard
Middlesbrough
Appleby
Ennerdale
Blengdale
Miterdale
WESTMORLAND
The Stang
Dunnerdale
Grizedale
Lindale
Kendal
Dalton
Barrow
Allerston
Masham
Hambleton
Scarborough
Jervaulx
Thirsk
Fountains
Mallon
Settle
Lancaster
YORKSHIRE
Bowland
Knaresborough
YORK
York
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Northwich
Delamere
CHESTER
DERBYSHIRE
NOTTS
CHESHIRE
Mallock
Sherwood
Oakamoor
Stoke
Swynnerton
Nottingham
Derby
Colgrave
Bagot
Stafford
Haughmond
Cannock
Foremark Woods
Shrewsbury
Charnwood
Habberley
Long
STAFFS
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Launde
LEICESTER
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Packington
Walcot
Birmingham
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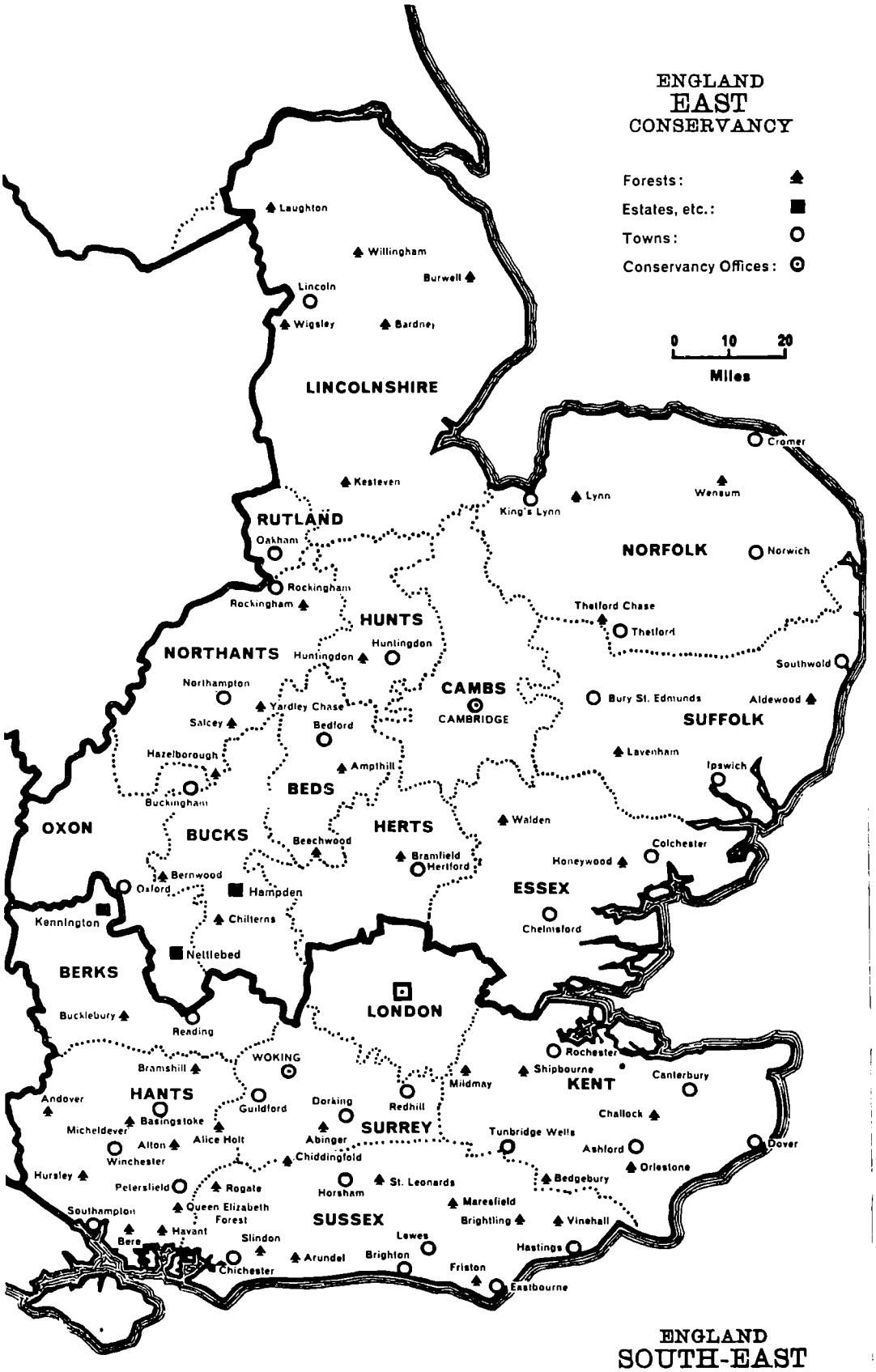
Mortimer
Arden
Warwick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Bardney
LINCOLNSHIRE
Cromer
Kesteven
Lynn
Wensum
King's Lynn
RUTLAND
Oakham
NORFOLK
Norwich
Rockingham
Rockingham
Thetford Chase
Thetford
HUNTS
Huntingdon
Huntingdon
NORTHANTS
Southwold
Northampton
CAMBS
CAMBRIDGE
Bury St. Edmunds
Aldewood
Yardley Chase
Salcey
Bedford
SUFFOLK
Hazelborough
Lavenham
Ampthill
Ipswich
Buckingham
BEDS
OXON
BUCKS
HERTS
Walden
Beechwood
Colchester
Bramfield
Hertford
Honeywood
Bernwood
Oxford
Hampden
ESSEX
Kennington
Chilterns
Chelmsford
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BERKS
LONDON
Buckleybury
Reading
Rochester
WOKING
Shipbourne
Canterbury
Bramshill
Mildmay
KENT
Andover
HANTS
Guildford
Dorking
Redhill
Challock
Basingstoke
Micheldever
SURREY
Tunbridge Wells
Alton
Alice Holt
Abinger
Ashford
Dover
Winchester
Chiddingfold
Hursley
Orlestone
Petersfield
Rogate
Horsham
St. Leonards
Bedgebury
Southampton
Queen Elizabeth
Forest
Maresfield
Brightling
Vinehall
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Brighton
Chichester
Friston
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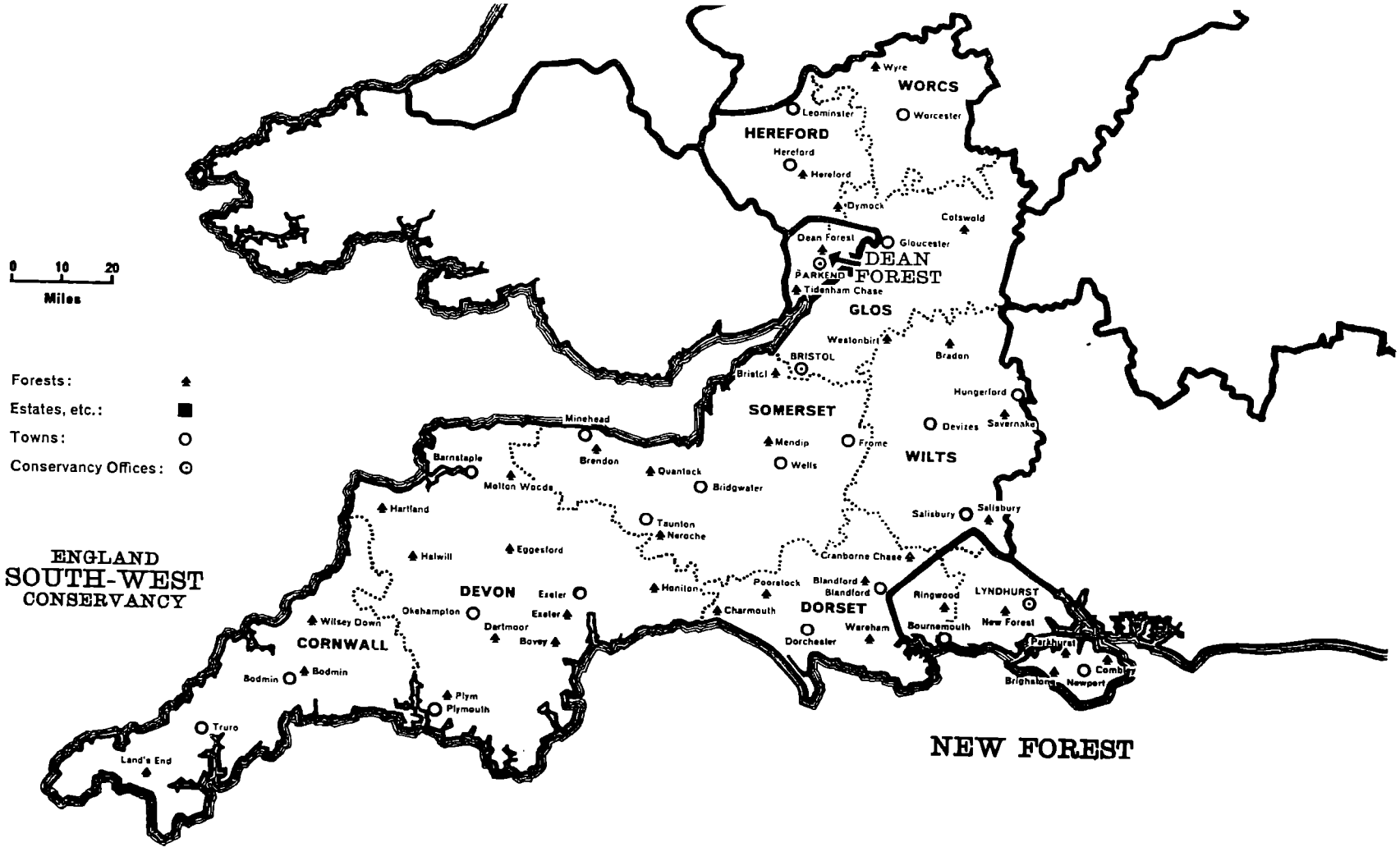
ENGLAND
SOUTH-EAST
CONSERVANCY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Dymock
Cotswold
Dean Forest
Gloucester
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FOREST
PARKEND
Tidenham Chase
GLOS
Westonbirt
Bradon
BRISTOL
Bristol
Hungerford
SOMERSET
Devizes
Savernake
Minehead
Mendip
Frome
WILTS
Barnstaple
Brendon
Quantock
Wells
Molton Woods
Bridgwater
Hartland
Salisbury
Salisbury
Taunton
Neroche
Halwill
Eggesford
Cranborne Chase
DEVON
Exeter
Honiton
Poorstock
Blandford
Blandford
Ringwood
LYNDHURST
Okehampton
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Charmouth
DORSET
Wilsey Down
Dartmoor
Bovey
Dorchester
Wareham
Bournemouth
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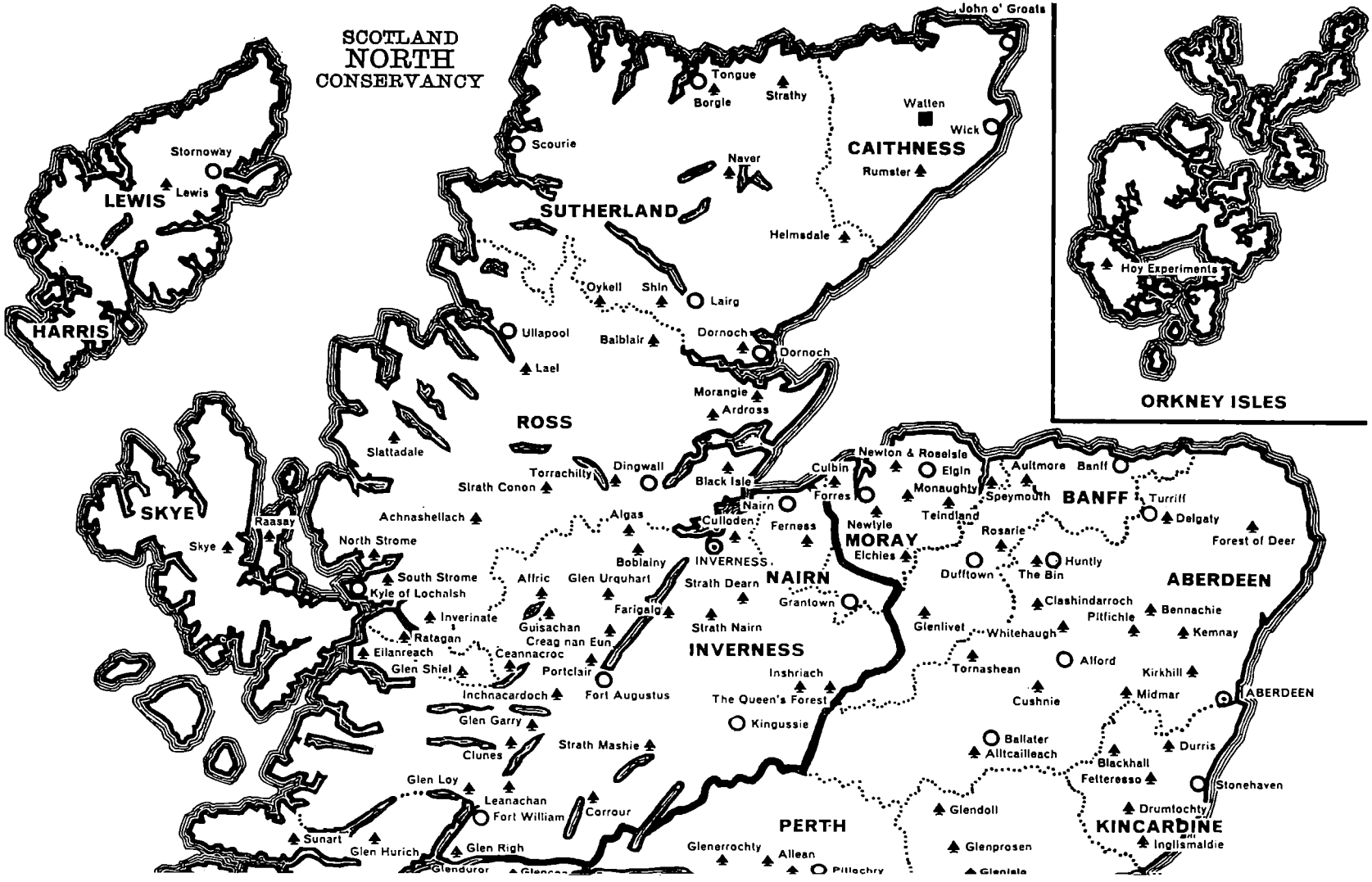
Newport
Truro
Land's End
NEW FOREST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Wick
CAITHNESS
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Helmsdale
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Shin
Lairg
Ullapool
Balblair
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Dornoch
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Morangie
Ardross
ROSS
Slattadale
Torrachilty
Dingwall
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Black Isle
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Lewis
LEWIS
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SKYE
Raasay
Skye
Achnashellach
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South Strome
Kyle of Lochalsh
Inverinate
Ratagan
Eilanreach
Glen Shiel
Inchnacardoch
Glen Garry
Clunes
Glen Loy
Leanachan
Fort William
Corrour
Sunart
Glen Hurich
Glen Righ
Glenduror
Algas
Culloden
Ferness
Nairn
Boblainy
INVERNESS
Affric
Glen Urquhart
Strath Dearn
NAIRN
Farigaig
Guisachan
Creag nan Eun
Ceannacroc
Portclair
Fort Augustus
Strath Nairn
INVERNESS
Inshriach
The Queen's Forest
Kingussie
Strath Mashie
PERTH
Glenerrochty
Allean
Pillochry
Glenprosen
Glenisla
Glendoll
Culbin
Forres
Newton & Roseisle
Elgin
Aultmore
Banff
Monaughty
Speymouth
BANFF
Turriff
Delgaty
Forest of Deer
Teindland
Newlyle
MORAY
Elchies
Rosarie
Dufftown
Huntly
The Bin
ABERDEEN
Grantown
Glenlivet
Clashindarroch
Bennachie
Pitfichie
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Kemnay
Tornashean
Alford
Kirkhill
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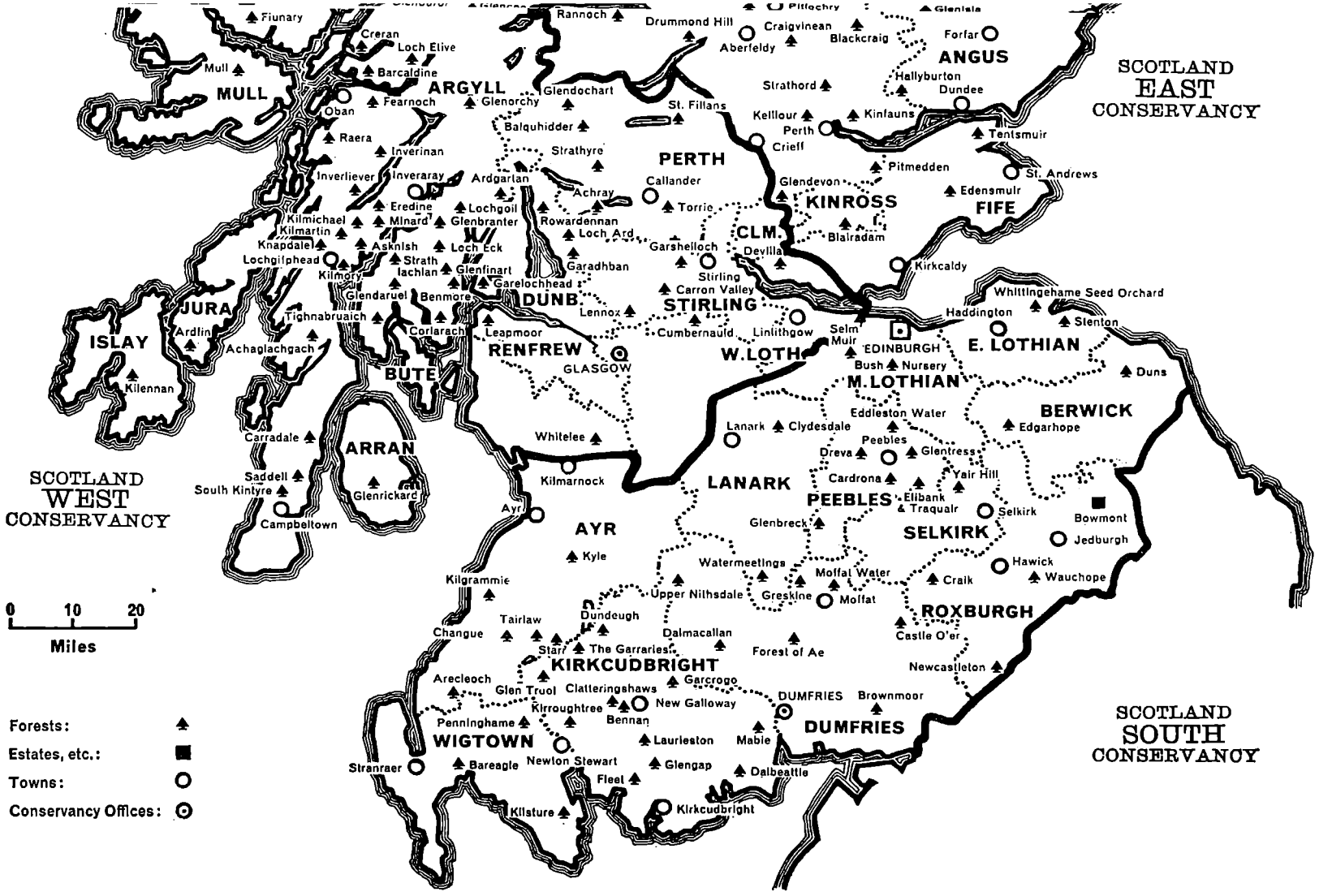
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KINROSS
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DUNB
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RENFREW
GLASGOW
W.LOTH
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M.LOTHIAN
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JURA
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Fionary
Creran
Loch Etive
Mull
Barcaldine
Oban
Fearnoch
Glenorchy
Glendochart
Rannoch
Drummond Hill
Aberfeldy
Craigvinean
Blackcraig
Forfar
Hallyburton
Dundee
Strathord
Kelllour
Kinlauns
Perth
Crieff
Tentsmuir
Pitmedden
St. Andrews
Edensmuir
Glendevon
Blairadam
Kirkcaldy
Raera
Inverinan
Balquhidder
St. Fillans
Strathyre
Inverliever
Inveraray
Ardgarlan
Achray
Callander
Torrie
Eredine
Lochgoil
Kilmichael
Minard
Glenbranter
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Rowardennan
Loch Ard
Garshelloch
Devilla
Knapdale
Asknish
Loch Eck
Lochgilphead
Kilmory
Strath
Iachlan
Glenfinart
Garadhban
Stirling
Carron Valley
Glendaruel
Benmore
Garelochhead
Lennox
Cumbernauld
Linlithgow
Selm
Muir
Haddington
Whittingehame Seed Orchard
Stenton
Tighnabruaich
Corlarach
Leapmoor
Ardlin
Achaglachgach
Bush Nursery
Duns
Kilennan
Eddleston Water
Carradale
Whitelee
Lanark
Clydesdale
Peebles
Edgarhope
Dreva
Glentress
Saddell
South Kintyre
Glenrickard
Kilmarnock
Cardrona
Yair Hill
Elibank
& Traquair
Selkirk
Bowmont
Campbeltown
Ayr
Glenbreck
Jedburgh
Kyle
Watermeetings
Hawick
Kilgrammie
Moffat Water
Craik
Wauchope
Upper Nithsdale
Greskine
Moffat
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Castle O'er
Starr
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Forest of Ae
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Clatteringshaws
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Bareagle
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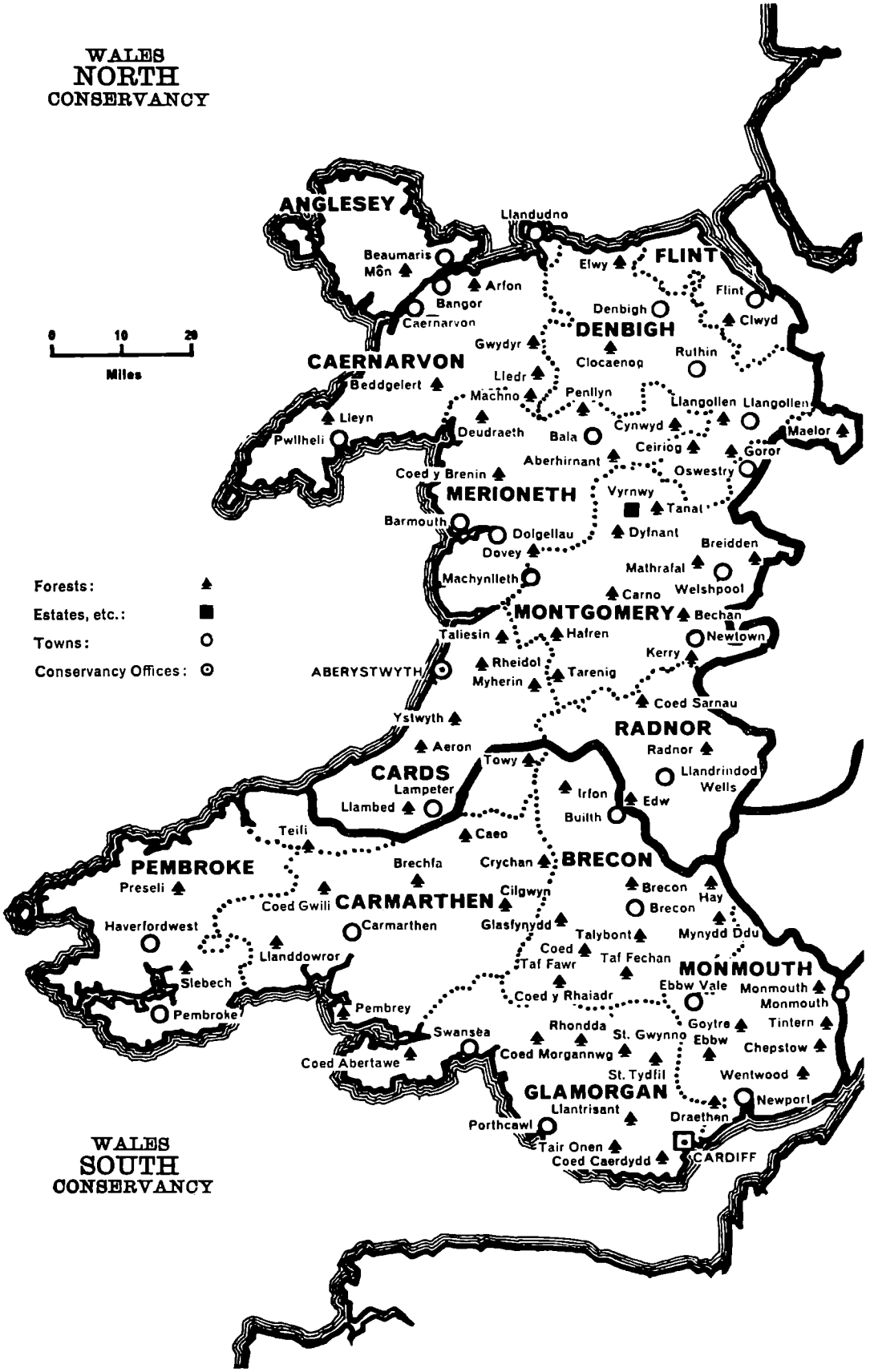
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Estates, etc.:
Towns:
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Clocaenog
Ruthin
CAERNARVON
Beddgelert
Lledr
Machno
Penllyn
Llangollen
Llangollen
Lleyn
Pwllheli
Deudraeth
Bala
Cynwyd
Maelor
Ceiriog
Goror
Aberhirnant
Oswestry
Coed y Brenin
MERIONETH
Vyrnwy
Tanat
Barmouth
Dolgellau
Dyfnant
Dovey
Breidden
Mathrafal
Welshpool
Machynlleth
Carno
MONTGOMERY
Bechan
Taliesin
Hafren
Newtown
Kerry
ABERYSTWYTH
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Myherin
Tarenig
Coed Sarnau
Ystwyth
RADNOR
Aeron
Radnor
Towy
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CARDS
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Irfon
Llambed
Edw
Builth
Teifi
Caeo
PEMBROKE
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Crychan
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Haverfordwest
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Taf Fechan
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Slebech
Ebbw Vale
Monmouth
Monmouth
Pembroke
Pembrey
Coed y Rhaiadr
Goytre
Tintern
Rhondda
St. Gwynno
Ebbw
Swansea
Coed Morgannwg
Chepstow
Coed Abertawe
St. Tydfil
Wentwood
GLAMORGAN
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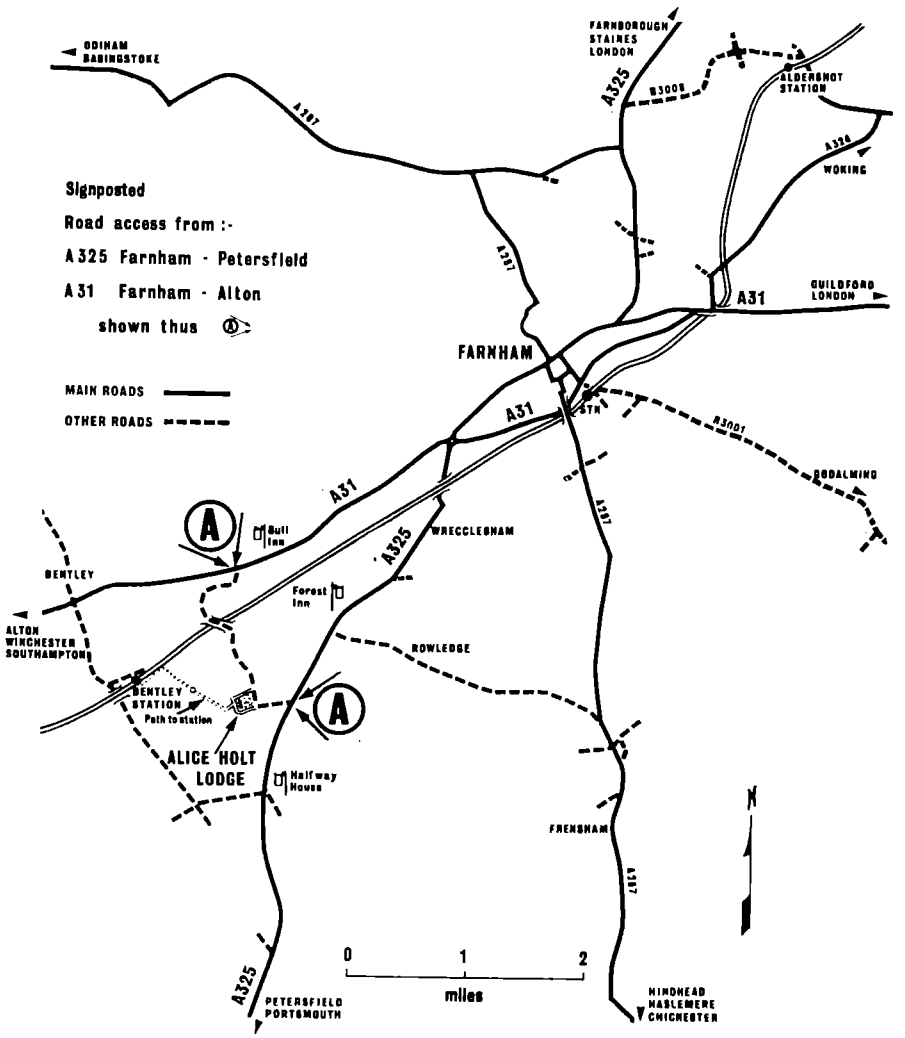

FIGURE 5: Approaches to Alice Holt Research Station, which lies 3½ miles south west of Farnham, Surrey, between the Farnham–Winchester road, A31, and the Farnham–Petersfield road, A325—A and A mark signposted approach roads.

INDEX

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