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FORESTRY COMMISSION

REPORT ON FOREST RESEARCH

for the year ended March 1967

LONDON
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1967

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All the photographs are by the Forestry Commission's Photographic Section. Figures in the text have all been supplied by the respective authors.

The cover design is by Mrs. T. K. Evans, F.R.P.S., of the Commission's photographic staff.

INTRODUCTION

By J. R. THOM
Director of Research

Advisory Committee on Forest Research

It is with particular pleasure that we congratulate Sir Frederick Bawden, Chairman of the Advisory Committee on Forest Research, on his Knighthood. Sir Frederick has been a member of the Committee for some six years, and Chairman for the last two years. During that time several important changes in the direction and emphasis of forest research have resulted from his inspiration and advice.

The Committee met on 21st October 1966 in London and considered the report of the first Visiting Group; recommendations were made for the constitution of the second Visiting Group, and for the subjects to be covered.

Visiting Group

In July the first Visiting Group appointed by the Advisory Committee visited research centres in Scotland, and the Forest Research Station at Alice Holt to inspect the work of the Genetics, Silviculture (provenance of seed only), and Seed Sections. The Chairman of the group was Professor P. F. Wareing, with Professor J. D. Matthews and Dr. N. W. Simmonds. T. D. H. Morris acted as Secretary. The Group was asked to give advice on the programmes and direction of the work and report on matters of organisation, staffing, scientific method or techniques which seem pertinent. In addition visits were made to seed stands, tree banks, progeny and clonal trials in Scotland and England together with trial plots at Alice Holt. The Seed laboratory and extractory were also visited. We are most grateful to the members of the Group for their meticulous attention to our problems, and for their constructive report. We for our part found the preparatory work and self-analysis involved extremely worthwhile, and are convinced of the value of this type of investigation.

Natural Environment Research Council

The Forestry and Woodland Research Committee of the Natural Environment Research Council held three meetings during the year. It is clear that a more positive approach to many of the problems relating to basic forest research will now be made through this Committee. Already numerous grants have been allocated to University workers in different spheres, and the Commission will now play a minor role in supporting basic research. Consideration is also being given to the expansion of facilities for basic research either at the existing University Forestry Departments or by other methods.

Organisation

The Publications Branch, based on London, has, after a brief period of association with the Library, resumed its independent status. The Library now comes within a central Information Service under the Research Liaison Officer. This is a new appointment created to improve communications between Research and the field. He also supplies a much needed service to the Research station.

Programmes

A major task within the year has been the introduction of a formal Project Register within the Research Division. Briefly the Register defines and lists all experimental work currently in hand in the Sections. It is intended to revise the Register annually, and additions to the Register will only be made after the consideration of project plans and in the light of the resources available.

Information and Communications

Further attention has been given to the problem of getting information quickly to the user and in an assimilable form. The brighter cover and shorter text of the last Report seem to have been generally appreciated, and a considerable effort is being made to bring forward the publication date. Tardy publication has been a common criticism.

Meetings have been held with the Timber Growers' Organisation and the Scottish Woodland Owners' Association to explain what information is available, and to discuss how best this should be conveyed to private woodland interests as well as to Forestry Commission staff. It is hoped that the system explained in a recent issue of our Library Review has helped considerably to this end.

The Forest Research Division has always provided advisory service especially on pests, diseases, and miscellaneous tree health problems. This is good as it means that we are kept in touch in a practical way with forest problems. Also it may spark off a line of research to a section worker, simply as the result of an innocent query. To strengthen our advisory work in Pathology and Entomology in particular, two senior foresters were transferred to Edinburgh to improve the coverage in Scotland. To give some idea of the amount of work involved in dealing with enquiries from outside sources, the various Sections at Alice Holt and Edinburgh answered no fewer than 3,500 queries during the year.

Visitors

We welcomed during the year many distinquished visitors from abroad including Mr. Bjarnasson, Head of the Icelandic Forest Service; Mr. A. O. Lawrence, Chairman of the Forestry Commission, Victoria, Australia; Ir. H. A. van der Meiden, Director in the Dutch Pulp Industry; Professor Dr. J. Schmitt-Vatt of the Waldbau Institute, Freiburg. In addition we had visitors from Canada, Eire, Finland, France, Japan, Kenya, South Africa, Thailand, U.S.A., Zambia and New Zealand.

We also had visits from the Forestry Commissioners during October as part of their annual tour in South East England. In July we held an open day for Conservators, and during the winter we held two full-week courses for District Officers and Assistant Conservators from four Conservancies, as part of the five-year programme to cover all Commission field staff. We also were delighted to have a visit from the Technical sub-Committee of the Timber Growers' Organisation of England and Wales. Parties visited us from the Universities of Aberdeen, Edinburgh and Oxford, and from Bognor Regis Training College, London University, Farnborough Technical College, and Merrist Wood Agricultural College, Surrey.

Staff Visits Abroad

In March, P. A. Wardle attended a preparatory meeting at Freiburg, Germany, for the Working Group on Forest Accounting (Section 31 of I.U.F.R.O.).

A. I. Fraser, W. H. Hinson, A. R. Sutton and J. A. Stirling, visited Finland in May and June to study drainage research and methods.

A. I. Fraser visited Canada from June to September on detached duty with the Ministry of Defence, and also visited various research establishments.

R. Faulkner went to Hungary in September to attend the Study Group field excursions arranged by Section 32 of I.U.F.R.O.

N. Dannatt went to Zambia as an Economic Consultant to the Zambian Government from September 1966 to April 1967.

L. C. Troup went to Stockholm in September and October to attend the F.A.O/E.C.E/I.L.O. Joint Committee and Symposium on tractor extraction.

D. A. Burdekin went to Versailles in October to attend the F.A.O. International Poplar Commission Working Group on Diseases.

A. F. Mitchell visited Eire in October and November to collect information for use in the revision of W. J. Bean's "Trees and Shrubs Hardy in the British Isles".

G. G. M. Taylor and A. J. Low visited Northern Ireland and Eire in October to study peat drainage and the performance of species, notably Lodgepole pine.

G. M. Buszewicz went to Zambia in November and December to advise on seed procurement, storage, testing and distribution.

Conferences

The Sixth World Forestry Congress, which was held in Madrid in June, 1966 was attended by D. R. Johnston (Planning and Economics) and R. Lines (Silviculture, North). The first meeting of the British Forest Pathology Working Group was held in April at the Commonwealth Forestry Institute, Oxford, and as a result seven papers were presented at a meeting of the Federation of British Plant Pathologists in London in February, 1967. Three of the papers were given by members of our Pathology Section.

The Air Pollution Congress, which was held in October, was attended by D. H. Phillips, head of the Pathology Section.

The Operational Research Society Conference held in September was attended by P. A. Wardle.

"Agriculture '67"—A symposium organised by the Department of Agricultural Economics at the University of Newcastle, in February, was attended by A. J. Grayson.

The next major Conference will be the I.U.F.R.O. Conference in Munich in September, 1967.

Promotions

During the year R. Faulkner was promoted to Assistant Conservator as Head of the Genetics Section; J. M. B. Brown (Ecologist) was promoted to Principal Scientific Officer; Miss J. J. Rowe (Mammals and Birds) was promoted to Senior Scientific Officer; C. I. Carter (Entomology) was promoted to Experimental Officer.

Staff Changes

D. R. Johnston left Planning and Economics for East England Conservancy and his place was taken by J. A. Spencer.

D. T. Seal took over as Silviculturist (North) on promotion to Assistant Conservator.

O. N. Blatchford and R. M. Brown (District Officers) joined the Research staff during the year as Research Liaison Officer and Assistant Silviculturist (South) respectively.

J. G. Grevatt (District Officer) joined Planning and Economics.

A. H. Ghori joined Planning and Economics as an Assistant Experimental Officer.

J. A. Drummond and D. M. Morgan (District Officers) joined Work Study Branch from the field.

K. A. Karnahan joined Work Study as a Technical Works Engineer.

Miss S. B. Page and Miss C. M. Davies (Executive Officers) left Planning and Economics and the Library respectively on transfer.

W. G. Gray retired in January 1967, and a large gathering at Kennington Nursery said farewell to him. Joining the Commission in 1922, he moved to Kennington near Oxford in 1925. There, for more than 40 years, he developed outstanding skills as a nurseryman which, combined with great patience and capacity for hard work, made Kennington renowned for the perfection of techniques and the quality of plants.

Farewell gifts included a cheque from Commission friends, pewter tankards from the Commonwealth Forestry Institute, and a beautifully prepared illustrated booklet to remind him of his long association with the Rothamsted staff.

Bill Gray gained the respect and affection of all who worked with him and colleagues of all ranks have had reason to be grateful to him. We wish him a long and happy retirement.

Winston Churchill Memorial Trust

We are particularly pleased to report the award of travelling Fellowships to two of our staff, Miss L. M. McMillan and N. P. Danby. From a field of 2,500 applicants 75 awards were made, and to have gained two of these is a considerable achievement and reflects great credit on the two people concerned. Miss McMillan, a Senior Scientific Assistant in our Seed Section, will be visiting Seed Testing Stations in America to study techniques in seed testing, viability and dormancy. N. P. Danby is a Research Forester at Ardross, Scotland, and he will tour the coastal areas of North West America and South East Alaska to see, in particular, those areas where Lodgepole pine is growing naturally, and to acquaint himself with forest and community life.

REVIEW OF THE YEAR'S WORK

By R. F. WOOD
Conservator, Research Division

PART I

Forest Tree Seed

The only substantial collections from home sources were in Scots and Corsican pine, other species yielding poorly. These two pines yielded on average 16 oz to the bushel of cone for Scots, and 8 oz to the bushel for Corsican pine. To obtain the quantities required (stocks being low) it was necessary to extend collections to unregistered stands; an unsatisfactory procedure which it is to be hoped we shall not have to repeat in future.

The desired reserve of three years' supply is now held in store for all conifers other than Hybrid larch.

The seed required for a given planted area continues to fall, but the trend has been much more marked in the Commission as compared with the private forestry sector. Service functions continue to bulk much larger than research. It has been possible to help certain Commonwealth countries on storage and testing problems, and we continue active co-operation with the International Seed Testing Association. Useful progress has been made in replacing the old, standard, seed dressing of red lead, introduced many years ago as a protectant (in which role it was quite ineffective) but maintained as a colorant to facilitate sowing operations. Certain "Waxoline" dyes which do not require the seed to be moistened with water for application seem likely to replace it, hence it may be possible to treat the seed centrally without fear of deterioration. Work has also been done on a number of the stages in the extraction and cleaning process.

Nursery Investigations

Nutritional work continues to be the major element in the programme, the joint investigations with the Rothamsted Experimental Station being the central activity. (See Part II, pages 133–140.)

Amongst nursery techniques, mention is made of the old subjects of season and density of sowing. A completed series of experiments indicates that there is no general case for autumn as against spring sowing, though there were several favourable results from autumn sowing. Yield of seedlings in Sitka spruce is rather surprisingly sensitive to density of sowing, half-normal rate producing percentages of viable seed sown nearly double those of twice-normal rate sowings. Low seedbed density also reduced the incidence of frost damage.

Nursery trials of dyes to replace the standard red lead seed treatment (see also Forest Tree Seed, page 22) tested blue and yellow "Waxoline" colours against the red lead with respect to bird damage in seed beds. The birds, however, showed no party affiliations. The dye auramine yellow in a "straight" trial of colorants gave as good yields of seedlings as red lead for most species, and significantly better for Lodgepole pine and Norway spruce.

A considerable amount of work has been done on the range of slow release fertilisers now becoming available. "Enmag", a commercial formulation of magnesium ammonium phosphate with added potassium chloride or sulphate, was tried in a number of nurseries with added nitrogen in various forms, in comparison with the present standard fertiliser régime based on potassic superphosphate. In this (very wet) season "Enmag" did not show consistent advantages. It appears possible, however, to apply this fertilizer to seedbeds immediately before (or even after) sowing, which may be useful where preparation has for some reason been delayed. Potassium metaphosphate was also included in a number of trials of régimes in English and Welsh production nurseries, but again the results were inconsistent, with little general advantage to the slow release fertilisers over the standard régimes.

The high rainfall of the season precluded any useful test of salt damage on transplants.

The long-term fertility experiment at Teindland, Moray, continues to produce the largest seedlings under hopwaste plus PK.

No promising new herbicides have appeared from this season's screening tests. The long-term trials of simazine (now in their fifth year) show no build up of toxic effects from any rates on the sands at Wareham, Dorset; but on the loams at Kennington, Oxford, applications of twice or four times the standard rate resulted in growth reductions or damage.

Some preliminary work has been done on a new project concerned with the production of tubed stock, a standard technique in semi-arid regions, which may yet have certain applications in temperate countries where bare-rooted stock is the standard planting material.

Afforestation of Difficult Sites

The north of Scotland contains the greatest area of doubtful types, and most of these represent a combination of nutritional and exposure problems, to which are often added practical difficulties in carrying out drainage and cultivation. In Wales, on the other hand, doubts about plantability are usually restricted to the upper elevational limit. New trial plantations in Sutherland and Ross include provenance comparisons in Sitka spruce and Lodgepole pine, and also fertiliser levels. Nutrition, and the ability to withstand exposure, is an important topic at the present time. In Wales, intensive experiments are established on five sites at high elevations.

Certain industrial sites, where tree growth is of importance for amenity, have attracted experimental work on a small scale. Current interests are the old shale heaps in the Lothians, and deposits of pulverised fuel ash from modern power stations. It is of some interest that alder shows up well on this material, as it does on so many raw mining spoils. In this field, however, we are concerned to a greater extent in consultation than in actual research.

Further developments in the flag-tatter technique of estimating exposure have included a detailed survey over 200 acres of hill ground at Whitrope Beat, Wauchope Forest (Roxburghshire), where exposure contours have been mapped from the records of some forty flags. Anemometer records have been compared with flag-tatter rates from a number of sites, and, as expected, the relationship is somewhat loose, since we already have evidence that flag tatter is not related in a linear fashion to wind velocity at the higher wind speeds. This does not, of course, lessen the value of the flag as a biological device. An improved flag mount has been designed and put into use.

Cultivation and Drainage

The Teindland (Moray) experiment planted in 1952, which is the best of the heathland cultivation experiments old enough to give any indication of the effects of different degrees of cultivation on yield, has been assessed again recently. Height measurements, and estimates of yield classes of the various crops are given. Observations have also been made in certain (slightly older) Conservancy trials of ploughing intensities. There is now pretty convincing evidence that the growth responses to intensive cultivation, always provided the method is suited to the particular site, will be large enough to render the extra investment profitable. Responses in the "demanding" Sitka spruce are relatively much greater than in the pines. We do not as yet know the *shape* of the response to intensity of cultivation well enough.

Two recent drainage experiments on clays in the south (Halwill, Devon, and Orlestone, Kent) are well established and the treatments are beginning to "work", judged by borehole records. At Halwill, four-year-old sprüce in mixture with alder (*A. rubra*) appears better than in pure crop. An important series of experiments is being established on peaty gley soils in Scotland and Wales, in Sitka spruce crops of various stages from the early thicket stage to the pole crop. How late in the life of the crop one can install improved drainage systems, and obtain profitable responses, is a very critical question at the present time, since the answer to it governs the priorities over considerable areas. The large experiment at Kershope, Cumberland, in thirty-foot crops, has an extensive coverage of boreholes, and an interesting refinement is the computer programme to print out maps of borehole levels direct from the data.

A particularly awkward problem is set by the practice (common in the early nineteen-fifties) of ploughing at planting spacing on the contour, without adequate drainage off the site from the plough furrows.

Further advance in drainage on the deep peats is closely tied to the development of machines. In the large Flanders Moss (Stirlingshire) drainage experiment, it has become clear that once the initial drainage and cultivation have been done, and the bog surface has been broken, it is impracticable to deepen drains further by machinery. It is thought that no peat drainage treatments in the older experiments have been intensive enough to produce significant increases in rootable volume, hence the absence of clear responses. Certainly the responses of young Lodgepole pine to controlled water levels in the peat in the joint Macaulay Institute/Forestry Commission experiment at Inchnacardoch, Inverness-shire, are abundantly clear.

Nutrition of Forest Crops

Further attention has been given to forms of phosphate. Trees are not so fussy about the availability of P as are agricultural crops, and so it appears economic to use the rock phosphates with their relatively low cost per unit of P. We require a compromise in particle size which is easy to apply, without undue reduction of effectiveness.

It is most interesting at this comparatively late stage to have convincing evidence of reductions in survival rates in newly-planted crops (in this case Lodgepole pine) from the spot application of ground Gafsa Rock Phosphate. However, the losses were not important on the practical scale, and the remedies are obvious.

Further experience has been gained with potassium applications at planting on peats, and it seems clear that this is desirable for Lodgepole pine on some poorer peats, such as raised bogs. Potassium metaphosphate might be expected to prove useful in these conditions, but for some unexplained reason produces plants with lowish nitrogen content, compared with potassic superphosphate.

There is further evidence that Sitka spruce picks up more nitrogen on Welsh peats than on Scottish ones, and it is hoped to follow this up with peat analyses.

In the older crops, the evidence is building up nicely that pole-stage pine stands in the north, on certain sands and deficient mineral soils, are likely to give substantial responses to nitrogen.

It is of much interest that the effects of nitrogen applied seven years ago to pole-stage crops of spruce at Halwill, Devon, and Corsican pine at Pembrey, Carmarthenshire, are still sizeable and significant.

Site Classification

While we have a great deal of work bearing on site, we have as yet no direct attack on site classification in the full sense. It has, however, now found its way on to the list of projects. A visiting worker, Mr. D. G. M. Donald of Stellenbosch University, South Africa, started a small project in Corsican pine; thirty stands from the south, midlands, and east of England, and South Wales, were studied, and soils and foliage samples are being analysed. There appears to be little correlation between performance and climate or gross site factor (aspect, slope, elevation, etc.), but perhaps it is to be expected that over a limited climatic range, soil factors will prove dominant.

Regeneration of Tree Stands

A good seed crop in Sitka spruce in 1964 resulted in very prolific natural regeneration in the large experiment in the Forest of Ae, Dumfries-shire, which is mainly concerned with the size of felling coupe and the stability of crop margins. The fate of this regeneration, which locally runs to 40,000 seedlings to the acre, is being studied in detail.

A similar experiment to that mentioned above, at Redesdale, Northumberland, has included studies on the disposal of felling slash and the cost of replanting. At present the indications are that replanting through more or less evenly distributed slash is satisfactory and the cheapest course. However, planting following the machine chopping of slash was a good deal less expensive than through the undisturbed slash, and the combined cost of this treatment was not inordinately higher, which suggests that if the labour component rises markedly in future, the use of machinery may well be justified. Where recultivation is required, some form of disposal will in any case be necessary. At present burning is very costly, and efforts are being made to improve technique.

Experiments established three or four years ago, in Scotland and Wales, on canopy density in underplanting of Japanese larch, are now beginning to produce useful information. It is noteworthy that species planted under Japanese larch appear more sensitive to canopy density at a moist western site such as Michaelston, in Coed Morgannwg, Glamorgan, than at a drier eastern site such as Drumtochty, Kincardineshire. (See Figs 1 and 2, pages 56–57.)

Scots pine, even of the better quality classes, can usually be replaced by higher yielding species. Douglas fir and *Abies grandis* are strong candidates on some of the better pine sites in east Scotland. Tentsmuir, Fife, has analogous problems to Thetford Chase. Corsican pine is more productive than Scots, but its establishment has proved very expensive. At Thetford, trials of a range of species under different canopies of Scots pine, as in the older experiments using birch and alder covers (see page 59), have shown that many species can be established readily enough with the virtual elimination of growing season frosts, and with (no doubt) the reduction in evaporation stress. Thinning is now being conducted in the overwoods, and fresh experiments are being laid down to see what is the least effective canopy. Plainly, for ease of working, the sparser the overwood the better.

Arboreta, Forest Plots and Species Trials

New plantings at the main centres include a number of subjects of mainly arboricultural interest, or of speculative importance only to forestry. These include a number of Mexican species which are new to us, and further representation of *Eucalyptus* is also a long shot, economically speaking. The two most promising *Nothofagus* species, *procera* and *obliqua*, may be ranked rather higher since their ease of establishment and remarkable growth rates must advance their claims, wherever there is any case to establish broadleaved crops. A good deal of attention has now been given to the unpleasant stem canker occurring in some of the fastest growing young stands of *N. procera*, and if its causation is not wholly clear, at least it seems possible to typify the sites where it is most likely to occur, and thus avoid the trouble. These seem to be low-lying valley situations in regions where climatic conditions are specially favourable to fast growth, and it is assumed that extreme alternation of temperature (rather than low temperature as such) is the key factor.

Notes are given on the development of a range of species established some fifteen to twenty years ago under high covers of birch, alder, and larch at Thetford Chase, Norfolk and Suffolk. The environment here is quite notorious for the frequency and severity of unseasonable frost, which has proved most restrictive in the establishment of crops on bare ground, and incidentally, in the regeneration of the existing pine crops (see also Forest Pathology, page 97 and Ecology, page 83). As in the more recent replicated experiments in the regeneration of pine crops, these older trials have clearly indicated that a surprisingly wide range of species will grow with considerable vigour, provided their establishment can be effected under cover. Thetford is a good example of the environment where the ultimate system of management will have to pay specially close attention to the biological factors.

Provenance

This was one of the fields of work considered by the Visiting Group (see Director's Introduction, page 1). R. Lines has recently compiled a report on standardisation of methods in provenance experimentation for Group 22 of the International Union of Forest Research Organisations.

Lodgepole pine presents us with the most important provenance problems at the present time. The tour by J. R. Aldhous and H. A. Maxwell to North-west America in 1965 resulted in the acquisition of a valuable collection of material, particularly from the general area of the Skeena River. We still do not have an adequate coverage from north coastal regions however. A recent assessment of an experiment planted at the Forest of Deer, Aberdeenshire, in 1959 has given useful information on susceptibility to easterly coastal exposure, and has shown that the poor resistance of the notorious Lulu Island Lodgepole pine is shared by that from the drier south-eastern parts of Vancouver Island.

The provenance of European larch is now well enough understood for all practical purposes. Work on Norway spruce opened rather late in the day, and we may have lost by this, since all the indications are that we should have been obtaining more of our seed from south-east Europe. We have now reasonably satisfactory experiments in Western red cedar, *Thuja plicata*. In Douglas fir efforts have been made to extend the coverage by obtaining more material from the Oregon coast.

A small amount of work has been done on a range of species of secondary (or reserve) importance. Without some (albeit modest) estimates of variability, it is difficult to assess the species.

Weed Control in the Forest

Work continues on the effectiveness, safety and economic advantages of herbicides for the more important weeds and stages in the establishment of the crop. The herbicide clorthiamid (Prefix) which has some useful properties, has been shown to be hazardous in plantation. Dicamba seems likely to prove economical on sites where bracken weeding is expensive. Work Study Section (see page 118) is now developing techniques of herbicide application.

Tree Stability

The winter of 1966–67 was continuously windy, and damage was widespread although the total area blown was by no means alarming. Root investigations by tree pulling have shown a small but significant gain in rooting depth between intensive and minimal draining treatments in one of the older experiments at Newcastleton Forest, Roxburghshire. The large aerodynamic study in Redesdale Forest, Northumberland, is now well under way; the 80-ft masts and instruments have been satisfactorily erected above the forest. Several months' wind velocities have been recorded by the data logger, and it is encouraging that the wind profiles show very similar patterns to those obtained from model stands in wind tunnels. We may therefore be able to return to model work with added confidence for specific enquiries.

An experiment has been laid out at Kielder Forest, Northumberland, in a Sitka spruce crop clearly susceptible to blow, to compare a range of thinning intensities on the stability of the crop. The current hypothesis is that under these conditions the unthinned crop will prove the most stable.

Further surveys have been made on "sporadic" blow (i.e. of individual stems or small groups), which is often the precursor of more general windthrow. It is now very clear that the side of the recently cleaned drain is a more hazardous position than the side of an uncleaned drain or the area between drains. Hence drain cleaning should be undertaken well in advance of the crop reaching the susceptible height, and drain-side trees removed.

In response to a Research questionnaire, Scottish conservators have estimated that about 40 per cent of the sites planted to Lodgepole pine are likely to exhibit moderate to severe basal bowing due to early instability. This trouble is chiefly important in the fast growing coastal provenances of the tree, which are increasingly planted, and otherwise extremely well suited to exposed, moist infertile sites. Further experimental work is being undertaken to avert early instability.

Growth Problems in Pole-stage Sitka Spruce

Loss of crown density, accompanied by deformation of the leader, is a common symptom in Sitka spruce on marginal sites, which usually have in common some impediment to rooting. Most also fall in areas of comparatively low rainfall.

A thinning experiment at such a site at Blairadam, Fife, to test whether early thinning can avert the onset of such symptoms, has suffered from windblow. As expected from other evidence, unthinned plots suffered least. Worst hit were those receiving crown thinnings.

Several experiments have now been established to find out what part the Green spruce aphis (*Elatobium*) plays in these troubles. Comparisons of basal area increment are being made between untreated plots, and plots kept free by spraying with malathion. More detailed studies are being made by the Entomologist (see page 104).

Spacing in Plantation

A review of experiments established in 1935–36 is in progress. Experiments which have not been thinned (which is a possible treatment for short rotation pulpwood production) show that, while there is some "loss" of production between the closest spacings (3 ft) and the widest (8 ft), if sizeable material only be considered (taken here as trees of 1·5 hoppus ft or more) the picture is reversed. Form of growth and branch development has not deteriorated unduly up to spacings of 8 feet, except in Scots pine where there is a deterioration between spacings of 6 feet and 8 feet, which may well be of economic significance. Unfortunately, Lodgepole pine is not well represented, but there is every reason to expect similar trends. Spacing in Scots pine is illustrated in Plates 4 to 7 inclusive on the centre pages.

Poplars and Elms

The high productivity of *Populus trichocarpa* and its hybrids under British conditions becomes increasingly clear; an ideal poplar for us would certainly be a *P. trichocarpa* selection, or have this north American balsam as a parent.

Selection of elms continues, and we now have 72 clones established as stools. No worthwhile success has yet been achieved with hardwood cuttings, which would be the most convenient method of propagation. But the mist technique with softwood cuttings continues to give satisfactory results, though the larger-leaved elms (such as Dutch elm), are not so easy as the smaller-leaved ones. Some work has been started on layering, which might prove a useful technique to the less well-equipped nurseryman. The testing of clones against Dutch elm disease continues, and it is hoped to put out preliminary reports on this work shortly.

Ecology

Notes on the main features of the weather of the period under report are given. Increasing interest in climatological affairs has encouraged the formation of a small group at Alice Holt to exchange ideas on weather effects, instrumentation, etc.

In the course of regeneration studies on Corsican pine at Thetford Chase much has been learned about the forest climate. The climatological station at Grimes Graves, which is on a small heath surrounded by forest, has in eight years shown an even chance of frost in July, and is distinctly frostier than open country not so far away at Mildenhall. Some of the regeneration clearings are even colder, and it is only under canopy that the night climate of this notoriously frosty neighbourhood is improved by afforestation.

Measurements of light interception of canopies in regeneration experiments, have shown that Corsican pine can tolerate shade conditions where the interception is as high as 65 per cent.

Two further occurrences of Dieback disease (*Brunchorstia*) have been noted in Thetford Chase, but there are no grounds to fear any general epidemic. As in the Pathologist's report, attention is called to the widespread browning of Corsican pine foliage which is thought to be a climatic effect, though the fungus *Hendersonia acicola* may play a part.

Soil Moisture, Climate and Tree Growth

Observations of soil moisture at the fixed study sites continue, and the neutron soil moisture gauge (described in the 1966 *Report*) will be the main source of data of this kind. Access tubes have been provided at the principal study sites, and these are visited fortnightly, and records are made at 10 cm intervals down the profile. Simple calibration is sufficient where the interest is only in changes in moisture status in a given soil, but more work is necessary for absolute calibration. Moisture data are recorded on Lector forms in the field, which are then automatically transferred to punched tape for computer handling. This is one of numerous applications of the Lector system in forest research. Seasonal changes in moisture status can be expressed in various ways, and Fig. 3, page 88, shows an informative graphical presentation in which point values of moisture readings are plotted against time and depth, equal values being joined to form contours, based on observations at Bramshill Forest, Hants.

We have been in touch with the Meteorological Office over refinements to the Penman formula for potential evapotranspiration, which is the best available expression of evaporation as a climatic factor. The Garnier gauges at Alice Holt (part of a network initiated by F. H. W. Green of the Nature Conservancy) continue to give values very close to those calculated from the Penman formula from data collected at Farnborough, Hants.

Forest Genetics

Scots and Corsican pines coned moderately, and our older clonal seed orchards of Scots pine should make a sizeable contribution of some 30 lb of seed from the winter's collection. Further work has been done to improve the estimates of crop yields from seed stands.

Selection of Plus trees has concentrated on Sitka spruce, and some 330 are on the books, though several Conservancies remain to be surveyed. Studies in the propagation of Sitka spruce, comparing the rooting of cuttings in the growth room and in the mist house, against grafting, from a number of individual candidate Plus trees, has given some important leads. Especially notable is the big variation between trees in ease of propagation, and grafting success is not related to cutting success. The extra controls of the growth room (air temperature and photoperiod) over the mist house, where only the rooting medium temperature is controlled, gave much better results with the cuttings. Over 40 per cent success is now to be expected on average with grafting, but it has been found that "secondary" scion-wood, i.e. from once-grafted plants, gives much better results. A national tree bank for Sitka spruce selections is being established at Wauchope, Roxburghshire, and grafting material will in future be taken from this, and not from the original trees.

The poor seed-set in artificially pollinated cones of pines gives rise to a good deal of concern, since it delays the progeny testing programme. Excessive conelet drop is another trouble in the pines. These topics are being investigated in a joint study with the Forestry Department, Aberdeen University, whose interest in basic work in forest genetics is of much value to us.

Efforts to grow Sitka spruce in the greenhouse for accelerated progeny testing ran into a snag in the second year, it is thought due to insufficiently lower temperatures in the rest period. Experiments on winter-chilling are being undertaken to find whether this can be remedied easily.

Forest Pathology

Work on *Fomes annosus* susceptibility is necessarily long-term. Present evidence does not suggest there will be big differences in the inherent susceptibility of species to death from *Fomes* attack on young plants; for this aspect of *Fomes* loss, the time taken over the most vulnerable stage of growth may be more important. There is evidence, for instance, that whilst Corsican pine and Scots pine are equally affected in very early years on *Fomes*-infested sites, Corsican pine "stops dying" sooner than Scots pine.

There is now useful evidence in support of the working hypothesis that top-dying of Norway spruce is a physiological disorder, preconditioned by something that happens in mild winters, and triggered off by environmental disturbances which increase the exposure of the crown, e.g. thinning, brashing, etc. It will be interesting to see whether the notably mild winter of 1966–67 is followed by widespread occurrences of the trouble. The pathological side of replanting difficulties with Corsican pine in East Anglia seems to tie in well with the unfavourable frost climate over grass and/or felling slash. This is a special regeneration problem, also mentioned under Ecology (page 83) and Regeneration (page 55).

In further joint studies with the Forest Products Research Laboratory, Princes Risborough, on Blue Stain in pines, combined fungicidal and insecticidal sprays have given promising results.

The testing of poplar clones for resistance to Bacterial canker has now been standardised on an international basis. A poplar disease new to us has arrived, Leaf spot brought about by *Marssonina brunea*, which is important in Europe. The poplars are a good group for basic studies in virus diseases and we are co-operating with Dr. Tinsley of the Department of Forestry at Oxford University in this field. (See Part II, Biddle and Tinsley, page 156) and Plates 2 and 3 on the centre pages.)

Further work has been done on the control of *Didymascella* (*Keithia*) *thujina*, which is very damaging in the nursery to Western red cedar, *Thuja plicata*. This is largely to assist private forest nurserymen, since it is difficult for them to apply the practical remedy open to the Commission, which is to avoid the disease by rotating *Thuja* crops through a series of nurseries.

Subjects of enquiries are much influenced by the sort of weather we have been having, and one or two leaf fungi seem to have appreciated recent cool, moist summers. Of more importance is an outbreak of Needle browning in Corsican pine, most frequent in the north, the cause of which is not known, but which appears climatic in origin.

Forest Entomology

The routine pupal census of the Pine looper moth, *Bupalus piniarius*, showed some slight increase in numbers, but nothing alarming. In further work on the

Douglas fir Seed wasp (*Megastigmus spermotrophus*), malathion is still the only insecticide which has given field control. Population counts of the Seed wasp have now been carried out over four seasons, and seed infestation varies from about 20 per cent (in the one good seed year) to 80 per cent in the poorer seasons. A satisfactory measure of control of the Pine shoot beetle (*Tomicus piniperda*) in stacked logs, already attacked by the beetle, has been obtained by spraying with Gammalin in oil. This might well be useful to correct errors in normal harvesting practice. User trials are now under way of whole-plant dipping in Gammocol against the weevil *Hylobius abietis*.

The Green spruce aphis, *Elatobium abietinum*, is undoubtedly a cause of increment loss of Sitka spruce, and studies on paired plots (infested and free) are now under way to estimate the size of this loss. The method adopted being of some precision, we may also gain information on the pattern of increment over the stem, and also on the effects of climatic variation on increment. We are also looking at host plant susceptibility through the analysis of extracted sap by chromatographic techniques. Any easily discernible differences discovered would of course be of use to the breeder. Through their appearance in the catch of the suction trap, more is now known of the flight periods of the winged stage of this aphid.

The regular operation of the suction trap has yielded a number of dividends. Beside the primary interest in the adelgids, a good deal has been learned about the flight periods of a number of other forest insects.

Mammals and Birds

Grey squirrel control methods continue to be studied in liaison with the Infestation Control Laboratory of the Ministry of Agriculture, Fisheries and Food. Protection trapping is now a well-established method. Trials have shown that recolonisation by squirrels is quick, hence it is vital to reduce numbers *just before* and *during* the damage-susceptible period. Warfarin has proved satisfactory at Scottish squirrel population levels, but legislation would be required before it could be tested or used generally in England.

Work on deer includes methods of age determination, population studies by ear-tagging of calves, and the improvement of natural feed by fertilisation. It is hoped to find suitable equipment for radio tracking.

A German proprietary product (zinc phosphide on sunflower bait in cellophane packets) failed against voles. In nurseries, formulations of the fungicide thiram (*Fernasan S and Arasan*) gave considerable protection to seedbeds against birds. But for regular protection where damage is to be expected, there seems every reason to use half-inch mesh netting. The attractive idea of using a hawk silhouette to frighten away birds (which is not new) always seems to founder over the carrier; kites require wind, and balloons behave badly if there is too much.

It seems that chemical deterrents will prevent fallow deer browsing for at least eight weeks. It is just possible this might be useful under very special circumstances. Electrified polythene netting has deterred fallow deer, without however deterring hares, in one case. Scottish trials of electric fencing against deer will shortly be published. Synthetic fibres as twines for deer netting have been exposed over five summers to study losses in tensile strength on exposure to light, etc. Black polythene has been the most successful of the materials under trial, losing only 18 per cent of the wet twine breaking strength.

Planning and Economics

This section is part of the Management Services Division of the Headquarters organisation. Research or research-like activities of the Section continue to be published in this *Report*, however.

Working Plans

Soil surveys to the 6-inch to the mile scale were completed for six different forests, where soil factors have special bearing on management problems. Such surveys are building up a good general picture of site characteristics and the performance of species, besides suggesting cultural measures (drainage, cultivation etc.) which may be profitable on certain types; analogies often being with sites on which research has been carried out. The stability of crops is an important part of the work, since we are now in the position to classify and predict windthrow hazard.

Economics

Service is provided to other Branches and Divisions (including Research) of the Commission. The profitability assessment of a specific forest operation is one of the more important aids to management. Planning at the regional level is an increasing feature of the Commission's work; in this Economics may be concerned in the optimisation of a particular activity over a number of forests; this type of approach may be appropriate in considering supplies to a particular industry. A similar functional approach has been applied to the planning of plant supplies, and in this, seasonal uncertainties have had to be taken into account explicitly.

A different type of exercise has been undertaken where the object is to consider a range of activities in a single management unit, for example, establishment and maintenance on the clay areas in East Anglia.

A major field of work is the study of the records required in management information systems, especially for financial control. Detailed planning procedures for particular activities have also received attention.

Mensuration

A publication entitled *Thinning Control in British Woodlands* (F.C. Booklet 17, H.M.S.O. 10s. 6d.) has been prepared on the practical aspects of thinning control to supplement the recently published *Forest Management Tables* (F.C. Booklet 16, H.M.S.O. 30s. 0d.).

A field survey of stacked to solid volumes in pulpwood has been carried out, including density determinations.

Summaries are given of recent assessments in modern replicated thinning experiments. The very intensively measured experiment in Douglas fir in Alice Holt Forest has not as yet produced significant differences in yield, attributable to thinning treatment, but the trends suggest that it will. Perhaps most interesting are the summarised results of thinning and spacing experiments using nursery transplants. As these "crops" seem to behave similarly to older ones, there may be further applications for this technique, which was first used by Japanese workers.

Work Study

Another Branch of the Management Services Division, Work Study, is organised in seven general purpose teams, offering a regional service and conducting investigations into harvesting and silvicultural operations, with, in addition, an experimental team concerned mainly with machinery investigations, and a further team at present concentrating on a single operation (brashing). The Machinery Investigation Committee lays down the Mechanical Research programme.

Work Study has continued its studies on logging systems. In shortwood logging, attention is being paid to the size of pile, and to reducing the manual component in piling. Modern timber carriers, such as the Robur unit described here, are showing to advantage; an attractive feature of them is the low density of roads, to each square mile of forest, required. Cable crane systems may have special local applications. The Kershope Winch system (developed in North West England Conservancy) has advantages for short pulpwood extraction by sledge on soft ground where it is difficult for tractors to work.

For tree-length extraction, the frame-steering tractors of different sizes equipped with winches appear likely to gain the field. The small German Holder tractor (illustrated, Plate 10) has been developed into an excellent unit for thinnings extraction; larger machines are being studied for heavier timber.

A prototype helmet and ear muff outfit has been designed for workers using chain saws. (See Plate 8.)

Progress has now been made towards the right outfit to enable the deep-digging Finnish Lokomo plough to work satisfactorily under British conditions.

A portable spraying outfit has been designed which will allow operators to apply herbicides over an acre from one position of the power unit and tank.

In addition to the above mechanical topics, a number of methods are under study. For the weeding of plantations (one of the most expensive of silvicultural operations) the appropriate places for hand, chemical and machine methods are being investigated. Brashing is another costly operation, and difficult to study because of its long-term interactions with subsequent operations such as thinning and harvesting.

It is now felt however, that we are nearly able to define the optimum intensity. An old topic reborn is line thinning, and Work Study has taken part in a joint study which suggests that useful savings can be made in the first thinnings by adopting this practice. One of the advantages is that it obviates the need for brashing.

Mechanical Development

The Mechanical Engineering Branch of the Headquarters organisation is responsible for research and development in forest machinery. The programme is controlled by the domestic Machinery Development Committee. Field trials of certain machines are conducted by the Work Study Branch (see page 114). The Assistant Chief Engineer (Mechanical) mentions a number of the more important developments in the cultivation, draining, and harvesting, which are the main areas in which research is likely to be profitable.

Experimental Workshop

A short note is given on the activities of the Workshop, which has prepared a variety of instruments and devices for all sections of the Division. (See Plate 1 on centre pages.)

Timber Utilisation Development

The joint programme of research on home-grown timbers with the Forest Products Research Laboratory (Ministry of Technology) is in its ninth year. Brief mention of some of the topics in the programme is made here, fuller reports will be found in the *Reports* of the Forest Products Research Laboratory.

Further useful experience has been gained with the Laboratory's Economy Drier. Larch and Douglas fir fencing timbers were brought down to the Ministry of Transport's moisture specification for preservative treatment within five days. One-and-a-quarter inch through-and-through sawn beech behaved well in the economy drier. Scots pine chipboard billets, however, showed a marked variability in moisture content after eight days, which seems to be a feature of accelerated drying of roundwoods.

The service trial of round home-grown fence posts continues. After eight years in Scotland, no creosoted post of Sitka spruce or birch has yet failed, nor after seven years in England and Wales have any creosoted posts of Scots pine or the common hardwoods failed. Less than a third of the *uncreosoted* posts remain standing in Scotland, and less than a quarter in England and Wales.

Mechanical barking at the Brandon Depot, Thetford Chase, produces large quantities of bark, and it has been considered of some interest to see whether this can be composted and disposed of economically for horticultural purposes.

Design and Analysis of Experiments

Owing to staff shortages, the Statistics Section has been working under considerable pressure. Designs for about 70 different investigations, covering the normal experimental range, but with increasing attention to special Work Study problems, have been completed during the year. The library of computer programmes is now very comprehensive, but 35 new programmes have been written. The I.C.T. Sirius computer continues to give most reliable and trouble-free service. A Calcomp Graph Plotter has been added to the ancillary equipment, and we are grateful to the Royal Aircraft Establishment for their kind assistance in its installation. A few preliminary applications show the great promise of this technique in our work. (The Calcomp Plotter is illustrated on Plate 9.)

Publications

The Publications Branch has been reconstituted as a separate entity from the Library, which now falls under the Research Liaison Officer.

Eleven new priced publications were issued through Her Majesty's Stationery Office, and twenty-eight publications were re-issued after some degree of revision. It is hoped to make increasing use of the Research and Development Paper series to carry rather specialised material on limited initial distribution. Titles will be listed here, and in the *Library Review*, and will be available on application to the Publications Branch, Forestry Commission, 25, Savile Row, London, W.1.

Research Information

With the appointment of a Research Liaison Officer we have begun to organise a central information service. General and specialised forestry literature is well documented, and our problems are not so much at this primary level, but are concerned more with access, selection, and presentation of information. It is particularly hoped that the Information Section will make an important contribution to the current awareness of research results in the field.

PART II

This part contains reports on work undertaken at other research organisations and supported by Forestry Commission grants. The Natural Environment Research Council, through its Forestry and Woodlands Research Committee, is now the principal agency for the support of basic forest research in the Universities, and the Forestry Commission will in the future only give grants-in-aid for work which is in direct support of its own programme.

Included here for convenience (but really belonging to another category) are reports on work carried out for us under special arrangements at the *Macaulay Institute for Soils Research*, Aberdeen; *Rothamsted Experimental Station*, Harpenden, Herts; and the *Joint Fire Research Station*, Boreham Wood, Herts.

Mr. H. G. Miller and Dr. B. L. Williams (who has now replaced Dr. J. B. Craig) of the *Macaulay Institute* continue the studies in tree nutrition (with special reference to nitrogen) at Culbin Forest, Moray. A good deal of attention has been given to the statistical problem of expressing sample tree analytical and other data on a crop basis. Work on peat physical chemistry has concentrated on methods of measurement, and it is hoped to apply techniques developed to field experiments, where the effects of drainage and tree growth on peat are being studied.

Short extracts are reprinted from the *Rothamsted Annual Report* for 1966 on work by Miss B. Benzian, Dr. J. Bolton, and Dr. G. E. G. Mattingly. Miss Benzian mentions a new slow-acting nitrogen fertiliser, isobutylidene diurea (IBDU). In the two rather moist summers of 1965 and 1966, single applications of IBDU applied before sowing compared quite favourably with the same amounts of nitrogen as "Nitro-Chalk" top-dressed in several applications later in the season.

Experiments with the slow release PK compound, potassium metaphosphate, have continued. It seems an excellent way of giving phosphorus and potassium, though not consistently superior to potassic superphosphate in a series of trials in production nurseries (see Aldous and Atterson, page 30). As striking here are the gains attributed to the application of K in potassium nitrate (supplementing potassic superphosphate) at mid-season.

A longer report by Miss Benzian and Mr. S. C. R. Freeman deals with experimental late-season top-dressings of nitrogen and potassium. It has always been of interest to know the effects, on survival and growth, of nutrient content in seedlings or plants, but it has been difficult to separate these from the consequences of increased size brought about by improved nutrition. However, by careful timing in relation to the cessation of growth, it has been found possible to make very substantial increases in contents of N, K, or both, without altering the size of the plant. The effects of doing this so far observed, have been to reduce susceptibility to autumn frost in Sitka spruce and Western hemlock, to advance flushing dates somewhat in the subsequent spring, and to increase height growth a little in the subsequent growing season. Possibly the greatest ultimate interest may be in the behaviour of plants of specially high nutrient concentration (brought about by whatever means) in highly testing environments, such as extreme exposure.

Dr. G. A. Salt of the *Pathology Department, Rothamsted*, has continued his studies on the pathology of the germinating seed and young seedlings in Sitka spruce. These have given us a much better understanding of the biological factors concerned with losses in the seedbed, from the pre-germination stage onwards.

Studies reported here confirm that the endophytic fungus isolated previously by Dr. Salt, may well be a significant cause of pre-emergence losses where seed remains for any length of time in the soil at lowish temperatures (10°C or thereabouts), but is not likely to be of importance when soil temperatures are adequate for speedy germination. The observation that the fungicide thiram prevents infection by this fungus, even at the low temperatures which it prefers, is of value.

Dr. Salt has looked at the biological effects of the oil-soluble "Waxoline" dyes which we think are likely to replace the standard red lead as seed colorants. They were, if anything, beneficial from this point of view, an encouraging confirmation of our own results (see pages 30 and 141). Combined fungicidal and colouring treatment seems perfectly feasible. This will not however control losses due to very early "damping-off" associated with the fungi *Pythium*, *Cylindrocarpon*, and *Fusarium*. These losses are considerable, though very difficult to judge without the most intensive observations.

From the *Department of Forestry and Natural Resources, Edinburgh University*, we have five reports. Dr. A. J. Hayes has continued his work on the complex succession of fungi inhabitating and playing a part in the breakdown of Scots pine litter. He hopes to publish this investigation in full shortly. He has also, with Mr. A. Manap Ahmed, commenced detailed studies on the fungus *Crumenula sororia*, which we have associated with poor, checked Corsican pine crops and regarded as of purely secondary importance. It has now turned up on otherwise vigorous Corsican pine in Scotland, and of more importance, on Lodgepole pine; hence these studies are timely.

Mr. Mills gives a short note (a fuller account will be found in *Forestry*, 1967 Supplement (85–90)) on fish population in the Glentress Burn which flows through Glentress Forest, Peebles-shire. The study will show how silvicultural practices affect this other forest resource. Of immediate interest is the estimate that the biomass of trout is nearly four times greater in young plantations where there is abundant vegetation on the banks, than in older plantations where there is little.

Dr. Malcolm has embarked on a project of the first importance, a study of the locality factors in over-thirty-year-old Sitka spruce in relation to productivity. Thus far he has concentrated on the selection of the sampling sites and on the methods to be adopted in the various physical and chemical soil determinations. The availability of Forestry Commission data collected for management purposes has allowed him to make some preliminary analyses of the influence of gross climatic characteristics. Even when omitting crops with known history of "checking", no obvious relationships have appeared. Note also the rather similar indication for Corsican pine (Binns, page 51). It seems rather curious that the forester is apparently able to perceive broad regional trends, which, on analysis, appear to be very weakly expressed in quantitative terms.

Dr. W. A. Fairbairn has conducted a further and more precise enquiry into the effects of light on the growth of young seedlings of a range of species. Clear and consistent results were obtained. Seedlings of six species subjected to a range of light intensities are illustrated in Figure 4, page 155. Detailed results will be published later.

Dr. T. W. Tinsley and Mr. P. G. Biddle of the *Department of Forestry, Oxford University*, are concentrating on poplars in the early stages of their work on viruses, since vegetatively reproduced clones have many practical advantages for study. Poplar mosaic virus is obviously common (see also Phillips, page 99, and

Plates 2 and 3 for symptoms). It has been shown that reductions of growth are associated with infections by the virus, and that clones react differently, some showing greater growth reductions than others. (Figures 5 and 6, pages 157 and 158.) Efforts to find whether the growth reduction due to the virus is related to the age of the tree by studying different age classes of the clone "Robusta" have been inconclusive, but the picture should be clearer when measurements have been carried on for a few more seasons.

Poplar mosaic virus can be maintained in herbaceous species, but so far there has been no success in transferring viruses (or suspected viruses) from a number of other forest tree species to herbaceous plants.

Also from Oxford, Drs. L. Leyton and E. R. C. Reynolds and Mr. F. B. Thompson report briefly on their work on the elements of the hydrological cycle in woodlands and moorlands. Very detailed studies have been made on the root systems of Douglas fir in connection with observations on soil moisture distribution, and these results will shortly be published. Much has been done on interception of rainfall by tree canopies, and useful techniques have been developed in the more difficult investigation of interception by moorland vegetation such as heather, bracken, and *Molinia*. Further work has been done on sap flow in tree stems, and a new technique for automatic recording will be presented at the 1967 I.U.F.R.O. congress in Munich.

Professor P. F. Wareing and Mr. D. R. Causton of the *Botany Department, University College of Wales, Aberystwyth*, report further on their study of dry matter increment in birch and sycamore. Experimental modifications in form and leaf production are brought about by decapitation and debranching treatments in young trees. This year's results confirm the suggestion from the first year's work, i.e. that birch has a compensatory mechanism for loss of crown in exhibiting higher net assimilation rates. With sycamore, on the other hand, leaf area ratio is the important thing, and the "performance" of the leaves is not affected by the treatments.

Dr. D. J. Read, of the *Department of Botany, Sheffield University*, has begun studies in soil moisture in an experiment at Rosedale, Allerston Forest, Yorkshire, in which conventional ploughing treatments are compared with a reproduction of the old agricultural "rigg and furr" system (a series of broad low undulations, once favoured on heavy soils). In his first season, most attention has been paid to instrumentation, and in the very moist conditions tensiometers proved much more useful than resistance blocks. While surface conditions in all the treatments were closely related to rainfall, at depth the "riggs" (the raised part of the system) appear to have had some effect in raising moisture tensions throughout the season. (See Figure 7, page 163.) A more thorough instrumentation is planned.

Dr. Myles Crooke of the *Department of Forestry, Aberdeen University*, provides a short note on progress on the large experiment on the relationship between titmice populations and the Pine looper moth at Culbin Forest, Moray, which was fully described in the Report for 1965. It is now proposed to commence winter feeding in a further effort to influence the population of titmice in the plot in which nesting boxes have already been installed.

From the *Department of Soil Science, Aberdeen University*, Dr. J. Tinsley and Mr. A. A. Hutcheon report the completion of the studies on the effects of fertilisation on forest litter, which has been carried out at Bramshill Forest, Hants, with associated laboratory studies. Statistical analysis is now being undertaken, and the whole investigation will subsequently be published.

Mr. A. J. M. Heseldon and Mr. M. J. Woolliscroft of the *Joint Fire Research Organisation*, Boreham Wood, Herts., gave a short report on the continuing investigations into the spread of fires in forest fuels. This has moved in recent seasons from the laboratory model stage (covered in previous *Reports*) and is now concentrating on the statistical study of data collected at routine controlled burns, undertaken as a fire protection measure. Staff from the Fire Research Organization have also attended, and instrumented, controlled burns undertaken by the Forestry Commission in the New Forest.

PART I

Work carried out by Forestry Commission Research and Development Staff

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FOREST TREE SEED

The functions of the Seed Section have remained unchanged, namely:—

The maintenance of the Register of Seed Sources.

Annual determination and execution of seed collection targets at home, and seed importation.

Seed extraction for England and Wales and the technical supervision of this work in Scotland.

Storage and testing of seed.

Seed supply to the Forestry Commission and to private forestry.

Research into problems connected with the above.

Register of Seed Sources

During the year under review the Seed Officer took over from the Forest Geneticist the responsibility for the maintenance of the Seed Register. The selection of seed sources for registration remains with the Forest Geneticist, the Seed Officer looking after records and exploitation.

During this year the changes in the Seed Register were as follows:—

	Number	*Area (acres)*
New selected stands	6	23·0
New seed orchards	2	2·5
Stands felled	1	1·5
Stands lost by windblow	1	4·0
Stands thinned	4	85·6

Seed Procurement

Seed crops at home were not very good and the only economical collections which could be made were for Scots pine and Corsican pine. Due to the acute shortage of these species in store, the collection was organised on the largest possible scale, including unregistered sources.

Seed imports continued to be necessary, and 10,612 lb were purchased in order to maintain the planting programme. As usual, attention was paid to ensure that the imported seed lots originated from the most suitable climatic regions.

Seed Extraction

Seed extraction consists of a chain of processes; cone drying, seed extraction, de-winging, cleaning and grading. Each individual stage may require a different technique according to species. The volume of processed cones at the seed extraction plants was almost double that of last year. The amounts of seed obtained from these cones are recorded in Table 1. The average seed yield per bushel of cones was for Scots pine 8 oz. and Corsican pine 16 oz.

TABLE 1

SEED PROCURED IN FOREST YEAR 1967

Species	Home-collected (pounds weight)			Imported (pounds weight)			Grand Total
	General	Registered	Total	General	Registered	Total	
Scots pine	1,740	331	2,071	—	—	—	2,071
Corsican pine	138	1,018	1,156	1,000	—	1,000	2,156
Lodgepole pine	8	—	8	6	—	6	14
Norway spruce	—	—	—	1,648	—	1,648	1,648
Sitka spruce	—	—	—	4,993	—	4,993	4,993
Douglas fir	—	—	—	1,002	1,500	2,502	2,502
European larch	—	5	5	—	11	11	16
Japanese larch	—	—	—	—	10	10	10
Hybrid larch	—	1	1	—	—	—	1
Western hemlock	—	—	—	—	—	—	—
Western red cedar	—	2	2	415	—	415	417
Noble fir	—	—	—	—	—	—	—
Grand fir	—	—	—	1	—	1	1
Lawson cypress	—	—	—	—	—	—	—
Other conifers	—	—	—	23	—	23	23
Total conifers	1,886	1,357	3,243	9,088	1,521	10,609	13,852
Oak	—	—	—	—	—	—	—
Beech	—	—	—	—	—	—	—
Other hardwoods	—	—	—	3	—	3	3
Total hardwoods	—	—	—	3	—	3	3
Grand Total	1,886	1,357	3,243	9,091	1,521	10,612	13,855

TABLE 2

CONES COLLECTED AND PROCESSED IN THE EXTRACTION PLANTS

Bushels

Species	England and Wales	Scotland			Total
	Alice Holt	Millbuie, Black Isle	Speymouth	Tulliallan, Devilla Forest	
Scots pine	695	704	2,902	356	4,657
Corsican pine	1,192	—	—	—	1,192
Hybrid larch	—	—	—	—	—
Western red cedar	—	—	—	2	2
Noble fir	13	—	—	—	13
Total	1,900	704	2,902	358	5,864

TABLE 3

SEED STOCK IN HAND

Pounds weight

Species	Amounts held from General and Registered Sources			Total
	General	Registered Stand	Seed Orchard	
Scots pine	2,155	426	54	2,635
Corsican pine	1,152	1,576	—	2,728
Lodgepole pine	4,717	—	—	4,717
Norway spruce	2,484	—	—	2,484
Sitka spruce	5,372	—	—	5,372
Douglas fir	2,523	1,491	—	4,014
European larch	55	866	—	921
Japanese larch	1,716	10	—	1,726
Hybrid larch	78	50	1	129
Western hemlock	481	2	—	483
Western red cedar	434	4	—	438
Noble fir	379	3	—	382
Grand fir	973	—	—	973
Lawson cypress	3	10	—	13
Other conifers	262	—	—	262
Total conifers	22,784	4,438	55	27,277
Oak	—	—	—	—
Beech	89	—	—	89
Other hardwoods	14	—	—	14
Total hardwoods	103	—	—	103
Grand total	22,887	4,438	55	27,380

Seed Storage

The seed is stored in refrigerated chambers at +2°C or −5°C according to species and the storage longevity. The main aim is to have in hand stock for at least three years ahead. Table 3 shows that this has been achieved with the exception of Hybrid larch, seed of which is very difficult to obtain. As regards the composition of the stocks, effort is being continued to increase the proportion of seed from the registered sources.

It should also be mentioned that seed storage services are provided for private forestry and the developing Commonwealth countries.

Seed Testing

The testing of stocks in hand required 835 seed samples, i.e. 79 samples less than last year. On the other hand, the number of samples for research work increased from 272 to 542 due to tests required for the storage investigation on seed dressing (colorant), and seed extraction techniques. Private forestry had supplied only 14 samples and the Commonwealth countries 21. The total number of tests performed was 208 less than last year.

TABLE 4

TESTS PERFORMED ON SEED

Test	Service	Research	Total	Total of previous year
Purity	466	50	516	656
Seed size determination	472	95	567	709
Germination	1,152	536	1,688	1,689
Biochemical (Tetrazolium)	24	13	37	34
X-Ray	5	6	11	18
Cutting	2	138	140	98
Moisture content	500	107	607	601
Cone test	1	36	37	6
Total	2,622	981	3,603	3,811

Seed Supply

The downward trend in the quantity of seed sown in Forestry Commission nurseries, despite a steady planting programme, has continued, and this is the first year that the Commission's seed requirement has been below that for the private forestry sector. During the last ten years the Forestry Commission's improvement in seed economy is quite substantial, some 14,000 lb less conifer seed being used per year as compared with the sowings made ten years ago for a similar planting programme. On the other hand, the fall in consumption in the private forestry sector, which is expanding its rate of planting, is more gradual; their requirements dropped by only 1,500 lb during the same period.

These improvements in seed economy may be expected to have widespread effects. A lesser area of seed sources is required, home collections should meet our seed requirements earlier than expected and, moreover, the nursery area can be substantially reduced.

Research

Due to the heavy load of service work the Seed Section continued to be almost entirely a service section. However, service work as outlined above requires the continuous support of research and as much as possible was carried out.

In connection with seed storage assistance for the Commonwealth countries there is an increasing demand for advice on how to store and test the tropical forest tree seeds. This required an extra effort in research on species which are not involved in our ordinary practice. During the year under review the author undertook a six weeks' assignment to Zambia to advise on the organisation and conduct of seed service and research. Nigeria has similar problems and our assistance may be invited in 1967.

Active co-operation with the International Seed Testing Association was continued. Here the author is a member of the Forest Tree Seed Committee. During the year the programme has been worked out for the next year's work on improvement and standardisation of seed testing methods, which is required for the next revision of the International Seed Testing Rules in 1968.

TABLE 5

SEED SUPPLIED FROM THE CENTRAL SEED STORE FOR SOWING, SPRING 1967

Pounds weight

Species	Amounts Supplied from General and Registered Sources to:							Grand total
	Forestry Commission			Private Forestry			Export Research Gifts, etc.	
	General	Regis-tered	Total	General	Regis-tered	Total		
Scots pine	19·5	74·3	93·8	242	180	422	31·1	546·9
Corsican pine	22·2	218·0	240·2	72	333	405	7·0	652·2
Lodgepole pine								
Coastal	166·0	—	166·0	92	—	92	11	269
Inland	20·4	5·3	25·7	42	—	42	52	119·7
Norway spruce	115·5	13·4	128·9	560	—	560	20·3	709·2
Sitka spruce	627·1	2·8	629·9	509	—	509	25	1,163·9
Douglas fir	153·3	6·2	159·5	388	—	388	9·1	556·6
European larch	9·9	35·2	45·1	171	119	290	4·1	339·2
Japanese larch	149·2	27·2	176·4	639	—	639	4·6	820·0
Hybrid larch	30·6	85·6	116·2	41	—	41	17·3	174·5
Western hemlock	10·0	—	10·0	84	—	84	5·3	99·3
Western red cedar	18·5	10·6	29·1	54	—	54	0·3	83·4
Noble fir	161·7	60·3	222·0	83	—	83	3·8	308·8
Grand fir	123·3	—	123·3	114	—	114	12·8	250·1
Lawson cypress	—	5·6	5·6	14	43	57	0·6	63·2
Other conifers	84·6	—	84·6	10	—	10	30·6	125·2
Total conifers	1,711·8	543·5	2,255·3	3,115	675	3,790	234·9	6,280·2
Oak	353·0	—	353·0	—	—	—	121·0	
Beech	—	—	—	—	—	—	14·0	
Other hardwoods	1·0	—	1·0	2	—	2	4·3	
Total hardwoods	354·0	—	354·0	2	—	2	139·3	495·3
Grand total	2,065·8	543·5	2,609·3	3,117	675	3,792	374·2	6,775·5

Regarding other research activities, the new seed extraction plant continued to provide problems, of which quick and safe cone opening and seed de-winging were the most urgent. The cone drying process was speeded up by improving the hot air circulation in the drum-kiln. The work on the development of a new seed de-winging machine has progressed well, and if everything goes as anticipated this machine should be completed during the next year.

The search for a supplementary colorant dressing to replace the unsatisfactory red lead technique came to its final stages. To avoid increased moisture content of seed, which reduces the storage life, it was necessary to rule out many dyes which require water.

Several "Waxoline" type dyes were examined and an application technique was standardised. The dye is applied in powder form, and oil at the rate of about

2 ml per lb of seed is used as the adhesive material. It was found that the germination was not impaired or retarded after almost one year's storage. The investigation on storage of this seed is being continued. (Field trials with these colorants are reported on page 30.)

Seed dormancy remains an obstacle to speeding up germination in the laboratory and nurseries. Search for suitable means for breaking dormancy was continued, and some promising results were obtained with potassium nitrate pretreatment. Further evidence is being collected.

The Forestry Commission is still very dependent on imported seed for the afforestation programme, and here a quick check of seed origin can be a valuable safeguard against the great waste of money involved in sowing unsuitable provenances. The prospects of making progress are quite good, partly through strict morphological determinations, and partly through physiological tests.

G. M. BUSZEWICZ

PUBLICATIONS BY STAFF MEMBERS

MAXWELL, H. A., and ALDHOUS, J. R. Seed collection in North-west America. *Comm. For. Rev.*, 46(1) 1967 (51–62).

NURSERY INVESTIGATIONS

The scale of work in England and Wales was a little greater than in previous years; besides work at the three main centres (Alice Holt, Hants.; Wareham, Dorset; and Kennington, Oxford) a series of fertiliser experiments was laid out in several Conservancy nurseries. Similar work on fertilisers, with the emphasis on slow-release forms of nitrogen, also formed a large part of the work in Scotland.

Experiments run jointly with the Chemistry and Pathological Departments of Rothamsted Experimental Station, at Kennington and Wareham, formed a large and important part of the programme. (See Part II, pages 133–146, for work directed by Rothamsted.)

Nutritional experiments occupy a major place in our research, but a number of other subjects are receiving considerable attention; in addition officers engaged in nursery research have been actively collaborating with forest management in investigations into the rationalisation of nursery organisation and the improvement of nursery techniques.

Autumn and Spring Sowing

The third and final year's experiments were completed comparing growth and yield of seedlings from sowing in late autumn, with sowings made between February and April, with and without previous stratification. Douglas fir, Western hemlock, Western red cedar and Lawson cypress seed was sown at Elms nursery (Thetford, Norfolk), Alice Holt, Kennington and Wareham.

In most nurseries, seed sown in the autumn produced some of the tallest seedlings but the yield was variable and often small.

Height growth of Douglas fir was consistently best from February sowings of stratified seed, with autumn dry-sown seed producing seedlings nearly as tall. Growth from stratified seed sown in March was also good but not quite so consistent. The highest number of Douglas fir seedlings was consistently produced from stratified seed sown in February. At Thetford, dry seed produced about a third of the number of seedlings produced by stratified seed. Elsewhere dry seed sown in February yielded well. Yields from seed sown in late autumn were variable.

Western hemlock and Lawson cypress responded similarly, the tallest seedlings being from sowings in February or March of stratified seed. Plants from seed sown dry at the same times were nearly as tall. Growth from autumn-sown seed was variable; at Thetford, such seedlings were as tall as the best, but elsewhere they were generally inferior. No treatment consistently gave the highest yield for either species. Seed stratified and sown in March was most consistent, followed by February-sown seed. Autumn-sown seed gave the poorest yields at three nurseries, but at Kennington autumn-sown Lawson cypress seed had the highest yield while autumn-sown Western hemlock also yielded well at the same nursery.

Western red cedar responded similarly in height growth to Western hemlock and Lawson cypress, but the best yields were more consistently high from late sowings, and low from early sowings. Thetford was an exception in that the April sowings virtually failed.

These results support the conclusion drawn from previous experiments in this series that autumn sowing is an unreliable technique. For the species in these experiments, February or March seem to be the best times to sow.

Date and Density of Sowing

At Newton Nursery, Moray, a date and density of sowing experiment is repeated annually and is giving some interesting results. The survival of seedlings is definitely influenced by density of sowing. Table 6 shows that increasing the density above normal reduced the end-of-season survival of Lodgepole pine and Sitka spruce seed, while reducing the density improved the end-of-season survival of the spruce but not of the pine.

TABLE 6

END-OF-SEASON SURVIVAL AS PERCENTAGE OF VIABLE SEED SOWN IN NEWTON 5/63 EXTN. 66

Percentage

Sowing density	Washington Lodgepole pine	Queen Charlotte Is. Sitka spruce
½ × normal	43	61
Normal *	43	50
2 × normal	33	33

*"Normal" sowing density was 1,200 viable seeds per sq yd for Lodgepole pine, and 1,800 viable seeds per sq yd for Sitka spruce.

Also in this experiment, differential frosting of the Sitka spruce was caused by a −5°C frost on 4th September. The percentage of seedlings damaged increased with increasing seedling density as shown in Table 7.

TABLE 7

FROSTING OF ONE-YEAR-OLD SITKA SPRUCE IN NEWTON 5/63 EXTN. 66

No. of seedlings per sq yd	500	1,000	1,500	2,000
Percentage damaged by frost	5	12·5	20	28

Note: The percentages in this table were obtained from a smoothed curve drawn through the plotted experimental results.

Date of Sowing—a Comparison of Two Provenances of Sitka Spruce

Sitka spruce seed from Queen Charlotte Islands, British Columbia, and from the west coast of Washington, U.S.A. was sown at six dates between early March and late May at Kennington and Wareham.

At Wareham, tallest seedlings were obtained from sowings in late March, while yields were highest from the first sowings and decreased with later sowing dates. At Kennington, in contrast, the tallest seedlings were obtained from the earliest sowing (mid-March) and the later sowings gave shorter seedlings; the yield of seedlings at Kennington, however, increased with later sowing.

It is unusual for yields from two nurseries in the same season to show opposite trends in respect of yield from late sowings, and this result suggests that the moderate May rainfall in the more freely draining soil at Wareham may have been insufficient for seedling survival, whereas on the slightly heavier soil at Kennington it was adequate. Washington seedlings grew slightly taller than Queen Charlotte Island seedlings. Different origins gave similar seedling yields.

Seed Dressings

Seed Colorants as Bird Repellents

Norway spruce and Corsican pine seed treated with two "Waxoline" dyes, blue and yellow, applied to seed very lightly dressed in linseed oil and talc, was sown beside seed dressed with red lead (the established treatment) and untreated seed. The sowings were made at Kennington and at Wareham. At both nurseries, birds attacked all plots. The untreated seed, and the seed treated with blue or yellow dye were as heavily attacked as, or more heavily attacked than, the seed treated with red lead.

Alternative Seed Colorants to Red Lead

A dye, auramine yellow, was tested as colorant for seed in place of red lead on a range of species. "Waxoline" yellow was also included in all tests in which Sitka spruce was sown. At Kennington, seed dressings had no effect on the growth or yield of Sitka spruce, Western hemlock or Douglas fir; nor, at Wareham, on Scots pine, Corsican pine or Sitka spruce; nor, at Alice Holt, on Japanese larch or Sitka spruce. At Wareham, European larch seedlings grown from seed dressed with red lead were significantly less vigorous than seedlings from seed dressed with auramine yellow. At Alice Holt, yields of Lodgepole pine and Norway spruce were significantly lower on plots sown with seed dressed with red lead, than on plots sown with seed coloured with auramine yellow.

Trials of New Fertilisers

Several fertilisers, which are either being marketed on a small scale or which are not yet on the market, were included in experiments in the past year. The most widely tested material was "Enmag", a commercial formulation of magnesium ammonium phosphate mixed with either potassium chloride or potassium sulphate. The manufacturing process of this formulation is not yet finally fixed, and batches used from year to year have varied in the ratio of the relatively insoluble magnesium ammonium phosphate, and the uncombined components in which the nitrogen is easily soluble. In the batch manufactured in 1966, only 30 per cent of the nitrogen present was in the insoluble form. This, taken in conjunction with a wet spring season in most nurseries, is thought to be the reason why plants raised with "Enmag" were not, generally, as large as had been anticipated.

Trials in Scotland

Further trials of "Enmag" fertilisers, kindly provided by Scottish Agricultural Industries Ltd., were laid out in five Scottish nurseries in 1966. (See *Report* for 1966, pages 21–23, for information on earlier trials.) As the ratio of nitrogen to phosphate and magnesium in magnesium ammonium phosphate is too low to give a balanced nursery fertiliser, the "Enmag" used in the trials was supplemented by two forms of nitrogen, sulphur-coated urea (ex Tennessee Valley Authority) and urea formaldehyde, both of which it was hoped would also release nitrogen slowly. These supplements were added to "Enmag 144"—which has a lower N/K ratio than the previously used "Enmag 283"—with the aim of achieving a final NPK ration of $1\frac{3}{4}$:1:2 (by comparison "Enmag 283" has an NPK ratio of 1:$1\frac{3}{4}$:$1\frac{1}{4}$).

Various formulations of this "Enmag"/nitrogen mixture were tested. Results were extremely variable between nurseries, and the standard treatment (potassic superphosphate before sowing plus top-dressings of nitrogen and magnesium) was best for Lodgepole pine at two nurseries and worst at one. The only consistent results were that the mixtures with sulphur-coated urea, applied before sowing, produced pine seedlings of the same height as those produced by "Nitro-Chalk" top-dressings, or by "Enmag 283". With spruce, the "Enmag"/sulphur-coated urea mixture produced paler green seedlings than either "Nitro-Chalk" top-dressings or "Enmag 283", indicating that nitrogen was becoming deficient on the plots treated with this fertiliser. There seemed to be little to choose between the urea-formaldehyde/"Enmag 144" combinations, none of which produced above-average seedlings at any site.

The 1965 experiments at Fleet and Inchnacardoch, where "Enmag 283" was compared with potassic superphosphate + "Nitro-Chalk" + Epsom salt, were continued, with no further fertiliser additions at Fleet. At Inchnacardoch, because of suspected potassium deficiency, all plots were sprayed with a potash solution which improved the colour in all cases. "Enmag" produced the largest 2+0 seedlings of Lodgepole pine and Sitka spruce, at both nurseries, when it was top-dressed six weeks after germination, but not where it was applied 14 days before sowing (see Table 8). Note also from this table that at Inchnacardoch top-dressing potassic superphosphate produced smaller plants than when this fertiliser was applied before sowing.

TABLE 8

MEAN HEIGHT OF TWO-YEAR-OLD SEEDLINGS FROM 1965 FERTILISER EXPERIMENTS AT INCHNACARDOCH AND FLEET NURSERIES

inches

Fertilisers applied		Fleet 3/65		Inchnacardoch 1/65	
		Washington Lodgepole pine	Washington Sitka spruce	Alaskan Lodgepole pine	Washington Sitka spruce
"Enmag 283"	B	7·35	4·41	2·83	3·47
	T	7·55	4·60	3·93	3·81
Potassic superphosphate* (Fisons 48)	B	7·17	4·57	3·15	3·55
	T	7·11	4·54	2·76	3·07

* Top-dressings of nitrogen were given in mid-July and mid-August to the potassic superphosphate plots, which also received foliar sprays of magnesium sulphate.

Notes: B = fertiliser applied before sowing.
T = fertiliser top-dressed six weeks after germination.

Isobutylidenediurea (IBDU), which has shown promise in other countries as a slow-release source of nitrogen, was tested at three nurseries in Scotland in 1966, these being Benmore, Argyll; Bush, Midlothian; and Tulliallan Heathland, Clackmannanshire. Two species were sown—Sitka spruce and Douglas fir (see Table 9 for the quantities of nutrients applied in each treatment at the middle rate). The lowest rate supplied 50 per cent, and the highest rate 150 per cent, of the middle rate. IBDU is obtained from Mitsubishi Chemical Industries Ltd., Japan.

TABLE 9

FERTILISERS USED IN IBDU TRIALS IN SCOTLAND

Treatment (Fertiliser Combination)	% N	% P	% K	Application Rate lb element/acre			Time of Application
				N	P	K	
"Enmag 144"	5·75	10·3	19·25	30	53	100	Before sowing
IBDU	32·8	—	—	60	—	—	Before sowing
"Enmag 144."	5·75	10·3	19·25	30	53	100	Before sowing
"Nitroform"	38·8	—	—	60	—	—	Before sowing
"Enmag 144"	5·75	10·3	19·25	30	53	100	Before sowing
"Nitro-Chalk"	21	—	—	60	—	—	Before sowing
"Enmag 144"	5·75	10·3	19·25	30	53	100	Before sowing
"Nitro-Chalk"	21	—	—	60	—	—	As one top-dressing in Mid-August
*Potassic superphosphate (Fisons 48)	—	8·8	16·6	—	53	100	Before sowing
"Nitro-Chalk"	21	—	—	90	—	—	As two top-dressings (each 45-lb. N/acre) in mid-July and mid-August.

* Three foliar sprays of magnesium sulphate applied at 14-day intervals beginning mid-July.
Note: Other treatments received magnesium in the "Enmag".

At only one site (Benmore) and on only one species (Sitka spruce) was there a significant effect of rates on height at the end of one year, and in this case height was increased by increasing the rate. By far the greatest effect on height was the increase from top-dressing nitrogen, as compared with applying it before sowing. At all sites, and with both species, top-dressing was very significantly better than before-sowing applications of any type.

Only with Sitka spruce at Tulliallan was "Nitro-Chalk", applied before sowing, poorer than IBDU and "Nitroform" (urea formaldehyde); at the other two sites there were no differences. At no site was there any difference in height between IBDU and "Nitroform"-treated seedlings.

With seedling numbers, the only significant effects were on Douglas fir at Benmore, where application of "Nitro-Chalk" before sowing markedly reduced seedling numbers compared with IBDU and "Nitroform", which did not differ in their effect.

These results seem to indicate that IBDU and "Nitroform" are less soluble than "Nitro-Chalk", but their nitrogen content is not released slowly enough to last the full growing season. It is not proposed to continue experimentation with these two materials in the North.

As "Enmag 283" should be mostly insoluble in water, apart from its potash content, which is less than 1/5 by weight, it would seem possible to apply it, even on the day of sowing, or as a later top-dressing, without injuring germinating conifer seed. To test this, an experiment was carried out at Tulliallan heathland nursery using Hybrid larch and Douglas fir, where "Enmag 283" at the usual rate of 11 cwt/acre was applied on a series of dates from 7 days before to 28 days after sowing; this included an application immediately before sowing, when it was cultivated into the top four inches of soil, and one immediately after sowing as a top-dressing. The results at the end of the first growing season were that none of the "Enmag" dressings had had a significant effect on numbers of seedlings of either species, and only for Hybrid larch was height significantly affected by treatment. Where "Enmag" was applied 7 days before sowing, the height of the 1+0 Hybrid larch was less than in any of the other treatments, which did not differ significantly from one another. Although this difference was very significant, it only amounted to half an inch, the mean height for the experiment being three inches. The conclusion from this is that "Enmag" can be applied at any time around sowing or germination without injuring germinating seed.

As "Enmag 283" has rather high phosphate and magnesium levels, some toxic effects may be produced by the repeated use of this fertiliser over several years, either as a direct effect of high P and Mg levels in the soil or as an effect on soil reaction from the Mg. To see if this is likely, and to work out possible alternative fertiliser régimes, an experiment was begun in 1966 at Fleet in which rates of up to three times that normally recommended were applied before the following seedlings were lined out: 1+0 Lodgepole pine, 2+0 Western hemlock and 1+0 Grand fir. Table 10 gives the results of this experiment at the end of the first year.

TABLE 10

MEAN HEIGHT OF TRANSPLANTS FROM FLEET EXPERIMENT 5/66

inches

Treatment	Lodgepole pine (1+1)	Western hemlock (2+1)	Grand fir (1+1)
No fertilisers applied	2·0	7·3	3·1
Potassic superphosphate before sowing + 2 top-dressings of "Nitro-Chalk"	2·5	8·9	4·0
Two top-dressings of nitrogen and potash to lines ("Enmag 283" *two years* before lining-out*)	2·7	10·5	4·2
"Enmag 283" before lining-out	3·6	12·2	6·3

*This was a treatment applied to a previous experiment.

The superiority of "Enmag" applied just before lining-out can easily be seen from this table. The differences between rates were not significant for Western hemlock and Grand fir. For Lodgepole pine there was a very significant negative quadratic effect from rates, i.e. the middle rate produced taller seedlings than the lowest or highest rates. This may be an indication of damage occurring at the highest rate, but as there was no significant interaction between rates and fertilisers, the other two fertiliser régimes must have been having a toxic effect as well as "Enmag". It is, in fact, surprising that no visual signs of fertiliser damage appeared as the highest rate of "Enmag" supplied, almost 500 lb P/acre, which is rather more than *ten times* the normal rate. Soil analysis done for this experiment at the end of 1966 indicates that where this rate was applied the level of phosphate in the top four inches of soil was 62·5 mg P/100 g, which is nine times greater than the level thought to be adequate. Magnesium levels have also been greatly increased in the "Enmag"-treated soils and it was thought that this might render the soil less acid. pH determinations did not show any noteworthy differences between "Enmag"-treated soil and that given potassic superphosphate plus "Nitro-Chalk". There was, however, a noticeable reduction in pH value where only "Kay-nitro" was applied, the reduction being from 5·2 (for "Enmag" and potassic superphosphate-treated soils) to 4·6. Plots given no fertiliser treatment had a pH value of 5·0. Another difference between the fertiliser régimes was that the potash content of the soil was much higher at the end of the season where "Enmag" had been applied, than where potassic superphosphate had been applied, even though the rates applied were similar (see Table 11).

TABLE 11

POTASH LEVELS IN THE SOIL FROM FLEET EXPERIMENT 5/66 AT THE END OF 1966

Fertilizer	lb K applied per acre			mg K/100g Soil			
	Rate of Application			Rate of Application			
	1	2	3	0	1	2	3
"Enmag 283"	114	228	343	—	7·7	12·5	16·5
Potassic superphosphate	100	200	300	—	3·6	3·6	3·6
"Kay-nitro"*	75	150	225	—	4·8	6·8	7·6
No fertiliser applied	—	—	—	1·1	—	—	—

* Applied as two top-dressings in summer each at half the rate shown. The other potash sources were applied 14 days before lining-out.

Trials in England and Wales

Fertiliser régimes based on (i) magnesium ammonium phosphate (in the commercial formulation sold as "Enmag"), (ii) potassium metaphosphate and (iii) potassic superphosphate, were compared in replicated experiments on fourteen species spread between seven Conservancy nurseries. Most species were included both as seedlings and transplants in two or three nurseries.

Details of the fertiliser régime are given in Table 12. It should be noted that both potassium metaphosphate, and magnesium ammonium phosphate, contain two or more nutrients in a fixed ratio, reflecting the molecular composition of these compounds, and comparison of such fertilisers in experiments is inevitably confounded with the comparison of rates of nutrient supplied. In these experiments, régimes based on each of the selected compounds were compared, and in examining the results, consideration has to be given not only to which were the best régimes, but also to the question whether the régimes selected were the best way of using each of the compounds.

The results of the experiments showed that by the end of the growing season, Norway spruce, Lodgepole pine and European larch in seedbeds grew significantly taller under the "Enmag" régime in both nursery experiments in which each was sown, while Sitka spruce and Douglas fir grew better in one out of the two nurseries in which they were sown. The other pines and larches, Western hemlock and Red cedar did not respond differentially to any régime. European larch, Lawson cypress and Noble fir seedlings each grew best in one nursery under the potassium metaphosphate régime. In transplants, out of 30 experiments, there were significant differences at the end of the season only in three instances, one lot of Norway spruce and one lot of hemlock having responded better to "Enmag", and one lot of Grand fir raised on potassic superphosphate being inferior to those on either of the other treatments. In the early part of the growing season, transplants on "Enmag" plots had made a better start than those on other régimes, but this early advantage was subsequently lost.

From these experiments, there appears to be an advantage using "Enmag" on seedbeds at least for certain species, but a less clear advantage for transplants. 1966 was characterised by some heavy rainfall in April and in July, so that risks of damage by scorch from fertilisers applied in the spring, or top-dressed, were slight: evidence has yet to be obtained on the response to slow-acting fertilisers in a dry spring and early summer.

TABLE 12

FERTILISER REGIMES

"ENMAG" EXPERIMENTS IN ENGLAND AND WALES

lb per acre

Régime	Nutrients Supplied											
	Incorporated in soil before sowing or lining out				Top dressing				Total			
	N	P	K	Mg	N	P	K	Mg	N	P	K	Mg
(i) Magnesium ammonium phosphate "Enmag"	72	132	92	114	68	—	—	—	140	132	92	114
(ii) Potassium metaphosphate + Epsom salts	—	69	84	22	138	—	—	—	138	69	84	22
(iii) Potassium superphosphate + Epsom salts (Fisons '48)	—	48	93	22	138	—	69	—	138	48	161	22

Damage to Transplants by Fertilisers

Two forms of commercial fertiliser "Enmag" containing magnesium ammonium phosphate, for use on transplants, were compared with potassic superphosphate and potassium metaphosphate at Kennington, Wareham and Alice Holt, and also at Crumbland nursery in Tintern Forest (Monmouthshire). One of the fertilisers based on magnesium ammonium phosphate included potassium chloride, the other potassium sulphate: the two forms were included to test the possibility that the formulation with chloride might give rise to more damage on newly transplanted transplants that that containing sulphate.

Although a wide range of the common conifers were included in the trial, the spring (particularly April) was so wet that no damage was observed on any species.

Late-Season Top-Dressings on Seedbeds

Previous work (Benzian 1966, Benzian *et al.*, 1966) has shown that late top-dressings applied to seedbeds of Sitka spruce, using fertilisers containing N and K, could influence the concentration of these nutrients in the seedlings without increasing their size.

Seedbeds of nine conifer species raised conventionally were given top-dressings of 48 lb of N, or 96 lb K, per acre, or both, in September 1966. Table 13 summarises the results of foliage analysis of seedlings lifted in early November.

Most species in these experiments have taken up nitrogen from the late-season top-dressing. Evidence for uptake of K was less pronounced. The most outstanding difference in content of potassium in foliage was with Norway spruce at Alice Holt, where plants without late-season top-dressings of K had only about half as much potassium in the foliage as plants given a late-season K top-dressing. Differences in Sitka spruce were small; in no instance were seedlings as impoverished in K as those reported by Benzian for some seedlings from Wareham. This difference has to be attributed to variations in site history, the experiments described here being on land which formerly for many years had been given liberal application of composts. Often more potassium was found in foliage where only K had been applied, compared with plants given both N and K.

The late nitrogen top-dressing killed a few spruce and hemlock seedlings shortly after application. This was associated with damp foliage just above soil level in fully stocked seedbeds.

Long-term Maintenance of Fertility

The long-term fertility trial at Teindland nursery was continued into its seventeenth year in 1966. The early part of the year was very dry, which delayed germination, and this was followed by an exceptionally wet summer (more than six inches of rain fell in June). Although the seed origins used were similar to 1965 (Washington Coast Sitka spruce and Lodgepole pine), the germination and height of the treated Sitka spruce was better than in 1965, but of the Lodgepole pine was poorer. However, the Sitka spruce on plots which received no manures was smaller in 1966 than in 1965 (see Table 14). There was therefore a greater difference between treated and untreated spruce seedlings in 1966. The top-dressings in 1966 were done using "Kay-nitro", which supplies potash as well as the usual nitrogen. The highest rate of this produced larger pine seedlings, but smaller spruce seedlings, than where hopwaste only was applied. Hopwaste plus inorganic fertilisers continues to produce the largest seedlings of both species. A very severe early frost (−5°C) during the night of 4th September 1966, caused considerable damage to the treated spruce in this experiment (25–30 per cent damaged), but did not injure any seedlings in the untreated plots. While this might be a nutritional effect, it is also probable that the treated beds represent a sward—a good radiating surface with insulation from the ground, whereas the small untreated seedlings are to a greater extent in the microclimate of the soil surface. The conclusion from this is not that we should grow smaller plants, but that either the nutrition of the treated seedlings is out-of-balance, or a more northerly provenance of seed should be used.

TABLE 13

EFFECT OF N AND K TOP-DRESSINGS IN SEPTEMBER ON N AND K IN SEEDLING FOLIAGE

Nursery	Species	Treatment	Foliage Analysis (% oven-dry weight)	
			N	K
Kennington	Sitka spruce	O	1·8	1·03
		N	2·4	0·92
		K	2·0	1·03
		NK	2·5	0·97
Wareham	Sitka spruce	O	2·0	0·94
		N	2·3	0·96
		K	2·0	1·12
		NK	2·4	1·20
Alice Holt	Sitka spruce	O	1·9	0·85
		N	2·3	0·73
		K	2·0	1·08
		NK	2·3	1·03
	Lodgepole pine	O	2·2	0·62
		N	2·1	0·78
		K	2·0	0·90
		NK	2·2	0·85
	Norway spruce	O	1·9	0·50
		N	2·5	0·56
		K	1·8	1·03
		NK	2·1	0·86
	Japanese larch	O	1·5	0·34
		N	1·6	0·46
		K	1·1	0·53
		NK	1·5	0·62
Kennington	Western hemlock	O	2·0	0·79
		N	2·3	0·78
		K	1·9	0·90
		NK	2·4	0·75
	Douglas fir	O	1·8	0·97
		N	2·0	0·82
		K	1·8	0·94
		NK	2·2	0·81
Wareham	Corsican pine	O	2·5	0·86
		N	2·6	0·84
		K	2·5	0·84
		NK	2·6	1·02
	Scots pine	O	2·3	0·62
		N	2·6	0·61
		K	2·3	0·64
		NK	2·7	0·78
	European larch	O	2·2	0·80
		N	2·5	1·06
		K	2·2	1·13
		NK	2·5	1·05

TABLE 14

MEAN HEIGHT OF ONE-YEAR-OLD SEEDLINGS FROM THE TEINDLAND LONG-TERM FERTILITY TRIAL—AT THE END OF 1966

inches

Treatments			Species	
Basal	Top-Dressings lb/acre		Lodgepole pine	Sitka spruce
	N	K		
None	0	0	1·15	0·87
PK	45	37	1·52	1·28
PK	90	75	1·61	1·92
PK	135	112	1·70	1·70
PK	180	150	1·90	1·97
Hop waste	0	0	1·83	2·24
PK plus hopwaste	90	75	2·22	2·29

Simazine on Transplants

Experiments on the long-term effects of simazine, applied annually at 1, 2, 4, or 8 lb active ingredient per acre to newly-lined-out transplants, continued into the fifth year. At Wareham, none of the seven conifer species was affected in height growth or survival by simazine at any of these rates. The species were Corsican pine, Scots pine, Lodgepole pine, Japanese larch, Sitka spruce, Western hemlock and Lawson cypress. At Kennington survival rates and growth of Sitka spruce and Douglas fir were much reduced on plots given 4 and 8 lb per acre; while beech, Scots pine, Lodgepole pine and Corsican pine all showed some symptoms of damage on plots treated at the higher (above-standard) rates.

Weed control was good on all treated plots except those at the lowest rate of 1 lb per acre.

New Herbicides on Transplants

Two newly introduced herbicides manufactured by Messrs. Dupont were sprayed onto Douglas fir, Norway spruce, Corsican pine and Western hemlock transplants at Bramshill, Hants.

Both materials, "Sinbar" (3-tert-butyl-5-chloro-6-methyl uracil) and lenacil, were applied overall at 0·5 at 4·0 lb in 150 gallons water per acre, using a "van der Weij" sprayer which applied a logarithmically decreasing concentration of active ingredient in a uniform volume of spray solution.

Lenacil failed to control weeds at the rates tested. "Sinbar" gave some weed control down to 1·5 to 1·0 lb per acre, but at these rates the hemlock and Douglas fir sustained scorch which persisted to the end of the growing season. Corsican pine was resistant to the herbicide at up to a little over 2 lb, while Norway spruce was intermediate in resistance between Corsican pine and the other two species.

Control of Cutworms (Larvae of the Noctuid moth *Agrotis segetum* Schiff.)

At Kennington nursery, DDT at 2 and 4 lb per acre, BHC at 0·5 and 1 lb per acre, carbaryl at 1·5 and 3 lb per acre and aldrin at 3 lb per acre, were each applied to plots in the second half of July and to half the number of plots again in mid-August. Each plot was isolated by a polythene screen six inches tall and cutworm activity, and in particular the number of seedlings severed at ground level by cutworms, was recorded. The aim of the experiment was to find alternatives to aldrin for cutworm control.

While the germination of seedlings in the experiment was less than desirable, least damage occurred on plots sprayed with aldrin, BHC at 1 lb (single or repeated spray) and carbaryl at 3 lb (repeated spray). Control plots had more damage than any treated plots except those sprayed with carbaryl at 1½ lb (single or repeated spray).

The results agree with those obtained in the similar experiment in 1965 when also aldrin gave the best control, with the better treatments using carbaryl, DDT and BHC only slightly inferior.

Production and Use of Tubed Seedlings

Preliminary work has been carried out on the initiation of projects on the raising and subsequent forest use of conifer seedlings grown in short plastic tubes. This technique, which is a modification of the container-planting techniques well known in semi-arid regions, has in recent years been the subject of considerable research in Canada and may well have applications in temperate forestry practice. Extension of the planting season, increased speed of planting, and easier and more effective matching of plant requirements against nursery stock held, are among the possible advantages from its use.

In the early stages, the results of the investigations carried out in Canada will be used as a basis from which to develop satisfactory methods for use in British conditions. During the first year's work, it is intended to investigate the influence on seedling growth of the material used for filling tubes, the depth of seed cover applied after sowing, and the dimensions of the tubes employed. Survival and growth of tubed seedlings planted in the forest will also be studied.

Nursery Demonstrations

Demonstrations of the effect of soil pH, nutrient deficiencies, seedbed sterilization, etc. on seedlings were continued at Bush and Newton nurseries (near Edinburgh and Elgin respectively) in 1966 for the benefit of visitors. It is intended to discontinue the Newton demonstrations from 1967 onwards as the number of visitors there does not now justify the provision of special demonstrations.

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AFFORESTATION OF DIFFICULT SITES

Planting on High and Exposed Sites in the North

In last year's *Report* the need for a new series of trial plantations was described, and in the year under review four new sites were planted at Torrachilty (Ross-shire), Balblair and Strathy (Sutherland). The Balblair experiment has used an above-standard basal level of nutrition on three provenances of Lodgepole pine and two of Sitka spruce, pure and in mixture, on the assumption that a well-nourished plant can better withstand the effects of exposure. An adjacent experiment compares a range of nutritional inputs, and top-dressing of the trial plantation will depend on the latter's results. Acquisition of three other sites is proceeding in areas where existing Forestry Commission holdings are not representative of extensive, doubtfully plantable ground. In addition advice has been given, and plants of appropriate provenances supplied to assist Conservancy trial plantations.

Many of the trial plantations established in the early 1950's have provided evidence on the basis of which Conservancy staff have changed local plantability standards, and hence the trial plots are now surrounded by extensive new plantations. It has been decided, where appropriate, to use these trial plots to investigate their response to high nutrition, especially the effects on spruce of repeated nitrogen applications. As future tree stability is of interest, modern drainage systems will be superimposed on those trial plantations which justify the expense.

Plantations at High Elevations in Wales

The studies have continued for the fourth year at the five sites in mid-Wales. Most of the new work has been concentrated at Hafren Forest (Montgomeryshire), where small trials with pre-potted plants and individual shelter have given some encouraging indications. A detailed survey of the sites will be carried out in the coming year, and the results to date written up.

Tatter flags and anemometers have again indicated the extreme conditions that prevail on these sites, but nevertheless Sitka spruce is growing surprisingly well at elevations above 2,000 ft at the two inland sites—Radnor and Mynydd Ddu (Brecon).

Industrial Sites

The roots of five-year-old trees growing on pulverised fuel ash at Connah's Quay, Flintshire, were examined during the winter. Most of the trees, including False acacia, *Robinia pseudoacacia*, and a balsam poplar, *Populus trichocarpa*, had developed hardly any fresh root system since planting, but a few vigorous alder, *Alnus glutinosa*, were found to have lateral roots extending up to 12 ft from the stem. None of the roots had penetrated the compacted ash layer 9 to 12 in. below the surface, but some roots of alder that had found their way through fractures made in the layer at planting had continued to grow successfully beneath it. On this evidence, alder, together with broom—established on the site by direct sowing—appear to be very tolerant of this material.

Members of the staff of Greater London Council visited the Research Station during the winter to discuss tree planting on filled gravel pits. Though a number of species are able to grow quite well on the usual types of filling, special problems may arise at some pits to hinder survival and vigour.

Liaison has been maintained with the Livingston New Town Development Corporation and the associated County Councils of West Lothian and Midlothian. A small comparison of five species with and without pot-planting, will be planted over three seasons (starting in 1967), on typical shale heaps.

Estimation of Exposure by Flag-tatter

The first year's results of an extensive correlation of flag tatter with absolute elevation, exposure assessed by Abney level, and estimated exposure, has been analysed, and exposure contour maps have been drawn. This study is based on 43 flags distributed over approximately 200 acres on the Whitrope Beat of Wauchope Forest (Roxburghshire). At two flag sites, anemometers were erected beside the flags, and a comparison is now being made of run-of-wind with flag tatter.

The run-of-wind recorded by anemometers alongside flags at a number of sites in other parts of Scotland is also being studied. Preliminary examination indicates a rather loose relationship between tatter and total wind run, and this is not altogether unexpected, since there is some evidence that the rate of tatter increases non-linearly with higher wind speeds. Since the flags are always used for comparison with other flags and with existing tree growth, this is not necessarily a disadvantage.

After some serious delays in mass production, new and cheaper patterns of flag and flag mount have been evolved and tested alongside the older patterns. The flag itself is identical to the old one, but is sewn onto a thinner high tensile steel wire, which has an eye at each end at right angles to the wire. The new mount consists of a ¼ in. high-tensile steel wire rod which is secured to a strong fence post by staples. On this rod is a hard polythene sleeve supporting the actual bearing, which is a Tufnol washer. The eyes of the flag wire are slipped over the vertical mount and it is prevented from blowing off by a small plastic knob screwed onto the top. These new-pattern flags are now in use in north and west Scotland to throw light on the upper planting limit, and it is expected that they will shortly be extended to other parts of Scotland and northern England.

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CULTIVATION AND DRAINAGE

Cultivation of Heathland

Experiment 81 planted in 1952 at Teindland Forest (Moray) has now been assessed after fifteen growing seasons. The early promise reported after ten years growth (*Report* for 1964, page 159) has been maintained. The extent of the beneficial results of increased cultivation are so marked that practical economic gains might be expected from a wider use of complete ploughing in suitable localities. The main results at fifteen years are summarised in Table 15.

TABLE 15

TEINDLAND EXPERIMENT 81, PLANTED 1952

CULTIVATION, HEIGHT GROWTH AND ESTIMATED YIELD CLASS

Yield class hoppus ft
Heights in ft

Cultivation Treatment	Lodgepole pine		Scots pine		Sitka spruce	
	Dominant Height	Estimated Yield Class	Dominant Height	Estimated Yield Class	Mean Height	Estimated Yield Class
A. Deep, spaced furrow ploughing	16·10	82	12·60	71	3·53	20
B. Tine, spaced furrow ploughing	16·93	88	12·40	70	10·23	78
C. Shallow, complete ploughing	19·00	100	13·90	79	14·60	112
D. Shallow, complete ploughing + sub-soiling at 9 ft intervals	18·50	94	14·37	80	11·30	88
E. Deep, complete ploughing	20·30	105	15·27	88	16·90	130
F. Deep, complete ploughing + surface rotovation	19·03	101	15·03	85	15·50	120
Standard Error (±)	0·55	—	0·41	—	1·70	—

The estimates of yield class given in Table 15 are based upon the height/age relationship and are of course less reliable at this age than estimates made in the later life of a stand. Estimates have, however, been made on the basis of measurements at ten years and thirteen years, and these agree closely with those given. It should be explained that these estimates are almost certainly conservative, being based on the heights measured, which are all less than Top Height, particularly for Sitka spruce. The results have a high level of statistical precision due to the excellent design of this experiment, and analysis of the results after transformation to Yield Class values shows no serious loss of precision.

The assessment after twenty years' growth of three further cultivation experiments has been completed. These experiments were established by field staff in

North and East Scotland, and are located at Millbuie Forest (Inverness-shire), Clashindarroch Forest (Aberdeenshire) and Fetteresso Forest (Kincardineshire). The results after ten years' growth were presented and discussed in Forestry Commission Bulletin No. 32, *Afforestation of Upland Heaths*, 1960, page 49. The results after twenty years' growth are presented in Table 16.

These experiments were all planted with alternate row mixtures of Scots pine and Sitka spruce after similar cultivation treatments. Manuring comparisons showed no significant response to the addition of phosphates.

TABLE 16

PLOUGHING EXPERIMENTS AT MILLBUIE, CLASHINDARROCH AND FETTERESSO, AFTER TWENTY YEARS' GROWTH

Yield class hoppus ft
Height in ft

Ploughing Treatments and Species	Millbuie 11 P.46 Ht.	Millbuie 11 P.46 Y.C.	Clashindarroch 36 P.47 Ht.	Clashindarroch 36 P.47 Y.C.	Fetteresso 1 P.46 Ht.	Fetteresso 1 P.46 Y.C.	Mean of* 3 Sites Ht.	Mean of* 3 Sites Y.C.
Deep, spaced furrow								
Scots pine	11·5	46	15·3	61	13·6	54	13·09	52
Sitka spruce	1·9	—	16·5	81	14·4	65	9·83	— †
Shallow, complete								
Scots pine	11·4	46	16·3	65	15·8	63	14·14	56
Sitka spruce	2·9	— †	17·6	86	18·2	90	11·97	— †
Deep, complete								
Scots pine	12·4	50	16·7	67	17·1	68	15·12	60
Sitka spruce	3·3	—†	18·4	91	21·1	108	13·45	— †
Standard error (±)	—		—		—		Scots pine 0·60 Sitka spruce 0·90	

* There are two replications at Millbuie and Fetteresso and one at Clashindarroch.
† Yield Class values for Sitka spruce not determined, species still partly checked at Millbuie.

Analysis of these results confirms that the difference between the sites is highly significant, but despite the overriding effect of this factor, the treatment differences remain significant at the 10 per cent level.

The results given in Tables 15 and 16 will be presented and discussed in greater detail in a Research and Development Paper now in course of preparation, but three points of practical importance are suggested by the data:—

That differences between sites which are often collectively described as "Upland Heath", are of crucial importance in the choice of the best cultivation treatment and in the choice of species, if the best return from the site is to be secured.

That the response to additional cultivation on certain heathland sites may be of sufficient magnitude to render the extra investment profitable.

That there is a good chance for the production of healthy crops of Sitka spruce on *certain* heathland sites, provided the site preparation is adequate.

Following upon these encouraging results, a further series of experiments is planned to investigate the response level which can be obtained by more advanced cultivation techniques, and to attempt to clarify the nature of the limiting factors on various sites.

Drainage

Surface Water Gleys

Work was completed in the new experiment at Halwill Forest (Devon) where drains have been introduced into a six-year-old crop of Sitka spruce. Boreholes were installed in the autumn prior to drainage, and these have indicated that the site is badly in need of improved drainage. During the period November 1965 to May 1966 water levels never fell more than 11 in. below the surface, and for most of the time the average level was between 5 and 7 in. below the surface. During the summer of 1966 the soil only dried out during the months of June and July.

The three-year-old experiment at Orlestone (Kent) increases in interest steadily. The boreholes indicate a continued steady improvement in conditions, with the 3 ft deep drains now giving the lowest levels in boreholes in all drain spacings. Last year the 3 ft deep drains were only outstanding at the closest spacing. The Red alder, *Alnus rubra*, which was planted in mixture with the Douglas fir, has grown extremely well. In the four-year-old experiment at Halwill (Devon) there is now a strong indication that the Sitka spruce in mixture with Red alder is growing faster than in pure crop.

Following the progress of soil survey work in Yorkshire, it has become clear that many of the forest areas have large tracts of gleyed soils. This is particularly marked in areas overlying Estuarine clay deposits, and much interest in improved drainage is now being shown by local staff. In response to this interest a number of advisory visits have been carried out and new experiments are planned in the near future.

Work continues in the three-year-old experiment at Rosedale, Allerston Forest, Yorkshire, where Dr. Read of Sheffield University has been carrying out detailed soil moisture studies. A note of progress to date appears in Part II of this *Report* (pages 162 to 164).

Peaty Gleys

The new experiment at Hafren Forest (Montgomershire) was completed during the year. This crop was sixteen years old at the time of drainage, and growth to date has been poor. The site is extremely wet, and great improvements in growth are expected.

The survey and layout of the new experiment at Clocaenog Forest (Denbighshire) has also been completed. This crop is twenty-six years old, but growth is extremely variable. A substantial portion is in check, and most of the crop is only 20 ft tall.

The establishment of the large drainage experiment in a 30-ft tall crop of Sitka spruce at Kershope Forest (Cumberland) continues. During the year approximately 1,000 chains of rackway were cut, and drains of 2 ft to 3½ ft depth prepared by back-acting digger mounted on a Long-wide County tractor. Costs for these operations, inclusive of local overheads were:—

Felling of Racks	£2 2s. 0d. per chain
Drain digging	£3 7s. 0d. per chain (Average depth 30 in. approx.)
Total	£5 9s. 0d. per chain

At this level of cost, the operation is almost certainly uneconomic for field application, but if a significant improvement in crop stability is achieved and the felling is partly costed to production, it may prove to be of value as a means of spreading the period over which large areas of unstable forest can be harvested. It should also be appreciated that the cost of drainage on such sites would be shared by the successor crop as well as the existing crop.

An extensive series of boreholes has been maintained on this site since October 1965, with a view to observing the changes in soil moisture status following drainage. Hand-prepared contour maps had suggested that a reliable picture of the water status of the site could be derived from the borehole data, and a computer programme has been prepared for the production of print-out maps direct from the data. Trial runs with this programme have been very successful. From the data it appears that the mean water table on this site lies only nine to ten in. below the surface for most of the year, but fluctuations in the level of the water table are very rapid in response to rainfall. With some 60 in. of rain fairly uniformly distributed throughout the year, prolonged periods of low soil water levels cannot be expected, and tree rooting is therefore almost entirely superficial. The maximum and minimum water levels recorded were 4·4 in. below the surface in June 1966 and 17·2 in. below the surface in July 1966.

Contour Ploughing

A particularly acute form of drainage problem encountered in some of the Border forests arises from the practice of contour ploughing. During the early fifties, much of the ploughing in this area was carried out on contour or semi-contour alignments, with no proper provision for drainage from the plough furrows. The effect of such ploughing is to pond water behind every plough ridge and to present a barrier to surface run-off. The effects on tree growth are two-fold, first to reduce the effective rooting zone available and hence to reduce tree vigour, second to promote instability by reducing the extent of rooting and by maintaining the surface horizons in a wet and plastic state for most of the year.

Sites which have been treated in this way present a particularly difficult problem for amelioration at reasonable cost, and the expected early onset of windthrow reduces the time available for any ameliorative treatment to have a significant effect. Work upon this problem is to be treated as a matter of urgency.

Deep Peat

No new experiments have been laid down in the South. The large experiment at Clocaenog (Denbighshire) is already proving interesting with both Sitka spruce and Lodgepole pine making good growth. The Glenamoy tunnel plough treatments have proved disappointing, largely because of the difficulty of maintaining an adequate outfall from the tunnels into the ploughed cross drains.

Work upon the large experiment at Flanders Moss, Achray Forest (Stirlingshire) continues. No satisfactory mechanical method has as yet been found for drain deepening once the surface of the bog has been cut over by ploughing for cultivation and initial drainage. Until suitable maintenance equipment is developed, it is clear that initial drainage must be as deep and as intensive as posssible, as it may be many years before improvement can be carried out except by hand labour.

A number of new sites have been selected in North Scotland for further experiments to determine the optimum drainage intensity for various types of deep peat. Work in this field is of necessity closely linked to the rate of development of new mechanical equipment.

The evidence examined to date suggests that the present best field practice is likely to be insufficient for long-term stability, particularly on exposed sites. The lack of significant growth response to increased drainage intensity in older experiments suggests that the drainage has never been sufficiently intensive to provide materially greater volumes of aerated peat for root exploitation.

That trees can respond to differences in the depth of the water table in deep peat is confirmed by the joint experiment with the Macaulay Institute at Inchnacardoch Forest (Inverness-shire). Results after four years' growth for Lodgepole pine appear in Table 17.

TABLE 17

DRAINAGE OF DEEP PEAT AT INCHNACARDOCH FOREST

Water Table Level relative to ground surface (cm)	Tree Height (ft)	Current Shoot Length (ft)	Remarks
0	0·62	0·06	Survival 65%, 1-year needle retention, colour yellow or pale green.
10	1·62	0·44	Progressive improvement towards:–
20	1·75	0·49	
30	2·11	0·65	
50	2·77	0·91	Survival 100%, 3-year needle retention, foliage dark green.

For demonstration purposes a deep peat site at Eddleston Water Forest (Peebles-shire) has been reserved for Research use and a range of experiment plots has been laid down covering the history of peatland research to date. The site is within 12 miles of Edinburgh and should be of value to visitors to the Research station and to students from Edinburgh University.

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NUTRITION OF FOREST CROPS

Manuring of Young Crops on Peat Soils

Several types of rock phosphate of differing solubilities (in citric acid) are available, and as they either have a higher total phosphate content or are coarser in grain size, they may be more suitable than the one in common use, i.e. Gafsa rock phosphate (Ground mineral phosphate or G.M.P.). A series of long-term trials is being laid down and the first one at Shin Forest, Sutherland, compares the rock phosphates shown in Table 18.

TABLE 18

ROCK PHOSPHATES USED IN EXPERIMENT 8 P.66, SHIN FOREST, SUTHERLAND

Source of rock	Per cent phosphorus of rock	
	Total P	Citric-soluble P*
Gafsa, Tunisia, N. Africa	13	4·75
Nauru Island, S.W. Pacific	17	4·5
Kola Peninsula, N.W. Russia	17	1·0

* Phosphorus extracted by 2 per cent citric acid (Wagner Test)

Ground and unground Gafsa phosphate rock were included in this experiment as the unground material is easier to handle and distribute in the forest, and can also be dropped from aircraft, but its phosphate may be less available because of its coarseness—it has the texture of fine sand.

Planting in this experiment was done in April/May 1966 using Lodgepole pine, but the phosphate treatments were not applied until the first week of August 1966. Although the phosphates were not applied until 2–3 months after planting, the ground Gafsa phosphate reduced survival of the trees where it was applied immediately around each tree (see Table 19 for the results). The linear reduction in survival was statistically very significant.

TABLE 19

FIRST-YEAR SURVIVAL OF LODGEPOLE PINE IN SHIN FOREST, SUTHERLAND, EXPERIMENT 8 P.66 TREATED WITH GROUND GAFSA ROCK PHOSPHATE

Rate of application (oz/tree)	1	2	3½	7
Survival (per cent)	98·5	95	94	89

Neither ground Gafsa phosphate *broadcast* at similar rates per acre, nor any of the other types of rock phosphate, whether broadcast or spot applied, reduced survival. This reduction in survival by ground Gafsa where spot applied is even more surprising, as at the two higher rates care was taken to throw it around the tree and not on top of it or at the root collar. Spot application of G.M.P. should not be done by placing the fertiliser at the root collar; instead, it should be scattered in a ring around each plant or thrown at it from a distance which distributes the fertiliser over a larger area, but the latter method is only possible under relatively calm conditions.

It may be that broadcasting phosphate on peat is better, or at least just as effective, as spot application, and several methods of broadcasting by machine before ploughing are being tried out on a field scale. By broadcasting *before ploughing*, no phosphate is lost in furrows and a double dose is obtained under the ridge.

The experiment at Arecleoch Forest, Ayrshire, comparing potassium metaphosphate and potassic superphosphate mentioned in the *Report* for 1966 (page 32), has been repeated at Selm Muir Forest, Midlothian, where similar results are being obtained. The Selm Muir site is also deep acid peat. The Arecleoch Experiment is now showing the best growth with the middle rate of potassic superphosphate, i.e. 4½ cwt Fisons "48" per acre (providing 44 lb P and 84 lb K per acre), and the worst with the lowest rate of potassium metaphosphate. This result is what was expected from foliage analyses in previous years.

On Scottish peats, trees treated with potassium metaphosphate generally have lower nitrogen concentrations in the needles than trees given corresponding amounts of P and K in soluble form, and usually look poorer. The first of these statements seems to be true for the only existing comparison in Wales, though, with the generally higher foliage nitrogen concentrations found there, this may not be important. If it became generally available, potassium metaphosphate would be very convenient for top-dressing peat plantations, so we need to find out the reasons for this nitrogen effect.

At Racks Moss, a large, raised, lowland bog in Mabie Forest, Dumfries-shire, an experiment was laid down in 1964 comparing rates of potassic superphosphate with ground Gafsa phosphate on Lodgepole pine, all broadcast at planting. Table 20 shows some of the results from this experiment and illustrates the following points. Potash, in addition to phosphate, at planting increased mean height by almost 6 in. by the end of the third growing season. This peat is extremely low in total potassium, and potassium deficiency symptoms were obvious in the G.M.P. plots early in the third growing season. This diagnosis has been confirmed by foliage analysis which shows lower potassium concentrations in foliage from the G.M.P. plots, than in foliage from plots receiving potassic superphosphate (Fisons "48"). In addition to being taller than trees in the G.M.P. plots, the trees which received potassic superphosphate had longer needles and thicker stems as judged visually in the experiment. These results suggest that on peats such as this, potash in addition to phosphate may well be necessary at planting.

Experiments on season of application of PK and NPK fertilisers, and on types of synthetic nitrogen fertilisers, were established on deep acid peat at Eddleston Water Forest, Midlothian, during 1966.

We do not know, on potassium deficient peats, if potassium fertilisers should be applied at planting, or whether they can be delayed until symptoms show without serious setback to the trees. An experiment was begun in 1964 at Rheidol Forest, Cardiganshire, comparing potash fertilisers applied at planting with no potassium, and with provision for top-dressing when necessary. After two years the potassium concentration in the needles of the untreated trees averaged 0·36 per cent; in the treated ones it averaged 0·87 per cent. The height differences are not quite statistically significant, but the untreated plots show up clearly by their yellow colour. The plots set aside for top-dressing will be treated in 1967.

TABLE 20

FOLIAGE ANALYSIS AND MEAN HEIGHT OF LODGEPOLE PINE IN MABIE FOREST, DUMFRIESSHIRE, EXPERIMENT 5 P.64

Treatment	lb nutrient applied per acre		Needle nutrient concentration (% oven-dry wt.)			Height at 3 years (ft)
	P	K	N	P	K	
3 cwt G.M.P. per acre	44	0	1·40	0·17	0·21	2·90
¼ oz Fisons 48 per plant*	6	11	1·44	0·10	0·27	3·08
2½ oz Fisons 48 per plant†	23	44	1·28	0·13	0·34	3·35
4½ cwt Fisons 48 per acre	44	84	1·50	0·16	0·50	3·36
9 cwt Fisons 48 per acre	88	168	1·50	0·20	0·75	3·08‡

Notes:

* Broadcast around the plant to a distance of 8 inches

† Broadcast around the plant to a distance of 15 inches

‡ Low mean height in this treatment is due to above-average beating-up necessitated by deaths due to fertiliser scorch.

It was remarked in the *Report* last year that the nitrogen concentrations in the needles of Sitka spruce grown on Welsh peats seemed to be much higher than on Scottish peats (and are indeed often very high by any standard), and the same observations have been made this year. For example, in the experiment at Rheidol described above, the concentration ranged from 1·8 to 2·4 per cent; on a deep peat at Clocaenog, Denbighshire, from 2·2 to 2·6 per cent; at Tarenig Forest, Cardiganshire, from 1·7 to 2·1 per cent, and another experiment at the same forest, but where the fertiliser is potassium metaphosphate, from 1·2 to 1·7 per cent. All trees have been given phosphate.

No useful speculation about the reasons for these high values and the contrast with Scottish results is possible without further basic information, mainly in the first place about the composition of the peat; unfortunately it has not yet been possible to arrange for chemical analysis of Welsh peats.

Manuring of Pole-stage Crops

Foliage analysis data are available from three of the current pole-stage manuring experiments in Scotland, all on Scots pine. In these trials two levels were used of a NPK fertiliser (Scottish Agricultural Industries No. 6) supplying 120 lb N, 50 lb P and 100 lb K per acre at Rate 1 and twice these quantities at Rate 2. The sites in question are at Speymouth Forest, Moray; Inchnacardoch Forest, Inverness-shire; and Devilla Forest, Clackmannanshire. Nitrogen is the only nutrient for which the concentration has increased significantly at all sites, and as needle weight has also been increased significantly at all sites, an interim conclusion may be that on medium or poor Scots pine sites in Scotland we may expect to obtain growth responses from an application of nitrogen. The only experiment from which we have growth data so far is Speymouth, where there has been no obvious increase in height since the experiment began three years ago, but basal area has been significantly improved. Converting the basal area assessment data into approximate volume gives volume increments of 55 hoppus ft and 63 hoppus ft per acre over 3 years for Rates 1 and 2 respectively, compared with untreated control plots. As little treatment effect would be likely in the first year, these increments represent the extra volume put on in two years, and as such the levels of response are certainly encouraging.

The Corsican pine sample plots at Culbin, which were top-dressed in 1963 with 150 lb nitrogen per acre as "Nitro-Chalk", still continued to grow at the increased rates with little sign of a decrease (see *Report* for 1966). Further larger-scale applications of nitrogen are intended at Culbin and Speymouth in 1967 because of these encouraging results.

Two years ago (*Report* for 1965) we gave details of some of the pole-stage experiments dating from 1959. Measurements have been made for a further two-year period, and most of the effects noted have been maintained. These experiments and some others are discussed in a recent paper (Binns and Grayson 1967), together with the prospects for wider use of fertilisers on established crops in Britain.

A very important point about the use of nitrogenous fertilisers is the persistence of the response from a single application. The results from the two experiments in the south in which responses to nitrogen have been seen, given in Table 21, show that the effect has lasted for seven years.

TABLE 21

RESPONSES OF POLE-STAGE CROPS TO NITROGEN

Forest	Species	Yield Class	Age at Treatment	% Increase in Basal Area Increment due to Nitrogen			
				1959–1961	1962–1963	1964–1965	1959–1965
Halwill, Devon	Norway spruce	100	32	19*	10	19***	16§
Pembrey, Carmarthenshire	Corsican pine	80	23	37***	40**	31*	36§

* Increase significant at 5 per cent
** Increase significant at 1 per cent
*** Increase significant at 0·1 per cent
§ Statistical tests have not been applied to the total increase

At Pembrey the effects on the nitrogen concentration in the current needles had disappeared by 1961, and there were no effects on needle weight. At Halwill no effects of nitrogen on the needles were detected at all, but this may be due to the small number of trees sampled.

Demonstrations of Nutrient Deficiencies

The "deficiency garden" (a demonstration in which nutrient deficiency symptoms are induced by heavy applications of other nutrients) on deep, acid peat planted with Lodgepole pine and Sitka spruce at Selm Muir Forest, Midlothian, is situated about 1,000 ft above sea level on a very exposed peneplain. Between mid-December 1966 and mid-January 1967, in plots which had received no potash, the pine suffered side shoot die-back and the current side shoots of the

TABLE 22

FOLIAGE ANALYSES FROM PERMANENT SAMPLING SITES

Species	Needle wt. (mg Oven-dry)	Nutrient Concentration (% oven-dry wt.)					N : P : K (ratio)
		N	P	K	Ca	Mg	
Sitka spruce (growing well)	*7·6* 5·5—9·8	*1·37* 1·12—1·75	*0·22* 0·16—0·33	*1·15* 0·68—1·54	*0·25* 0·13—0·35	*0·12* 0·10—0·13	6¼ : 1 : 5¼
Sitka spruce (in partial check)	*5·1* 3·5—6·1	*0·93* 0·65—1·52	*0·13* 0·08—0·15	*0·75* 0·54—1·11	*0·33* 0·22—0·47	*0·10* 0·07—0·12	7¼ : 1 : 5¾
Lodgepole pine (Washington Coastal Provenance)	*16·9* 10·1—22·6	*1·42* 1·15—1·67	*0·16* 0·11—0·21	*0·54* 0·38—0·68	*0.09* 0·06—0·19	*0.07* 0·06—0·09	8¾ : 1 : 3¼

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

spruce drooped and turned yellow. These injuries must have been due to low winter temperatures even though this past winter was not reckoned to be severe. The occurrence of this type of injury is paralleled in forest nurseries and in agricultural crops where potash deficiency renders a plant less hardy. Shoot die-back of Lodgepole pine is not uncommon in Scotland, and the wider use being made of potash-containing fertilisers should help to prevent such die-back.

A further "deficiency garden" is being established in 1967 on deep peat in the new demonstration area at Eddleston Water Forest, Midlothian, by planting plots of pure Lodgepole pine of two provenances and of Sitka spruce.

Permanent Foliage Sampling Plots

The 1966 foliage samples from the permanent plots in Scotland and North England have given the results shown in Table 22. The main difference between these results and those of 1965 is that the phosphate concentrations in both lots of spruce and in Lodgepole pine dropped. The needle weights of the good spruce and of the pine were less than in 1965. It is interesting to note that since we began these plots three years ago the spruce in partial check has consistently had a higher calcium concentration in its needles than the good spruce.

It has still not proved possible to find time to select permanent sampling sites in Southern England and in Wales, but it is hoped to do this during the coming year. The need for a datum line in different regions and for different species, to iron out year-to-year variations in nutrient concentration caused by the vagaries of our climate, will become increasingly urgent if large-scale fertilisation of established crops becomes a reality, since foliage analysis will be one of the methods used to screen stands selected as possibilities for treatment.

Intensive Manuring at Establishment

The fertiliser/herbicide trials on mineral soils reported last year have shown that newly planted conifers seem to derive little benefit from nitrogen in their first two years, except perhaps for *Pinus radiata*. There are some suggestions, however, that potassium may be beneficial early on for some species.

Foliage Analysis

In spite of a small number of samples from Conservancies (some programmes of fertilisation have had to be cut back because of shortage of money), over 2,100 samples were received at Alice Holt during the Autumn and Winter, about two-thirds coming from Scotland and Northern England. Most of the samples have been analysed for N, P, and K, a small number have had Ca and Mg determined as well. Nearly all the analyses were complete by the end of the period covered by this *Report*.

W. O. BINNS
J. ATTERSON

PUBLICATIONS BY STAFF MEMBERS

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BINNS, W. O. One Spoonful to be Taken each Spring (or Research on Forest Nutrition). *Arbor* 4 (3) 1966 (21–23).

BINNS, W. O., and GRAYSON, A. J. Fertilization of Established Crops: Prospects in Britain. *Scot. For.* 21(2) 1967 (81–98).

SITE CLASSIFICATION

British foresters have for many years talked about the need to classify forest sites: by which we mean studying forest sites in relation to the growth of our main tree species, so as to predict those factors likely to limit the growth of any species on any site. The practical effect of such a scheme would be to enable the forester to choose his species with greater assurance, and to decide which factors of the site he should try to improve. However, the youthfulness of most British forests, and of the forest soils, makes this an even more daunting task than in countries which have long-established forests of native trees.

While it is true we have nibbled at the problem from several directions—the Ecologist has been studying site factors for many years, a large part of the Soils programme is devoted to examining some of the factors of soil moisture and climate which may be important for tree growth, and Working Plan soil surveys have produced useful information on the need for drainage and the liability to windthrow in several forests—up till now there has been no full-scale attack on site classification. Such a project has at last been authorised, and should be started during the next year.

Meanwhile Mr. D. G. M. Donald, a lecturer in Forestry at Stellenbosch University, South Africa, who spent some months at Alice Holt during the year, has started off a small project on Corsican pine. Thirty stands, covering the Southern part of England, East Anglia, and touching the Midlands and South Wales, have been studied, and soil and foliage samples taken during the winter are being analysed. Within the range of sites studied, meteorological and gross site factors (such as aspect, slope, altitude, etc.) show no obvious relationship with performance over a range of yield classes from zero to 220. Multivariate analysis may reveal more than the eye can see, but we suspect that soil factors, if anything, are more likely to show correlations with tree growth.

Even if this project produces no useful answers, the experience gained in selecting factors, in sampling and measuring, and in assembling and processing the data, will be invaluable for the larger project to come.

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REGENERATION OF TREE STANDS

Estimates of Seed Fall

The seed trapping experiments on Douglas fir described in previous *Reports* are being continued, but it is still too early to draw any conclusions on the periodicity of good seed years.

Natural Regeneration of Sitka Spruce

Cone crops in 1966 were inadequate to justify investigations into seedfall. However, as a result of the good seed year of 1964, prolific natural regeneration exists within the large felling experiment at the Forest of Ae (up to 40,000 seedlings per acre). The progress of the existing seedlings is being studied in order to establish the season and cause of losses. Within sample quadrats all seedlings are located, marked and periodically inspected. A similar procedure is to be undertaken in small-scale direct seeding trials.

Slash Disposal

Following preliminary trials at Balblair and Oykel Forests (Ross-shire and Sutherland), a comparison of four slash treatments was undertaken in 1965–66 at Redesdale Forest (Northumberland). The crop felled was Sitka spruce of approximately 45 ft in height, and extraction by horse and radio-controlled winch left a fairly even cover of branchwood, the uniformity of which was assessed. Thereafter four replications of four slash treatments were applied and timed, in plots varying in size from 0·5 to 1·27 acres, at a time when the slash was still green with adhering needles.

Replanting on a graded incentive scheme was organised to preclude bias, and was again timed. Similarly, beating-up will be timed in 1967. First year survival was not affected by treatment.

From Table 23 it is concluded that at current wage levels replanting through uniform slash (even when fresh) is the cheapest effective course, but that chopping is likely to become competitive as wage rates increase and as the equipment is improved.

TABLE 23

REPLANTING FOLLOWING CLEARFELLING OF SITKA SPRUCE, REDESDALE FOREST NORTHUMBERLAND

Slash Treatment	Approximate Cost* (£)	Mean Stocking Achieved (plants/acre)	Excess Replanting Time
Heap and burn, complete	40†	1,410	Datum
Heap and burn, partial	13	1,480	+29%
Chopping	5	1,460	+20%
Slash retained	Nil	1,290	+78%

* These costs are based on observed time (excluding labour oncost, but including a charge for the chopping machinery) and are therefore relative estimates rather than the absolute or normal costs to be expected.

† The costs of burning are particularly affected by scale and time according to the weather, and in the conditions pertaining constitute an over-estimate of the best that can be achieved.

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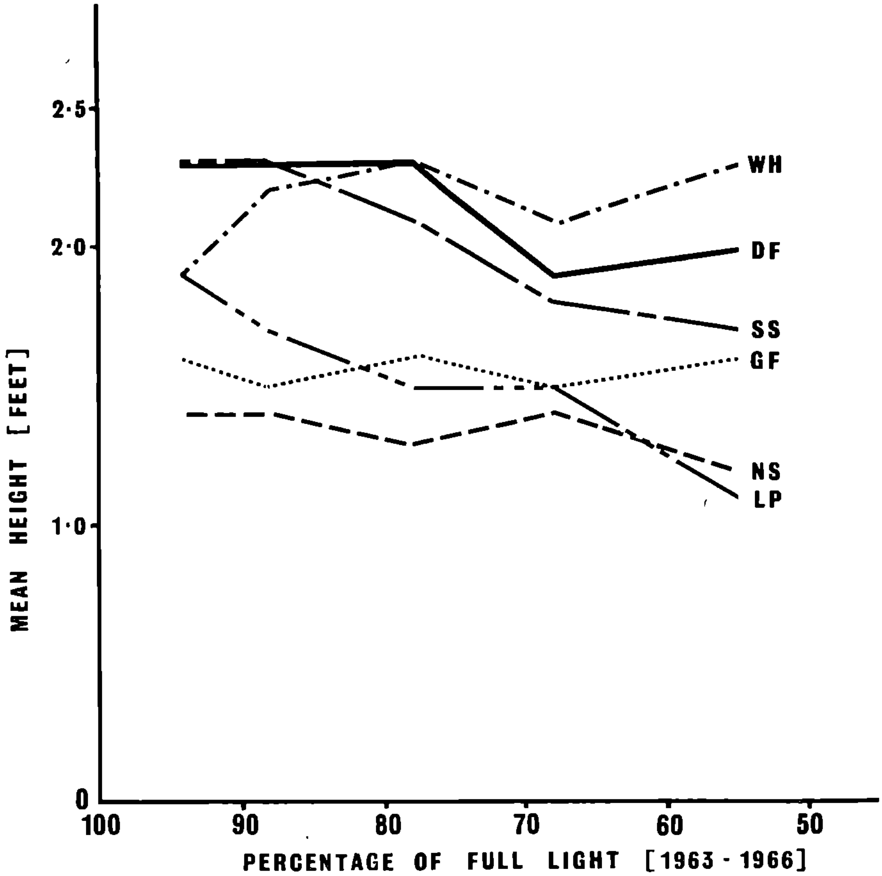

FIGURE 1: Underplanting of Japanese larch, Drumtochty. Mean height at three years of six species under various densities of overwood expressed in terms of light conditions.

Where cultivation is required for the subsequent crop, slash would have to be removed. Preliminary trials show that considerable savings can be made using hydraulic equipment. Trials of auxiliary fuels to ignite mechanically piled branchwood in wet weather are proceeding.

A more detailed description of work to date has been accepted as a paper for the 1967 I.U.F.R.O. Congress.

Felling Area Sizes in Sitka Spruce

The first experiment planted in 1962–64 at the Forest of Ae (Dumfriesshire) has shown significantly greater plant survival of both Norway and Sitka spruce in the smaller clearings. However, this result must be qualified by the fact that deer have on occasion gained access and the probability of their entry is greater than in the larger clearings.

There have been no important differences in the height attained at three years of age of Norway and Sitka spruce replanted immediately, one, and two years after felling, but the re-invasion of weeds becomes increasingly evident with delayed planting. A detailed vegetation survey concluded that, following the

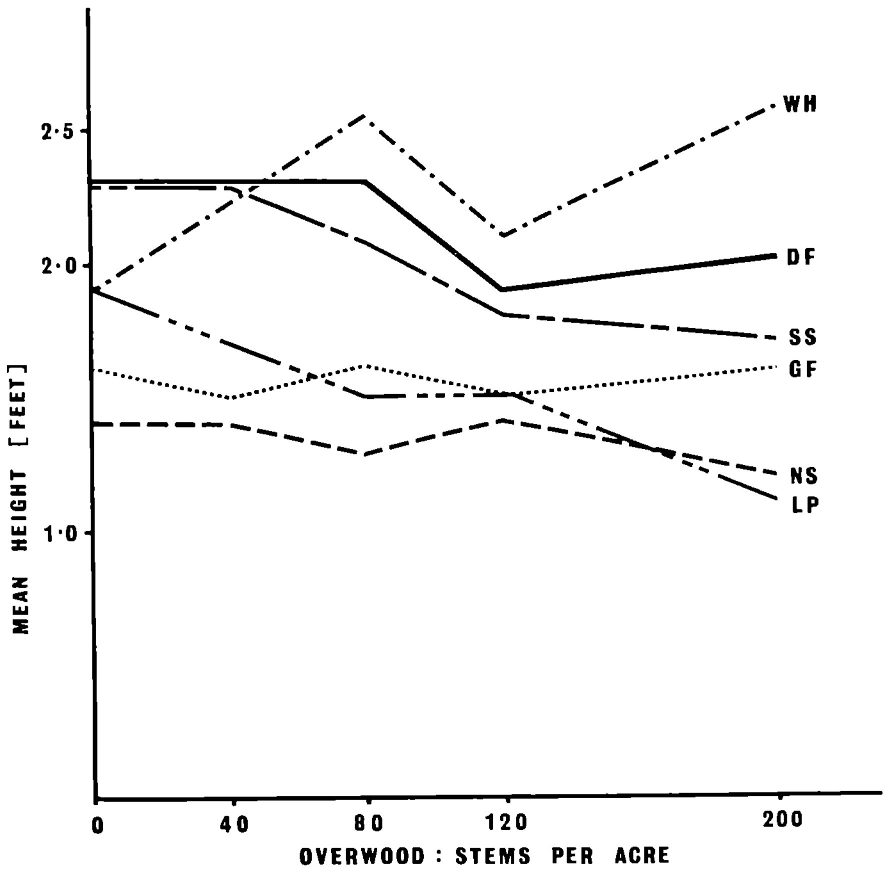

FIGURE 2: Underplanting of Japanese larch, Drumtochty. Mean height at three years of six species under various densities of overwood expressed as stems per acre. Key: W.H.=Western hemlock; D.F.=Douglas fir; S.S.=Sitka spruce; G.F.= Grand fir; N.S.=Norway spruce; L.P.=Lodgepole pine.

felling of a fully stocked crop, weeding had not, and would not, be required after clearfelling on peaty podsols, basin peats, or plots less than 0·3 acre irrespective of soil type, but that surface-water gleys were most prone to re-invasion of grasses. This survey re-inforces previous recommendations for speedy felling and replanting of wind-damaged crops with special emphasis on surface water gleys.

Assessment of peat shrinkage following clearfelling has been periodically carried out at fifteen sampling points within the experiment. No significant reductions in peat depth have occurred in the 4½-year period between felling and re-invasion by vegetation which concluded the assessments.

The second experiment in this series (Redesdale, Northumberland) has not yet suffered a large amount of windthrow on the margins of the felling areas. Anemometers in the centre, and at the edges, of a sample of clearings are establishing the general wind pattern. Replanting of this experiment has been described under slash disposal.

Underplanting of Japanese Larch

A new experiment has been established at Allerston (Yorkshire) comparing five species under various densities of overwood. This extends experimental coverage on to two sites where cultivation and frost hazards may be of importance. Part of the clearfelled control has been deeply cultivated using a ripper which has achieved disturbance from 3 to 5 ft in depth. In the July preceding felling the site was treated with mist-blown paraquat, and a very good initial kill of grass was obtained, which it is expected will obviate or at least reduce the need for subsequent weeding. Experimental work on this topic is described in the section on pre-planting control of grass.

The parallel experiment at Drumtochty Forest, Kincardineshire, now three years old, has had its first height assessment, and Figures 1 and 2 illustrate a reduction in growth with increasing overwood density for underplanted Lodgepole pine and Sitka spruce. The mean heights of Grand fir, Norway spruce and Douglas fir are as yet little affected by overwood density, but there is a suggestion that Western hemlock prefers shadier conditions. The close similarity between the graphs confirms that annual measurement of light by instantaneous reading photometers is meaningful.

A joint experiment with Edinburgh University investigating the light demands of six species was established at Bush Nursery (Midlothian). (See also Dr. W. A. Fairbairn's report on page 154.)

No new experiments have been initiated in the South, but as with the Drumtochty Experiment described above, assessments in the two older experiments at Michaelston, Coed Morgannwg, (Glamorgan) and Radnor Forest are proving informative. The results do not correspond exactly with those from Drumtochty and are therefore worthy of comment.

At Michaelston both Norway and Sitka spruce show a marked reduction in growth with increasing overhead cover. In the case of Sitka spruce the mean annual height increment in the clear-felled plot is more than double that under 200 stems per acre, and in Norway spruce the increment in the open is over 50 per cent greater than that under 200 stems per acre. Intermediate cover densities have produced intermediate increments.

Western hemlock and Lodgepole pine both show a maximum increment under 30 stems per acre, though the differences between 0, 30 and 60 stems per acre are not large. The increment under 30 stems is more than 50 per cent greater than that under 200 stems per acre for both species.

Douglas fir and *Abies alba* show an optimum under 60 stems per acre, but again no large differences between 0, 30 and 60 stems per acre. The difference for both species between the increment under 60 stems per acre and 200 stems per acre is more than 60 per cent.

Abies grandis shows a maximum height increment under 120 stems per acre, but the differences between all treatments are not large.

At Radnor, which is a year younger, the trends are similar though the differences smaller. The two spruces, however, show maximum growth in the clear-felled area, and all the species show poorest growth under 200 stems per acre.

Regeneration of Scots pine

A new underplanting experiment in yield class 120 Scots pine, comparing Douglas fir and Grand fir under a range of overwood densities, has been planted at Culbin Forest (Moray). First year survival (especially that of Douglas fir) has been significantly lower in the clear-felled treatment than in those with an overwood ranging from 100 to 350 stems per acre. It was noteworthy from the timed replanting that the slash of this good, narrow-crowned crop, provided no measurable hindrance to the work.

The three experiments referred to in last year's *Report*, investigating the replacement of poor Scots pine in East Scotland, were established, and a review of the need and scope for regeneration research in moderately productive Scots pine was begun.

At Tentsmuir (Fife) an experiment comparing spring and summer (July) planting of Corsican pine, using normal and potted plants, was established. The problems here are analogous to those at Thetford, where Corsican pine is potentially more productive than the Scots it is intended to replace. However, great difficulties due to local frost, drought and insects have been encountered. Potted plants, planted both in spring and summer, have more than doubled first-year survival rates. Following a soil survey of the whole forest the potential of alternative higher yielding species will be investigated.

One new experiment has been established at Thetford as the next stage in the investigations. The existing underplanting experiments had demonstrated the effect of an overwood in reducing the incidence of frost, and had also shown that it was quite possible to establish a wide range of species (including Corsican pine) under cover. The amount of cover left was proving too dense for the underplanted crop after two years, and some thinning has been done. However, the new experiment is designed to study the effects of overhead cover on the establishment and growth of two important species, Corsican pine and *Abies grandis*.

A range of densities of cover have been left, and an additional clear-fell treatment is included. The lightest cover, 50 stems per acre, may prove too sparse to reduce the frost risk, but obviously we wish to know how little cover is necessary to obtain protection from frost, and at the same time allow the underplanted crop to grow unrestricted without the need to thin the overwood.

Erosion Following Clear-felling of Spruce

Two experiments at Benmore (Argyll) have been established. In the first, water, litter and soil will be collected from a finite area (limited by plastic edging), whereas the other consists of open plots in which changes in micro-topography will be assessed. Both experiments will include slash-covered plots. These experiments are largely trials of technique but should indicate whether the theoretical risk of topsoil loss in these conditions is large enough to justify an expansion of effort.

A. I. FRASER

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HENMAN, D. W. The Case for Wider Spacing. *Timber Tr. J. Supplement*, April 1966 (page 21).

ARBORETA, FOREST PLOTS AND SPECIES TRIALS

Arboreta and Forest Plots

Recent planting at the Kilmun Arboretum at Benmore Forest in Argyll has included specimen-tree groups of *Juniperus chinensis*, *Cunninghamia lanceolata*, *Nothofagus cunninghamii* and a wide range of *Eucalyptus* species from Tasmania and South-east Australia. Plots of *Picea breweriana*, *Juniperus virginiana* and *Cupressus macrocarpa* have also been added. Work is now well advanced in the Arboretum extension and a considerable number of ornamental trees and shrubs have been planted in geographic groups under a light overwood of larch. A new entrance from the recently completed car park has been made at the lower edge of the extension, and when the pathway system is completed it is intended that this will form the principal access route for visitors to the Arboretum and Forest Plots.

At the Crarae Forest Garden near Minard Forest, also in Argyll, specimen-tree groups planted recently have included *Picea* x *lutzii*, *Chamaecyparis nootkatensis*, *Alnus rubra* and four species of *Eucalyptus*.

In the second year in the International Seed Exchange scheme, Westonbirt Arboretum provided seed from 140 species of trees and shrubs, and there have been many requests from all over the world. Seeds were obtained last year from this Exchange of 20 species required, but germination has been poor. About 100 species have been requested this year.

At Bedgebury, a second experiment on the susceptibility to vandalism of labels of different types, mounted in various positions, is being laid out. Seed has been provided for several special requests.

Species Trials

Miscellaneous Species

A collection of the less common *Abies* and *Picea* species planted in England in 1964 is now growing very well on all sites. A small series of montane spruces was planted in conjunction with a provenance trial of *Picea engelmanni*, on three sites, in the South of England. Two new species of *Nothofagus* were sown (*N. pumilio* and *N. alpina*) and the plants will be added to the trial of *N.procera* and *N. obliqua* in the New Forest and, if there are enough, elsewhere.

A range of Mexican species has been planted out in groups in Bedgebury, Westonbirt, Plym, Radnor and the New Forest, and a number have been distributed to private owners and institutions who are well placed to give these new introductions a trial.

Thetford Species Trials

With the increasing interest in second rotation crops at Thetford, it is perhaps opportune to note the progress of some of the species underplanted beneath thinned-out crops of birch, alder or larch in our older experiments on the deeper sands of the Worlington and Worlington Methwold series.

These plots are of reasonable size (from ½ to 1 acre each) and were planted in 1944 and 1951, so that they are now well established and have survived a range of bad seasons.

Table 24 shows the relative growth of the various species to date:

TABLE 24

SPECIES TRIALS UNDER HIGH COVER AT THETFORD CHASE (NORFOLK AND SUFFOLK)

Species	Planting Year	Name of Area	Depth of Sandy Soil (inches) over Chalky Boulder Clay	1966 Mean Height (ft)	Apprx. 1966 Mean Shoot (in.)	Comments
Western hemlock	1951	Olleys Species plots	18–32	21·2	20	
	1951	Lynford Species plots	14–30	14·2	18	
	1944	Bromehill plots	30–48	43·0	—	Growing excellently. (Height only approximate.) Raised under European larch planted 1905.
Lawson cypress	1951	Olleys Species plots	18–32	19·4	14	
	1951	Lynford Species plots	14–30	11·6	12	
	1944	Bromehill plots	30–48	32·0	—	Early deer damage caused irregular stocking. (Height only approximate.)
Western red cedar	1951	Olleys Species plots	18–32	19·0	15	
	1951	Lynford Species plots	14–30	11·7	15	
Picea omorika	1951	Olleys Species plots	18–32	19·6	18	
	1951	Lynford Species plots	14–30	11·0	15	Overcrop was thin and there was rather much early frost damage.
Abies grandis	1951	Olleys Species plots	18–32	15·4	24	A very good plot—now growing fast.
	1944	Bromehill plots	30–48	47·0	36	A remarkable plot growing very fast and of excellent colour. (Height only approximate.)
Abies nobilis	1944	Bromehill plots	30–48	18·0	12	An extraordinary comparison with the same-aged *A. grandis*.
Abies nordmanniana	1951	Olleys Species plots	18–32	7·2	14	
	1951	Lynford Species plots	14–30	4·5	7	
Douglas fir	1944	Bromehill plots	30–48	31·0	—	These trees were held back by *Adelges* as so often happens with underplanted Douglas fir. (Height only approximate.)

One of the most interesting points about these results is the striking comparison between growth at Olleys and the growth of the same species at Lynford.

In all cases performance is much better at Olleys despite the fact that there is no great difference in soil depth—certainly not enough to cause such wide variation in the early stages of the plantations. Reference to the original vegetation descriptions, however, throws some light on the problem, showing that there was scattered heather (*Calluna*) over the Olleys area but practically none at Lynford, no doubt indicating the rather more acid top soil conditions preferred by most conifers. Another factor is elevation—Lynford being 50 ft lower than Olleys and with reports of more severe frost damage in the early years.

Abies grandis is worth special mention, for not only is it showing continued excellent shoot growth after 22 years on the deep sand at Bromehill but is also giving very promising results on the shallower soil at Olleys. It is certainly a species worth further trial, especially as it is likely to be fairly resistant to *Fomes annosus*. Hemlock, Red cedar, *Picea omorika* and Lawson cypress have all made good growth, but it remains to be seen how for the fungus *Fomes annosus* will trouble these species later.

Nothofagus species are not represented in these older plantings, but it should be noted that *N. procera* and *N. obliqua* have so far beaten all other species in their height growth for the first seven years on the deeper soils, their mean height growth being 12·4 ft and 15·7 ft respectively.

The relatively poor performance of the Douglas fir when underplanted is in line with experimental results elsewhere—this species always seems to suffer badly from *Adelges* unless the cover is removed or very heavily thinned out at an early stage.

Nothofagus species

The incidence of severe stem cankers on *N. procera and N. obliqua* was briefly noted in the *Reports* for 1963 and 1964 and a warning given that any larger-scale plantings of these otherwise promising hardwood species should be delayed pending further information.

A wide survey has now been made, including all research plots and a large sample of Conservancy plantings, so that rather more guidance can now be given as to the sort of sites where serious trouble might be foreseen.

This survey was extended to cover the range of small plots (up to 0·5 acres) of both species in a number of Commission forests in Scotland and Northern England; most of these date from 1955–59 and a few from 1936–40. Their growth to date indicates that both are potentially vigorous species in the North as well as in the South, capable of faster early growth than any other broadleaved species except eucalyptus and poplars. On a number of the more favourable sites in the North, rates of growth are at present comparable with those of vigorous conifers, and very little different from *Nothofagus* on similar sites in England and Wales. For instance at Kilmun Forest Plots (Argyll) the following data are recorded at the age of 10 years:

N. obliqua—top height 29 ft Basal area per acre 55 sq ft hoppus.

N. procera—top height 34 ft Basal area per acre 60 sq ft hoppus.

Practically all the worst canker damage has occurred in Wales or the Forest of Dean—always in or near valley bottoms and usually where there have been very rapid rates of growth, but although the bad sites are so often low lying, examination of ring growths has shown that the trouble is mainly associated with periods of very low winter temperature and seldom with spring frosts. It is, however, clear that low temperature is not the sole factor because there is far less canker damage in the east than in the west, and hardly any in Scotland.

The evidence suggests that rapid growth in areas subject to a very wide range of temperatures give the greatest risk and, to test this, thermographs have been set up at the top and bottom of the badly affected plot at Flaxley in the Forest of Dean; unluckily, the winter of 1966–67 was extremely mild so that little can be expected from this first season's records.

Inspection of sections of thinnings from older stands that now appear free from this type of damage, has shown that some of the trees have had patches of cambium killed in the early years but have recovered. It appears that after the trees reach a breast-height girth of about 12 to 14 in. they are less vulnerable, though this may be due to the better climatic conditions under a closed canopy.

The general conclusion from our present evidence is therefore that larger-scale plantings of *Northofagus* are feasible, but the bottoms and lower slopes of valleys should be avoided, particularly in Wales and generally in the west. Areas exposed to north and east winds are also risky. At high elevations growth is too slow.

Of the two most commonly planted species, *N. procera* is usually the more satisfactory, always of superior form and suffering far less from the twig and crown die-back so often found with *N. obliqua*, particularly on exposed or frosty sites. It was notable, perhaps especially in Scotland, that damage to the crown by frost was less, and vigour greater, in the western half of the country, but there is considerable variation between regions. On sheltered frost-free sites, however, *N. obliqua* sometimes gives a higher volume, but still with poorer form than *N. procera*. Where canker damage occurs, *N. procera* usually suffers more than *N. obliqua*, but only on the very worst sites has the damage been sufficiently severe to affect the main crop.

Eucalyptus species

In the *Eucalyptus* trial area at Glenbranter Forest in Argyll, the first plot was planted in 1964 and consisted of *E. urnigera* (of Crarae, Argyll origin). This failed during the following winter and was replaced in 1965 by a plot of *E. delegatensis* (ex Tasmania), which failed in turn during the 1965–66 winter. The reason for these failures, as was mentioned in the *Report* for 1965, may well have been the location of the trial area on a south-east facing slope (i.e. facing the early morning sun), which would subject the young trees to severe temperature fluctuations during periods of cold weather.

A further eight plots, 0·1 to 0·2 acres in area, have been planted in 1966, and the following seven species are now represented: *E. coccifera, E. cordata, E. pauciflora, E. urnigera* (the latter by plots of low and high elevation origins), from Tasmania; *E. camphora, E. niphophila, E. parvifolia*, from New South Wales and Victoria. It will be of considerable interest to see how well these species withstand their first winter in the field.

During 1967 it is hoped to plant plots of a number of additional species, using plants currently in stock. Further species and provenances which offer some prospect of winter hardiness in Scotland will be added to the collection as and when seed is available.

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PROVENANCE

General

A report has been compiled on the "Standardisation of Methods for Provenance Research and Testing" (Lines, 1967) as a result of the meeting of the Provenance Working Group of Section 22 of the International Union of Forest Research Organisations, at Pont-à-Mousson, France, in September 1965. This report was based on discussions between more than 60 leading provenance and genetics workers, and it is hoped that it will help to promote greater standardisation and improved techniques in planning and carrying out provenance research throughout the world.

Lodgepole Pine

The most important immediate result of the tour of western North America made in 1965 by J. R. Aldous and H. A. Maxwell was the purchase of about 70 lots of seed from British Columbia, including 16 provenances from the Skeena Valley and 14 from the Bulkley Valley. Seed from two elevation ranges at the same place was obtained for a dozen provenances. The main gaps in the collection are the coastal muskeg sites around Prince Rupert and the off-shore islands such as Queen Charlotte Islands. Together with provenances already in store, and some home-collected sources, it was possible to select from nearly 100 seed lots for a new nursery experiment to be sown at Newton, Moray. This contains 26 representative provenances, ranging from Alaska to Oregon. At Wareham a selection of 13 origins from areas of low rainfall and, in some cases, calcareous soils, has been sown. These will be used in trials at Thetford and other areas on the Eastern side of the country. Further experiments are planned for sowing in 1968 when some of the gaps in coastal provenances have been filled.

Two new experiments were planted on poor exposed sites at Shin, Sutherland, and South Kintyre, Argyll, to test three Alaskan provenances in comparison with the widely-used Washington coastal source from Long Beach. Two origins (Terrace and Hope), which may show characteristics intermediate between inland and coastal types, and a home-collected lot, originally from Queen Charlotte Islands, are also included. These experiments are planned to establish the silvicultural role of the northern coastal seed origins, which have so far shown considerable promise on very exposed and highly infertile sites in north Scotland. Resistance to blasting winds, freedom from basal bow, and later wind stability may prove just as important as rapid early growth, so that plots of 100 trees have been used to allow these experiments to continue until the second thinning at least.

Assessments continue in the 35 existing provenance experiments with this species in the north, and a general summation of the knowledge obtained from these experiments was published during the year (Lines 1966). A more detailed account of all these experiments is being prepared for publication, but the results of one of them provides some useful interim pointers.

In 1959 an experiment was planted on a worked-over peat bog (from which peat had previously been harvested for fuel, etc.) at the Forest of Deer, Aberdeenshire, with 11 provenances, and 7 others were added in 1960. This forest is in the bleak Buchan district, where climatic troubles make Scots pine unsuitable and previous experience with Lodgepole pine had also been unhappy. Table 25 shows the mean heights at three and six years, and the damage by wind-blast when the trees were three years old. Both sections are on adjacent and very similar sites, so that it is probably legitimate to compare them at the same age, although one was assessed in 1965 and the other a year earlier.

TABLE 25

MEAN HEIGHT AND DAMAGE BY WIND-BLAST OF VARIOUS PROVENANCES OF LODGEPOLE PINE, FOREST OF DEER, ABERDEENSHIRE

Provenance or Origin	Mean height in feet		Score for damage by wind-blast. High score is worst.
	3 years	6 years	
Ladysmith, Vancouver Island, British Columbia	2·03	5·41	71·3
Long Beach, Washington coast	2·62	6·89	40·7
Keyport, Washington coast	2·13	5·53	55·4
Inchnacardoch Forest, Inverness-shire, Expt. 16 (ex U.S. Coast?)	2·70	7·12	42·9
Newport, Oregon coast	2·58	6·57	43·7
Tidewater, Oregon coast	2·66	6·72	43·9
Florence, Oregon coast	2·59	6·67	41·4
North Bend, Oregon coast	2·58	6·76	45·6
Oakridge, Oregon Cascade Mt.	1·45	4·03	57·4
Cascadia, Oregon Cascade Mt.	1·53	4·05	63·8
Inchnacardoch Forest, Expt 80. (ex Hat Creek, British Columbia)	1·78	5·08	61·7
Skagway, Alaska	1·62	4·19	50·0
Kirroughtree Forest, Galloway, Expt. 1 (ex Queen Charlotte Island)	2·42	5·30	53·7
Courtenay, Vancouver Island, British Columbia	3·15	6·98	52·3
Sooke, Vancouver Island, British Columbia	2·58	5·79	71·0
Fort Fraser, British Columbia	1·74	4·65	64·0
Culbin Forest, Moray, Expt. 12 (ex Alberta)	1·70	4·44	53·0
Cypress Hills, Saskatchewan	1·42	3·98	48·3

Early survival was good in nearly all provenances or origins; the poorest being Cypress Hills with 75 per cent. There were highly significant differences in height between provenances at three and six years. The Courtenay seed source gave the most vigorous trees at three years, exceeding all the well-known rapidly-growing United States coastal origins. The other Vancouver Island sources, Sooke and Ladysmith, grew less fast. At six years old the tallest origin was the home-collected one from Inchnacardoch Forest which is probably of Washington coastal provenance. It was not significantly taller than the one direct from Long Beach, and their appearance was very similar. The other U.S. coastal sources were similar in height except for Keyport, the only one from the land-locked Puget Sound, rather than the open Pacific coast. The Keyport trees were significantly poorer in height and could be grouped with those from Sooke and

Ladysmith, whereas the Courtenay provenance was as tall as the best U.S. coastal lots. The northern coastal origins, Skagway and Queen Charlotte Island (via Kirroughtree Forest), differed significantly in height, Skagway being particularly slow-growing. This Alaskan provenance comes from one of the drier parts of coastal Alaska, not far from Haines, which in earlier experiments was poorer than one from Hollis in the Outer Islands of Alaska.

It would seem on this early evidence that provenances from the Skagway-Haines area are best avoided, if seed can be obtained from the Outer Islands or Queen Charlotte Islands, but the new experiments planted this year should clarify the issue. In the meantime, efforts are being made to increase seed supply of the desirable northern coastal origins from home sources. Of the inland provenances, the tallest was the home-collected lot originally from Hat Creek in the southern interior of British Columbia. The Fort Fraser trees were somewhat shorter and the remainder were, not unexpectedly, poorer still. The poor performance of these inland origins helps to explain why the older stands at Forest of Deer (which were of similar origin) were unsatisfactory. The Cypress Hills provenance represents the most easterly part of the range of the species in Canada, and it is known that natural hybrids with *Pinus banksiana* occur there. So far, hybrids are not obvious in this collection.

The damage to foliage probably resulted from cold, dry (or salt-laden) north-westerly winds early in 1962. It caused various degrees of foliage browning and even death of buds. There was no correlation between tree height and foliage browning, but very highly significant differences between provenances. In general the inland provenances were more blasted than the coastal ones, but the worst blasting of all was on the Ladysmith provenance, while Keyport again proved different to the other U.S. coastal sources. The trees planted in 1960 were rather small to be affected, but the Sooke trees were damaged to a similar degree to those from Ladysmith, while the Courtenay ones were much less affected. A single plot of Lulu Island, British Columbia, provenance had a score of 58. Thus there is evidence here that the provenances from the drier zone at the south-eastern end of Vancouver Island can be grouped with the notorious Lulu Island provenance as being very susceptible to blasting winds. Many field observations of these provenances on exposed sites confirm this and point to the preferability of the Washington coastal sources for such sites. Courtenay is clearly a provenance that needs to be repeated to see if it is really exceptional or whether the seed was incorrectly labelled.

Published studies of variation in Lodgepole pine have indicated that needle dimensions and anatomy are among the characteristics which vary according to geographic origin, and which might be used for provenance identification. In view of this a study was made by a student vacation-worker of material from the large pre-war provenance experiment at Millbuie, Black Isle Forest, Ross-shire, with the object of determining, if possible, needle characteristics suitable for differentiating between provenances or important provenance groups. Samples of the 1965 foliage were obtained from randomly chosen trees of 19 provenances, and measurements made of needle length, width and thickness. In addition, the number of resin canals present at the base, mid-point and tip of the needles was recorded. A full analysis of the data has not yet been completed, but from a preliminary examination it appears that both needle dimensions and resin canal data differentiate readily between broad groups of provenances; appropriate statistical treatment may well make possible more precise differentiation.

European Larch

The experiment planted in 1947 at Drummond Hill, Perthshire, under the auspices of the International Union of Forest Research Organisations, has reached a stage when some provisional conclusions can be drawn. A full account has been prepared for the I.U.F.R.O. meeting at Munich in September 1967 and the main results are as follows: The provenances which grew very fast in the nursery and in the first few years in the forest were not usually the best ones at twenty years. This is partly because the experiment has been very badly affected by larch canker and later die-back, and the best provenances now are those which showed most resistance to disease. These are low-elevation East European provenances from Parchowitz in Czechoslovakia and Proskau in Polish Silesia. Both show characteristics similar to true Sudeten larch though neither comes from the native area of this variety. The next best provenances are all from stands outside the natural range of European larch and include the "Scottish" provenance, Aldroughty, and a number from the North German lowlands. The low-elevation Austrian provenances were moderately vigorous but rather susceptible to canker and die-back, while the Alpine provenances from Austria and Switzerland were in general poor in vigour and severely affected by canker and die-back. Several of the parallel English experiments in the I.U.F.R.O. series also showed considerable canker damage on susceptible provenances, but in none of them has die-back occurred on the catastrophic scale found at Drummond Hill.

Norway Spruce

There is increasing evidence from experiments all over Europe that the most vigorous provenances come from eastern Europe. To see whether these provenances are also the best ones to use in Britain, a collection was obtained in 1964 of ten Rumanian provenances which were sown together with others from France, Switzerland, Bulgaria and Austria. Some of the plants were lined out at Benmore nursery this year for planting in 1968. We were also fortunate enough to obtain some of the seed collected by the Danes during their seed collection tour in Rumania in 1962, and eight seed lots from Polish stands, also through the Danish State Forest Service. We wish to thank Mr. V. Gøhrn and Mr. H. Barner for their kind co-operation. These provenances were sown at Benmore in 1967, together with others from France, Switzerland, Austria and Lithuania.

One set of provenances from France, Switzerland, Poland and South East Europe, planted in 1966 at Brendon, Somerset, Dean, Gloucestershire, and Cannock, Staffordshire, has been beaten-up fully. Another similar set will be planted out next year.

Western Red Cedar

The experiments planted in 1962 at Benmore, Argyll, and in 1963 at Thornthwaite, Cumberland, can now be considered established, but both have suffered from various pests and diseases. At Thornthwaite the experiment was originally planted in 1962, but failed due to drought and weevil attack. It was replanted in 1963 and after three years showed significant height variation between provenances, the tallest being one from Ashford, Washington. Another from Shuswap Lake, British Columbia, was almost as tall. Both provenances come from higher elevations and are further from the coast than the less vigorous ones, but it is too early to establish a pattern of behaviour. The Benmore experiment suffered badly from the severe winter of 1962–63 when nearly all plants were killed back to half their height. Since then, frequent damage from browsing roe deer, in spite of strong efforts to control them, has nullified any provenance differences and a deer fence has had to be erected.

Douglas Fir

Many of the plots of the Douglas fir provenances from Manning's collecting areas in Washington and Oregon, planted in 1954, have had their first thinning. They have been assessed for a first evaluation. The best are still most likely to be those from between Puget Sound and the Columbia River. However, there are no provenances in this series from the Oregon coast, or further south, and in New Zealand these are the most promising areas and there is some reason to think that this may be so in Britain. Seedlings from some coastal Oregon sources with some from selected sources (Manning's Bonded Seed) from Washington were lined out for planting out next year.

Seed from six more sources near the Oregon coast has been acquired, five of them through the new I.U.F.R.O. scheme, and twelve more from Vancouver Island and the coast of British Columbia, a region with potential interest for more northerly and severe sites.

OTHER SPECIES

Pinus ponderosa

The one early trial at Findon in the Black Isle Forest (Ross-shire) and Thetford (Norfolk) contains provenances only from a small region at the extreme northwest of the vast range of the species. Seed has now been sown of five sources in Washington and three in Oregon. Control will be standard imported Corsican pine, as this is the species with which *P. ponderosa* will have to compete for wider scale planting.

Abies alba

The two replicates in the South of the large provenance trial being carried out by Silviculture Section (North) were badly frosted before planting and have made no positive growth in height. They have been beaten-up, and the experiment in Radnor is being given general fertiliser.

Abies lowiana

The provenance trial of sources ranging from mid-Oregon to mid-California had to be lined out in August because the plants were all making so much growth, particularly in roots. A small set of these provenances was planted out at Lulworth in Wareham Forest (Dorset), under high shade at the end of August, to see whether this is a possible method of treating such plants. Sites for the full experiment have been selected and, in some cases, prepared.

Abies grandis

A small experiment to test two Vancouver Island provenances against three from Washington Cascades has been planted out on three sites.

Abies amabilis

Seed from five sources, two in Washington and three in Oregon, has been sown, for a first look at the provenances of this variable, but often most promising, species.

Abies magnifica

Seed from three sources in Oregon has been sown. This is the first provenance trial for this species, one in which single trees frequently produce extremely vigorous growth in girth.

Abies procera

The small trial of one Oregon source, two Danish and five home collections, has been lined out for planting next year.

Picea engelmanni

Five provenances of this species have been planted out in an experiment which includes *Picea glehnii*, *P. albertiana*, *P. glauca* and *P. spinulosa.*

Sequoia sempervirens

The series planted in 1965 has grown much better at Alice Holt than at Plym (Cornwall). The outstanding provenance is the most northern, from Brookings, Oregon, of which several plants exceed 6 ft in height. In the absence of hard frosts the more southerly ones may decrease this lead in the next few years. A second series, including some repeats, was sown last year and lined out this year.

R. LINES
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PUBLICATIONS BY STAFF MEMBERS

LINES, R. Choosing the Right Provenance of Lodgepole Pine (*Pinus contorta*) *Scot. For.* 20(2) 1966 (90–103).

LINES, R. Standardisation of Methods for Provenance Research and Testing. *Paper to Section* 22 *I.U.F.R.O.* 1967. Munich. 53 pages.

LINES, R. *The Planning and Conduct of Provenance Experiments.* Forestry Commission Research and Development Paper No. 45, 1967.

WEED CONTROL IN THE FOREST

Rhododendron (*Rhododendron ponticum*)

An account of experiments between 1964 and early 1966 has been published in a paper on "Control of *Rhododendron ponticum* in Forest Plantations" by J. R. Aldhous and R. Hendrie. (*Proc. 8th British Weed Control Conf.*, pages 160–166.)

In the paper, experiments are described, leading to provisional recommendations of a low-volatile ester of 2,4,5-T in oil, or in water, for control of *Rhododendron* in young forest plantations. Picloram* at up to 8 lb, dicamba at up to 16 lb, and paraquat at up to 4 lb per 100 gallons of water were ineffective against *Rhododendron;* picloram caused serious malformation of the shoots of nearby planted trees, while dicamba caused slight damage.

Since the experiments described above, a comparison was made at Wareham, Dorest, starting in July 1966, using water, water + oil, and oil alone as diluents for 2,4,5-T applied to regrowth of *Rhododendron* in various seasons and stages of growth. Initially, a good kill of foliage has been obtained but it is too early to determine the extent of resprouting from stools.

Bracken (*Pteridium aquilinum*)

Experiments in England and Wales in 1966 and the latest assessments on previous years' experiments are described in a paper "Bracken Control in Forestry with Dicamba, Picloram and Chlorthiamid" by J. R. Aldhous (*Proc. 8th Brit. Weed Control Conf.*, pages 150–159). Most of the work described in the paper was with dicamba. At 4 to 6 lb per acre, applied as a spray before planting, dicamba reduced or eliminated bracken on sites with a mean annual precipitation of 30–35 in.; bracken on sites where complete control was obtained in 1964 has recovered very little. Little difference in response was found following applications during spring and early summer.

Picloram gave good control of bracken at 2 to 3 lb per acre when applied post-planting, but caused excessive crop damage.

Chlorthiamid at 4 to 6 lb per acre gave good bracken control only where there was a deep cover of bracken litter.

An experiment at Eddleston Water Forest, Peebleshire, was laid down in 1965–66 to compare the effects of dicamba* and chlorthiamid ("Prefix") on dense, vigorous bracken and on tree species planted in spring, 1966. Three rates of each herbicide were applied—4, 6 and 8 lb (active ingredient) per acre—and both were in granular form. Both herbicides, even at the lowest rate, successfully controlled the bracken on this site during 1966. Chlorthiamid, which was applied in spring, 1966, did not begin killing the bracken until the middle of June. Dicamba was applied in autumn, 1965 and spring, 1966, and successfully controlled the bracken when applied at either date.

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* Full details of the names, formulae and properties of the chemicals mentioned in this section can be found in the 4th Edition *Weed Control Handbook*, ed. E. K. Woodford, publ. Blackwell, Oxford.

Brand names of weedkillers which are currently marketed can be found in the *Agricultural Chemicals Approval Scheme List of Approved Products* (Ministry of Agriculture). Dicamba is also known as "Banvel D", picloram as "Tordon" and chlorthiamid as "Prefix".

The effects of the herbicides on the tree species planted are summarised in Table 26 which is for the April applications of 4 lb (active ingredient) of the herbicides.

TABLE 26

LIVE TREES AT THE END OF THE FIRST GROWING SEASON AS PERCENTAGE OF THOSE IN THE HAND-WEEDED PLOTS. EDDLESTON, EXPERIMENT 5/65

per cent

Herbicide	Species							
	Scots pine	Lodge-pole pine	Sitka spruce	Norway spruce	Japanese larch	Douglas fir	Western hemlock	Syca-more
Dicamba	105	89	104	106	147	104	134	102
Chlorthiamid	82	89	80	70	77	54	32	96

From this table, it is obvious that chlorthiamid is much more damaging to tree species than dicamba, which for all species except Lodgepole pine has been less harmful than hand-weeding! Symptoms of damage from chlorthiamid did not appear on the trees until mid-August when the foliage of most species began turning yellow particularly at the higher rates. For neither herbicide did rate of application induce significant differences in percentage survival.

Dicamba at 1 and 2 lb (active) per acre was applied by mistblower in late spring, 1966 to bracken-covered sites at St. Fillan's Forest, Perthshire and Bennan Forest, Kirkcudbrightshire. Satisfactory results were obtained in 1966; these areas are to be planted in spring, 1967, after which the amount of necessary weeding will be recorded.

Woody Weed Control

Trials in the Forest of Dean compared basal bark sprays of 2,4,5-T in oil with 2,4,5-T in water thickened with sodium alginate. While 30 lb 2,4,5-T per 100 gallons oil gave good control when applied to frill-girdles, and reasonably good control when applied as a basal bark spray, neither 30 nor 45 lb of 2,4,5-T per 100 gallons of water was sufficient to kill trees, when applied by the same techniques. The only effect of the water-borne spray was curling of leaves.

Herbaceous Weed Control

Before Planting

Paraquat and chlorthiamid were applied to strips 3 ft wide and 6 ft between centres in a mainly grassy herbaceous sward at Queen Elizabeth Forest. Table 27 shows details of rates and times of treatment and the response of the vegetation by November 1966. The site was planted, each plot being halved and one half planted in October and the other in March.

TABLE 27

RESPONSE TO TREATMENTS APPLIED DURING THE 1966 GROWING SEASON TO CONTROL GRASSES AND BROADLEAVED HERBACEOUS WEEDS

Queen Elizabeth (Buriton) Forest Experiment 67—Assessed November 1966

Treatment	Treated			Key to symbols used
	May	July	Sept.	
Paraquat spray: 1 lb in 40 gallons water per acre	c	d	bc	a = vegetation dead, little regrowth or invasion by seedlings or weeds from outside treated area. b = vegetation dead, some seedling regrowth or invasion c = most vegetation dead but quite widespread regrowth. d = little or no effect.
Paraquat spray: 2 lb in 40 gallons water per acre.	b	bc	b	
Chlorthiamid 7½% granules 6 lb (a.i.) per acre 75 lb granules/acre.	a	a	ab	
None (Control)	d	d	d	

Table 27 shows that in this comparison, chlorthiamid has given more lasting control of grasses. In practice, when such land is planted, screefing would be unnecessary on most of the areas treated with paraquat in September at 2 lb of chlorthiamid. However, the chlorthiamid-treated strips look as though they will remain weedfree longer than those sprayed with paraquat.

The costs of materials, comparing chlorthiamid 6 lb (active) with paraquat at 2 lb per treated acre favour the latter (£11 against £5 10s.) but the cost of providing water must be added to the cost of paraquat; this could be up to £2 5s. per acre more. At the same time, chlorthiamid-treated plots may cost less to weed in the first year after planting.

A similar comparison of the effect of season of application of chlorthiamid and paraquat, in relation to season of planting of Corsican pine, was started at Thetford in the autumn of 1966. Some kill of grasses has been obtained but the full consequences of treatments will only become apparent in the 1967 growing season.

After Planting

In a trial, conducted jointly with staff of the Deputy Surveyor, New Forest, chlorthiamid applied in late April as a 7½ per cent granule at 4 lb and 6 lb per acre active ingredient (55 and 80 lb granules), killed or damaged about 10 per cent of *Abies lowiana* on the trial site. Some trees were killed outright, some were defoliated and some sustained damage at soil level. Characteristically, the damage was not visible until three to four months after treatment. The weedkiller was applied to patches a yard square each with a tree in the centre, Vegetation control was satisfactory except where vigorous bramble and local patches of creeping grasses (*Agrostis* spp.) invaded the treated patches towards the autumn.

A survey was made of all the known trials and experiments with chlorthiamid. From this it is apparent that this herbicide can cause severe damage to many forest species. Treatments in April are safest of those widely tested; Corsican pine, Sitka spruce, oak, beech and sycamore are the most resistant species, with Lodgepole pine, Scots pine and Norway spruce almost as resistant. Larches, Douglas fir, *Abies* species and Lawson cypress appear too susceptible (Departmental Report—"Progress Report on Prefix" Jan. 1967, J. R. Aldhous).

No information is yet available on the safe period after treatment for planting susceptible species.

Pre-planting Control of Grass under Larch and Pine Stands

The control of grass under larch or pine stands which are being regenerated has been investigated for the past few years. The treatment of such areas with paraquat has controlled grass sufficiently to obviate weeding in the first two growing seasons after planting, except for rhizomatous species such as *Holcus mollis* (Creeping Soft grass). With most grasses, season of application does not seem to matter as long as the grass is green when treated, although a better control of *Holcus mollis* is obtained when treated before autumn; June or July probably being the best months for treating this species. An area at Minard Forest, Argyll, was treated with 0·75 or 1·5 lb paraquat (3 or 6 pints "Gramaxone W") per acre on 1st February, 1965. The grass species was *Holcus lanatus* (Yorkshire fog) and was green when sprayed. At neither rate of application was weeding necessary in 1965 nor 1966, although grass recolonisation has been noticeably faster in plots treated at the lower rate.

Mistblower application of paraquat at Drummond Hill Forest, Perthshire, in early August and late September 1965 (see *Report* for 1966 for details of the spraying) compared very favourably with application from a pressurised knapsack sprayer, neither treatment requiring weeding except for occasional patches which it would appear had not been sprayed properly. Untreated control plots required hand-weeding and the rate of work was one man-day per acre. A further experiment in this series was established in 1966 at Port Clair Forest, Inverness-shire.

J. R. ALDHOUS
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PUBLICATIONS BY STAFF MEMBERS

ALDHOUS, J. R. Bracken Control in Forestry with Dicamba, Picloram and Chlorthiamid. *Proc. 8th British Weed Control Conference*, 1966.

TREE STABILITY

Records of Windthrow

The period from mid-November 1966 to the end of March 1967 has been characterised by almost continual high winds. It is difficult to distinguish any particular gales, though the last day of November and first of December 1966, and the last day of February 1967, appear to have been the days when the maximum amount of wind damage was done.

The other feature of the winter has been the widespread distribution of damage, with forests in all parts of the country reporting windthrow or windbreak. In spite of the high frequency of winds, the acreage actually reported damaged was only 340 acres, but a large proportion of this acreage consisted of tall and fairly valuable crops.

The annual variation in the acreage wind-damaged in Forestry Commission plantations is of interest. The area reported wind-damaged in the years under report is as follows:—

	acres
To 31st March, 1962	1,250
To 31st March, 1963	350
To 31st March, 1964	170
To 31st March, 1965	220
To 31st March, 1966	90
To 31st March, 1967	340

In the previous decade, 1953 was a disastrous season, and as these two very stormy years (1953 and 1962) followed some three years after sunspot maxima, it will be interesting to see whether the pattern is repeated.

Tree-pulling Investigations

Two main studies of rooting using the tree-pulling technique were completed during the year. In Brendon Forest (Somerset) comparisons were made between a pair of species on three different soil types. Douglas fir and Corsican pine were compared on a Humus iron podzol; Sitka spruce and Lodgepole pine on a Peaty gley podzol; and Sitka spruce and Norway spruce on a shallow Brown earth.

On the two sites where Sitka spruce was compared with other species, it was found to have a heavier root system, and a higher root/shoot ratio than either the Lodgepole pine or the Norway spruce, and was in each case one Yield Class more productive than the other species.

Douglas fir differed in much the same way from the Corsican pine, but the crops compared were not of the same age, and this could have accounted for some of the differences.

In Newcastleton Forest (Roxburghshire) the old drainage Experiment 13 was investigated to obtain further evidence of the effect of drainage on root development. Sample trees were pulled over in two plots which had received contrasting drainage treatments; one minimal and the other intensive. The results suggest that the trees in the intensively drained plots have responded slightly to the drainage since they are significantly more deeply rooted ($16\cdot9 \pm 1\cdot47$ in. as compared with $13\cdot2 \pm 0\cdot64$ in.) for those which received minimal drainage. The sample is really too small to draw firm conclusions, but the results suggest that further study would be justified.

Aerodynamic Studies

The main effort is still being concentrated on the large experiment at Redesdale Forest (Northumberland). The technique for raising the 80 ft-tall masts, with all the instruments attached, and without disturbing the forest, was successfully developed during the year, and several months' records of wind velocity profiles above the forest have been obtained. It was fortunate that the first few months of 1967 turned out to be very windy and a good range of wind velocities have been experienced.

Preliminary analysis of the results suggests a good correlation in relative wind velocities between the model forests used in earlier wind tunnel tests and the full field scale. There is also a suggestion of quite marked changes in "roughness" of the crop with changes in mean wind velocity. The wind velocities amongst the crowns of the trees inside this unthinned Sitka spruce stand never exceed 10 per cent of the velocity at the same height above ground outside the forest.

Thinning Studies

An experiment has been established at Kielder Forest (Northumberland) to compare the effect of a range of thinning intensities on the incidence of wind-damage. The lowest intensity of thinning in the range will be in fact a "no thinning" treatment, though it is anticipated that about 20 per cent of the volume will be lost due to death of trees. The other three treatments are 60 per cent, 100 per cent and 140 per cent of the Forestry Commission Management Tables intensity. (F.C. Booklet 16, *Forest Management Tables*, H.M.S.O. 1966, 30s. 0d. refers.)

The experiment will include crop measurements, but the main objective is to follow up the conclusions drawn from the aerodynamic studies that unthinned stands are least likely to subject individual trees to damaging wind forces. The site chosen for this experiment is very susceptible to wind damage, because it is exposed, and the soil type is a peaty gley which makes the crop very shallow-rooted.

Wind-loosening of Lodgepole Pine

A questionnaire was completed by the four Scottish Conservancies in which the area planted with south coastal provenances of Lodgepole pine, by age classes, was given. On the basis of 51 sample forests, Conservators were asked to estimate the area of Lodgepole pine with little, moderate or severe proportions of bowed stems. (Little: amount not worthy of special consideration. Moderate: under 50 per cent of crooked stems which would be removed as thinnings. Severe: over 50 per cent of stems with sabre butt.)

The survey showed a very large increase in recent years in the use of susceptible provenances—in a period which has also seen the extension of planting on to more exposed ground. Twenty-six per cent of the area of planted ground was estimated as likely to be moderately affected and fifteen per cent as severely affected. Apart from the possible inaccuracy of the above forecast, the main unknowns are the gross conversion losses associated with particular specifications and the degrade due to compression wood.

Three experiments on exposed sites at Shin and Strathy Forests (Sutherland), and Glentrool (Kircudbrightshire) were established in which 13 treatments are screened for effectiveness in minimising windsway. These include age and type of stock, method of planting, manurial treatments, etc. In previous experiments reduction of phosphate manure and delay in application proved unsuccessful.

Sporadic Windthrow

In two Border forests surveys of "sporadic" windthrow have been carried out on typical peaty gley soils, as such damage is frequently the precursor to more extensive damage. (In this context "sporadic" implied groups of one to five trees —larger groups bring many additional factors into play which are being investigated in other ways.) All sporadic windthrown trees were classified by position in relation to drains (on cleaned drainsides, on uncleaned drainsides and between drains) by height and by breast-height quarter-girth. A sample of the standing crop was classified on the same basis.

The survey suggested strongly that the risk of throw is greatest on cleaned drainsides (significant at the 1 per cent level) in spite of the fact that previous thinning would have concentrated on removing trees in this commonly recognised susceptible position. The similarity of height and girth distributions between standing and thrown trees suggested that there was no close relationship between windthrow and individual tree size. Also height appeared to be independent of position in relation to the fairly shallow existing drains. It was concluded that even more attention should be paid to the removal of trees standing on cleaned drainsides, and the need to complete drain deepening well before the onset of wind-susceptible crop height is emphasised. Also the rapid progression from sporadic to more extensive damage was noteworthy.

A. I. FRASER
S. A. NEUSTEIN

PUBLICATIONS BY STAFF MEMBERS

FRASER, A. I., and PYATT, D. G. Crop Stability Assessments in Man-made Forests. *Paper for the 6th World Forestry Congress, Madrid*, June 1966.

MIXTURES

Mixtures of Lodgepole Pine and Sitka Spruce

Before considering the need for further experimentation, an extensive survey of mixtures of Lodgepole pine and Sitka spruce has been carried out—its object being to attempt to define the conditions under which nursing benefit occurs. Twenty-four forests suggested by Conservators were visited, and a total of 91 sites were examined; details of site, establishment method and crop were recorded on punched cards. Summarisation and analysis is in progress, but it appears that sites on which Sitka spruce can be grown advantageously in admixture with Lodgepole pine are rare.

In many cases mixtures of these two species have had an "insurance" motive, the proportion of each species used depending on the estimated probability of success. Favourable interaction is not in this case the main motive, but rather an anticipated bonus. The conflicting factors involved are, that if the mixture is an intimate one the chances of suppression of the spruce is increased, whereas group or band mixtures increase the risk of rough pine. Also it is more difficult to justify supplementary manures to a mixed crop where the species with the greatest potential is relatively scarce. Economic calculations suggest that, on the sites in question, the potential gains by an admixture of less than 50 per cent spruce are not expected to be high.

Long-term Mixtures

At Lennox Forest (Stirlingshire) the site for a new experiment comparing a mixture of Red alder and Norway spruce, with each species planted pure, has been selected. The site is a surface-water gley on heavy clay in which the previous Sitka spruce crop, due mainly to shallow rooting, became unhealthy and windthrown in the early pole stage, in contrast to the deep rooting alder with which rides were demarcated. Norway spruce as yet is relatively healthy but its continuing health and stability is in doubt. Sitka spruce/alder mixtures are represented on a small experimental scale but it is thought probable that these species will not be compatible in the long term.

S. A. NEUSTEIN

MISCELLANEOUS INVESTIGATIONS IN PLANTATIONS

Growth Problems in Pole-stage Sitka Spruce

In 1966 an experiment was laid out in Blairadam Forest, Fife, to investigate the effect of different canopy densities and depths on the growth of pole-stage Sitka spruce in a region where fall-off in growth is known to occur. Two types of thinning were carried out during the summer, each removing 30 per cent of the standing basal area; in the first the prescribed basal area was obtained by marking large crowned dominant and co-dominant trees, while in the second only small-crowned trees from the lower canopy classes were marked. Unthinned plots provided a third treatment. Unfortunately, gales during the 1966–67 winter have caused considerable windblow within the experiment, as well as in the surrounding plantation which was thinned at the same time, and its future is in jeopardy. In view of past experience at Blairadam the occurrence of windblow after thinning was not altogether unexpected. It is of considerable interest, however, that the amount of windthrow to date has been greatest in the plots thinned by removing upper canopy class trees, and least in the unthinned plots, suggesting that thinning from above is undesirable in windthrow-susceptible areas.

At the Forest of Ae (Dumfries-shire) observations have continued in the experiment set up in 1963 in an attempt to quantify increment loss due to *Elatobium* defoliation. Very few aphids were found in the experimental area during 1965, but during 1966 a build-up in population was successfully controlled by malathion spraying in June. To date no significant difference in basal area increment has been observed between the treated and control plots. Three similar experiments are currently being established in the north-east of Scotland, an area in which severe *Elatobium* attack is known to have occurred in the past. The forests concerned are Deer (Aberdeenshire), Rosarie (Banffshire) and Fetteresso (Kincardineshire). Assessments and control measures began in spring 1967.

Spacing in Plantations

Of more than 100 spacing experiments established in 1935 and 1936, 44 have been maintained in the Silviculture (North) area, and a review of these is now in progress. In terms of volume production, initial spacings in the range of 3 ft by 3 ft to 8 ft by 8 ft do not appear to produce significantly different total volumes by 30 years of age, if subject to normal thinning régimes.

A further study of a limited number of experiments which have been maintained unthinned since planting is of interest in this respect. (See Table 28.)

These data suggest that if pulpwood rotations with no thinning are contemplated, then initial spacings of under 8 ft are not required to achieve maximum volume production from the site.

From a general review of these experiments it does not appear that the form of the trees or the degree of branch development suffers unduly from spacings as wide as 8 ft, except in the case of Scots pine (see Plates 4 to 7). Owing to the lack of representation in the series, it is not possible to be sure about the effect of spacing on Lodgepole pine, but with some provenances, for example South Coastal, one would expect a similar development to Scots pine.

TABLE 28

MEAN VALUES FOR FOUR "R" SERIES SPACING EXPERIMENTS IN PINE ALL OF YIELD CLASS 100 AT 29 YEARS

Initial Spacing	(1) 3 ft×3 ft	(2) 4½ ft×4½ ft	(3) 6 ft×6 ft	(4) 8 ft×8 ft
Mean Top Height, feet	35·5	34·8	34·1	34·8
Mean Total Volume Production, hoppus, feet.	2,100	1,940	1,430	1,380
Mean "Effective" Volume Production, hoppus, feet.	760	1,230	1,120	1,270

Note: "Effective" Volume production has been arbitrarily defined as being composed of live trees containing 1·5 hoppus ft or more of timber volume.

The fear with these pines is that much of the "effective" volume may not in fact be merchantable, due to the frequency of stem malformation, which is usually concentrated in the more valuable lower portion of the tree. At a slightly closer spacing, such as 6 ft, the proportion of good stems in the crop is usually sufficient to permit thinning to produce a well-formed final crop. Studies of the effects of wider spacing upon timber quality have begun, but no results are as yet available.

Most of the spacing experiments were established upon reasonably good sites, and it is not possible to be precise about the possible interaction of spacing with adverse site conditions, but some general observations may be made. The period of "check" due to heather competition is prolonged at wider spacings with Sitka spruce, but the use of closer spacings could probably be obviated by the use of chemicals to control heather invasion of the site. There is some evidence, for Sitka spruce, that widely-spaced plantings suffer more severely than closely-spaced on frosty sites. Some experiments were abandoned because of the uneven development due to this factor. One which was retained and has now formed complete canopy in all spacings, shows a marked degree of stem deformation at 8 ft which diminishes progressively to the 3 ft spacing.

A. J. LOW
G. G. M. TAYLOR

POPLARS AND ELMS

Poplar Varietal Studies

Varietal Trial Plots

Further evidence was obtained of the ability of *Populus trichocarpa* and its hybrids to succeed on a wide range of sites in Britain. Of special interest were the data collected at the northernmost trial, at Brahan Castle Estate, near Dingwall, Ross-shire, where at fourteen years of age the volume of a plot of *P. trichocarpa* (clone CF) was nearly twice that of the next most productive plot, of *P.* 'Androscoggin', and more than three times that of the fastest growing plot of *P.* x *euramericana.* Not surprisingly this is one of the most productive plots in the country. Data for *P. trichocarpa* and *P.* 'Androscoggin' are given in Table 29.

TABLE 29

POPLAR TRIAL PLOTS: BRAHAN CASTLE ESTATE, ROSS-SHIRE
HEIGHT, GIRTH AND VOLUME AT 14 YEARS

Clone	No. of trees per acre	Mean height (ft)	Mean breast height girth (in)	Basal area (ft^2 q.g.)	Volume per acre over bark (hoppus ft)
P. trichocarpa	134	66·3	43·2	109·12	2,934
P. 'Androscoggin'	118	58·0	35·2	63·22	1,603

Several cultivars of *P.* x *euramericana* are represented on the site but none had a volume at 14 years in excess of 920 hoppus feet per acre. The fast rate of growth of *P. trichocarpa* inevitably interests growers; unfortunately the most vigorous clones are either susceptible to bacterial canker or inclined to produce excessively large numbers of branches. Only one clone under trial, a selection from Washington State, U.S.A., appears to have any commercial future.

Specimen trees of *P.* 'Gelrica' and *P.* 'Robusta' were felled at several trials to provide logs for testing by the match industry.

Varietal Collection

At present nearly 500 clones are held in the collection, though about ten clones introduced for identification, and a further twenty believed to be duplicates, will be destroyed at the end of the current season.

Populetum

Only one clone was planted during the winter, but a number of recently imported clones are being propagated for early inclusion and all available space will probably be filled within the next two years. A total of 301 clones has now been planted.

Spacing of Poplars

Measurements of girth were taken in the major experiments. At Lynn Forest, Norfolk, close-spaced plots in the earliest planted experiment were thinned during the winter, those with the trees planted at 8 ft for the second time, those planted at 14 ft for the first time. The experiment was laid down in 1953 and 1954. Neither of these spacings appears to be attractive if the object is to produce veneer logs.

Pruning of Poplars

The large experiment at Cannock Chase, Staffordshire, was again assessed, when further pruning treatments were applied to selected trees. Preliminary results, which have already confirmed that heavy pruning has an adverse effect on the radial growth of poplar, suggest that in practice light prunings undertaken annually may hinder growth *least* of any treatment. Supplementary experiments have been started at Alice Holt Forest, Hampshire, and at Rogate Forest, Sussex, to see if there is any relationship between season of pruning and the production of epicormic shoots.

Distribution of Poplar Cuttings

A total of 9,550 nine-inch cuttings of the approved clones were distributed to trade nurseries and private estates during the winter. This compares with a distribution of 19,000 in 1966 and 22,600 in 1965; many nurseries have now built up foundation stocks from cuttings we supplied earlier. Though cuttings were again sent to research workers in Great Britain in relatively large numbers, the demand for material from overseas workers was the lowest for many years.

Bacterial Canker Investigations on Poplars

Much of the field work on bacterial canker will now be undertaken at a heavily infected site at Blandford Forest, Dorset. During the winter newly introduced clones to be screened for resistance to the disease were planted there for the first time. Previously the work had been done at Fenrow Nursery, Aldewood Forest, Suffolk, and at other centres in East Anglia. For the fourth year in succession commercial clones were planted on the site to observe their long-term behaviour in conditions leading to natural infection.

Elm Clonal Collection

Several fresh selections of English and Dutch elms were made during the year and will be added to the collection as soon as plants can be raised. To date 72 clones have been established in stool beds at Alice Holt.

Propagation of Elm

Work continued on methods of raising plants from hardwood cuttings but results, as in previous years, were disappointing. None of the treatments applied to the cuttings markedly improved their rooting, and the rate of survival was generally less than 10 per cent. Experimental stocks continued to be raised from softwood cuttings in mist, and no special problems were noted. Large-leaved elms such as Dutch elm again tended to be more difficult to root than small-leaved subjects such as Wheatley elm, however, and special techniques may have to be devised to improve their survival. The "take" of elm in mist varies between about 50 per cent and 70 per cent, depending on the species and time of insertion.

Propagation from layers is now receiving attention and, during the winter, selected plants were lined out at wide spacing so that studies can begin during the coming season. The basic techniques and possible variations in rooting ability between species will be examined in the first instance.

Elm Establishment Studies

Elms that grow vigorously in the first year or two after planting tend to be unstable and may require staking. Methods of improving their stability are being tested at Alice Holt. Elms respond well in the nursery after being cut back to the root collar—straight and vigorous shoots are invariably thrown out from the cut stump—and the technique is being tried with newly-planted stock in the forest. So far, survival has not been affected by cutting back but there is no evidence yet that the treatment has increased stability. Both root suckers and plants raised from softwood cuttings have grown well after being cut back at planting. Methods of chemical weed control are being tested at Alice Holt.

Elm Disease Testing

Further clones were planted in the Elm disease trial at Alice Holt, and will be inoculated with the causal organism, *Ceratocystis ulmi*, when properly established. Trees planted and inoculated in previous years were assessed for susceptibility to the disease by measuring the amount of crown die-back that occurred during the growing season. Several clones have now been assessed on three occasions and it is hoped to summarise the results shortly.

J. JOBLING

FOREST ECOLOGY

The Weather of the Year

Less aberrant on the whole than its predecessor, the year ending March 1967 showed some noteworthy features. Most significant, perhaps, was the very mild, yet not abnormally wet, winter, allowing, in most districts, steady progress with nursery work and forest planting.

Most important in general is the weather during the three months April to June, the time when drought and frost may cause losses and checks to growth in young plantations. April 1966 was cold and, except in north Scotland, wet: mid-April brought to England the only substantial snowfall of the winter. Rainfall was generally above average in May and far above in June; there was no problem of drought damage to young trees in plantations or nurseries and survival rates were generally high.

As to frosts, whereas their frequency in Thetford Chase (notably during the last few days of May) was rather greater than in 1965, there appears to have been no widespread damage, such as the frost of 19th and 20th May 1965, caused to Sitka spruce and some other sensitive trees in most parts of the British Isles. In neither year was anything comparable with the late May frosts of 1961 recorded.

The summer was marked by temperatures below, and rainfall above, the average, with September the only dry month: some nominally wet districts of the north and west had less than average rainfall in the summer. Sunshine amount was near normal, or rather below. These conditions were reflected in the prevalence of some fungus diseases of foliage.

November was a cold month, though not so conspicuously cold as November 1965. Apart from several frosty days at the New Year, the rest of the winter was very mild in England and Wales; in Scotland, too, severe weather was short-lived, but in December snow was frequent, flooding being caused in north-west Scotland by melting snow in mid-December. Gales, mainly during December, or in the last week of February, were widespread, but nowhere disastrous.

One may perhaps summarise the year's weather by saying that the oceanic ingredients in our climate usually dominated the mixture.

The steadily mounting interest in the influence of weather on forests, which is exemplified by current research on wind and storm damage, on forest hydrology; on frost damage in regeneration clearings, and on lowered susceptibility in certain weather conditions to fungus and insect diseases, led in October 1966, to the formation of a working group of those most closely concerned. This Weather Group, under the chairmanship of A. I. Fraser (Assistant Silviculturist, South) will, amongst other things, concern itself with the exchange of information, the development of appropriate methods of observation and recording, and the adaptation and testing of suitable instruments.

Corsican Pine Studies

Summer Frost Damage: Thetford Chase, East Anglia

As in 1965, this work was centred in Thetford, with a continuation of the survey of minimum temperatures and of damage by frost in the growing season to newly planted stock. Broadly the pattern of grass frosts was similar to that of 1965, but with frosts more frequent and severe in spring, less frequent in October. The interim results were summarised for a symposium on "Frost" in March at Aberystwyth (University College of Wales Geography Department):—

(i) In experimental planting of Corsican pine and other species under light pine cover, the frost risk was considerably reduced, as compared with normal planting after a clear fall. On radiation nights the difference in minimum temperatures at 15 cm amounted to about 4°C, rarely to 6°C. At 60 cm above ground the corresponding difference was 2°C to 3°C.

(ii) Trees planted on grass-free cultivated ground are more favourably situated in relation to frost than trees planted in vegetation, particularly the dense grass cover which arises on chalky soil after felling. On radiation nights, thermometers at 15 cm recorded a temperature 2°C to 3°C higher over bare soil than over grass. More active heat loss from grass at night, more radiation gain by the bare soil by day (some of the heat being returned at night to the lowest layer of air), and less interference with turbulent exchange at night over the soil, may all contribute to this difference.

(iii) The eight years' observations at the silvi-climatological station at Grimes Graves show an even chance of slight air frost some time in July: with rare exceptions in July and August, grass frosts occurred in every month and were more frequent and severe than in open country at Mildenhall. Some of the replanted clearings proved colder than Grimes Graves.

(iv) Midsummer frosts (minima at 15 cm −3°C to −5°C) on 4th July 1965, and 30th June 1966, caused slight frost rings, and some scorch of tips of current needles, but no more serious damage to Corsican pine. Death or die-back of shoots as a result of the more severe frosts of late May and early June (minima at 15 cm −6°C to −10°C) was restricted to small pines on the coldest sites.

(v) Evidence was gained that severe frost damage to Corsican pine during the growing season presupposes a minimum temperature near the ground lower than −5°C. But the influence of duration of frost (in the short nights of May and June) which may well be important, has not been looked into: nor has consideration been given to the different, and probably more severe, action of frost with wind.

(vi) Examination of stem sections indicated a cessation of cambial activity about the last week in September; the frequent moderate frosts of October 1965 caused no evident injury. Nor did the earlier milder autumn frosts of September 1966 leave evidence of damage.

Influence of Shade

In connection with regeneration experiments involving the planting of Corsican pine under shade, EEL photoelectric cells have been used to estimate the interception of light by the canopy. From a value of about 50 per cent at the time of planting, there was an increase to 60 to 65 per cent after two years, due to expansion of crowns of the overwood trees. Young Corsican pines, though with thinner stems and leaves than trees of the same age in full light, have appeared to tolerate well this degree of shading.

A nursery experiment, involving four degrees of artificial shade, besides a full daylight treatment, was set out in Alice Holt with three-year-old plants in March 1966. The treatments will continue for one or two years more: but an interim assessment in October showed significant reductions of diameter increment and dry weight of tops under the stronger shades (transmitting respectively about 15 per cent and 6 per cent of full daylight). More marked were the thin, weak needles of the strongly shaded plants and the reduction in number and size of the buds.

In this same nursery, some plants surplus to the experiment are being used in a preliminary study of the periodicity of Corsican pine root growth. The first clear evidence of fresh extension of root tips was seen on one tree on 14th March and this was general on 23rd March, soil temperature at 30 cm being 5·6°C and 7·0°C on these dates. But there were indications of sporadic root growth during the winter months—scarcely surprising in view of the high temperatures prevailing. For several days around 1st February, the soil temperature at 30 cm was at, or above, 7°C: thereafter there was a fall and no lasting recovery to values above 7°C until the sunny days in the third week of April, when bud elongation became general.

Seed Production and Natural Regeneration

Although the year as a whole had not a good record for warmth or sunshine, the summer and early autumn of 1964 were sunny and very dry in England, with the result that Corsican pine stands produced abundant flowers in 1965. In February 1967, 144 seed traps were put out in three 30-year-old stands in Thetford Chase, in a study of the course of seed fall and the year-to-year changes in its amount. As in 1962, the last full mast year, cones began to open, in dry sunny weather, in mid-March (noted first on 18th March in Alice Holt and Thetford Chase). The 1962 seed resulted in negligible natural regeneration—nor indeed had past experience encouraged us to expect any. Accordingly an effort is now being made to trace some of the main sources of loss between mature cone and seedling. Much seed is destroyed by squirrels in the full cone on the tree; more is doubtless devoured on the ground by squirrels, pigeons, pheasants, finches or mice: some may survive till germination time, but fail then because of unsuitable temperature, moisture, or ground cover.

Health and Disease

In Thetford Chase two very local occurrences of dieback disease (*Brunchorstia pinea*) have been added to the five identified in 1963; but there is nowhere any sign of an increase towards an epidemic. A widespread, but seldom severe, bronzing of the current foliage in the late summer was again noted throughout the country in 1966. This has been tentatively associated with cool, cloudy summer weather, but a possible causal connection with the fungus *Hendersonia acicola* (recovered from most of the diseased material) is being examined by the pathologist.

J. M. B. BROWN

PUBLICATIONS BY STAFF MEMBERS

FRASER, A. I. Recording some Aspects of a Forest Environment. *Paper for the British Ecological Society Symposium* 1967: The Measurement of Environmental Factors in the Study of Terrestrial Ecology.

SOIL MOISTURE, CLIMATE AND TREE GROWTH

Soil Moisture and Evapotranspiration Studies

General

The routine collection of soil moisture data from our five forest sites (see *Reports* for 1963–1966) has continued, but as 1966 was not a particularly unusual season we shall not comment individually on each of the sites. The neutron soil moisture gauge acquired in 1965 will clearly be the main source of soil moisture data for deep, freely-drained sites such as we are currently examining, However, much remains to be done in connection with this technique, regarding calibration and data processing, before the benefits of the system are fully realised. Dr. Kitching, who was leading these activities, left the Forestry Commission in August 1966 to take an appointment with the Geological Survey.

Feltwell, Thetford Chase, Norfolk

Measurements of girth increment with band dendrometers over the four years since the experiment started, given in Table 30, show marked differences from year to year.

TABLE 30

GIRTH INCREMENTS, FELTWELL

inches

Corsican pine, planted 1926	Girth increment			
	1963	1964	1965	1966
150 stems per acre, underplanted with beech	0·571	0·719	0·783	0·525
600 stems per acre	0·353	0·422	0·488	0·322

While much remains to be found out about the site factors concerned, we know that Corsican pine grew poorly in many places in 1963, probably as a result of the preceding cold winter. The poor growth in 1966 is almost certainly due to the demands of developing cones for the heavy seed crop falling in early 1967.

Drainage Studies

A member of the Soils Section, in company with a Silviculturist, a Work Study officer, and a field District Officer, visited Finland in June 1966 to see forestry on peat, research on the drainage and hydrology of such sites, and the machinery and planning involved. The demonstrations of large drain ploughs drawn by winch were remarkable for the very great efficiency achieved, with no idle time whatsoever between hauls, and the very good speeds obtained. These ploughs were similar to the Lokomo but usually incorporated modifications made locally, suggesting some dissatisfaction with, or shortcoming of, the original design. A more fundamental change—the substitution of a hollow steel wheel, of similar radial section to the plough body, for the body itself—appeared to be a real advance, and it might enable such ploughs to operate with an important proportion of the plough penetrating mineral material. Otherwise the system seemed to be more suitable for very large areas of deep peat where drains would scarcely cut into the mineral soil even at the edges of the bogs. Bucket diggers were considered to be as, or more, economical under other conditions. It is interesting to compare these views with those expressed by Troup in the *Report* for 1966 (page 81), formed as a result of his experience with a Lokomo plough at Kielder Forest in Northumberland.

It was very helpful to see the current research techniques in peat drainage and hydrology; many of these methods would be applicable to our own peatland, although, generally speaking, great caution is needed in the application of Finnish experience to British conditions.

The members of the party were greatly indebted to Professor Heikurainen for his personal kindness to the party and the great pains he took in arranging a successful tour.

Instrumentation and Techniques

Neutron Soil Moisture Gauge

This equipment, which was fully described in the 1966 *Report*, has been used regularly throughout the year. Twenty access tubes, each some 2·5 metres long, are now installed at each of our three main sites (Bramshill, Burley and Rendlesham), ten in each species plot. During the growing season visits were made about every fortnight to each site, readings being taken at 10 cm depth intervals in each tube and recorded on Lector forms (see below, and the *Report* for 1966, page 87).

The equipment has performed quite reliably, and the ability of our own staff to deal with most of the electronic servicing required has been an advantage. After consultation with the Radiological Protection Service, and a review of our practice, we no longer require field operators to be Designated Radiation Workers, nor to wear film badge dosimeters. These precautions are, however, retained for servicing or performing tests with the unshielded probe.

We are in touch with other users of this type of equipment and the Forestry Commission is represented on a Neutron Moisture Gauge Users' Group, set up under the auspices of the Hydrological Research Unit at Wallingford.

Although for studies of *change* in soil moisture storage, simple calibration techniques are satisfactory, both the presence of neutron absorbing elements, such as boron, and the bulk density of the soil, are known to affect accurate calibration. When tests at present in progress on these factors are completed, we should be able to reap the full benefits of the system.

As with any automatic or semi-automatic technique, it is only too easy to amass a vast amount of data, and there is a serious danger of being drowned in a sea of moisture-content readings. The results from the neutron moisture gauge can be looked at in several ways. One is to study the total moisture content for a profile, and regard changes over time as changes in profile storage. Another way is to plot the moisture contents (or counts) down the profile at different dates and look at the effects of rainy and dry periods on the shape of the curve (see *Report* for 1966). More recently we have tried a different presentation, in which the counts are plotted as point values, the co-ordinates being time and sampling depth. Contours of equal count are then drawn in, and an example of such a "map" is shown in Figure 3, together with values for rainfall and E_0. It can be seen that the counts are steady at the 150 cm depth, but that drying and wetting take place during the year above this.

Data Logging

All readings from the neutron moisture gauge have been recorded in the forest on Lector forms. This system requires the use of special, very accurately printed forms, which are marked in the forest. The information encoded in this way is read by a Lector Document Reader and transferred to punched paper tape,

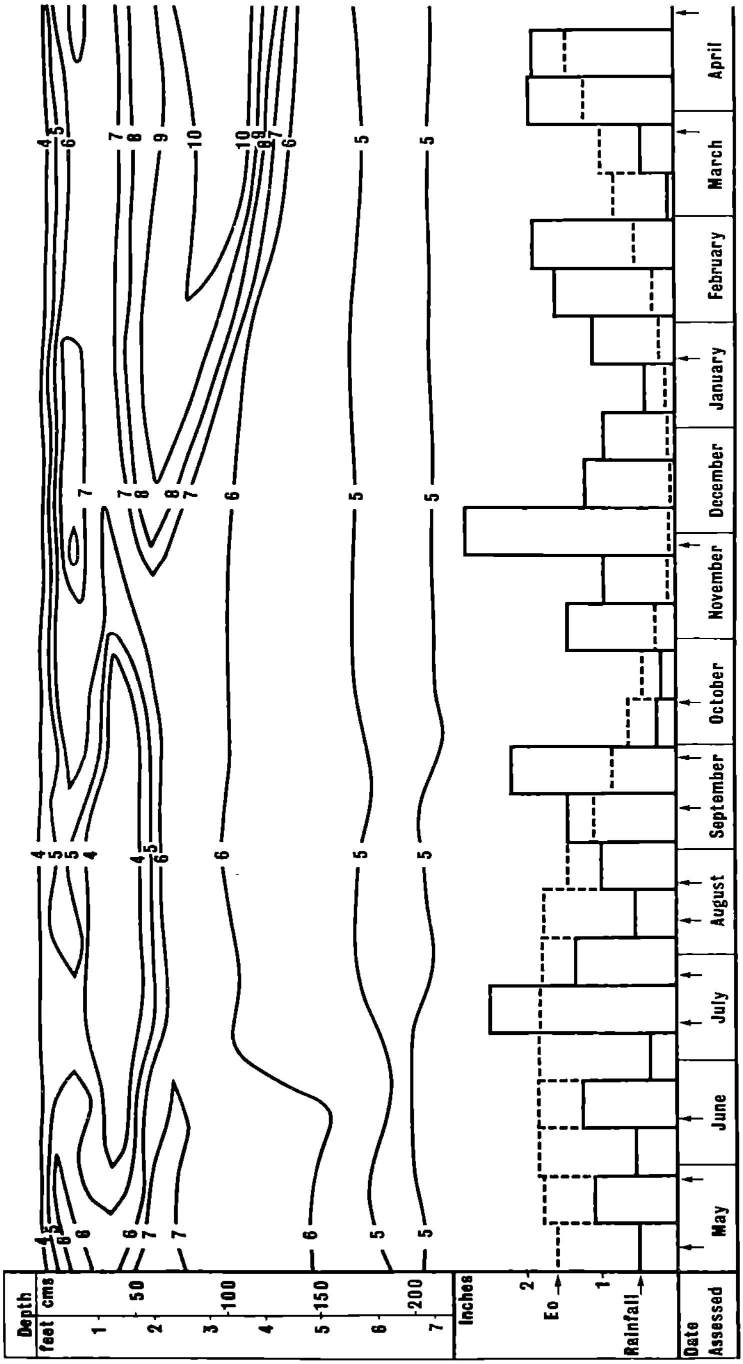

FIGURE 3. Contour diagram of lines of equal counts per minute (× 1,000) from the neutron soil moisture gauge, with rainfall and open water evaporation (E_0). Bramshill Forest (Berkshire and Hampshire), 1st May 1965 to 5th May 1966.

which can then be read directly by the computer. Writing of figures and copying of the data are thus both eliminated. After early teething troubles due to poorly marked forms the system has worked fairly well, but the need to use a Document Reader situated in London, on contract, has robbed it of some of its advantages.

Potential Evapotranspiration

The computer programme prepared to calculate Penman's formulae for open water evaporation (E_0) and potential evapotranspiration (E_t) has been modified to accept data copied directly from Meteorological Office Monthly Weather Reports. Another programme has been used to assess the effects of alteration of various constants in the E_t formula. It would seem, for example, that a value of 0·15 for the albedo, or reflection co-efficient, is more appropriate to forest crops than the figure of 0·25 for "short green cover" normally used in E_t calculations.

We are in touch with the Meteorological Office over the form and use of the Penman formulae, and we are studying with interest the modifications they are making to the Heat Budget term, to allow for latitude and reduction of incoming solar radiation by air pollution.

Garnier Gauge Records

The two similar Garnier gauges maintained at Alice Holt are part of a network of stations. The data has recently been discussed by Green (1964) and he has produced tentative maps of Potential Evaporation from the watered grass.

In Table 31 results are presented for the Alice Holt installation for 1966, with Rainfall and Sunshine records, and for comparison, Penman formula (1962) calculations made by the Meteorological Office from data collected at South Farnborough, Hants.

TABLE 31

EVAPORATION RECORDS—ALICE HOLT LODGE 1966

Month	Potential evaporation (in) (E_t)			Penman Formula Estimates (Met. Office) Average 1962–66		Rainfall at Alice Holt 1966 (in)	Sunshine daily mean hours	
	Lysimeters		Calculated Value*				Normal from tables	Actual 1966
	A	B		E_t	E_0			
January	−0·41	0·10	0·25	0·18	0·30	2·00		1·40
February	0·50	1·02	0·40	0·53	0·88	5·41		1·20
March	1·17	1·16	1·00	1·21	1·73	0·54		4·50
April	1·23	1·64	1·64	1·98	2·83	3·89	5·05	3·20
May	2·84	2·89	3·29	3·20	4·00	2·76	6·20	7·25
June	3·73	3·41	3·73	3·59	4·49	2·44	6·90	7·45
July	3·97	3·62	3·44	3·42	4·27	2·62	6·50	5·50
August	2·94	2·71	3·28	3·04	3·80	2·60	6·30	6·65
September	2·32	2·24	1·77	1·89	2·70	1·28	4·60	5·25
October	0·61	0·76	0·65	0·75	1·07	4·41		2·20
November	0·74	0·87	0·20	0·31	0·52	2·11		2·10
December	0·30	0·72	0·15	0·11	0·18	3·60		1·20
Totals	19·94	21·14	19·80	20·21	26·77	33·66	—	—
Summer months	17·03	16·51	17·15	17·12	22·09	15·59	5·93	5·88

* See Technical Bulletin No. 4 Ministry of Agriculture, 1954 "The Calculation of Irrigation Need".

These show annual totals very similar to the measured E_t values, but which are below the E_0 values for open water.

The weather in 1966 tended to be moist and rather windy. Oasis effects on the lysimeters were not expected to cause differences, as there were only five occasions when there was morning dew on the gauges but not on the surrounds.

There are considerable differences between the monthly totals of the table—the lysimeters usually exceed the estimates in the winter months, with the position reversed in summer.

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FOREST GENETICS

Seed Crops

The year 1966 was a disappointing seed year for all species other than Corsican pine, which coned moderately well in east and south-east England, and Scots pine which produced a moderate crop in most parts of Britain. Estimates indicate that a total of some 30 lb of seed should be harvested in spring 1967 from the older Scots pine clonal seed orchards at Newton, Strathord, Stenton, Lynn and Bradon Forests.

The new procedure for the estimation of seed crops which is mentioned on page 66 of the *Report* for 1966, was repeated, with minor modifications, during the year.

One of the principles of the system is that future crop assessments will normally be made on two, or four, permanent plots of numbered seed trees in each stand in order to ensure that the same sample trees are used for estimation in successive years. In 1966 the Forest Management Division arranged for the harvested cones from each sample tree to be counted separately during the course of normal cone collection operations. Similar counts will be made in future years thus permitting tree by tree, plot by plot, and stand by stand comparisons to be made of the actually harvested crops against the estimates.

Checks have been carried out in seven stands of Scots pine (from three Conservancies), and eleven stands of Corsican pine (from four Conservancies) in which collection efforts were concentrated during the winter 1966–67. The results should enable any major source of error in the crop estimation procedure to be pinpointed, and corrected. Similar checks will be made for other species when the cone crops are sufficient to permit economic collections.

Survey of Plus Trees

Most activity was again centred on Sitka spruce and with the assistance of three students from Aberdeen University a further 119 candidate Plus trees of this species were selected. This figure brings the total number of selected trees to 332. The regional distribution of Sitka spruce Plus trees is given in Table 32.

TABLE 32
Number of Sitka Spruce Plus Trees by Regions

Region	Number of Plus Trees
North Scotland	30
North-West Scotland	60
West Scotland	68
North-East Scotland	6
Central Scotland	0
South-West Scotland	9
English/Scottish Borders	11
North-West England	4
North Wales	139
South Wales	5
South-West England	0
Others	0
Total	332

Other Plus tree selections were made for Corsican, Scots, and Lodgepole pines, Douglas fir and beech. Intensive surveys have still to be conducted in South-west Scotland, the Scottish Borders, South Wales and South-west England. In practice, particularly in stands where crown competition is severe and on steep hillsides, it is often difficult and costly in time to measure accurately the tree height, branch thickness and branch angle. For this reason the rules of the selection procedure will, in future, be relaxed when accurate assessments cannot be made readily from the ground.

Vegetative Propagation

Results of the 1965–66 experiments on the rooting of Sitka spruce cuttings at Grizedale, which were referred to in the *Report* for 1966, are now available. The investigations were based on 36 cuttings collected from the tenth to the twelfth nodes from the top of each of 16 candidate Plus trees. The cuttings were collected in October 1965 and were transferred to the Grizedale growth-room where they were inserted in a 1:3 peat/sand mixture maintained at a constant temperature of 21°C (70°F). The air temperature was 18·5°C (65°F) and a 20-hour photoperiod was maintained throughout the rooting period which extended to late May 1966. A second and similar collection of cuttings was made from the same trees in February 1966. This material was inserted into a similar rooting medium maintained at 21°C (70°F) in the mist-house until July 1966. The air temperature and photoperiod were uncontrolled. Additionally, approximately 30 grafts were made in the Grizedale glasshouses of 13 of the 16 clones; the scion-wood was collected from the ortets. Table 33 summarises the percentage success of rooting cuttings under the two régimes and of grafting under glass.

TABLE 33

PERCENTAGE OF SUCCESSFUL SITKA SPRUCE GRAFTS AND CUTTINGS ROOTED AFTER EITHER INSERTION IN A GROWTH-ROOM IN OCTOBER 1965 OR IN A MIST-HOUSE IN FEBRUARY 1966 AT GRIZEDALE NURSERY

Clone Number and Origin	Growth-Room. Inserted Oct. 1965. Percentage rooted in May 1966	Mist-House. Inserted Feb. 1966. Percentage rooted in July 1966	Glasshouse. Grafted Mar. 1966. Percentage successful Sept. 1966
457 Ratagan	11	56	—
458 Ratagan	8	8	—
459 Ratagan	39	6	—
1000 Ratagan	11	6	70
1001 Ratagan	0	8	42
1002 Ratagan	0	0	4
1003 Ratagan	0	3	12
1004 Ratagan	3	0	0
1005 Ratagan	61	6	50
1010 Inverinate	61	6	41
1011 Inverinate	11	0	79
1012 Inverinate	25	0	54
1013 Inverinate	8	0	50
1014 Inverinate	67	31	75
1015 Inverinate	6	3	30
1016 Inverinate	0	0	79

The data shows a wide clonal variation in the success of both rooting and grafting. Clones which can be readily grafted do not necessarily root easily and *vice versa*. Three clones (23 per cent of the sample) were difficult but not impossible to propagate by one or other of the methods; however, these clones gave such poor results that ease of propagation may, for practical reasons, become a prime criterion of selection for Sitka spruce Plus trees which are to be included in the breeding programme. The greater success in the growth-room, compared with the mist-house, is probably closely linked with the more uniform growing conditions and extra day-length. Strict comparisons cannot be made because of the differences in times of collecting and inserting the material. Compared with the 1964 experiments (see *Report* for 1964), when 60 per cent success was obtained from rooted cuttings, these results are quite disappointing and may be attributable to two factors. Firstly, in 1964 the cuttings were collected locally and inserted on the same day, whereas in 1965–66 the cuttings were in transit for four to five days. Secondly, fewer clones were used in 1964 and these may have included a high proportion of clones which normally root easily.

In general practice the overall percentage success of grafting Sitka spruce has now been increased to 44 per cent. A small trial with secondary scion-wood material (collected from young grafted plants) almost doubled the percentage success in comparison with primary scion-wood (collected from the parent tree).

Tree Banks

Propagation of the Sitka spruce candidate plus trees by grafting is now keeping abreast of the rate of selection, and a National Tree Bank for the species was started during the year at Wauchope Forest, Roxburghshire, Scotland. Because of the difficulties of obtaining scion-wood from the parent trees, collections from which have to be made by climbing, coupled with the indicated improved grafting success from secondary scion-wood, it is intended to utilise this Tree Bank to meet all scion-wood requirements for the future clonal seed orchard grafting programmes, which are scheduled to begin in approximately five years time.

A tree bank for Corsican pine was also started at Alice Holt Forest.

Controlled Pollination

The yield of seed from artificially controlled pollinations in Scots and Lodgepole pines has been disappointingly small since the first crossing-programme in 1958. Normally there are, in each Scots pine flower, approximately 40 ovules which are potentially suitable for developing into viable seed; in good seed years some 20–30 viable seeds are obtained from wind-pollinated trees in the forest. However, from artificial pollination of isolated flowers only six viable seeds have, on average, been obtained from each collected cone. Furthermore, there are large clonal variations in the amount of both natural and/or induced flower and/or conelet-drop between the time of flowering and cone harvesting—most of it occurring during the first three months following flowering. Thus in some seasons the mean number of seed *per artificially pollinated flower* has often been as low as 2–3 seeds, a factor which has severely restricted progress in the programme of progeny-testing.

During the period 1962–65 several minor trials were conducted with the object of demonstrating the main causes of flower losses and the low "set" of viable seeds. The factors under test in these trials included:—shape and size of isolation bags or tubes and the material used in manufacture; age of pollen; time of pollen application; the use of pollen/talc and pollen/BHC mixtures, and artificial abrasion of flowers to simulate wind-damage. The results of these trials were generally inconclusive, due mainly to the small number of flowers available per clone and treatment. Also in some experiments there were clone and treatment interactions. There were, however, indications that short 4 in. (10 cm) × ¾ in. (1·9 cm) celluloid tubes were superior to 15 in. (38 cm) or 18 in. (46 cm) × 9 in. (23 cm) "Terylene" bags fitted with P.V.C. windows; that short P.V.C. tubes caused severe damage to developing flowers; that freshly collected pollen was more effective than pollen stored at 25°F (–5°C) and at a relative humidity of 12 per cent for 12 months—and that pollen applications were being made a little too early and before the female flowers were fully receptive.

In 1966 further attempts were made, by a joint team from the Genetics Section and Aberdeen University Forestry Department, to elucidate the problems of seed setting and conelet and flower-drop more fully. This team carried out a joint programme of investigations centred on the Tree Bank at Newton and in clonal seed orchards at Drumtochty and Bradon.

The work consisted of a series of field and/or laboratory projects covering:

(*a*) Repeated applications of pollen during the period of flower receptivity.
(*b*) Single applications of pollen during three different stages of flower development.
(*c*) Removal of various proportions of the flower crop by hand.
(*d*) Single or repeated applications of ANA (alpha-naphthalene-acetic acid), a hormone which delays and reduces flower and fruit drop in apples.
(*e*) Recording diurnal variation in temperature inside different types of pollination bags and tubes.
(*f*) Investigations into the distribution of stained pollen grains in the pollen chamber and nucellus of the ovule after artificial application.
(*g*) Germination of pollen grains and development of ovules after artificial pollination.
(*h*) Methods of isolation including single flower and whole plant isolations.
(*i*) Pollen mixed with an inert carrier.
(*j*) Pollen taken from cold store and exposed to the air for varying periods of time before use.
(*k*) Freshly collected and stored pollen.

Certain treatments were applied to both grafted and forest-grown seedling material and from three to five clones were used for each experimental treatment using a minimum of 50 flowers for each treatment and clone. Over 8,000 flowers were required for the programme.

Some of these investigations will be repeated or expanded in 1967. The results will be fully reported elsewhere at a later date.

Glasshouse Investigations

Work on the development of early-test procedures for the screening of progenies of Plus trees under partially controlled environmental conditions was continued with Sitka spruce, European, Japanese and Hybrid larches.

An attempt to grow Sitka spruce progenies under glass for more than one growing season was unsuccessful. The plants developed abnormally in the second year after over-wintering in the unheated glasshouse. This problem appears to be associated with a winter-chilling requirement and further work with the object of finding the over-winter treatment necessary to permit normal development in the following season is currently in progress. This experiment is confined to Sitka spruce and European larch and involves three winter-chilling treatments, namely, plants transferred to an open nursery area for a period of six weeks, or, for 12 weeks, or, plants retained in a fully ventilated glasshouse without heat or extended photoperiod. The plants used in each of these treatments were subjected, in spring 1967, to alternative dormancy-breaking treatments—in a cold glasshouse without heat or supplementary light, or, in a heated glasshouse at 15·5°C (60°F) with an artificially extended photoperiod to provide a 15-hour day-length. Dates of bud "flushing" are being recorded and a series of assessments involving measurements of several characters affecting growth and development will be made throughout the 1967 growing season.

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PUBLICATIONS BY STAFF MEMBERS

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FOREST PATHOLOGY

Death and Decay caused by Fomes annosus

Earlier reports have included summaries of work done on the protection of first-rotation crops from invasion by *Fomes annosus* by means of chemicals and by use of the competing fungus *Peniophora gigantea.*

Problems of succession on already infested land have also been investigated, and in this connection studies are being made of the relative susceptibility to the fungus of various tree species. Some information has been gathered from field observations, but this cannot be fully relied on, and must be supported by the results of controlled experiments. Such trials have been set up, but they take a long time to yield final results. Some trees may be killed a few years after the start of the experiments, when their roots first come into contact with the sources of infection, but in those species (which form the majority) in which butt-rot is the most common and serious form of the disease, differences in species emerge only gradually, through a study of successive thinnings. They thus cannot be fully assessed until a late stage in the growth of the crop, though preliminary information may be obtained by the exposure and study of the roots of some of the trees in the experimental plots.

Results from these experiments so far relate only to killing of young trees. All the species studied (which include all the conifers commonly planted by the Forestry Commission) are killed by the fungus in their early stages of growth and it appears likely that the main early difference between species lies in the time at which deaths cease or are reduced in number, rather than in any inherent differences in susceptibility in the young plants. The various species differ in their initial rates of growth, and the roots of those that grow rapidly after planting soon come into contact with sources of infection, and are killed relatively soon. On the other hand these fast-growing trees quickly reach a stage when their root systems are less easily destroyed by the fungus. It is at this stage that inherent differences between species in their susceptibility to killing, to root-rot and to butt-rot, start to emerge.

The results so far are preliminary and limited in extent, but those for Scots and Corsican pine are of some interest. In the first rotation, pure stands of Scots pine are more severely affected by *F. annosus* than are those of Corsican. In the second rotation, however, both species at first appear to be equally severely affected when following Scots pine (whose stumps provide a most effective inoculum source for both species), but observations on some older replants suggest that deaths in plantings of Scots pine then continue longer than in those of Corsican. If further evidence is found to support this finding, therefore, there may ultimately be a reduction in *Fomes* losses in forests such as Thetford (Norfolk and Suffolk), where Corsican pine has been chosen to succeed Scots because of its greater productivity.

Top Dying of Norway Spruce

This disorder, which appears to be physiological in origin, shows as a reduction in growth, followed by browning of foliage and eventual death of the crown or sometimes of the entire tree. Investigations on it have continued during the year.

It is now clear that Top dying results from the operation of at least two separate factors. The first may be called the *conditioning factor*, which acts during a relatively mild winter and causes a reduction in growth in the following season. The degree of growth reduction varies from site to site, indicating that the effects of the conditioning factor may vary in degree. When the effect of the conditioning factor has been sufficiently strong, a proportion of the crop is rendered susceptible to what may be called a *precipitating factor*. Several factors which affect the movement of air through the crop, such as brashing, thinning, gappiness of crop and relative exposure of site may be included under this heading. It may be suggested, then, that Top dying symptoms appear after a combination of conditioning and precipitating factors have upset the physiology of the tree.

Field Studies

A survey of all compartments of Norway spruce in three divisions of Coed Morgannwg Forest in South Wales was undertaken during the year. The extent of Top dying in each of these compartments was assessed, and records were taken of a number of site factors which might relate to the condition. It was found that a large number of Norway spruce stands in the Margam division (fifteen out of eighteen compartments) were affected by Top dying, but only a small number in the Rheola division (four out of seventy-seven). The third division, Cymer, contained four Norway spruce compartments, one of which was affected. The percentage of affected trees in the different compartments varied considerably; there were six compartments in the Margam division with over forty per cent of the crop affected.

The survey is now continuing with a study of the effect of the conditioning factor (assessed by means of growth measurements) in different compartments in the area.

Laboratory Studies

It is possible that the effect of relatively mild winters on Norway spruce is to reduce the level of carbohydrate reserves in the tree. Carbohydrates have been extracted from Norway spruce material for analysis during the season. First results are variable but there is some indication that a decrease in levels of carbohydrate occurs after flushing.

Effect of Low Temperatures on the Establishment of Corsican Pine

The continuation of this work has shown the progressive effect of low temperatures. In plots of trees planted in hand screefs in a grass mat where a mean minimum temperature of 26·4°F (—3·1°C) was recorded on cold spring nights, the mean height of the plants after three growing seasons was 8·8 in. Similarly, over shallow plough screefs made through litter and chopped brash, now being invaded by grass, the corresponding temperature was 26·0°F (—3·3°C), and the plant height 9·4 in. On the other hand over bare soil in a small plot at the same place, the temperature was 30·3°F (—0·9°C), and the plant height 20·8 in.

Though various factors contribute to the environment differences in the study areas, the greatest and most important appears to be that of these low temperatures in the early part of the growing season on the sites with a grass mat, litter or brash, or a combination of these. On such sites, but not on the bare soil plots, the plants have shown symptoms and a growth habit like those of plants damaged by cold, and supporting experiments with a cold chamber have produced similar symptoms on Corsican pine plants subjected to night temperatures of 27°F (−2·8°C) or below.

In the plots at Thetford where check by cold has occurred, the plants show a progressive loss of vigour, and earlier observations would suggest that many of those now looking stunted and poor will eventually die.

Some aspects of this work have already been reported by Hurst (1966).

Blue Stain in Pine Timber

Studies on Blue stain in pine, carried on jointly with the Forest Products Research Laboratory, Princes Risborough (Ministry of Technology), have been continued. Following conflicting results obtained from experiments briefly summarised in earlier reports, a monthly felling experiment with Scots pine logs was laid down, the first felling being in May 1966. At each felling, two untied Latin squares were laid down in a forest ride, and the individual plots (each consisting of one saw log) were treated with the insecticide lindane (gamma-BHC), the fungicide tribromophenol, or both, or left untreated as controls. The plots were assessed for blue stain after three months. Three random cuts were made across the logs, and the percentage of the area of the cut surfaces affected by Blue stain was estimated. Notes on the presence or absence of bark beetles were also made. Nine monthly assessments have now been made, and the results so far have been fairly consistent. Considerable Blue stain was present in control logs felled in May, June and July, when the beetle population was also high. Little stain was found in the August-felled logs, and almost none in those felled from September to January (to which the last available assessment refers), when almost no beetles were present. So far, the fungicide has caused some reduction in Blue stain, and the insecticide has usually given a somewhat better result, while the two combined have consistently reduced the staining to a very low level. In only the earlier months was Blue stain sufficiently abundant to give a satisfactory separation of the treatments, however, and the experiment will be continued to cover at least two full seasons.

A leaflet on the practical implications of Blue stain for the timber trade was published during the year. (F. C. Leaflet 53. *Blue Stain* by B. W. Holtam. HMSO 6d.).

Bacterial Canker of Poplar caused by Aplanobacterium populi

The work on Bacterial canker of poplar is directed towards establishing a reliable method of screening poplar clones for resistance to the disease. At an international meeting (of the Working Group on Diseases, International Poplar Commission, F.A.O.) held at Versailles in October 1966, it was agreed that a standard method of inoculation should be used for all screening tests in Europe. All inoculations in these tests will now be made with a pure culture of *Aplanobacterium populi* at leaf scars produced by detaching leaves in the spring and autumn. These inoculations will be assessed one year later and scored according to a standard system. The first collection of clones to be inoculated by the standard method was planted in 1967 at Blandford (Dorset), where poplar canker trials are now being concentrated. Previous canker tests had been carried out mainly at Fen Row Nursery in Suffolk.

Further observations on natural outbreaks of Bacterial canker have confirmed that bacterial slime exudations occur throughout the growing season but only in very limited quantities in the summer and autumn. Observations are being continued on possible infection sites for the bacterium during the season.

Leaf Spot of Poplars caused by Marssonina brunnea

Marssonina brunnea (E. & E.) Magn. was recorded for the first time in Britain during 1966. Its presence was confirmed at only one site and it was not causing serious damage to the poplars. However, observations will be made during 1967 to determine whether the disease is more widespread and whether it causes premature defoliation of poplars as it does on the Continent.

Poplar Mosaic

With Dr. T. W. Tinsley, of the Commonwealth Forestry Institute, Oxford, and members of his staff, who are working on virus diseases of trees, an examination was made of poplar stocks in the Allotment Field, Alice Holt. Symptoms of Poplar mosaic were found on stocks of many clones, some of which were heavily infected. The stocks have since been rogued, and will be re-examined in the coming season to estimate the result.

TABLE 34

POPLAR MOSAIC

EXAMINATION OF POPLAR STOCKS, ALLOTMENT FIELD, ALICE HOLT, 1966

High percentage of infected plants

P. trichocarpa J2
P. "Serotina VB"

Moderate infection

P. "Heidemij"

Small numbers of infected plants

P. "Eugenei PU"
P. "Robusta PH"
P. "Robusta AE"
P. "Robusta H"
P. "Gelrica VB"
P. "Gelrica HA"
P. trichocarpa C
P. trichocarpa CF
P. tacamahaca × *trichocarpa* 32
P. tacamahaca × *trichocarpa* 37

No infected plants found

P. trichocarpa T3

Table 34 gives the results of the 1966 examination.

The leaves illustrated in Plate 2 in the centre pages show typical vein-clearing symptoms of this virus disease or disease complex. On poplar stocks in nurseries, leaves showing the symptoms most clearly, commonly appear in mid-season about half way up the plants. For comparison, Plate 3 shows leaves with symptoms of magnesium deficiency, which was rather common in 1966. These deficiency symptoms appear on leaves at the bases of the plants, and are readily distinguished from those of the virus disease.

Needle Blight of Western Red Cedar caused by Didymascella thujina (Keithia thujina)

Investigations were continued in nurseries in westerly areas in which one spray application of cycloheximide, given at the normally recommended time in late March, had sometimes failed to give control of Needle blight. This disease appeared in the Fleet Nursery, Kirkcudbrightshire, in South Scotland, and Tair Onen Nursery, Glamorgan, in South Wales, in 1965 and experiments at these nurseries were therefore carried out in 1966. The results differed from those obtained in 1965 in Wiston (Slebech) Nursery, Pembrokeshire, where three sprays were then needed to give adequate control (*Report* for 1966, page 73). In 1966, Needle blight was less severe than in 1965, and at both the Fleet and Tair Onen, one spray application gave satisfactory control, and the effect of further applications was slight.

Cycloheximide is not readily available in this country, and trials were therefore carried out with other materials. Fentin hydroxide (Du-ter), dodine acetate (Melprex), dithianon (Delan), streptomycin (Spikespray), and an organomercurial fungicide ("P.P." Mercurial Fungicide) were all applied twice in these experiments, once in March and once in April, but none gave a useful measure of control. Further trials are planned, to test a number of readily available chemicals applied at frequent intervals throughout the growing season.

Studies with a spore trap using Millipore filters showed that ascospores of *Didymascella thujina* were readily trapped from the atmosphere over an infested plot of Western red cedar. The spores were present in large numbers in June and early July, but few were then trapped until early September, when a second peak emission occurred. This second peak was much smaller than that in the earlier part of the year, but may provide spores that either overwinter on the foliage or cause infections that develop the following spring. In view of this, leaf surfaces of Western red cedar plants were examined for spores of *D. thujina* over the autumn and winter, using the Collodion strip method. Many ascospores were found on the foliage from August until early December, but there was then a sudden reduction. Nevertheless, very small numbers of apparently viable spores were still present in early April, and in March a few spores showing infection pegs were found. These few spores may be sufficient to initiate infections in the spring.

Seed Pathology

Results of health tests of samples of conifer seeds carried out at intervals over a number of years have now been drawn together, and suggest that the samples with a high germination are relatively free of moulds, but those with a low germination are commonly heavily contaminated.

A pilot trial in which seed was treated by Maude's thiram/hot water method (Keyworth, 1965, 1966) showed that this method was worth further study.

General

Advisory work continued to increase, and 421 enquiries were dealt with, 125 from Commission staff and 296 from others. Eighty-six visits were paid as a result of the queries. Two foresters and one experimental officer now spend a large part of their time on this work. An additional forester will shortly move to Scotland, partly to improve the advisory service there, and partly to carry out disease survey and research work.

The growing season in 1966 was again mainly damp, dull and cool. Earlier, in the first few months of the year, wide variations in temperature were experienced, mild and very cold spells alternating with one another. An unusual blackening of lower foliage associated with this period was seen on Western red cedar, mainly on hedge plants. The symptoms, which were rather like those briefly described by Day & Peace (1934), differed from the normal bronzing of red cedar plants, which occurs every year on nursery plants, but is reversible.

The alternating mild and cold conditions also seem to have been the likely cause of extensive death of bark on poplar stems, found to have occurred in several places at some time in the dormant period between the 1965 and 1966 growing seasons.

Over the past few years, perhaps associated with a series of poor, cool summers, three diseases appear to have increased markedly. Two are of no significance in forestry, as they occur on Weeping willows and Lombardy poplars. The first is the anthracnose of Weeping willow caused by *Marssonina salicicola*, attacks by which on leaves and shoots caused widespread damage for the third year in succession, and appeared to have increased considerably this season. Most records were from the more southerly half of the country.

On Lombardy poplar, the leaf blotch, again caused by a *Marssonina*, *M. populi-nigrae*, also seems to have increased. It attacks the leaves, causing an early leaf fall that progresses upwards from the base of the crown. If crowns are repeatedly attacked, they die back from the base, and the trees may be so much weakened that they die.

The third disease, which is probably mainly climatic in origin, causes a spectacular browning and death of the needles of Corsican pine, and there is growing concern about this damage in some localities. Death of the needles occurs in the later part of the summer, and is confined to the current year's growth. There is wide variation between individual trees in the intensity of the damage, and in affected stands, healthy trees can be found immediately adjacent to those showing severe damage. The common needle fungus *Hendersonia acicola* has usually, but not invariably, been found on damaged needles, and where it was absent, no other fungus of importance was found. The exact pathological status of *H. acicola* is not known. It does not appear to play any primary role in this damage, though it may be parasitic on needles adversely affected by some other agency. The browning has been much more prevalent in the north and west than in the south-east, and this distribution helps to support the view that the disorder is mainly climatic.

In another section of this report, it is noted that *Marssonina brunnea* has now been recorded on poplars in this country. A less important new record is of *Fusicladium fraxini* Aderh., which was found on ash near Dunoon, Argyll. The affected leaves exhibit purple or violet areas that later become brown and necrotic.

Dothistroma pini (whose perfect stage, *Scirrhia pini*, Funk and Parker, has recently been reported from British Columbia (Funk and Parker 1966)), now the cause of a major needle blight on pines in many parts of the world, was again recorded from Wareham, Dorset, where it appeared on beds of *Pinus ponderosa* at the end of February 1967. The disease, which causes red spots and bands on needles of all ages, leading to their death in late autumn, winter and spring, was first recorded in Wareham in the autumn of 1954, though it is thought to have been present in the area for several years before this. So far it has not spread to other parts of the country, perhaps partly because of efforts to eradicate it and partly because for optimum growth and spread it appears to need a higher rainfall than that of south-east England and of other parts of Britain to which pines from the Wareham nursery have mainly been sent.

Mr. D. Alexander, of Brunel University, worked with the Section for six months. Mr. D. Seaby, of the Queen's University, Belfast, spent three months with the Section, and during his visit designed and made a volumetric spore trap, mainly intended for use in connection with the work on Needle blight of Western red cedar.

Members of the Section took part in the first meeting of the British Forest Pathology Working Group, held at the Commonwealth Forestry Institute, Oxford, in April 1966. At the first paper-reading session of the Federation of British Plant Pathologists, held in London on 17th February, 1967, they presented papers on Bacterial canker of poplar, Needle blight of Western red cedar, and some problems in the establishment of Corsican pine in the second rotation.

During the year, revised editions of the leaflets on Honey fungus *(Armillaria mellea)*, *Fomes annosus*, and Needle blight *(Didymascella thujina)* of Western red cedar were prepared, and that on *Honey Fungus* (Forestry Commission Leaflet No. 6. H.M.S.O. 1s. 9d.) was published. Also published were the Forest Record No. 61, *Brunchorstia Dieback of Corsican pine*, by Dr. D. J. Read, of the University of Sheffield (H.M.S.O. 1s. 9d.), and Forest Record No. 63, *Forestry Quarantine and its Biological Background*, which was a paper presented to the Sixth World Forestry Congress by D. H. Phillips and D. Bevan (H.M.S.O. 2s. 0d.).

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D. H. PHILLIPS

PUBLICATIONS BY STAFF MEMBERS

PHILLIPS, D. H., and BEVAN, D. *Forestry Quarantine and its Biological Background.* For. Rec. For. Comm. Lond. No. 63. 1967.

PLATE 1: The Experimental Workshop at Alice Holt Research Station (p.121)

PLATE 2: Forest Pathology (p. 99)

Leaves of poplar of clone 'Heidemij', showing the symptoms of the virus disease Poplar mosaic. The symptoms show mainly as a pale clearing of the veins of the affected leaves.

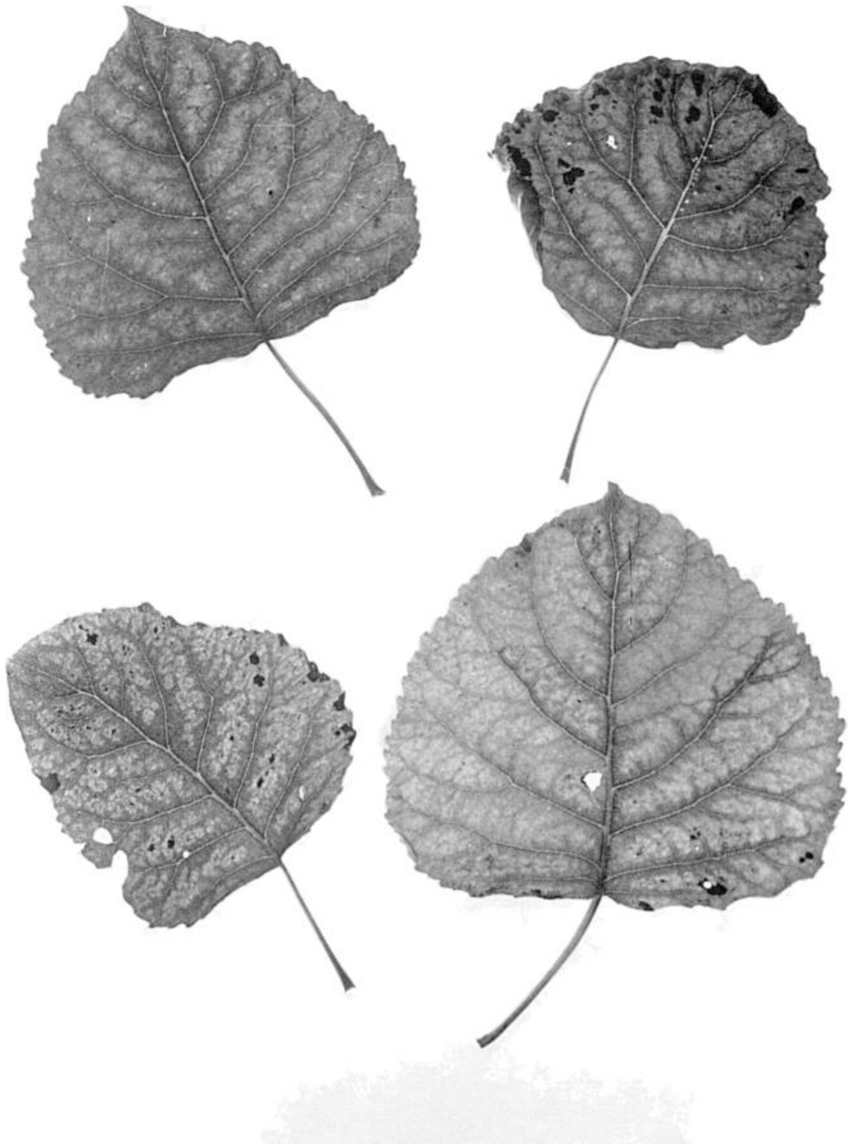

PLATE 3: Forest Pathology (p. 99)

Leaves of poplar of clone 'Gelrica VB', showing symptoms of magnesium deficiency. The symptoms show as a clear marginal yellowing of the lower leaves of the plants.

PLATE 4: Planted at 6 feet × 6 feet.

PLATE 5: Planted at 8 feet × 8 feet.

Scots Pine, Slaley. Experiment 1 P36. "R" series, unthinned except for removal of dead trees. Photographs taken at 30 years old. Note moderately straight growth and moderate branch development of trees planted at 6-ft spacing, as compared with frequency of malformed stems and coarse branching of trees planted at 8-ft spacing.

SPACING IN PLANTATIONS (page 78)

PLATE 6: Planted at 6 feet × 6 feet.

PLATE 7: Planted at 8 feet × 8 feet.

Scots Pine, Slaley. Experiment 1 P36. "P" series, regularly thinned to C/D intensity. Photographs taken at 30 years old. Note increased development of coarse branch habit as a result of thinning, and frequency of badly shaped stems in 8-ft spacing despite thinning to favour the best trees.

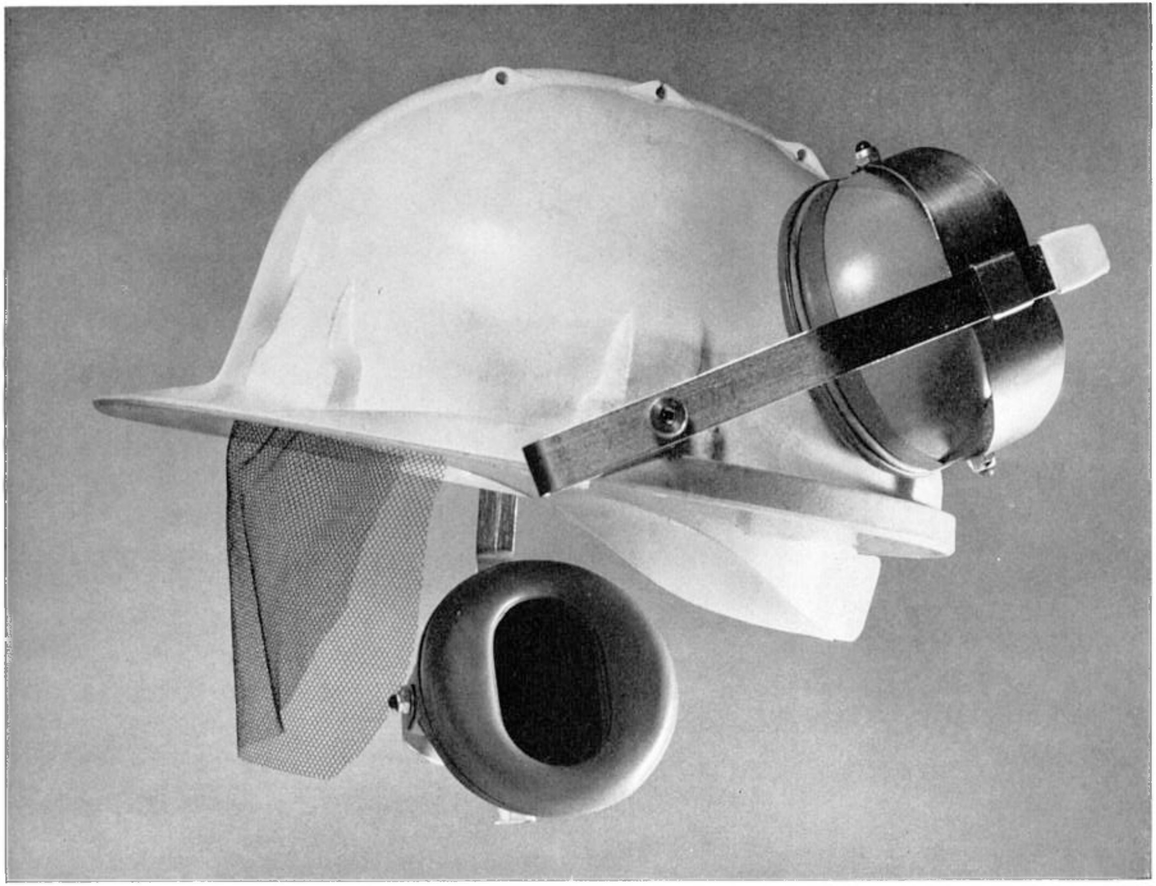

PLATE 8: Work Study (p. 117)
Safety helmet combined with ear muffs. Note the eye net which gives protection against flying particles.

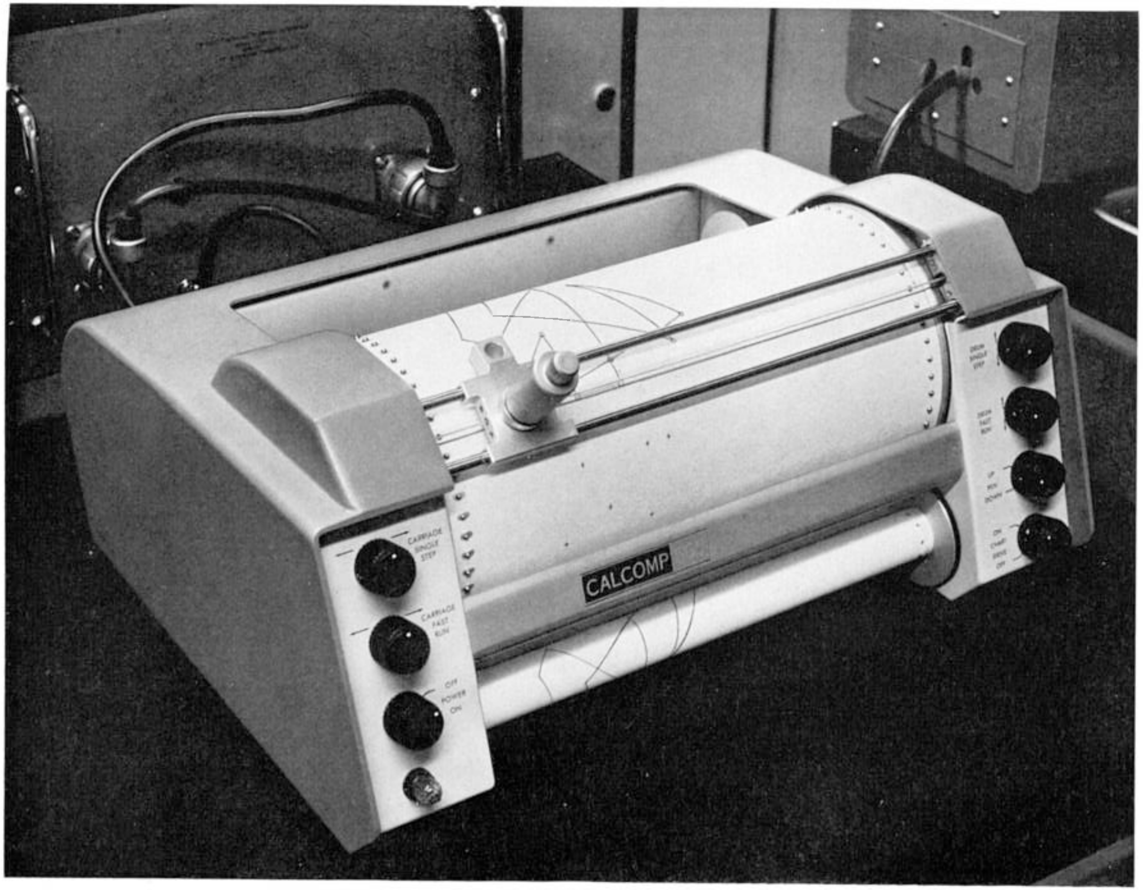

PLATE 9: Design and Analysis of Experiments (p. 124)

The Calcomp plotter fitted to the Sirius computer. The plotter has a step size of 0·01 inch, and will plot at a speed of 18,000 steps per minute.

PLATE 10: Work Study (p. 116).

The Holder A20 tractor modified for its forest role

FOREST ENTOMOLOGY

Pine Looper Moth, Bupalus piniarius

During the winter of 1966–67 populations of Pine looper pupae showed some slight increase in 36 of the 48 units surveyed. The highest compartment mean pupal count found in England, 5·2 pupae per sq yd, occurred in Cannock Chase, and that in Scotland, 6·4 pupae per sq yd, at Millbuie, Black Isle Forest.

Douglas Fir Seed Wasp, Megastigmus spermotrophus

Following laboratory tests of insecticides done in 1966, a further series of tests was carried out with BHC, malathion and an additional material, fenitrothion. This last gave satisfactory results although it was somewhat less effective than malathion and BHC. It was shown that the effectiveness of malathion and fenitrothion is mainly due to contact action, whereas BHC is effective by its fumigant action alone.

Fenitrothion was selected for field trial against the seed wasp on the strength of the laboratory tests, and the fact that it is reported to remain effective for 10–14 days. However, no control was achieved. This leaves us in the position that malathion is the only insecticide so far found to be effective in the field. The persistence of this material is low, perhaps only 24 hours in warm weather, so that several applications may be necessary to achieve satisfactory control.

Population studies were continued by means of seed-trapping and assessment of cone samples. Seed-trapping is now in its fourth year, and assessment of cone samples has been done for five years. The years 1962, 1963 and 1964 were generally poor for Douglas fir cone-production. Whilst 1965 was a comparatively good year, at least in some of the stands under investigation, 1966 was the poorest year yet. The infestation of good seed crops in 1965 was found to be of the order of 20 per cent, or less, whereas infestation of 80 per cent, or more, was typical of poor crop years.

Control of Pine Shoot Beetle, Tomicus piniperda

An experiment was carried out to test the effectiveness of post-attack treatment by spraying stacks with Gammalin, at four concentrations (0, 0·25, 0·5 and 0·75 per cent) and in two diluents, i.e. water compared with diesel oil. These eight treatments were applied at the rate of one gallon of solution to a 100 sq yd of bark surface using a mist-blower.

It was found that Gammalin in oil was significantly more effective than in water. Control of *Tomicus* broods in both inner and outer logs was successful, though effects of changing concentrations were relatively small.

Control of Hylobius abietis and Hylastes species

The *Report* for 1966 mentioned experiments which suggested that dipping whole plants in 1·6 per cent Gammacol is an improvement on dipping tops only in 5 per cent Didimac, for control of *Hylobius*. The Gammacol treatment is now undergoing user trials. During the year an experiment was started to determine whether this treatment is also effective against *Hylastes*.

Green Spruce Aphis, Elatobium abietinum

(*a*) *Defoliation/Increment loss*

A study was started in which the volume increment was measured in pairs of adjacent Sitka spruce plots, one of which has a recent history of defoliation by *E. abietinum* and the other has remained free. The method (see *Report* for 1966), which involves accurate measurement of internodal discs from 20 trees in each plot, will aim primarily to determine that part of the variation in increment which may be ascribed to the aphids' activities. Information will also be sought on the pattern of increment within the tree and the crop, as well as the effect of climate on this pattern.

(*b*) *Host plant susceptibility*

Techniques of extracting sap for analysis are being investigated and include acetone elution of macerated needles, and suction from cut branches. Initially, interest has been focused on the seasonal abundance of free amino-acids in the xylem sap. Using chromatographic techniques and suitable solvents, aspartic acid has been found commonly to occur throughout the winter and spring months.

(*c*) *Flight period*

As a by-product of the suction trap used in connection with work on *Adelges* spp. (see below, and *Report* for 1966), precise information has been gathered on the flight period during 1966. Alates were captured during the period 8th May–15th June, with the peak occurring between 13th May–8th June. The onset of flight coincided with a rise to 12°C in air temperature—a rather low reading for the initiation of flight activity if comparison is made with some agricultural crop aphid species.

Adelges on Conifers

Means of identifying the winged forms of the more commonly occurring *Adelgid* spp. have been investigated. Numerical analysis has been applied to morphometric data and results suggest that the method may provide a way of separating this particularly difficult group.

Progress has been made with transfer experiments of *Pineus pini* between secondary hosts. No galls, either of this species or of *Adelges nusslini*, upon the primary host, *Picea orientalis*, were found in 1966. The anholocyclic species, *Pineus pineoides*, which feeds on the stems of *Picea abies*, was recorded in Kent and Herefordshire.

Two peaks of *Adelgid* flight were observed through suction trap collections, the first in June and early July, and the second at the end of August and September. The summer flight is recognised as the migration of the sexupara form from the secondary host, whilst the autumn flight indicates departure of the gallicola form from the spruce primary host.

Suction Trap Collections

Apart from the information gained on the flight periods of *Adelges* spp. and of *E. abietinum*, an interesting, though fortuitous, yield of phenological data has accrued upon other groups and species of insect. Fourteen species of *Scolytidae* were taken in small numbers, all during the period April–June with the exception of *Pityogenes bidentatus* and *Pityophthorus pubescens* which appear to fly throughout the summer. Particularly large numbers of migrating aphids were caught this year. Daily catches at the end of September and first two weeks of October were heavy and dominated by one or two species, *Anoecia corni* being amongst the most abundant. The exclusively conifer-feeding *Cinara* spp. were trapped in June and also in mid-September. The oak-feeding species *Tuberculoides annulatus* and *Lachnus roborus* also appeared in the trap in small numbers. Unfortunately it is not possible to afford the time for identification of the whole catch, even of an economically important group such as the aphids. The trap does, however, provide an easy way of supplementing existing information on a variety of species not otherwise being studied.

Enquiries

There were 73 written enquiries to the Section from Forestry Commission and 51 from private sources during the year.

D. BEVAN

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MAMMALS AND BIRDS

Grey Squirrels

Investigations of methods of grey squirrel control are carried out in liaison with the Infestation Control Laboratory (Land Pests Branch) of the Ministry of Agriculture, Fisheries and Food.

Protection trapping of a vulnerable crop in non-isolated woodland, by cage-trapping in and around it just prior to the damage period, is being carried out for the sixth successive year. The previous results have suggested that recolonisation takes place within eight weeks of the area being cleared of squirrels by cage-trapping in March and in May. This emphasises that it is vital to reduce squirrel populations in and around a vulnerable crop immediately before and during the damage period.

No further field trials of Warfarin in Scotland were carried out. As was stated in the *Report* for 1966 (page 77), it has become apparent that the techniques can be successfully used to reduce numbers of squirrels in the Scottish trial areas where the populations are not of a high level. Legislation would be required to allow the technique to be further developed for use in England and Wales.

Deer

Work has continued on methods of aging deer. A study of the condition of bone marrow as an indicator of winter health in deer has been begun. The use of radio-tracking equipment for studying daily and seasonal movements of roe deer has been delayed by difficulties in obtaining sufficiently powerful transmitters of reasonable battery life for woodland conditions. Ear-tagging red deer calves has been continued in Galloway, South Scotland; census figures suggest that, on one forest, approximately a quarter of the calves have been marked each year. A study of the effects of fertilisers in improving natural feed for red deer has been begun.

Field-voles

Trials of a German product, Arrex E, showed that this was ineffective as a method of controlling field voles. Arrex E consists of orange cellophane packets, about one inch square, containing 1–4 sunflower seeds coated with zinc phosphide. Plots of poisoned and unpoisoned packets were laid out, and the rate of disappearance of the packets scored. The poisoned packets disappeared relatively slowly compared with the apparently similar unpoisoned packets. The plot treatments were then reversed: consumption of the poisoned packets dropped markedly, while unpoisoned packets were eaten freely in the previously "poisoned" plots.

Nursery: Protection of Seed from Birds

Seed-dressing trials with the thiram formulations, Fernasan S and Arasan, suggest that considerable protection from bird predation can be achieved. There appears to be some slight toxicity from the high rates of application used, but the technique may be useful where bird damage occasionally occurs. Where bird predation is a recurring nursery hazard, complete protection can be achieved by using half-inch mesh netting. Trials of a hawk silhouette suspended beneath a hydrogen-filled balloon suggest that this technique is of little value, particularly on windy sites where it is difficult to keep balloon and hawk high enough above the area.

Chemical Repellants in the Forest

Trials of chemical repellants have confirmed that "AAprotect" successfully reduces fallow deer browsing damage for at least eight weeks. Preliminary trials of Arcotal (a repellant which is to be marketed in place of Arikal) suggests that this also is effective for at least eight weeks. An experiment in which mothballs were scattered on the ground as a potential deterrent to roe deer browsing at Cranborne Chase, South-west England, showed that the presence of the mothballs had no effect on the incidence of damage.

Electric Fencing

Electrified polythene netting was apparently successful in preventing fallow deer damage to a half-acre plot of London plane and Grand fir over one summer and two winter seasons. However, hares damaged both the netting and the plants. Gramoxone herbicide treatment along the fence-line was required twice during summer to prevent vegetation causing electrical short circuits along the fence.

The electric fencing trials, conducted by S. A. Neustein, at Glenbranter in West Scotland, have been terminated after six years of use. The protection afforded was fairly good and publication of the details is proposed, as the method may be of interest for the protection of small plots.

Other Fencing

The Swyftyte fence in Thetford Chase, East England, continues to be satisfactory. Since the Swyftyte metal posts are expensive, a fence is now under trial which combines the advantages of high tensile spring steel wire with the cheaper conventional creosoted wood posts.

Trials of synthetic fencing materials have been carried out in Scotland by S. A. Neustein, who reports that:—

The comprehensive longevity comparisons of various specifications of synthetic twines used in deernetting which were established in the Spring of 1962 have now been exposed for five summers (four-and-half years). Table 35 presents the results in a simplified form.

TABLE 35

PERCENTAGE LOSS OF WET TWINE BREAKING STRENGTH AFTER FIVE YEARS

Material	Mean Loss of Strength %	Remarks
Nylon	80	None of the 5 specifications or preservative treatments is recommended.
Polypropalene	68	None of the 3 specifications or preservative treatments is recommended.
Terylene	49	Not recommended.
Polythene	51	Orange or green filament (whether superficially black-treated or not) is not recommended.
Polythene	18	Black. Recommended material for the upper portions of a roe deer fence.

Periodic testing will continue until the materials are used up.

Squirrel Questionnaire

The annual questionnaire on red and grey squirrels for the year ending September 1966 showed that the grey squirrel was increasing in numbers generally in South Wales, South-west and South-east Conservancies. Damage had also increased slightly, both in number of occurrences and severity. Red squirrels had declined generally in all conservancies in numbers, but no change was apparent in overall range.

JUDITH J. ROWE

PLANNING AND ECONOMICS

During the year Planning and Economics has been brought into a new Management Services Division, which forms part of the Forestry Commission's headquarters organisation and incorporates three branches: Planning and Economics, Work Study, and Organisation and Methods. Within the Planning and Economics Branch, work has continued in the four sections, Working Plans, Economics, Mensuration and Census. Aspects which have a high research and development content are reported upon below.

J. A. SPENCER

WORKING PLANS

Soil surveys at a mapping scale of 6 in. to 1 mile (1/10,560) were completed in the following forests during the forest year: Hamsterley (County Durham) Glentress (Peebles-shire), Ae (Dumfries-shire), Hafren (Montgomeryshire), Dovey (Merionethshire) and Kerry (Montgomeryshire).

Hamsterley Forest is situated in a heathland area of north-east England in a rainfall of 35–40 in. per year. Underlying rocks are grits and shales of the Carboniferous system, but much of the ground bears a mantle of fine-textured, glacial till (Boulder Clay), with impeded drainage. Although the area has a superficially heathy character, with heather, *Calluna vulgaris*, dominant, soils vary considerably and in a complex pattern.

The freely-drained soils, brown earths and humus–iron podzols have no major limitations, producing good, windfirm crops. By far the most productive stand in the forest, Grand fir of yield class 220, is growing on a humus–iron podzol, thereby emphasising the importance of rooting depth to tree growth *vis-à-vis* some other measures of soil "fertility".

Ironpan soils may also be deeply rootable if the ironpan is penetrable, or if it is first ruptured in soil preparation. Complete cultivation is advisable as it seems likely to produce an economic growth response on this type of soil (see G. G. M. Taylor, page 43 in this *Report*).

Surface-water gleys and peaty gleys developed on the glacial till are soils with impeded drainage, and give rise to shallowly-rooted, windthrow-susceptible crops. Flushed basin peats give rise to similar windthrow-susceptible crops, but infertile raised basin peats and hill peats have not yet produced pole-stage crops.

A survey of existing windthrow, in relation to soil types, crop top heights and relative topographic exposure, allowed the likely future importance of windthrow in forest management to be assessed. It was concluded that a small annual felling programme of 25 acres would cope with foreseeable damage at least during the next five years. This rather fortunate state of affairs exists partly because of the varied and frequently deep soils, and partly because of the height class distribution of the remaining crops.

Correlation of crop yield classes with soil types assisted with choice of species for replacement of unsatisfactory (larch) stands, and with drainage and fertiliser prescriptions where appropriate.

In contrast with Hamsterley, Glentress Forest has soils which are relatively uniform over large areas, so that the benefits to be derived from detailed soil survey are somewhat less striking.

Ae, Hafren, Dovey and Kerry forests are situated in the wet uplands of western Britain and have problems of windthrow and poor soil drainage. Surveys in forests of this type have been reported in the *Reports* for 1964 (Clocaenog, Denbighshire) and 1965 (Newcastleton, Roxburghshire).

D. G. PYATT

ECONOMICS

A considerable part of the Economic Section's work continues to be as a service to other Branches and Divisions of the Commission. The fields covered include the development of discrete tools of management, such as those for profitability assessment of specific forest operations, the provision of economic statistics, and advice on policy. An interest shared with many researchers in forest economics in other parts of Europe and in North America is forest-based recreation. This topic raises difficult questions of principle in relation to pricing and resource allocation, but the far-reaching implications for forest management of providing recreational facilities in a variety of ways, and on widely differing scales, deserve much fuller study than has yet been given to the subject.

In recent years new lines of work have grown out of the application of various guides to management which deal with specific types of investment.

In the first place there has been a growing effort devoted to planning problems arising at the regional level. The need to make the best use of resources in the light of new knowledge about the optimum intensity of individual forest operations, has been recognised for many years (see for example the section on "Economics in the Management of Forests", in the *Report* for 1961, page 70). A whole range of interactions exist in forestry but the complexity of the system makes it difficult, if not impossible, to optimise the working of the system as a whole. Various approaches may be adopted. One involves the optimisation of a particular activity over a whole group of forests, sometimes including forests in a number of Conservancies. An example of this type of approach is the programming of timber cut to meet a particular mill requirement (see *Reports* for 1964, pages 200–210, and 1965, page 71, and Forest Record No. 59, *Mathematical Models in Forest Management* pages 6–18 (H.M.S.O. 5s. 0d.)). Another recent line of work using this functional approach concerns planning the production of nursery stock. In this case the element of uncertainty in expectations of future plant requirements, future seedling yields and future lining-out successes has been taken into account explicitly. Using mathematical models and such other tools of operational research as are useful, optimum production arrangements can be planned, and means devised for the adjustment of operational programmes to changed requirements and production conditions.

An alternative approach to the problem of multiple interactions is to consider the interrelations of all activities, or at least a set of activities, in a particular management unit. Work has been done on establishment and maintenance operations in the clay areas of East England, and on the broad range of forest management operations in North Scotland. The aims of these reviews of resource use, on a regional basis, is to plan the best allocation of resources in the light of the implications of changed assessments of the profitability of particular operations.

A second major field of work has centred on the kind of records needed in management information systems, especially those required for financial control.

This work is done in collaboration with other Divisions of the Forestry Commission's headquarters. One line concerns financial control and the formulation of accounting systems. While investment appraisals generally deal with the longer-term aspects of planning, the function of financial control is to provide the means for shorter-term planning, and the adjustment of activities in the light of programme priorities and available resources. Another line of work which has been tackled involves the establishment of detailed planning procedures for particular activities. Thus in the field of plant production referred to above, an integral part of the whole system is the provision of appropriate planning techniques to control the programmes of sowing, lining-out and plant storage, as determined after the production model has been applied to the matching of requirements and production possibilities.

A. J. GRAYSON

MENSURATION

A new publication on the practical aspects of thinning control has been prepared for use in the field. This will supplement the *Forest Management Tables* (Booklet 16, published in July 1966, H.M.S.O. 30s. 0d.) which are intended mainly for office use. Several talks and demonstrations of the new system of thinning control have been given during the course of the year. (This new publication has since appeared as Booklet 17, *Thinning Control in British Woodlands.* (H.M.S.O., 10s. 6d.)).

Progress in the preparation of a booklet on standard measurement techniques has been slow because of the need to take account of possible changes when the metric system is introduced in 1972. A field survey of stacked to solid volume ratios, and wet and dry specific gravities of spruce pulpwood supplied to Bowaters mill at Ellesmere Port, was completed and the data is now being analysed.

Permanent sample plot work continued, and included the establishment of a replicated line thinning experiment in Scots pine at Millbuie, Black Isle Forest, in North Scotland. Table 36 summarises the present position for all permanent sample plots.

TABLE 36

NUMBER OF PERMANENT SAMPLE PLOTS

Country	Existing Plots	Plots lost through Felling, Damage, etc.	Total
England	381	93	474
Scotland	372	76	448
Wales	271	26	297
Great Britain	1,024	195	1,219

The replicated Douglas fir thinning experiment at Alice Holt was thinned again and the average annual volume increment for the five treatments following the first thinning is shown in Table 37.

TABLE 37

TOTAL VOLUME INCREMENT (MEASURED TO TIP OF EACH TREE) FOR THE DOUGLAS FIR THINNING EXPERIMENT AT ALICE HOLT

Hoppus feet per acre

Treatment	Annual Volume Increment 1962–1966	Mean Annual Volume Increment	
		1962	1966
Control (dead and dying trees removed)	195± 8·7	88	106
1·00 Management Table Thinning Intensity	205± 8·7	94	113
1·33 Management Table Thinning Intensity	180±16·6	96	110
1·66 Management Table Thinning Intensity	197±17·0	94	111
1·66 Management Table but crown thinning	188±11·7	90	106

Note: The differences between the volume increment for the various treatments are not significant at the 5 per cent level.

Table 38 shows the results for the first two growing seasons of the experiment at the Forest of Ae in South Scotland, to test the effect of varying degrees of release on the girth increment of young Sitka spruce trees of different dominance categories.

TABLE 38

GIRTH INCREMENT FOR THREE TREE CLASSES AND THREE DEGREES OF RELEASE

Inches true girth

Dominance Class of Released Trees	Number of competing dominants removed		
	1	2	4
Dominant	2·077±0·230	1·796±0·143	2·106±0·226
Co-dominant	1·080±0·156	1·462±0·225	1·290±0·119
Sub-dominant	0·350±0·103	0·683±0·168	0·850±0·123

Note: The initial differences in size between the trees selected for varying degrees of release within each dominance category mean that the percentage increments differ in some cases from the absolute increments quoted in Table 38.

The results of the replicated transplant thinning and spacing experiments in European larch, at Wareham and Alice Holt, are summarised briefly in Table 39.

The figures in Table 39 refer to wet weights of stem, branches and needles, but the dry weights show similar relationships. The results reflect reactions to spacing and thinning treatment which closely resemble those of tree crops at a much later stage of development. Ways of making more use of this research technique are being considered.

R. T. BRADLEY

TABLE 39

SUMMARY OF RESULTS FROM THE TRANSPLANT EXPERIMENTS

Thinning Experiment, Wareham			Spacing Experiment, Alice Holt		
Average spacing between trees remaining after thinning (inches)	Increase in weight for the 2 years from the time of thinning %	Total wet weight production %	Initial spacing at time of planting (inches)	Increase in wet weight for the 3 years from the time of planting %	Total wet weight production %
			3·0	83±10	89
4·5	54±19	74			
4·9	71± 7	74			
5·4	79± 6	80			
6·1	100±15	100	6·0	100± 6	100
7·1	57± 3	69			
9·0	56±11	68	9·0	107±23	102
			12·0	98± 5	93

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WORK STUDY

ORGANISATION

Over a three-year period the Work Study Branch has increased its strength from four to nine field teams. Seven teams are general purpose and undertake both silvicultural and harvesting investigations; they are based regionally and, in addition to their main studies, give a service to their regions, which consist of one or more Conservancies. The remaining two teams have special duties; an Experimental team, based on Kielder, is charged with machinery investigations, whilst the remaining team is studying brashing and is soon to turn to line thinning.

The programme for machinery investigations is formulated by the Machinery Investigation Committee, on which the Work Study Branch is represented. This programme is carried out mainly by the Experimental team but the other teams have also been heavily involved. A considerable number of developments and modifications is carried out at the engineering workshop at Alice Holt Research Station: the Work Study mechanical engineer is in direct charge of the workshop but with close professional liaison with the Chief Engineer and his officers.

Liaison, with outside bodies, notably the National Institute of Agricultural Engineering, are well developed. Recently, we have begun to establish contacts with those interested in ergonomic aspects of forestry. Ergonomics implies the relationship of the worker to his environment, which includes the tools and equipment that he is required to use.

MACHINERY INVESTIGATIONS

Although most of the work has been concerned with harvesting equipment, increasing resources have been deployed in the Silvicultural field and useful improvements have been made, and continue to be made, particularly in respect of weeding. In co-operation with the Economist and Harvesting and Marketing Division, operating costs for a range of extraction equipment have been calculated and used for the necessary reappraisals of optimum roading espacements. These, of course, vary with crop, terrain and mode of extraction, but it is worth noting that the modern forest tractors and timber carriers (tractors with hydraulic crane and tail-steering to a high capacity trailer) are associated with road intensities as low as two or three miles to the square mile of forest.

Shortwood Extraction Systems

By definition, shortwood systems are those logging systems which require the conversion of the tree length before extraction. A main feature of these systems is that they demand the preparation of adequate piles of material so that terminal time is minimised for expensive extraction machinery (terminal time comprises the following work elements: loading, movement between piles, and unloading). Since some of the equipment exceeds £5,000 in capital cost, high terminal times can greatly increase the unit cost of extraction. The optimum pile size varies with the characteristics and variables of crop and terrain, and the mode of extraction. Although much indicative data have been collected, there are blanks in our knowledge; a wide series of studies has therefore been started with this objective: to determine optimum sizes of pile associated with different logging systems.

One obvious drawback to Shortwood Systems is the heavy manual work involved in hand-piling or assembling. Although this has often been exaggerated, the physiological work-load is real enough and we are anxious to minimise it: to this end we have begun studies on multiple chokering for high lead cable cranes, e.g. the Isachsen No. 3 winch and/or Skyline. If successful, the result may be less piling work for the men without any reduction, or even an increase, in pay load. For the timber carriers, and other shortwood extraction equipment, no convincing means of reducing the hand-piling element are yet in sight. Despite this drawback, it is clear that shortwood systems are particularly applicable to small tree sizes and their development is an important goal. Brief notes on individual items that have been studied follow:—

M/F 165 "Robur" Timber Carrier

In the last report, mention was made of feasibility studies carried out on a County Super Four tractor with a rear-mounted Hiab 172 hydraulic grapple and 8-ton capacity, coupled trailer. These studies were encouraging but the anticipated defects of the equipment—in manoeuverability and balance and in respect of terrain limitations—were confirmed. The Robur outfit was imported from Sweden as a purpose-made timber carrier, and its superiority in cross-country performance soon became apparent. In particular it traversed stumps with fair ease (destumping of extraction racks had been necessary for the County) although, obviously, they should be cut as low as possible. Experience in the North of Scotland and the New Forest indicated that outputs of about 1,200 hoppus ft per day should be attained over average extraction distances of some 200 yd, at a cost of about 3½d. per hoppus ft including labour, labour oncost and machine charges. Bearing in mind the low roading densities associated with timber carriers, the appeal of these outfits is clear. Forests or groups of forests offering annual outputs of about 200,000 hoppus ft of shortwood should find them of interest. The next step in our investigations will probably be trials of all-wheel timber carriers such as the Swedish Drivax or M/F Flexor development.

Cable Cranes

Although cable cranes can be, and in some cases, *must be*, used to extract unconverted or minimally converted material, most of our experience has been in the extraction of pulpwood, and associated timber lengths. The main advance has been the development of a Skyline to extend the normal maximum, working range of the Isachsen No. 3 double-drum winch from 180 to about 300 metres. Although improvements are still necessary, the problem has now been answered substantially. Further work is needed to make the equipment extract uphill, and this is under way.

Kershope Winch

This equipment, developed by North-West England Conservancy, consists of a double drum winch mounted on the back of a Fordson tractor. The single, ⅜-in. wire rope, which can travel at speeds of from 30 to 90 ft per min, runs from one drum, round a snatch block in the wood and back to the other drum. Sledges of 20 hoppus ft capacity, used in pairs wherever the terrain allows, are clipped on to the line and pulled in, as empty sledges are returned to the wood. This winch, developed specifically for the extraction of short pulpwood, has produced notable cost reductions in North-West England Conservancy. It has obvious terrain limitations and, up to the present, is not suited for long pulpwood or timber extraction. However, for short pulpwood specifications, where ground conditions are too soft for a Holder tractor (see below), the winch has a place in the extraction "spectrum".

Tree-length Extraction Systems

These are logging systems in which the tree length, topped at the appropriate point, is extracted, as such, for conversion out of the wood. Sometimes, particularly in thinnings, minimal cross cutting is needed in the wood purely to ease the extraction phase. Tree-length systems have been regarded as sensitive to tree volume, that is, their efficiency increases with tree size. Although broadly true, the introduction of *light*, frame-steering tractors has made this less important. Broadly speaking, we would associate light machines with early and middle thinnings, and heavy machines with late thinnings and clear fellings. In both cases we have developed the techniques of multiple chokering (synon. "fish-hook yarding") since this minimises terminal time and the manual effort needed to assemble loads. Some of the machines we have investigated are noted below:

Holder A.20 Tractor

This tractor is a small frame-steering machine developed in Germany for the vineyards. We have converted it into a forest tractor (see Plate 10) by providing appropriate guards, a safety frame (currently on test for National Institute of Agricultural Engineering approval), a rear-mounted Vinje Junior winch, and a front-mounted log roller cum light dozer blade. Trials, although limited to Border conditions and to a restricted range of tree sizes, confirmed the machine's early promise: it seems certain to find a place in tree-length logging and is likely to replace both horse and winch extraction over considerable areas. Studies are continuing, but it is already possible to suggest annual outputs of about 100,000 hoppus ft with average load sizes of 20 hoppus ft. Costs for average extraction distances of 200 yd have been between 3d. and 4d. per hoppus ft., including labour, labour oncost and machine charges. However, if the system is to work, careful directional felling is needed, together with load assembly by the fellers: this is lighter work than assembly of shortwood piles, and involves bringing the tips or butts of two or three lighter trees together, ready for chokering; heavier trees are usually left where they are and chokered individually. The logging system developed round the Holder tractor includes the depositing of the extracted load on a simply-made conversion grid for immediate cross-cutting. Where tree lengths are, for any reason, not to be cut immediately, the log roller is of value since it stacks the poles quickly at ride or road side.

Hough Paylogger

Earlier studies on the County Timber Tractor had shown convincingly that the larger frame-steering machines had an undoubted place in the extraction of clear fellings and, possibly, in later thinnings. Unfortunately the County machine appeared only in prototype form and developments have ceased. Accordingly we imported an International Hough Paylogger for continuation studies. This is a rugged, 97 brake-horse-power, machine and studies in the South-West Conservancy have again indicated the low costs likely to be achieved by this sort of machine. Over average extraction distances of about 500 yd., all-in costs per hoppus ft have been as low as 4d. Annual outputs are likely to exceed 200,000 hoppus ft but, in many situations, lower annual outputs—and hence higher machine charges per hoppus ft—may often be worthwhile and produce lower costs than the displaced systems. Apart from the Hough, we have our eye on several other frame-steering machines.

M/F 165 Half Tracks for Tractors

In order to test further the half track principle we have fitted a M/F 165 with Swedish "Halvband" half tracks and hydraulic stabilisers. Its value is being assessed in the Borders and we are anxious to discover whether half tracks may have certain advantages over all-wheel machines.

At present a Kombi double-drum winch is fitted to the tractor, which is being used in a ground skidding role similar to that of the Holder tractor. Earlier trials in the New Forest indicated clearly that large frame-steering machines were more suitable for the extraction of large trees from clear fellings. The winch itself is capable of being used as a short-range cable crane (range is about 80 yd) and future studies will test the equipment as an aid to the extraction of material from small, inaccessible areas; it is also possible to extract two or three loads using the winch as a cable crane and then skidding the joint load away by disconnecting the lines; this system, too, will be tested.

Sepson Radio-controlled Winch

The Sepson winch, as imported from Sweden, operates on a frequency of 31 megacycles. Since the use of this frequency is not permitted by the Post Office, the Forestry Commission Radio Unit arranged for Storno Ltd. to replace the imported radio equipment by a prototype outfit, operating on the legal frequency of 458 megacycles. Studies were carried out in various Scottish forests and the conclusion was that the winch might find a place on the small forest or private estate where (*a*) an intensive road system already exists (maximum range is 170 yd), (*b*) there is little or no steep or rough going, (*c*) where trees are large enough to give easily assembled loads of 10–15 hoppus ft. The winch which we tested suffered from several mechanical failures, but we understand that these have been overcome in recent models. It remains problematical whether enough winches could be sold to allow the radio control to be produced at an economic price.

Chain Saws

Various chain saws were examined, more particularly to assess their suitability for chain-saw snedding. Plate 8 illustrates the prototype safety helmet/ear muff combination which has been developed as an answer to the noise problem. The N.I.A.E. have carried out vibration studies on a range of chain saws and results are being analysed. Development work on various measuring devices for attachment to chain saws continued: these promise to give useful reductions in the times associated with cross cutting of pulpwood.

Lokomo Plough

The *Report* for 1966 gave details of the development work proposed for this Finnish, deep draining plough, but progress has been disappointingly slow and fraught with difficulties. However, by extending the track plates of the B.T.D.20

tractor, and by replacing the rear-mounted mechanical winch by a hydraulic winch attached to the dozer A-frame, we have produced an outfit which seems to hold promise.

Chemical Spraying Equipment

Extensive studies have been made of spraying equipment, bulk storage and transport of diluents and protective clothing. Under development is a portable spraying unit consisting of a 100 cc engine fitted with a roller-vane pump; this supplies a live reel containing 500 ft of reinforced, polythene hose; at the delivery end is a Y-coupling which incorporates two pressure regulators; from this point two separate 60-ft hoses are provided so that operators can spray left and right from the main line; self-sealing couplings are provided, so that either or both hoses may be disconnected at will from the main line; the machine is mounted on a frame provided with carrying handles; total weight is about 120 lb and the whole is fairly easily transported between each set-up by the operators. The system requires bulk supplies of the herbicide to be disposed along the road or ride-side, and the sprayer is placed alongside these. Over one acre can be sprayed for each set-up. An alternative use is for pumping bulk supplies of herbicides into storage tanks within the wood (semi-rotary pumps have been used for this purpose), to keep conventional, knapsack sprayers supplied.

DEVELOPMENT OF METHODS

Weeding

As a result of studies we are attempting to define the respective places of weeding by hand, by machine and by chemical. Cost comparisons are, of course, to be included.

Brashing

Good progress has been made in the analysis of various methods and intensities of brashing and it seems likely that guidance on optima can soon be given.

Chain Saw Snedding

This has now become the accepted technique and training courses have been run by the Industrial Safety and Training Branch. It is estimated that overall production may increase by about 10 per cent as a result of the adoption of this method, and the impact upon the times for individual production jobs is being studied.

Line Thinning

Work Study Branch co-operated in a joint enquiry which aimed to determine the savings which might be effected by removing lines of trees as an alternative to conventional thinning. A concomitant of this approach is the elimination or reduction of brashing, and useful savings appear to be possible in many circumstances, in respect of first and second thinnings.

SERVICE TO MANAGEMENT

Regionally-based teams continued to provide an advisory service to the Conservancies. This included co-operation in running courses on hand and chemical weeding, and various extraction techniques. Several new tables of standard times were issued and many more are being formulated. In order to increase the spread of work study *knowledge*, short regional courses were held in several conservancies.

L. C. TROUP

MECHANICAL DEVELOPMENT

A new Committee, with membership limited to the Forestry Commission and known as the Machinery Investigation Committee, was set up to control the mechanical development programme within the Commission. The original Mechanical Development Committee remains in existence, however, to serve as a liaison body with outside institutions and organisations.

The programme of work continued mainly on ploughing, drainage and extraction problems, these being considered the main areas in which major savings can be achieved. The more important items under investigation in these fields were as follows:—

Tractors

Following the experience gained in modifying the Track Marshall 70 as a replacement for the Long Wide County, a modified version of the Track Marshall 55 with an extended frame was developed. Trials indicated that its performance matched those of the County and a number were ordered for use in the Commission.

An International Harvester TD500 tractor was also acquired for modification and evaluation as an alternative for ploughing in marshland areas.

In addition to this, a set of Goodyear Terra-Tyres and Wheels (size 67 in. × 42 in.) were purchased and fitted to a County Super 4-Wheeled Tractor for the purpose of testing this type of traction in similar conditions.

In order to assess the possibilities of the modern frame-steering logging tractors, a Hough S.7 Paylogger was purchased and is being tested on extraction work in various forest areas.

Cableways and Winches

The main problem in completing the work on the extended range Isachsen winch was the development of a suitable carriage. The solution to the problem is now in sight.

The Baco winch and cableway was installed in Scotland and has been undergoing trials. The results have not been as successful as originally anticipated, but this may have arisen to some extent from lack of experience in setting up and operating equipment of this type.

A. J. COLE

EXPERIMENTAL WORKSHOP

The Experimental Workshop, set up at Alice Holt in 1964, provides the Research Division with facilities for the design, manufacture and installation of experimental plant and equipment. The workshop is equipped with a lathe, a milling machine, an engraving machine, etc. and the facilities offered include the general machining and fitting of metals and plastics. See Plate 1, on centre pages.

Requests for the workshop's services have been received from all sections of the Research Division, and the industrial staff of three have been fully employed making experimental equipment.

Items of particular interest made during the year include the automatic insect and spore traps, soil sampling probes, wire pattern exposure flags, and the equipment used during the spraying of individual 70 ft-high trees, using a pneumatic mast.

The output of the plastic engraved labels used to mark experimental plots and individual trees exceeded 6,000. Over 300 vernier girthbands were also prepared during the year.

R E. STICKLAND

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TIMBER UTILISATION DEVELOPMENT

Properties of Home Grown Timber

The joint programme of research with the Forest Products Research Laboratory of the Ministry of Technology (at Princes Risborough, Buckinghamshire) entered its ninth year.

In the general programme, work on the comparison of the timber properties of Scots pine with Corsican pine continued.

In the course of the development work on the use of low-grade hardwood logs, it was shown that slats made from rotary peeled oak veneers, one-eighth and one-quarter inch thick, were suitable for making interwoven fencing.

Economy Drier (Pre-Drier) Development Project

During the year under review a quantity of oak, larch and Douglas fir posts and rails, cut to the Ministry of Transport's specification for motorway fencing, were dried in the Economy Drier. Five days' drying was sufficient to bring the larch and Douglas fir down to a maximum moisture content of 30 per cent of the oven dry weight, the level to which wood should be dried prior to preservative treatment, if it is to comply with the Ministry's specification.

Experiments were undertaken in drying round Scots pine billets prepared to a specification commonly used for chipboard manufacture. It was found that the moisture content of the billets was reduced from an average of 134 per cent to 33 per cent after eight days of drying; the range was 14 per cent to 65 per cent and it is clear that this variation in moisture content is one of the problems in the accelerated drying of roundwood. In another trial, 1¼-in. thick, through-and-through sawn, beech planking was effectively dried without any appreciable discoloration or other degrade; subsequent treatment in the drier for the relief of case-hardening was successfully carried out.

Fence Posts Trials

The eighth annual assessment was made of the service trials of round home grown fence posts, which were set up at nine sites in Scotland in 1957. So far, no creosoted posts have failed, while, of the untreated controls, only 32 per cent of the Sitka spruce and 20 per cent of the birch posts have survived. The surviving untreated posts are mainly in peat soils or on areas with a high rainfall. Of the posts treated with a water-borne preservative (of a type which is no longer marketed in Britain for use in contact with the ground), 85 per cent of the Sitka spruce and 75 per cent of the birch remain standing.

In England and Wales, where the trials were set up one year later using Scots pine and locally available hardwoods, which included ash, birch, alder, elm and sycamore, only 19 per cent of the untreated pine posts and 15 per cent of the hardwood posts remain, but no creosoted post has yet failed. Those posts which were treated with the water-borne preservative show much the same trend as those in Scotland. The first failures in the untreated chestnut were recorded, although 80 per cent of the posts of this species have survived.

Composting of Bark

A small experiment was set up in Thetford Chase to attempt to prepare compost from bark from the mechanical barking operations at Brandon Depot. Three series of five treatments have been included, the treatments are:—

Heavy application of urea.
Moderate application of urea.
Heavy application of ammonia-gas liquor supplied by the National Coal Board.
Moderate application of ammonia-gas liquor.
Untreated controls.

In addition to the nitrogenous material, triple super-phosphate was added to each of the treatments, including the controls.

J. R. AARON

PUBLICATIONS BY STAFF MEMBERS

HOLTAM, B. W. *Blue Stain*. Leafl. For. Comm., Lond., No. 53, 1966.

DESIGN AND ANALYSIS OF EXPERIMENTS

The Statistics Section has continued to provide an advisory and computing service to all Sections of the Research Division and of the Management Services Division, as well as to the Forestry Commission in general. The difficulties of recruiting qualified staff have continued and, through the year under review, the Section has been without one Scientific Officer and two Experimental Officers, despite the most strenuous efforts to fill these posts. Fortunately, Mrs. B. E. Witts, a former Scientific Officer in the Section, has been able to return to work part-time, and because of her previous experience, has helped to minimise the effects of the shortage. The Section also employed a student from the City University, London, during the industrial training period of his Sandwich Course. The severe shortage of qualified staff has necessarily somewhat limited the activities of the Section, and less progress has been made on a number of important problems than was hoped.

The Section has had a large number of visitors, including many from overseas. We were particularly pleased to welcome Dr. Richard Tomassone, from Nancy, and Professor Pierre Dagnelie, from Gembloux. Members of the Section also attended many conferences and meetings in Great Britain, and presented papers at some of these, including the European Meeting of Statisticians, held in London in September 1966.

Designs for experiments and surveys have been provided for about seventy investigations throughout the year. These have included the usual range of experimental work on nurseries, herbicides, replanting, regeneration, preparation of ground, thinning and pruning. Trials of new methods and tools in work study have also been given particular attention.

More than 30,000 separate analyses have been completed in the year under review. Many of these analyses have been applications of techniques of multivariate analysis, although as usual, the main bulk of the work has been concerned with the analysis of variance of experiments and surveys. The range of analytical techniques required in forestry research and management, however, continues to extend, and important applications have been found for many of the new techniques currently appearing in statistical and computing journals.

Computer Programming and Serviceability

The number of new programs prepared in the year for the Section's Sirius computer dropped slightly, as many of the year's analyses were adequately dealt with by existing programs. Nevertheless, thirty-five new programs have been written and added to the library.

The computer itself has continued to be exceptionally reliable and has been very fully utilised. Table 40 gives details of the use of the machine for each month, and Table 41 summarises these details, using the criteria laid down by the Treasury for computer records. As in previous years, the criteria of "serviceability", "availability" and "utilisation" have all remained at a consistently high level.

Graph Plotter

A Calcomp graph plotter, shown in Plate 9, has been added to the computer peripherals. Some considerable difficulty was experienced in getting the interface

TABLE 40

DETAILS OF COMPUTER OPERATIONS

Times in minutes

Month	No. of Faults	Production Time	Development Time	Idle	Repairs	Scheduled Maintenance	Supplementary Maintenance	External Causes
April 1966	1	9,422	1,826	73	0	821	0	0
May 1966	0	12,131	2,294	0	0	939	75	0
June 1966	1	8,662	2,860	0	105	561	0	0
July 1966	1	11,624	3,271	67	250	2,273	25	0
August 1966	0	8,305	1,234	27	15	723	0	0
September 1966	0	20,509	1,584	0	0	917	0	0
October 1966	1	12,817	1,769	0	0	1,348	190	440
November 1966	2	15,828	1,379	0	190	883	388	0
December 1966	1	8,167	1,436	50	20	922	20	0
January 1967	1	14,806	1,657	430	0	1,517	345	20
February 1967	5	27,533	1,846	160	225	895	383	55
March 1967	0	24,028	1,839	90	65	629	0	80

between the computer and the graph plotter manufactured and installed so that the plotter worked correctly, but thanks to the very generous help of Mr. K. Sanderson, of the Mathematics Division of the Royal Aircraft Establishment, the successful installation of the equipment was eventually achieved. The plotter is now working well, and proving a very useful addition to the range of computer output. It is clear that we have not yet begun to realise the full implications of the use of graphical output from computers, and this promises to be an exciting field of development in the near future.

TABLE 41

SERVICEABILITY OF COMPUTER

Month	Serviceability	Availability	Utilisation	Total Time Hrs.	Total Time Mins.
April 1966	1·000	0·932	0·994	202	22
May 1966	1·000	0·939	1·000	257	19
June 1966	0·991	0·945	1·000	203	8
July 1966	0·984	0·856	0·996	291	50
August 1966	0·998	0·928	0·997	171	44
September 1966	1·000	0·960	1·000	383	30
October 1966	1·000	0·915	1·000	276	4
November 1966	0·989	0·941	1·000	311	8
December 1966	0·998	0·911	0·995	176	55
January 1967	1·000	0·918	0·975	312	55
February 1967	0·992	0·963	0·995	518	17
March 1967	0·998	0·974	0·997	445	31

Statistics Section Papers

The following Statistics Section Papers have been prepared:—

No. 118. General index of computer programs for the Forestry Commission Sirius computer.

No. 119. The design and analysis of forest experiments.

No. 120. Sirius faults—diagnosis and repair.

No. 121. The assessment of the height of the crop in forest experiments.

No. 122. Filecode; a commercial programming language.

No. 123. Some general principles in the siting of work study trials.

No. 124. Two case studies in the application of principal component analysis.

No. 125. A further study of the properties of European and Japanese larch.

No. 126. Volume table for Scottish Pulp pulpwood billets.

No. 127. A volume table for Lodgepole pine.

No. 128. Volume table for Bowaters pulpwood billets.

No. 129. A keyword index of the 1964 *Research Report*.

No. 130. The statisticians use of electronic digital computers.

No. 131. A critical path through the woods.

No. 132. The use of electronic computers in photogrammetric surveys.

No. 133. Tree recognition by computer.

No. 134. Studies in part of a clear-felling exercise in an immature Sitka spruce crop.

No. 135. The multiple regression problem; a multivariate approach.

Enquiries regarding any of these papers should be directed to the Statistics Section at Alice Holt.

J. N. R. JEFFERS

PUBLICATIONS BY STAFF MEMBERS

JEFFERS, J. N. R. General Analysis of Non-Orthogonal Experiments. *Res. Note 9. Instn. Skoglig Mat. Statist. Skogshögsk., Stockh.*, 1966.

JEFFERS, J. N. R. Calculation of Life Tables for Insect Populations. *Res. Note 9. Instn. Skoglig Mat. Statist. Skogshögsk., Stockh.*, 1966.

JEFFERS, J. N. R. Association Analysis of Ecological Data. *Res. Note 9. Instn. Skoglig Mat. Statist. Skogshögsk., Stockh.*, 1966.

JEFFERS, J. N. R. Use of Electronic Digital Computers in Forest Research and Management—the New Generation. *Paper for the 6th World Forestry Congress, Madrid*, June 1966.

JEFFERS, J. N. R. Design and Analysis of Forest Experiments. *Biometrie-Praximetrie* 8 (2) 1966 (117–126).

JEFFERS, J. N. R. The Study of Variation in Taxonomic Research. *The Statistician*, 17 (1) 1967 (29–43).

JEFFERS, J. N. R., and WITTS, B. E. A Multivariate Analysis of the Relationship between Staff and Work Load. *Res. Note 9. Instn. Skoglig Mat. Statist. Skogshögsk., Stockh.*, 1966.

PUBLICATIONS

In May 1966 the Publications Branch was reconstituted as a separate entity, distinct from the Library.

Twelve new priced publications were issued through Her Majesty's Stationery Office, while three unpriced *Research and Development Papers* were published directly by the Forestry Commission.

Report

Report on Forest Research for the year ended March 1966 (12s. 6d.).

Forest Records

No. 58. Check List of Forestry Commission Publications, 1919–65, by H. L. Edlin. (4s. 6d.)
No. 59. Mathematical Models in Forest Management, by M. S. Makower, *et al.* (5s.)
No. 61. Brunchorstia Die-back of Corsican Pine, by D. J. Read. (1s. 9d.)
No. 62. Plantations on Medieval Rigg and Furr Cultivation Strips, by T. C. Booth. (3s.)
No. 63. Forestry Quarantine, and its Biological Background, by D. H. Phillips and D. Bevan. (2s.)

Booklets

No. 16. Forest Management Tables, by R. T. Bradley, J. M. Christie and D. R. Johnston. (30s.)
No. 18. Forestry in the Landscape, by Sylvia Crowe. (3s. 6d.)

Bulletin

No. 38. The Great Spruce Bark Beetle (*Dendroctonus micans*), by J. M. B. Brown and D. Bevan. (10s. 6d.)

Leaflets

No. 52. The Fallow Deer, by W. A. Cadman. (2s 6d.)
No. 53. Blue Stain, by B. W. Holtam. (6d.)

Research and Development Papers

No. 30. Methods of Planting on Single Mould-Board Cuthbertson Ploughing, by S. A. Neustein.
No. 31. Simazine Residues in Two Forest Nursery Soils, by J. R. Aldhous.
No. 32. The Utilisation of Bark, by J. R. Aaron.

These R. & D. Papers, being unpriced, are not stocked by Her Majesty's Stationery Office, but copies may be obtained, without charge, on application to the Clerk of Stationery, Forestry Commission, 25, Savile Row, London, W.1.

Acts of Parliament

The new *Forestry Act* 1967, published by Her Majesty's Stationery Office at a price of 4s. 6d., consolidates previous general *Forestry Acts* dating from 1919 to 1963, and should take precedence over those Acts in reference libraries and similar collections. The local *New Forest Acts* 1949 and 1964, for the New Forest of Hampshire, continue in operation as before. In addition, 28 publications were re-issued, after varying degrees of revision, to meet continuing demands.

H. L. EDLIN

RESEARCH INFORMATION

The appointment of a Research Liaison Officer in July 1966 recognised the need to relieve research workers from some of the time-consuming load of enquiries and of arranging visits and courses. At the same time it was felt that better liaison would lead to an improvement in the translation of research findings into field practice.

From the first there were obvious connections with the library services, and inevitably this has led to the creation of the Research Information Section, with the general role of the receipt, exchange, storage and dissemination of information.

It is the intention to increase the existing bank of information on forestry in the library by improving the ties with other libraries and research centres, and to supplement this by developing personal contacts with all Forestry Commission staff, and with other organisations.

Having obtained our information, it is necessary to find it again quickly and accurately. Considerable thought has been given to methods and equipment.

The simplest way of passing on information is to send as much, to as many people, as quickly as possible. The recipients may be confused, submerged and not greatly helped by this method. The alternatives are being explored, and it is hoped that one of the strongest features of the Information service will be its contribution to current awareness.

During the year we have held two courses, of a week each, for field District Forest Officers, received nine parties from academic institutions, and over 120 individual visitors.

The Library acquired 229 new books, lent out 1,523 to Forestry Commission staff and 296 to outside borrowers; borrowed 329 items, and obtained 127 photocopies from other libraries. Fifty-four translations have been commissioned for Forestry Commission staff.

Notice of new acquisitions appear in the *Library Review*, and it is intended that in future this vehicle will cover items of general and current interest as well as literature references.

O. N. BLATCHFORD

PART II

Research Undertaken for the Forestry Commission at Universities and other Institutions

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RESEARCH ON FOREST SOILS AND TREE NUTRITION

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Dr. B. L. Williams was appointed in November to fill the vacancy left by the resignation of Dr. J. B. Craig. Dr. Williams is to continue and expand the investigations into the physico-chemical nature of peat in relation to tree growth initiated by Dr. Keay and developed by Dr. Craig.

Tree Nutrition

The nitrogen fertiliser experiments described in the *Reports* for the years 1963 to 1966 have continued. A further experiment has been laid out at Culbin Forest (Moray) to investigate whether the application of boron, copper or zinc in the presence of heavy dressings of nitrogen would eliminate the occurrence of bud death and necrotic shoots described in the *Report* for 1966. A close watch is being kept on this experiment in order to characterise and describe the disorder more thoroughly. As yet no buds have aborted in any treatment, suggesting that the damage occurs at or soon after bud-break and not during the period of winter dormancy.

The investigations into the distribution and movement of nutrients within a forest ecosystem at Culbin Forest, in relation to applied fertiliser, continues (*Reports* for 1965 and 1966, also Miller 1966). The results from the initial whole-tree sampling carried out prior to the application of fertiliser have been subjected to detailed statistical analysis, in co-operation with the statistics section of the Macaulay Institute. Computer techniques were utilised to compare three methods of expanding data obtained on 29 sample trees, to a crop area basis. The technique used for results reported up till now, by which the crop was treated in five size groups, the mean result of the sample trees in each size group being multiplied by the number of trees in that group and these values summed for the forest total, was found to be inferior and to produce a slight under-estimate in comparison to the total tree summation method described by Baskerville (1965). By this, the regression of the logarithm of the weight of any tree tissue against the logarithm of basal area is derived, and this used to estimate the corresponding weights for every tree in the crop, these being subsequently summed.

The regressions using the Culbin sample tree data had correlation coefficients varying from 0·99 for the total weight of the tree to 0·82 for the weight of needles more than two years old. For the weight of nutrients contained in the various tissues, the relationships were somewhat less precise but still adequate. The inclusion of height as well as basal area in the regression formulae was found to produce a very highly significant improvement in these relationships, but as the height of the other trees in the crop was not known this could not be utilised in the expansion to an area basis.

The straightforward use of the mean of all the sample trees multiplied by number of stems per unit area produced, as expected, the poorest estimate. Unlike those of other workers (Ovington and Madgwick, 1959; Baskerville, 1965), however, this was an over-estimate, reflecting the fact that the sampling technique used was somewhat biased towards selection of the larger trees.

The final application of fertiliser to this experiment was made in 1966, and in February and March of 1967 a further complete sampling of the ecosystem was carried out in order to determine the fate of the applied fertiliser nitrogen. This involved the sampling of 75 whole trees, 75 square-metre quadrats for vegetation and forest floor, and 75 pits for the sampling of soil and lateral roots. On this occasion the fresh weights of all samples were determined in the field using a caravan equipped as a field laboratory, supplied by the Forestry Commission. It was also possible to make other considerable improvements in the sampling techniques on the basis of the experience gained during the initial sampling carried out three years previously. In addition, every tree in the crop has now been measured for height as well as basal area.

The collection and analysis of rainwater and litter-fall in this experiment has continued. The gradual increase in the weight of needle-litter falling in the treated plots, reported in the *Report* for 1966, was maintained during the year and by December the accumulated fall in the two heaviest treatments (300 and 450 lb nitrogen per acre per annum) had for the first time exceeded that of the control. The accumulated nitrogen content of the litter-fall in the heaviest treatment over the same period was more than double that in the control, reflecting the marked increase in the nitrogen concentration in the needle-litter as a result of the fertiliser treatment. In the case of phosphorus, potassium, calcium and magnesium, however, the different quantities brought down in each treatment simply reflect the changes in *weight* of litter-fall, there being no significant effect of the treatments on the *concentrations* of these elements.

Several greenhouse experiments were carried out during the year to investigate the response of Corsican pine to various levels and forms of nitrogen. In one of these, sampling was carried out at intervals throughout the duration of the experiment, in order to determine the patterns of nitrogen uptake and growth, and the relationship between these. To facilitate this a photographic means of measuring leaf area per plant was developed and used on these samples.

The results require further computation and analysis but they already show that this linking of simple growth analysis techniques to greenhouse nutrition experiments promises to be a useful approach, and it is proposed to develop it further. In future, however, it would seem preferable to conduct such experiments on second-year plants in order to avoid the disadvantage of having to deal with, and base conclusions upon, trees carrying simultaneously cotyledon, juvenile and adult needles in different proportions at different times. A preliminary trial into the techniques required to conduct satisfactory trace element experiments in the greenhouse has been initiated, to parallel the trace element investigations being carried out at Culbin.

Physical Chemistry

Due to recent staff changes it is not possible to record conclusive results in the present report. As a continuation of the work of Dr. Keay and Dr. Craig, however, preliminary investigations have been conducted to establish methods for measuring both reduction-oxidation potentials and oxygen diffusion rates in peat. Redox potentials can be successfully determined by measuring the electrical potential developed between a platinum electrode and a calomel reference electrode. For oxygen diffusion rates, on the other hand, the position is proving to be rather more complex, but in essence it should be possible to apply a set potential across a platinum micro-electrode and a silver anode, the final steady state current then being proportional to the rate at which oxygen diffuses to the platinum cathode. It is proposed to use these techniques to investigate the effect of drain depth and tree growth on the aeration of peat in an experiment being conducted in collaboration with Dr. R. Boggie, of the Peat Section of the Department of Pedology, at Inchnacardoch Forest (Inverness-shire), details of which have been given in the *Reports* for the years 1963 to 1966.

Laboratory investigations have been initiated into the physico-chemical behaviour of peat. Samples of both raw and acid-treated peat have been titrated with alkali, using a potentiometric method, from which the cation-exchange capacity and degree of base saturation of the peat can be deduced. The shape of the resulting titration curves suggests that the acidity of peat is due to the dissociation of more than one kind of chemical group, and work is now being directed towards investigating the chemical equilibrium involving the peat organic acid and inorganic ions.

Summary

Nutrition investigations continue to be concentrated on nitrogen with special emphasis being placed on the effect of fertiliser nitrogen on the distribution and movement of nutrients within a crop of Corsican pine on the sand dunes of Culbin Forest. A complete sampling of this ecosystem was carried out prior to the application of fertiliser and now, following three years of fertiliser application, a further such sampling has been conducted to determine the fate of the applied nitrogen. In the same forest, applications of boron, copper and zinc in the presence of nitrogen are being made to determine whether these will eliminate the bud death found to occur in nearby heavily nitrogen-fertilised plots. Greenhouse experiments into the growth and nitrogen nutrition of Corsican pine continue. Two approaches have been adopted to study the chemical and physical behaviour of peat in relation to tree growth. For application to field experiments, methods are being developed to measure oxygen diffusion rates and redox potentials. In the laboratory, investigations are being conducted into the acidic nature of peat and the chemical interactions between peat and inorganic ions.

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NUTRITION EXPERIMENTS IN FOREST NURSERIES

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Extracts from *Rothamsted Annual Report* for 1966

Isobutylidene diurea for Conifer Seedlings

A slow-acting N fertiliser, isobutylidene diurea (IBDU) (made in Japan and described by Hamamoto (*Proc. Fertil. Soc.* No. 90, 1966), was tested on Sitka spruce (*Picea sitchensis*) seedlings at Wareham Nursery in 1965. Two amounts of IBDU in 0·8–1·4 mm granules dug-in in late March were compared with three top-dressings of "Nitro-Chalk" applied in summer, supplying the same total N. Early in the season the plants with IBDU had excellent colour, but later they became slightly pale. However, the harvested seedlings were taller with IBDU than with "Nitro-Chalk":—

g N/sq yd	*Height (in)*	
None	0·4	
	"Nitro-Chalk"	IBDU
9	1·4	1·6
18	1·6	2·1
S.E.		±0·17

TABLE 42

COMPARISON OF FOUR NITROGEN FERTILISERS FOR SITKA SPRUCE SEEDLINGS IN 1966

Small N = mean of 6 and 12 g N/sq yd
Large N = mean of 18 and 24 g N/sq yd
Height (in.)

Without nitrogen	Wareham 0·4		Kennington Extension 1·1	
	Small N	Large N	Small N	Large N
"Nitro-Chalk"	1·8	3·0	2·2	2·8
Formalised casein	1·6	2·7	2·3	2·9
IBDU (0·8–1·4 mm)	1·4	2·9	1·9	2·7
IBDU (1·5–2·4 mm)	2·0	2·8	2·0	2·6
S.E.	±0·11		±0·12	

In 1966 two sizes of IBDU (0·8–1·4 and 1·5–2·4 mm) were compared at Wareham and Kennington Extension with formalised casein and "Nitro-Chalk". IBDU and formalised casein were applied before sowing, "Nitro-Chalk" was split into four top-dressings given at the beginning of June, July, August and September. Four amounts of the materials were tested. Table 42 shows that the largest amount of N increased seedling height 2½ times at Kennington Extension and 7 times at Wareham, with only small differences between forms of fertiliser. At Wareham (in autumn) the "Nitro-Chalk" plots were greenest, closely followed by coarse IBDU; plants with formalised casein and the fine IBDU were much paler. At Kennington Extension the differences were smaller—with "Nitro-Chalk" again best, followed by formalised casein and then by the two fractions of IBDU. The different nitrogen forms gave similar plant numbers in 1965 and 1966. Exceptionally heavy rain in July 1965, and in April and August 1966—especially at Wareham—may have favoured IBDU, which needs further testing to find its value in drier years.

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Slow-release Fertilisers for Conifer Seedlings

The experiment comparing potassium metaphosphate with potassic superphosphate (tested with and without top-dressings of potassium nitrate) and with potassium dihydrogen phosphate, was continued. Treatments and previous results were described in *Rothamsted Report* for 1964 (pages 55–57) and for 1965 (pages 56–57).

TABLE 43

THE EFFECT OF P AND K FERTILISERS ON ONE-YEAR SITKA SPRUCE SEEDLINGS AT WAREHAM IN 1966

	Rates applied (g element/sq yd)		Height (in.)	Dry matter of tops (mg/plant)	Colour score*	P (%) (in dry matter)	K (%) (in dry matter)
	P	K					
No fertiliser	0	0	0·5	34	6	0·17	0·28
Superphosphate only	9	0	0·4	38	6	0·26	0·24
PK compound (from super + KCl)	9	9	0·9	76	6	0·25	0·27
Potassium dihydrogen phosphate	9	12	1·5	114	5	0·22	0·33
PK compound + KNO_3	9	15	2·0	142	0	0·21	1·05
Potassium metaphosphate	9	12	2·3	159	2	0·23	0·52

* For the purple and yellow discoloration typical of K-deficiency (0 = no discoloration).

Rainfall in spring was more, and leaching more, than in 1965, but less than in 1964. Table 43 shows that the standard water-soluble PK compound (made from superphosphate and potassium chloride), which had been no better than superphosphate after the exceptionally wet spring of 1964, trebled plant height in 1965 and doubled it in 1966. Supplementing the PK compound with potassium nitrate in 1966 doubled seedling height, showing the large gains possible from supplying K in mid-season. Seedlings produced by potassium metaphosphate were of excellent size, but, in contrast to 1964 and 1965, had no more than 0·5 per cent K and were slightly discoloured, though not nearly as much as seedlings (containing less than 0·3 per cent K) grown with potassic superphosphate. As previously, KNO_3 top-dressings maintained percentage K about 1·0.

The effects obtained with conifer seedlings are much larger than those obtained with agricultural crops. Averaging 3 years' results, and with potassic superphosphate as standard, both potassium metaphosphate and potassium nitrate increased seedling height by half; potassium metaphosphate doubled percentage of potassium in the plants, and potassium nitrate trebled it. The concentration of P in the plants was little altered.

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EFFECT OF "LATE-SEASON" N AND K TOP-DRESSINGS APPLIED TO CONIFER SEEDLINGS AND TRANSPLANTS, ON NUTRIENT CONCENTRATIONS IN THE WHOLE PLANT AND ON GROWTH AFTER TRANSPLANTING

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Between 1947 and 1952, Sitka spruce seedlings grown with a wide range of manurial treatments were transplanted into uniformly manured beds, to study the effects in the transplant lines of treatment applied to the seedbeds (Benzian 1965). Despite some weaknesses in the technique some clear trends emerged. Thus, nitrogen applied to seedlings continued to give a small additional benefit in height in the transplants, but phosphate did not. Potassium effects differed from those of nitrogen and phosphorus in that small differences in the seedbed (especially a few of the positive ones), became considerably magnified after transplanting.

From these early results it was not possible to deduce whether any benefits from N or K dressings detectable *after* transplanting were wholly attributable to better growth made by the seedlings during the year of application, or whether larger concentrations of N and K carried over in the plants had played a part. A new series of experiments was, therefore, started at Wareham Research Nursery, Dorset, in 1964 and continued in 1965 and 1966 with the aim of producing nursery plants as uniform as possible in all respects, except for differences in their N (and in a few tests also their K) concentrations, and of observing their subsequent performance.

TABLE 44

FERTILISER APPLIED *UNIFORMLY* TO STOCKBEDS OF SEEDLINGS AND TRANSPLANTS, 1964 AND 1965

	Total per sq yd (per season)
Dug-in in March, before sowing or lining out:	
Potassic superphosphate	9 g.P, 9 g.K
Kieserite	3 g.Mg
Three summer top-dressings:	
"Nitro-Chalk"	
Seedlings	13·5 g.N
Transplants	9·0 g.N

The method adopted was to grow seedlings and transplants of several conifer species in long stock-beds uniformly manured with inorganic soluble fertilisers, using the same manuring régime as that adopted for our other experiments (see Table 44). In the early autumn an attempt was made to gauge the stage of development at which the plants had nearly stopped growing but were still taking

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up nutrients. The stockbeds were then split into smaller plots testing "late-season" top-dressings of N alone, or N factorially with K. (Details of these "late-season" top-dressings are shown in Table 45.) Despite the large amounts of fertiliser top-dressed on a single occasion, none caused visible damage in 1964, and only slight damage to Western hemlock in 1965.

The species tested were: Sitka spruce, *Picea sitchensis*, Norway spruce, *Picea abies*, Western hemlock, *Tsuga heterophylla*, and Corsican pine, *Pinus nigra* var. *calabrica*. All seedlings (1 + 0) referred to in this paper spent one growing season in the seedbed. Usually, transplants in our experiments spend one growing season in the seedbed and one in the transplant lines (1 + 1), but in this series some of the 1 + 1 transplants, for which it had been possible to increase nutrient concentrations, were lined out a second time to produce 1 + 1 + 1 plants.

TABLE 45

FERTILISER TESTED AS "*LATE-SEASON*" *TOP-DRESSINGS* ON SEEDLINGS AND TRANSPLANTS, 1964 AND 1965

	Applied in September per sq yd	
N × K tests:		
"Nitro-Chalk"	9 g.N	
Potassium chloride	9 g.K	
N tests:		
"Nitro-Chalk"	*Rate 1*	*Rate 2*
Seedlings	9 g.N	18 g.N
Transplants	6 g.N	12 g.N

The years 1964 and 1965 are the only two "treatment-years" for which "test-year" results are so far available. Late-season top-dressings were applied to seedbeds and transplant lines on 29th September in 1964 and, in an attempt to favour nutrient uptake still further, applications were made a week earlier in 1965. Analyses of whole plants sampled in November showed that for seedlings the percentage N and the percentage K were increased in both years; for transplants, the percentage N (after an unsuccessful attempt in 1964) was increased considerably in 1965, but the percentage K was unchanged in either year.

All crops for which N or K concentrations had been increased (seedlings only in 1964, seedlings and transplants in 1965) were tested. The procedure was to lift the plants (except Corsican pine) in November or December, grade them by height into inch-classes representative of most of the plants in the whole bed, and store them in polythene bags in a frost-proof store. The next spring, the plants were lined out on beds given a uniform dressing of soluble fertilisers, similar to that shown in Table 44.

Late-season Top-dressings 1964—Test year 1965

Table 46 gives results for the first pair of years—1964–65. It shows on the left side details of the rates of N and K applied as late-season top-dressings to seedbeds in September 1964, with the resulting concentrations of N and K in the plants, and on the right side scores for bud development after lining out in 1965 and plant heights at the end of that growing season.

N concentrations were large in 1964, a season with very little rain in late summer; seedlings of all four species had about 2 per cent N. Late-season top-dressings increased the already large N concentrations still further, i.e. to about 2·5 per cent for all species. All dressings gave similar increases, so rates are averaged in the table. In common with other 1964 experiments, potassium concentrations were small (0·5 per cent). Much K had been lost during heavy rain in March and May, and seedlings showed severe K-deficiency symptoms. Late-season top-dressings of potassium increased K concentrations to only 0·7 per cent—not enough to remove deficiency symptoms completely.

TABLE 46

EFFECT OF 1964 "*LATE SEASON*" *TOP DRESSINGS* OF N AND K ON %N AND %K IN PLANTS AND ON BUD DEVELOPMENT AND END-OF-SEASON HEIGHT AFTER TRANSPLANTING IN 1965

WAREHAM NURSERY, DORSET

Species	September 1964 Fertilisers top-dressed	November 1964 Percentage in dry matter* N	November 1964 Percentage in dry matter* K	May 1965 Bud scores	October 1965 Height inches	October 1965 Height cm
	1964 Seedlings (1+0)			1965 Transplants (1+1)		
N × K test:						
Sitka spruce	None	2·2	0·5	2·6	9·9	25
	N	2·6	0·5	2·8	10·2	26
	K	2·2	0·7	3·0	10·4	26
	NK	2·4	0·7	3·0	10·3	26
					S.E.± 0·22	0·6
N tests:						
Sitka spruce	No N	2·0	—	2·5	9·5	24
	N	2·6	—	2·6	9·8	25
					S.E.± 0·12	0·3
Norway spruce	No N	2·3	—	2·8	7·8	20
	N	2·7	—	3·1	7·6	19
					S.E.± 0·21	0·5
Western hemlock	No N	2·1	—	3·6	9·8	25
	N	2·5	—	3·5	9·2	23
					S.E.± 0·18	0·5

*Tops + roots.

In the spring, after transplanting, bud-development scores were obtained in the way described by Lines and Mitchell (1966). Thus, buds in the winter state were allotted a score of 1, buds swollen but not yet open—2, buds burst showing individual needles—3, and buds fully flushed—4. Buds were scored on four occasions at fortnightly intervals, but only scores for the date with the greatest contrast are shown in Table 46. K treatments speeded up bud development very slightly; the effects of N were small.

Height differences at the end of the growing season were positive but small, except for Western hemlock, where the extra nitrogen caused some decrease in height.

Late-season Top-dressings 1965—Test-year 1966

Table 47 gives results for the second pair of years—1965–66—set out in the same way as in Table 46. Two columns have been added: scores for frost damage taken in November 1965 and diameter measurements made at the end of the test-year in October 1966.

TABLE 47

EFFECT OF 1965 "*LATE-SEASON TOPDRESSING*" OF N AND K ON %N AND %K IN PLANTS AND FROST DAMAGE BEFORE LIFTING, AND ON BUD DEVELOPMENT AND END-OF-SEASON HEIGHT AFTER TRANSPLANTING IN 1966.

WAREHAM NURSERY, DORSET

Species	September 1965 Fertilisers top-dressed	Nov. 1965 Percentage in dry matter*		Frost damage scores†	May 1966 Bud scores	October 1966 Height		Diam. mm
		N	K			inches	cm	
	1965 Seedlings (1+0)				1966 Transplants (1+1)			
N × K test:								
Sitka spruce	None	0·8	0·4	3·4	2·9	8·8	22	4·0
	N	1·7	0·4	1·0	3·1	9·3	24	4·4
	K	0·8	0·9	0·0	2·9	9·1	23	4·2
	NK	1·4	1·0	0·5	3·4	10·0	25	4·5
						S.E.± 0·24	0 6	0·07
N tests:								
Sitka spruce	No N	0·9	—	2·2	2·8	10·5	27	4·5
	N	1·8	—	1·2	3·3	11·5	29	4·9
						S.E.± 0·14	0·4	0·09
Norway spruce	No N	1·1	—	No damage	2·6	8·1	20	3·7
	N	1·8	—		3·2	8·7	22	3·8
						S.E.± 0·17	0·4	0·07
Western hemlock	No N	0·8	—	2·8	3·5	10·4	26	4·3
	N	2·0	—	2·2	3·6	10·7	27	4·5
						S.E.± 0·22	0·6	0·05
Corsican pine	No N	1·3	—	No damage	2·9	2·6	7	4·6
	N	1·9	—		3·1	2·5	6	4·9
						S.E.± 0·08	0·2	0·08
	1965 Transplants (1+1)				1966 Transplants (1+1+1)			
N tests:								
Sitka spruce	No N	1·0	—	No damage	2·3	16·1	41	9·3
	N	1·6	—		2·7	17·7	45	10
						S.E.± 0·30	0·8	0·11
Western hemlock	No N	0·8	—	No damage	3·0	21·8	55	9·0
	N	1·6	—		3·4	24·3	62	9·8
						S.E.± 0·32	0·8	0·11

* Tops + Roots.

† The higher the score the more severe the damage.

The summer in 1965 was much wetter than in 1964. In 1964, total rain at Wareham Nursery for the months June to September was only 3·8 in.; in 1965 it was 13·0 in. In 1965, many seedlings were badly discoloured, suffering from shortage of both N and K; they had N concentrations of only about 1 per cent, half that of the previous year, and K concentrations of only 0·4 per cent. Late-season top-dressings of N applied in September 1965 to seedlings and transplants, increased N concentrations in the plants to between 1·4 and 2·0 per cent, and removed all N deficiency symptoms. K top-dressed on seedlings more than doubled K concentrations and also caused the typical K-deficiency symptoms to disappear. (The observation that top-dressings applied in September can remove deficiency symptoms of N and K might usefully be exploited for diagnostic purposes.)

Experiments in 1966 included two age groups: treated seedlings (1+0) tested as transplants (1+1), and treated transplants (1+1) lined out a second time and tested as older transplants (1+1+1).

In November 1965 several ground frosts were recorded in Wareham Nursery, with temperatures dropping to 22°F, 20°F and, on one occasion, even 18°F. This caused typical symptoms of frost injury in seedlings of Sitka spruce and Western hemlock. The scores in Table 47 show that N as well as K decreased frost damage considerably—an unexpected finding that will be important, should it be confirmed.

In 1966, bud development was again more advanced in plants with higher nutrient concentrations; this trend was more pronounced than in the previous year. Height and diameter growth of all species, except height of Corsican pine, were increased by late-season top-dressings. The increases were between 5 and 15 per cent for 1+1 transplants and about 10 per cent for the older transplants.

Conclusions

The main conclusions that can be drawn from these nursery experiments so far are that the percentages of N and K can be increased in several conifer species late in the season when growth has nearly ceased, thus making it possible to compare plants of different nutrient status for their frost susceptibility, bud development and subsequent growth.

The work has been continued in slightly modified form, the main difference being that in the treatment-year of 1966 the basal manuring was increased so that none of the plants had nutrient concentrations as small as those observed in 1965. Parallel tests have been started at Kennington Nursery near Oxford.

Acknowledgements

We thank members of the Chemistry Department at Rothamsted for chemical analyses.

SUMMARY

"Late-season" top-dressings of N and K applied in September increased nutrient concentrations in several conifer seedlings and transplants at a stage when growth had nearly ceased. For seedlings of Sitka spruce and Western hemlock, susceptibility to autumn frost was decreased by both N and K. After lining out, bud development was slightly accelerated and height growth at the end of the season slightly increased for most species.

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PATHOLOGY EXPERIMENTS ON SITKA SPRUCE SEEDLINGS

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Effects of Seed Treatments on Germination and on the Growth of Seed-borne Fungi and Bacteria

Oil-soluble "Waxoline" dyes and talc applied to seed treated with linseed oil may replace red lead as the standard colorant for Sitka spruce and other seed sown in forest nurseries. To determine if the new treatments have any fungicidal effects on seed-borne fungi, untreated Sitka spruce seed 61(7972) containing 86 per cent viable seed was compared with seed treated with linseed oil only, with oil plus talc and Auramine Yellow, with oil plus talc and Lithofar Red, and with a recognised fungicide as a 50 per cent Thiram dust applied to untreated seed and to oil-treated seed at 1 g and 2 g per 100 g seed respectively. The rates of oil, dye and talc applied were 5·6 ml oil per 1 lb of seed, plus 8 per cent of seed by weight of a mixture containing 95 per cent talc and 5 per cent dye. This was slightly in excess of the amounts used on Sitka spruce in nursery sowings. From each treatment 40 seeds were plated on potato dextrose agar, 10 seeds per plate, and incubated at 15°C.

TABLE 48

Treatments	Per cent 'clean' seed	Per cent seed yielding	
		Fungi	Bacteria
Control untreated	0	90	40
Linseed oil only	48	45	8
Oil and talc and Auramine Yellow	0	75	78
Oil and talc and Lithofar Red	8	88	30
Thiram only	35	2	62
Oil and Thiram	98	0	2

The fungi isolated were predominantly species of *Penicillium* with some *Mucor* and *Rhizopus*. Table 48 shows that linseed oil by itself suppressed the growth of fungi and especially of bacteria, probably a mechanical effect because it was nullified by the addition of talc and dye. By contrast thiram by itself inhibited the growth of almost all fungi, and at double strength with oil it inhibited both fungi and bacteria.

The effects of seed treatments on germination were tested at 20°C and after four weeks at 10°C on sterilized quartz grit, and in pots of unsterilized Old Kennington nursery soil (K. 101). Each treatment had four replicate pots sown with 50 seeds each.

Table 49 shows that oil alone decreased germination slightly at 20°C, and again the effect was nullified by adding talc and dye. At 20°C most of the viable seed germinated, but after four weeks at 10°C few untreated seeds germinated whereas seed dressed with thiram retained almost 100 per cent viability. Treatment with oil, talc and dye was beneficial, but much less so than treatment with thiram.

TABLE 49

GERMINATION AT 20°C AS PER CENT VIABLE SEED SOWN

Treatments	On quartz grit		In Kennington soil	
	At 20°C	After 28 days at 10°C	At 20°C	After 28 days at 10°C
Control untreated	81	2	100	28
Linseed oil only	71	59	80	71
Oil and talc and Auramine Yellow	87	53	100	72
Oil and talc and Lithofar Red	86	44	93	51
Thiram only	90	96	100	98
Oil and Thiram	74	91	86	94

Decreases in seed viability at 10°C were associated with striking increases in percentage infection by the endophytic seed fungus (*Report* for 1966, page 105). The seed contents of ungerminated seed from pots of Kennington soil were incubated at 15°C on potato dextrose agar (P.D.A.), and Table 50 shows the number that produced isolates of the fungus. In the three instances where 100 per cent germination of viable seed was recorded, the ungerminated seed plated represents the non-viable seed sown. From 600 seeds sown the 69 non-viable seeds plated produced 10 isolates of the fungus. This gives a natural infection level of less than 2 per cent, which at current sowing rates would represent an average of four infected seeds per square foot of seed bed. The results from incubating seed at 10°C suggest that infection as small as this could cause serious loss in the seed bed under optimum conditions for the spread of the pathogen. Thiram seed dressing promises to give complete protection, and waxoline dyes with talc and linseed oil partially limited infection, but the inhibition was probably more mechanical than fungicidal.

TABLE 50

RECOVERY OF ENDOPHYTIC SEED FUNGUS FROM UNGERMINATED SEED*

Treatments	Germination temperature			
	20°C		10°C	
	Number plated	Per cent infected	Number plated	Per cent infected
Control untreated	24	17	78	94
Oil only	57	5	41	56
Oil and talc and Auramine Yellow	22	5	37	70
Oil and talc and Lithofar Red	37	19	68	85
Thiram only	23	22	22	59
Oil and Thiram	48	15	36	25
Mean		13		72

* Includes 14 per cent non-viable seed sown.

Pathogenicity of the Endophytic Seed Fungus

A small cube of agar inoculum was placed in the centre of a filter paper resting on moist quartz grit in a Petri dish and 50 seeds sown, in 5 rows of 10, radiating from the inoculum. The first seed in each row touched the inoculum and the 10th seed was 3 cm from it. Twelve different isolates of the fungus were compared with a sterile agar block as control. The dishes were incubated at 10°C for one, two and four weeks and transferred to 20°C for germination.

TABLE 51

PER CENT GERMINATION AT 20°C

Time at 10°C		Position of seed in row					Mean of 10 per row
		1	2	3	4	5	
1 week	Control	80	90	90	80	65	82
	Inoculated	45	53	63	75	75	71
2 weeks	Control	60	75	70	80	70	69
	Inoculated	35	47	38	60	65	62
4 weeks	Control	35	35	35	30	45	38
	Inoculated	5	3	15	15	20	14

Most of the isolates were strongly pathogenic; after four weeks at 10°C a mean germination of only 4 per cent was recorded for eight of them, 22 per cent for one and 45 per cent for three. Table 51 has been simplified to show only the mean results of all 12 isolates. Although natural infection decreased the precision of the test, it is clear that seeds in inoculated plates died sooner the closer they were to the inoculum. When the contents of non-viable seed were plated the number of infected seeds per 100 sown was found to have increased in inoculated plates from 12 after one week to 72 after four weeks at 10°C, and in controls from 4 to 50 respectively. Unlike the damping off fungi *Pythium* and *Rhizoctonia*, the endophytic seed fungus kills only dormant seed. Seeds that have just started to germinate and young seedlings are not damaged, even at 10°C. Although the temperature for most rapid growth of the fungus was found to be near 15°C, Sitka seed germinates much sooner at that temperature than at 10°C, and therefore escapes serious loss. In an experiment done in 1962, before the presence of the seed fungus was suspected, dishes of soil from different nurseries were each sown with 100 seeds of Sitka spruce, of seed origin reference number 60(7111)1, and incubated at 20°, 15° and 10°C. Half the number of dishes of soil were autoclaved before sowing, and equal numbers of each were sown with untreated seed and seed that had been surface sterilised in sodium hypochlorite solution. Autoclaving the soil and surface sterilising the seed had no effect on percentage germination, and Table 52 shows the mean percentage germination at each temperature for each soil.

Incubation at 15°C for as long as 40 days caused only a slight decrease in seed viability, whereas at 10°C few seeds remained viable. Although the soils used ranged from heathland to agricultural types, with pHs from 3·3 to 6·5, the results were similar for all, with the possible exception of Bagley, which was the most acid soil used. The incidence of seed infection at the end of this experiment was not investigated, but it was confirmed later that seed from the same bulk as that used in the experiment was naturally infected. Clearly, seeds incubated at 10°C are highly susceptible to attack because they remain dormant while the pathogen is growing at near its maximum rate. At lower temperatures the growth of the fungus decreases but seeds remain dormant, so maximum loss could occur but would take longer. Temperatures near 10°C are common at sowing time in March but alternate with periods of higher and lower temperatures. A spell of higher temperature may induce germination and render seedlings immune from further attack, although subsequent low temperatures may delay growth and emergence. Losses in nurseries are therefore not necessarily related to the time taken for seedlings to emerge, but they are likely to be greater in Scotland where fluctuations in temperature over 10°C are usually less prevalent than in Southern England. Losses would also be expected to increase with earlier dates of sowing, and autumn sowing would be the most unreliable because in warm soil seeds would germinate early and escape damage, whereas in cold soil they would not germinate until the following spring and suffer maximum loss.

TABLE 52

PER CENT GERMINATION OF SEED HAVING 69 PER CENT VIABILITY

Source of soil		Incubation temperature °C		
		20°	15°	10°
Wareham	W 95	61	60	7
Ringwood	R 93	62	61	12
Bagley	B 52	59	60	30
Kennington	K 95	69	62	6
	K 90	64	51	7
	KE88	69	52	8
Mean		64	58	12
Incubation time in days		22	40	48 (+ 8 at 20°C)

Heat Treatment of Seed

Dusting seed with thiram has controlled the spread of seed-borne infection in the seed bed (Table 49), but this is not suitable for controlling natural infection in pathogenicity tests where fungicidal residues are not required. Investigations into hot water treatment are in a preliminary stage and a satisfactory treatment has not been found. Sitka spruce seed survived immersion in water at 56°C for 30 minutes without loss of viability, but higher temperatures were harmful. The fungus, inoculated into autoclaved seed and incubated for several months, did not survive temperatures of 50°C or more for 30 minutes. Naturally infected seed behaved differently and produced isolates of the fungus after treatment at 56°C for 30 minutes. There was little or no growth of surface moulds such as *Penicillia*, *Mucor* and *Rhizopus* after treatment at 50°C, and the method may therefore be of some use in decreasing mould growth in germination tests.

Germination Losses in Nursery Seed Beds

Attempts to identify and evaluate the various causes of poor stocking in nursery seed beds were continued at Old Kennington, Ringwood and Wareham nurseries. Because many seeds never appear as seedlings, special methods were required for recovering ungerminated seed from soil. On each plot five rectangles measuring 9 in. by 2 in. were each sown with 50 seeds and covered with quartz grit. A soil block larger than the rectangle of seed was removed at regular intervals after sowing, and the seeds and seedlings were extracted on suitable sieves. Plots were sown on three dates, at the end of March and April and in mid-May, on untreated and formalin-treated soil.

Seed sown between 18th and 22nd March germinated slowly, and 34 days later not more than 15 per cent had germinated in any of the three nurseries. There was no decrease in the viability of ungerminated seed as had occurred in laboratory experiments at 10°C. Most seeds eventually germinated and produced healthy seedlings by mid-May. Diseased seedlings were recorded in all nurseries in samples taken on 26th May and 16th June. The disease was a brown root rot associated with species of *Pythium*, *Cylindrocarpon* and *Fusarium*. During this period the number of healthy surviving seedlings at Kennington, Ringwood and Wareham decreased respectively to 53 per cent, 39 per cent and 84 per cent of viable seed sown. Smaller losses associated with the same fungi also occurred in formalin-treated soil.

With later sowings events occurred more quickly. Germination was completed and disease symptoms already present 34 days after sowing on 21st April, and 21 days after sowing on 10th May. Early sown seedlings suffered less from disease than the late sown, especially at Ringwood where the number of survivors from late sowing was only half that from early sowing.

These results are a repetition of those obtained last year, and show that in the last two seasons pre-emergence losses have had no significant effects on numbers of seedlings, and most loss has been due to root rot and damping-off in May and June. These losses are usually much greater than they appear from regular inspection of the seedbeds. Infected seedlings quickly dry out and blow away while other seedlings are still emerging, and the full extent of the loss is therefore not detected by a series of germination counts. Regular sampling of the seedbed suffers from similar inaccuracies and the number of seeds originally sown in the area sampled is not known. Only by sowing known numbers in small areas and sampling the whole at regular intervals can the various losses be determined accurately.

Growth of Seedlings in Partially Sterilised Soil

Soil sterilants last applied at Ringwood in December 1962 had remarkably persistent effects on improving survival and growth of Sitka spruce sown in 1963, 1964 and 1965. These effects had largely worn off by 1966 when there was no residual effect on seedling survival and only an 8 per cent growth response in plots that had metham-sodium.

At Old Kennington, where response to sterilants is mainly confined to the year of application, seedlings in untreated and formalin-treated soil grew to 1·38 and 2·25 in. respectively where manured with "Nitro-Chalk", and to 2·39 and 3·14 in. respectively with ammonium sulphate. Annual dressings of ammonium sulphate since 1962 had acidified the soil to pH 4·2 (in 0·01 $CaCl_2$) compared with 5·2 in plots supplied with "Nitro-Chalk".

In pots of Ringwood soil the nematode *Hoplolaimus uniformis*, added at the rate of 50 per 500g soil, slowed the growth of Sitka spruce seedlings, but the fungi *Pythium irregulare*, *P. ultimum*, *Fusarium oxysporum* and *Cylindrocarpon* sp.

had no effect on growth whether the nematode was present or not. This confirms earlier results that stunting in Ringwood soil is largely caused by the nematode, and these fungi, which are isolated more often than any other from roots, seem to have little effect on growth.

SUMMARY

An endophytic fungus in Sitka spruce seed greatly decreased the viability of dormant seed incubated for four weeks at 10°C in sterilised quartz grit or in unsterilised nursery soil. Seed incubated at 15°C and 20°C germinated and escaped serious damage. Infection was prevented and viability maintained at 10°C by treating seed with a 50 per cent thiram dust.

Seed from the same bulk as used in the laboratory, when sown in nursery seed beds in 1965 and 1966, mostly survived and germinated, but many seedlings became infected by species of *Pythium*, *Fusarium* and *Cylindrocarpon* and died soon after they emerged.

BIOLOGY OF FOREST SOILS: MYCOLOGY OF SCOTS PINE LITTER

By A. J. HAYES

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Investigations were continued for a third year into the microdistribution of fungi on decaying Scots pine needles, both in space and time. This was done to obtain tentative conclusions regarding the most frequent fungal species, and also to attempt to confirm certain hypothyses formulated on the basis of the first two years' sampling.

The eight square feet of the experimental area which had been previously used was therefore sampled for a third year. At two-monthly intervals needle samples were taken from two square feet of this area, twenty samples spaced at two-inch intervals being taken from each square foot, making forty samples on each sampling date. This means that the eight square feet were sampled completely three times in the year. The needle samples were then transferred quickly to the laboratory, surface sterilised, and plated out onto 2·5 per cent malt agar. The plates were subsequently examined at weekly intervals for three weeks and then discarded.

Although all the results have not yet been examined in detail, some preparation work has been carried out, and it is hoped to publish this study in its entirety in due course. However, certain trends are already clear. Needles at abcission appear to be commonly infected with *Graphium* sp. Where needles are not infected with this species until they reach the forest floor, infection seems to spread at a rather slower rate, the fungal reservoir presumably being contained in small portions of the previous season's needles which have been decaying at a slow rate. In a few cases it was noted that recently fallen needles were infected with *Pullularia pullulans* (*Aureo-basidium*) and this was rapidly replaced by *Graphium*. Nevertheless, whichever mode of infection takes place, the maximum incidence of *Graphium* occurs at about six months after abcission; and this species is then gradually replaced by *Verticicladium trifidum*. This stage appears to last for a varying period, but is eventually replaced by *Trichoderma viride* or else by *Penicillium funiculosum*. The latter is an extremely aggressive species, and seems to be capable of replacing *T. viride* without difficulty. A number of accessory species have also been noted at the *Verticicladium* and *T. viride*/*P. funiculosum* stages, including *Penicillium spinulosum*, *P. cyclopium*, *Aspergillus fumigatus*, *Paccilomyces varioti*, *Geotrichum candidum* and *Pachybasium hamatum*. While it is clear that any one of these may occasionally be present in association with the major species, or else replace it completely, the reasons underlying this phenomenon are not understood. It may well be that the precise microclimatic and micronutritional régimes of any one decaying pine needle are sufficiently different to confer a positive advantage on one or more of the accessory species, but in the absence of a sufficient corpus of knowledge of the climatic and nutritional requirements of many of these litter-inhabiting microfungi it is not possible to proceed further.

Nevertheless, there is now sufficient evidence to suggest that the pattern of fungal succession in decaying pine litter is rather more complex than has been suggested hitherto.

SUMMARY

Studies on the microdistribution of fungi in decaying Scots pine needles were continued for a third year. Sampling continued at two-monthly intervals on the same portion of the experimental area, and needles were surface sterilised and cultured in the same manner as hitherto. *Graphium* sp. proved to be the commonest species on newly-fallen litter, although there was some suggestion that this could be preceded by *Aureobasidium (Pullularia) pullulans*. *Graphium* was eventually replaced by *Verticicladium trifidum* which in turn was displaced by *Trichoderma viride* or *Penicillium funiculosum*. It was also apparent that there were a number of accessory species which could be present in association with *V. trifidum*, *T. viride* or *P. funiculosum* or else replace them entirely. However, the factors underlying this association or replacement remain obscure.

BIOLOGY OF THE FUNGUS CRUMENULA SORORIA

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Crumenula sororia Karst. is an Ascomycete fungus, with small black apothecia, which for many years has been associated with cankering on unthrifty crops of Scots Pine in Finland. From 1960 to 1963, however, Batko and Pawsey reported this same fungus on poor checked crops of Corsican pine and Scots pine in the South of England and South Wales (Ringwood, Wareham and Brechfa Forests), causing cankering at the base of the stem. In 1964, this fungus was also found on Corsican pine at Pitmedden Forest, Fife. Disturbing features of this attack were that some of the trees were up to 30 years old, and that these trees were in full vigour, growing on what was apparently a highly fertile site. There were other symptoms, in addition to the cankering, and these included copious resin bleeding and dieback. In the last year, *Crumenula* has also been noted attacking Lodgepole pine in three widely scattered areas of Scotland. The possible long-term impact of this attack on the planting policy of the Forest Commission is obvious, since Lodgepole pine is being planted on a growing scale. Indeed, Pawsey's statement (1964) is of particular relevance: "However, any further records of infection similar to that recorded at Pitmedden may call for a re-appraisal of its pathogenic potential".

Little is known of the biology of this fungus. The mode of entry, and time of entry, into the host do not appear to have been elucidated, and the relevant importance of the conidia and ascospores in the spread of the disease is likewise unknown. This lack of knowledge of the basic biology of the fungus, coupled with the reports of attack on Corsican pine and Lodgepole pine, are a potentially serious situation, and in an attempt to elucidate the biology of this fungus, the present investigation was set in train.

Three approximately $\frac{1}{10}$ acre plots were laid out in Pitmedden Forest, Fife, in 15-year-old Corsican pine, to serve as sites for controlled infection experiments. It soon became apparent that a proportion of these trees had already been infected, and these plots were then examined to distinguish infected from apparently healthy trees. Two main symptoms could be distinguished. The first was a typical canker, situated always at the node, which latter nearly always possessed a dead or recently dead branch on the cankered side. Typical compensatory growth occurred on the side of the trunk away from the dead branch. Some resin bleeding was noted, derived from slits in the bark over the canker. The second symptom consisted of a vertical slit in an internodal position, with active resin bleeding but no cankering.

Although anatomical investigation has not yet confirmed the exact site of entry, there is evidence that the fungus travels along the medullary rays to the pith, and then travels up and down in the pith. Infected wood is flinty, resin-soaked and black in colour, and surrounded by a zone of non-pigmented, resin-soaked wood. These anatomical investigations are continuing.

A study of the incidence of these cankers in relation to compass bearing is in progress, in an attempt to ascertain the relation of canker production to dew formation on the tree bark, or else to bark temperature. An examination of the soils and soil profiles of the infected areas has also been undertaken, together with an assessment of the proportion of the total rainfall actually reaching the rooting zone.

Cultural studies on the fungus itself have recently begun, partly to examine the characteristics of the fungus itself, and also to provide material with which to carry out infection experiments. Finally, a number of Corsican pine transplants grown in a greenhouse have been infected with *Crumenula*, to trace the course of the fungal attack and also to confirm the source of entry of the pathogen.

The co-operation of Forestry Commission staff in providing field facilities and planting stock is gratefully appreciated.

SUMMARY

Crumenula sororia Karst. (Ascomycetes) has long been associated with cankering of Scots pine in Finland, but in the last ten years attacks on poor checked crops of Scots and Corsican pines in the South of England and South Wales have been reported. More recently however, crops of apparently vigorous Corsican pine have been affected, and latterly there have been reports of infected crops of Lodgepole pine. The implications of this latter are obvious, as it is a widely-planted species. The symptoms of this disease include cankering, resin bleeding and dieback of the affected tree.

Studies on the biology of this fungus were commenced in October 1966, and at the present time include an anatomical investigation to determine site of entry and transference of the fungus through the host tissues, which it is hoped will be confirmed by a series of inoculation experiments on seedlings. In addition the role of site factors in the incidence and severity of the disease, and the growth characteristic of the pathogen, are also being examined.

FISH POPULATIONS IN FOREST STREAMS

By D. H. MILLS

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During the last year a fish trap has been built on the Glentress burn to catch all descending fish, and a census has been made of the resident trout population in four sections of stream running through plantations of different ages. The mean value for the standing crop or biomass of fish is 96 kilogrammes per hectare. The standing crop is highest (192 kg/ha) in those sections of stream flowing through young plantations with abundant vegetation growing on the banks and over the stream. The standing crop is much smaller (56 kg/ha) in the sections of stream flowing through mature forest where undergrowth is absent. The results of this census have been written up and presented as a paper at the Discussion Meeting, Wildlife in the Forest, of the Society of Foresters of Great Britain held at Cirencester in January (Mills 1967).

The trout were removed from these sections of stream after the census, and in January 6,100 eyed salmon ova were planted in this area in perspex boxes. A number of the boxes have been examined to determine the egg mortality, which was found to be 47 per cent and is exceptionally high (the mortality in the egg state is normally no more than 5 per cent). This high mortality was caused by heavy silt deposition in the stream, probably due to clearing of the drainage channels in this area.

A number of forestry management practices which may have a detrimental effect on fish populations are being noted.

SUMMARY

The mean value for the standing crop or biomass of fish in the stream running through Glentress Forest is 96 kg/ha. The standing crop is highest (192 kg/ha) in those sections of stream flowing through young plantations with abundant vegetation growing on the banks. The standing crop is much smaller (56 kg/ha) in the sections of stream flowing through mature forest where undergrowth is absent.

REFERENCE

MILLS, D. H. (1967). A Study of Trout and Young Salmon Populations in Forest Streams with a View to Management. *Forestry*, 1967 Supplement (pages 85–90)

ENVIRONMENTAL FACTORS AND THE GROWTH OF SITKA SPRUCE

By D. C. MALCOLM

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The main aim of this project is to try to identify and investigate the effect of those locality factors which, together or singly, result in differing rates of productivity in pure stands of Sitka spruce.

Limitations to the succesful use of the species remain inadequately defined, so that this study has been confined to healthy plantations over thirty years of age within a series of areas in Scotland, each of which is thought to be approximately uniform in terms of gross climatic parameters. This initial selection has allowed attention to be concentrated on physiographic and edaphic factors of sites where ultimate maturity of the stands as utilisable timber is relatively assured. The age constraint, while resulting in an integration of the climatic factors, has had the unfortunate effect of making it difficult to control possible genetic variability, since provenance differences are generally not recorded for stands of this age.

In the period under report most of the work has been devoted to the development of both field and laboratory techniques to characterise the site attributes thought to be important.

The determination of a plot size which is small enough to reduce some of the variability in edaphic factors, but large enough to provide a reliable estimate of productivity, results in the selection of a topographically uniform 0·1 acre circular plot as standard. An inner plot of 0·025 acres is then used as a basis for soil description and sampling.

Productivity has so far been recorded in terms of the yield class of the stand, entry to the published curves being made through top height measurements. Although open to criticism this method is still universally used as it allows a single assessment to be made. Other measures are being tested for comparison.

Soil profiles are described and sampled, particular attention being paid to the measurement of the stone content which can have important effects. The major horizons are also sampled for bulk density determinations.

Ground vegetation when present is recorded by species.

In the laboratory a range of physical and chemical determinations are made. Physical characteristics which relate to the availability of water in the soil are of obvious importance, but are difficult to make comparably in forest soils, on other than disturbed samples, which reduces their value. Methods of assessing soil fertility in respect of nutrients have mainly been developed for agricultural soils and, quite apart from questions of "availability" to trees of minerals extracted by these methods, problems arise due to the high organic content and generally low nutrient status of many forest soils. Some time has been spent in testing various extraction and analytical techniques and working up those selected onto a routine basis.

The availability of data derived from working plan assessments of yield class distributions for Sitka spruce over 25 years old in Scotland, made it possible to assess the occurrence of any simple relationships with gross climatic parameters. This was done by means of a multiple regression analysis of weighted average yield class for each forest, against geographic location and climatic parameters as independent variables. No significant pattern was distinguished even when areas recorded as being in check, or of less than 10 per cent of the forest area, were removed and the dependent variables recalculated.

The results available from the sample plots laid out in two forest areas, Glentress and Inverliever, do not yet allow of any detailed statistical analysis. Preliminary tests show, however, that simple straight-line relationships do exist between productivity and some single physiographic and soil physical and chemical characters. Of particular interest so far is an apparent strong relationship with exchangeable magnesium. It is not to be expected, however, that the relationships between single site attributes and the productivity of Sitka spruce can adequately explain the complex interactions between individual factors that together comprise soil fertility, or the potential productivity of a site growing Sitka spruce. When sufficient data are to hand these relationships will be explored further, using multivariate techniques.

SUMMARY

The development stage of this project to determine the effect of combinations of locality factors on the production of Sitka spruce. The results to date indicate that there is a relationship between site attributes and productivity in regard to Sitka spruce.

LIGHT RELATIONS OF SIX TREE SPECIES IN THE NURSERY AND IN THE FOREST

By W. A. FAIRBAIRN

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Following discussion with the Forestry Commission, a joint experiment was established in the spring of 1966 at Bush Nursery near Edinburgh, the object of the experiment being to investigate the response of germination and growth of six species (Norway and Sitka spruces, European Silver fir, Grand fir, Douglas fir and Western hemlock) to a range of light intensities. Light was varied within the nursery by lathe covers of different density, and in an adjoining plantation by using prepared clearings of different sizes.

Relative light intensities were measured over extended periods by barrier-layer cells and also periodically by EEL photometers. Soil temperatures at the surface and at six inches depth were also measured. The measurement and analysis of light was the responsibility of the University. The Forestry Commission Research Division undertook the standard nursery preparation and crop assessments, while there was a dual responsibility in regard to the temperature data.

At the end of the first growing season, seedling lengths, collar diameters and dry weights were obtained on a small sample and indicate characteristic species patterns. Germination and height also reflect consistent treatment effects. Figure 4 illustrates the range of growth of the six species in five intensities of light.

This preliminary experiment will be concluded in the autumn of 1967 and more detailed results will be published thereafter.

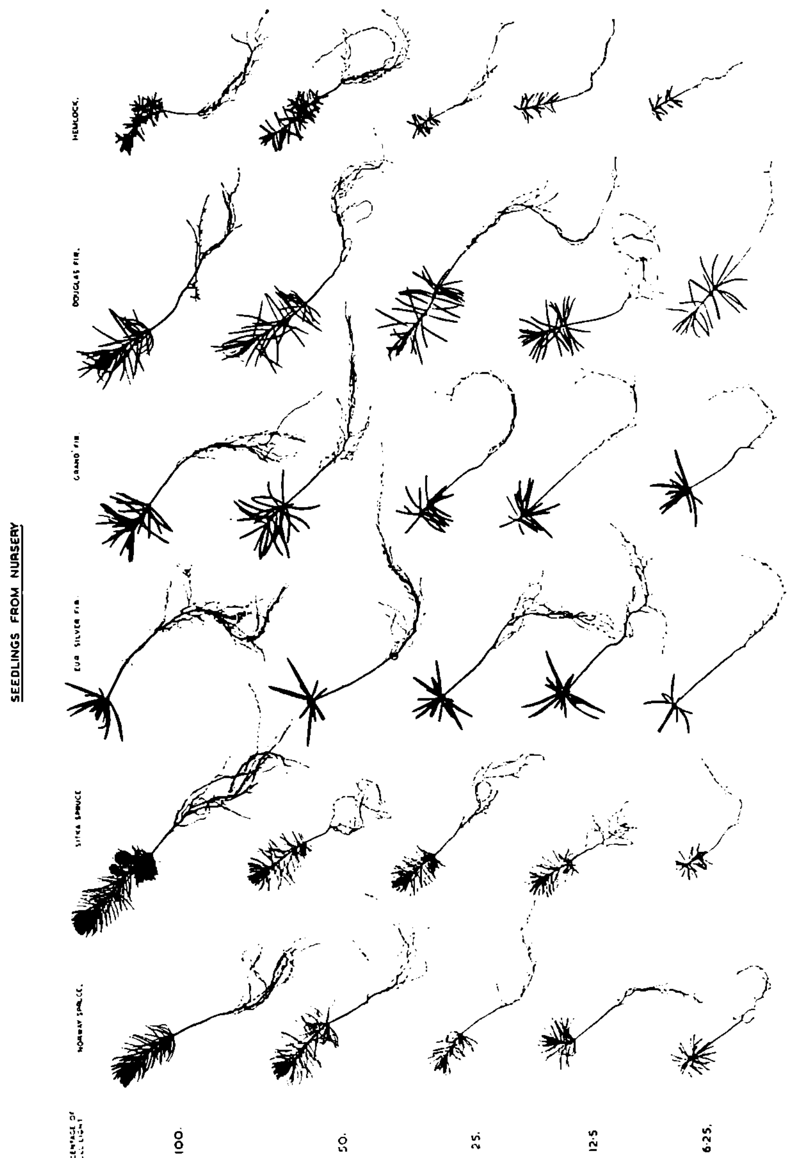

FIGURE 4. The range of growth of six species of seedlings from the nursery, in five intensities of light.

VIRUS DISEASES OF FOREST TREES

By P. G. BIDDLE and T. W. TINSLEY

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Present studies have concentrated on poplar mosaic virus. This is a suitable virus for fundamental work on the potential effect of viruses on tree growth. This approach has been extended to field surveys of other trees showing virus-like symptoms, and attempts have been made to transmit them to herbaceous host plants.

Poplar Mosaic Virus

The homogeneity of poplar stands makes this species ideal for studies on effects on growth. Particular emphasis has been given to this aspect of host plant physiology, but the programme is being extended to cover the effects of virus infection on variations in wood structure and composition.

Measurements in the Nursery

Measurements of height growth were made, at fortnightly intervals throughout the 1966 growing season, on a variety of second year stands of *Populus x euramericana* cultivars in the Grange Estate nursery of Messrs. Bryant and May Ltd. Figure 5 shows that the reduction in growth varied with different clones, but the reduction occurred steadily throughout the season without any significant peaks. There was no evidence that early defoliation had caused the reduction. Comparable data were obtained from different sites, with *Populus* "Eugenei" invariably being the worst affected of the clones investigated.

Measurements in the Plantation

Most other workers have studied the effects on growth in nursery stock. Such measurements may not reflect the situation in older stock, and to test this, one clone, *Populus* "Robusta", was examined using all available age classes on the very uniform site at Bliss Estate. Each age-class consisted of a natural mixed population of healthy and infected trees, the oldest trees measured being the 1958 planting stock. Comparison of the breast height diameters of these showed that there was a reduction in diameter growth, and that this varied considerably with the different ages, as is seen in Figure 6. It is not clear from these results if the disease continues to reduce the breast-height diameter with increasing age, as has been suggested by previous workers. The fact that there are two significant results in the 1958 and 1960 planting stock suggest, if anything, that the disease becomes more severe with time, but there is no statistically significant linear interaction of loss of diameter with time, to indicate any definite trend in the effect of the virus. This can probably only be shown after recurrent measurements have been made on all these crops over the next few years, and differences of increment of healthy and infected trees studied at the different ages.

The interpretation of these results is complicated by the lack of information on possible vectors of the virus. Field observations suggest that the virus is transmitted subterraneously over a limited range. If this is so, large healthy trees with a larger root system may be more liable to early infection, because the roots

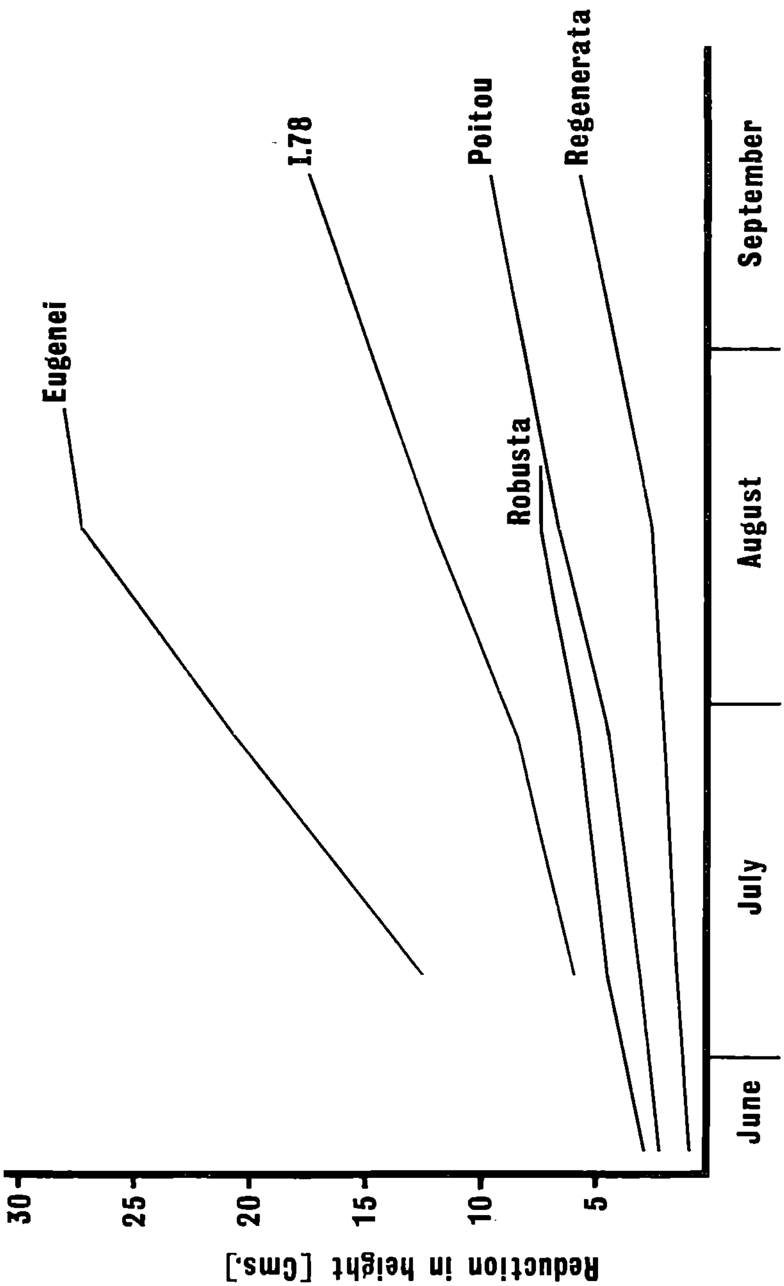

FIGURE 5. Reduction of height growth caused by Poplar mosaic virus on second year nursery stock. 1966.

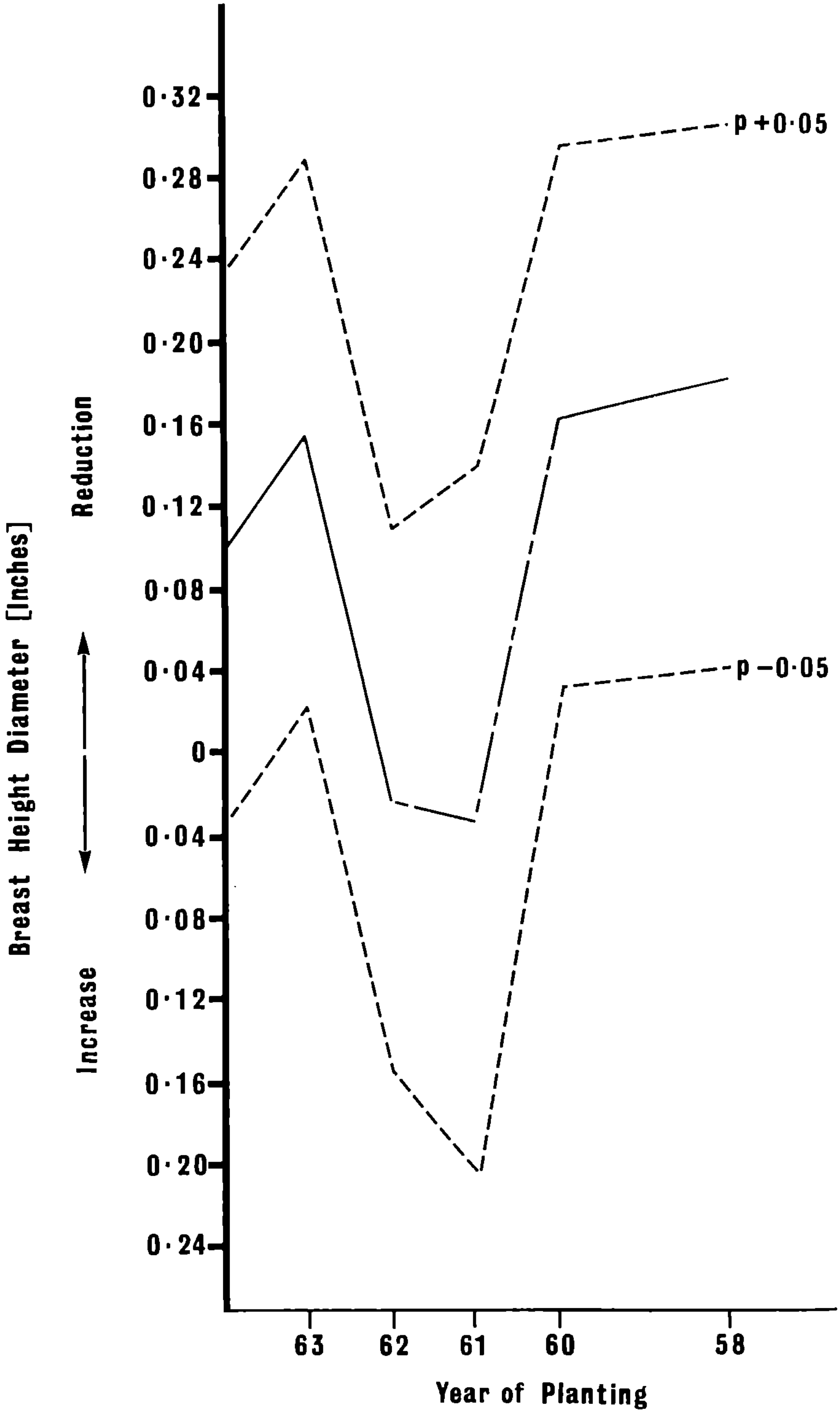

FIGURE 6. Differences in breast height diameter between infected and healthy trees at different ages caused by Poplar mosaic virus.

may grow into contact sooner with infected roots. Thus, there may be large trees just beginning to show symptoms in which the virus has had insufficient time to show an appreciable reduction of diameter. The apparently anomalous results of the 1961 and 1962 planting stock, which show a girth increase, may be caused by this, and the whole effect of the virus on these, and older stock, may be being masked by a slow spread of the disease. The effect of the virus may be more severe than is suggested by this graph, as it is not known how long trees have been infected and so for how long the virus has been reducing growth.

Experiments have been designed to test virus transmission by root contact and by nematodes. In addition, further attempts to transmit Poplar mosaic virus by sucking insects are being made.

No control measures can be advocated until the method of transmission is understood, but it would be obvious to reduce the sources of infection by rogueing out diseased plants in the stool beds. It is probable that little spread would occur with the use of healthy stock.

Laboratory Studies

Poplar mosaic virus can be maintained in a wide range of herbaceous host species. *Nicotiana megalosiphon* has proved the most suitable source of material for purification, as well as being the most sensitive species for detecting low concentrations of virus. *Vigna sinensis* "Local White Mala" has proved the most reliable local lesion host, but even here accurate bioassay is difficult because of the high residual variation. The instability of the virus particle makes purification by ultracentrifugation or by precipitation unsatisfactory. Best results are obtained with sucrose density gradient ultracentrifugation, gel filtration or charcoal absorption. An antiserum to the virus has been prepared.

Suspected Viruses in Other Forest Species

Virus-like symptoms have been observed in a wide variety of angiosperm species. A distinct mosaic of oak is apparently widely distributed, occurring in both Pedunculate and Sessile oaks, *Quercus robur* and *Q. petraea*. A range of widely different symptoms on ash has been noted, but only one of these appears to be widespread. Scions infected with these viruses have been grafted to apparently healthy stocks, but as yet no symptoms have been observed. Attempts to mechanically inoculate these viruses, as well as viruses from birch, Douglas fir, elm, Norway maple and willow to a variety of herbaceous plants have been unsuccessful. The mosaic disease of the common laburnum, *Laburnum anagyroides*, has been successfully mechanically transmitted to *Phaseolus vulgaris* and *Chenopodium quinoa*. The purification and properties of this virus are being investigated.

WATER RELATIONS OF FOREST AND MOORLAND VEGETATION

By L. LEYTON, E. R. C. REYNOLDS and F. B. THOMPSON

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Rooting and Soil Moisture

The object of this study is to relate the distribution of tree roots to the pattern of throughfall and stem flow and to that of moisture uptake down the profile, as reflected in diurnal and seasonal fluctuations in the water table. In developing sampling and recording techniques, a considerable amount of data has been, accumulated on the vertical and horizontal distribution of Douglas fir roots in a deep sandy soil in Bagley Wood, near Oxford, and these are now being worked up for publication.

Fluctuations in the water table below a hornbeam stand have been recorded and will be compared with rainfall and evaporation data, the latter obtained from a USWB Class A pan located at Farmoor Reservoir. Stem flow and throughfall have been recorded in this stand and rooting studies are being introduced.

Interception Studies

Data on rainfall interception losses from the above hornbeam stand and from a Norway spruce stand were presented at the Pennsylvania State University Symposium on Forest Hydrology: the Proceedings have now been published (Leyton *et al*, 1966). These investigations are continuing in the Norway spruce stand with a view to determining the effect of different intensities of thinning.

In the studies on interception by moorland vegetation, heather, bracken and *Molinia* grass, useful techniques have been devised for point quadrat measurements and for recording the wetting and drying of foliage. Improvements have been made in the automatic data logging technique using magnetic tape. Some of the results were presented at the British Ecological Society Symposium at Reading University on Measurement of Environmental Factors.

Heat Studies

A new technique has been devised, based on heat exchange, for automatically recording sap flow rates in tree stems. Tests are continuing and a paper on this is to be presented at the 1967 I.U.F.R.O. Congress in Munich.

The support of the Forestry Commission in providing a technician (Mr. E. A. S. Ogden) for assisting in the field studies is gratefully acknowledged.

REFERENCE

LEYTON *et al*, 1966. *International Symposium on Forest Hydrology*. Ed. Sopper, W. E., and Lull, H. W., Pergamon Press Ltd., Oxford and New York. 1966.

INFLUENCE OF LEAF-CHARACTERS AND GROWTH HABIT ON THE PRODUCTION OF DRY MATTER

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This is a second report concerning an experimental study of the effect of growth habit on dry-matter production in forest trees. In the previous communication the broad general results of the first year of a two-year experiment were presented (Causton and Wareing, *Rep. For. Res.* 1966, *For. Comm. Lond.*, page 103).

The two treatments applied (i.e. debranching and decapitation) to each of the two species, birch (*Betula pubescens*) and sycamore (*Acer pseudoplatanus*), were continued in some of the plants during the second year, but not in the remainder. Thus each of the four species-treatment combinations in the first year were divided into two groups and designated "treatment in both years" and "treatment in first year only". During the second year, six harvests were taken at four-weekly intervals throughout the growing season.

The birches which were debranched both years were very slow-growing at the beginning of the season, because they were allowed only one shoot meristem producing leaves. By August, however, they had shown considerable growth and had very large dark green leaves and a net assimilation rate about double that of the untreated birch at this time. The birches which were debranched only in the first year were also slow-growing at the beginning of the season, but since they quickly developed branches they grew more rapidly than the trees debranched in both years. Their net assimilation rate was also higher than that of the untreated plants for a time during the middle of the season, although this feature was not associated with large dark green leaves. Indeed, preliminary analysis suggests that the size of the individual leaves was no greater in the birches debranched during the first year only, than those of the untreated plants. The decapitated birches showed no features of special interest since their growth habit did not differ from the untreated plants.

In sycamore, net assimilation rate was not affected by the treatments, the differences in relative growth rate observed being due entirely to differing leaf-area ratio. Furthermore, the differences are only to be found at the beginning of the season and are caused by the time of bud-break on different parts of the plant. The only difference between decapitated sycamores and the untreated plants was a higher initial relative growth rate during May, which was due to a higher leaf-area ratio brought about by the fact that bud-break was earlier. Conversely, the lower relative growth rate shown by both series of debranched sycamores, as compared with the untreated plants over the same period, was due to the lower leaf-area ratio on account of a delayed bud break on the main stem.

The results from the second year of the experiment confirm and extend the findings of the first year. The compensatory mechanisms in birch referred to in the previous report, i.e. the increase in size of the individual leaves and an increase in net assimilation rate occurred again with greater magnitudes, although with such a drastic debranching treatment total growth was low compared with the controls. In sycamore the extra number of leaves produced on much-branched plants were individually smaller than those on unbranched plants, so that over most of the growing season the leaf-area ratio was scarcely affected.

EFFECTS OF CULTIVATION AND DRAINAGE TREATMENTS ON MOISTURE TENSION IN A WATER-LOGGED SOIL

By D. J. READ

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Tree growth is restricted over large areas of moorland in northern Britain by water-logged soils. Cultivation treatments used to date have had only limited success in ameliorating these conditions. Weatherell has established an experiment at Rosedale in Allerston Forest, North Yorkshire (described by Henman, 1965), to compare conventional single-furrow and deep complete ploughing treatments with plots consisting of "riggs and furrs". Drained and undrained plots of each treatment are included in the experiment and Scots pine is the main tree species.

Some investigation of the effect of cultivation and drainage treatment on soil and plant water relations in the experiment began in 1966. The aim of the investigation in the first year was to determine whether measurable differences of moisture tension occurred between treatments, and if so, the kind of instrumentation best suited to this type of experiment.

Moisture tension was measured by means of Bouyoucos resistance blocks and tensiometers. The blocks were arranged in groups of four, there being one group in each plot buried at 3, 6, 12 and 24 in. In this way replication between plots was achieved, but not within plots. At the beginning of the season one set of three tensiometers was placed in three undrained plots each of different treatments. Later in the season, tensiometers were also placed in the drained plots. In each group they were situated at 6, 12 and 24-in. depths.

A meterorological station was established and all instruments in the experiment were read at weekly intervals from June onwards. Leaf water deficits were determined at fortnightly intervals on three trees in the region of the instruments in each plot.

The measurements revealed that tensions within the experiment were extremely small throughout the growing season, and in view of the poor sensitivity of resistance blocks at the wet end of their calibration curves significant effects of treatment could not be discerned using this method.

As shown in Figure 7, rainfall was persistently high throughout the period of measurement, and averaged almost one inch per week. This fact, coupled with the high water-holding capacity of the soil, meant that the tensiometers were by far the most suitable instruments for soil conditions within the experiment. Tensiometer readings for three depths in the undrained plots through the season are presented in Figure 7. The interesting feature of these results is that, while in the upper regions of the profile the rigg appears comparable with the other treatments in showing a relationship between tension and rainfall, at the lower depth it shows a consistently higher tension throughout the season.

The important issue within the experiment appears to be whether any treatment is capable of reducing the water content of the soil below complete saturation so that, by improving aeration, it increases the available rooting space for the crop.

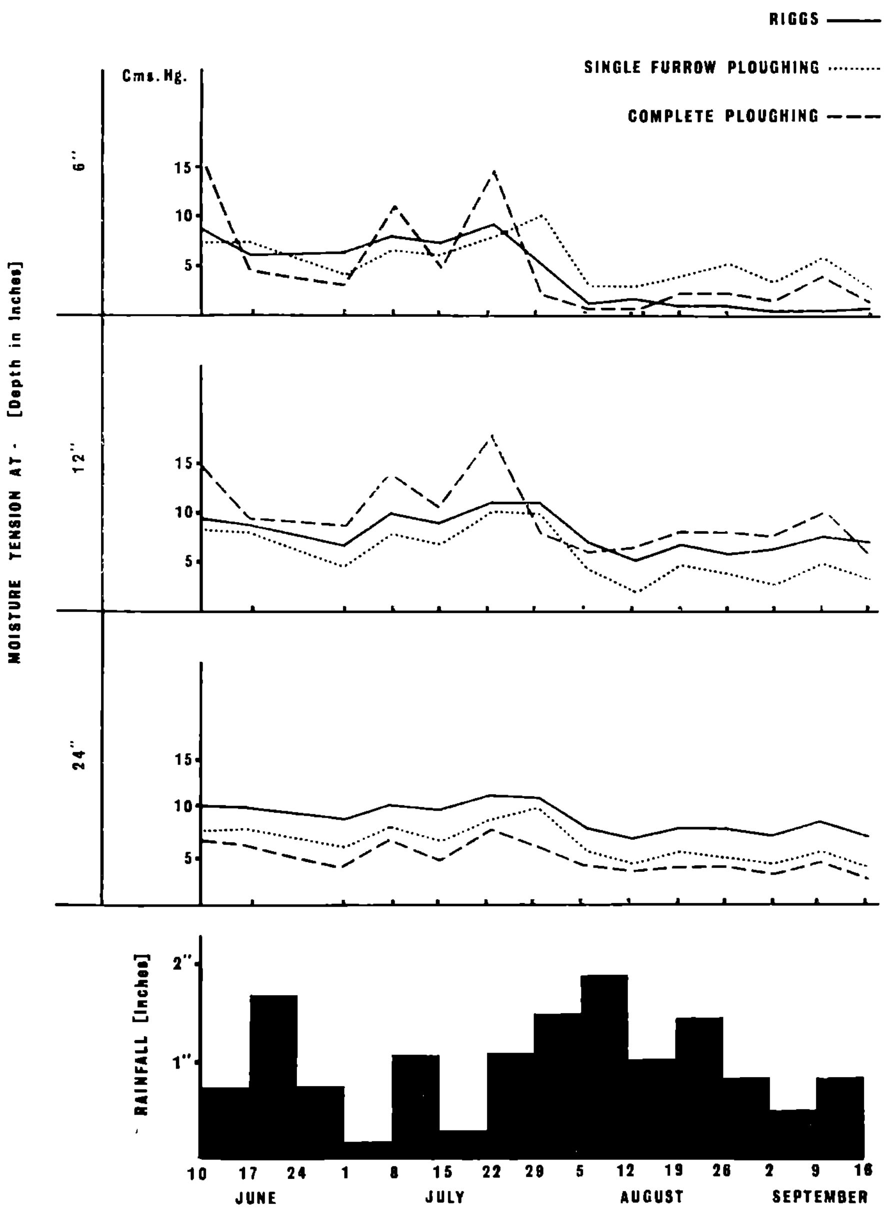

FIGURE 7. Relationship between moisture tension and rainfall for three cultivation treatments, at three depths. Data from single tensiometers.

In view of the lack of replication within the plots it is clear that these results do not provide positive evidence in favour of any particular treatment. They do, however, fulfil the aim of the pilot study in showing that differences between treatments may be detectable, and in showing which form of instrumentation is most suitable for the experimental area.

Extensive replication of the tensiometers together with increased needle sampling is planned for the coming season. Basic information may thus be obtained on the relationship between cultivation treatment, moisture tension and tree growth in regions of appreciable rainfall and normally impeded drainage.

REFERENCE

HENMAN, D. W. (1965). Drainage of Mineral Soils by "Rigging". *Rep. For. Res. For. Comm., Lond.* 1964 (page 25).

STUDIES ON TITMICE AND PINE LOOPER MOTH POPULATIONS AT CULBIN FOREST

By MYLES CROOKE

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The state of this long-term investigation was reported on in some considerable detail recently (Crooke 1966). Since the time of that publication work has continued along the same broad lines as were described there.

The mean Pine looper moth (*Bupalus piniarius*) counts (all figures as numbers of pupae per square yard) for winter 1965–66 were 1·8 in Plot 1 (in which nesting boxes have been erected), and 1·4 in Plot 2 (control), whilst the figures for 1966–67 were 2·1 and 1·3 for Plots 1 and 2 respectively. The means for the two plots thus continue to march in close agreement as they have done since 1954, whilst the overall trend is for the population density to be higher for the two winters quoted above than they were in the preceding three winters.

Nesting records for coal and blue tits were kept in 1965, but no census of breeding coal tits was made in that year. This reduction in field effort coincided with a period when no Forestry Commission grant-in-aid was made, but when grant support was resumed in 1966 the customary census of coal tits in Plot 1, based on the definition of territories via song-post recording, was carried out. This revealed that the breeding density in the *circa* 200-acre plot was 22–23 pairs, as compared with the 17–18 pairs recorded in 1964. Two pairs of blue tits also bred in the plot in 1966.

It is planned in future to census coal tits in both study plots, and to commence winter feeding in Plot 1 in an attempt to impose differential winter survival and hence possibly breeding rates on the two plots.

REFERENCE

CROOKE, M. 1966. Studies on Tit and Pine Looper Populations at Culbin Forest, Morayshire. *Rep. For. Res. For. Comm., Lond.* 1965 (pages 190–200).

CHEMICAL CHANGES IN FOREST LITTER

By J. TINSLEY and A. A. HUTCHEON

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The biennial collection of litter samples from the manurial plots and drainage water from the micro lysimeters laid out in Bramshill Forest in March 1962 was completed in October 1965, and the chemical analysis of the accumulated samples has been continued.

The results, together with those collected by Dr. Binns of the Forestry Commission, and his staff, on the growth increment of the Scots pine and composition of the needles resulting from the various nitrogen fertiliser treatments, are now being subjected to statistical analysis; a full account of the whole programme will be published in due course.

FIRES IN FOREST AND HEATHLAND FUELS

By A. J. M. HESELDEN and M. W. WOOLLISCROFT

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The main effort this year has been towards collecting more field data and increasing their scope and accuracy with a view to relating experimental and theoretical work to practical conditions.

Data from Controlled Burning

In the light of experience gained in previous years, a new version of the fire card used for reporting controlled burning has been produced for the 1967 season to record data from controlled burnings, to make the data more accurate and to make recording simpler. The straight line of marker poles set out to enable the position and speed of the fire front to be obtained has been replaced by three poles placed in a triangle; this avoids assuming the direction of spread before firing. The cards will be supplemented by photographs so that flame dimension and angle can be better determined.

The poor weather in the spring of 1966 interfered with the Forestry Commission programme of controlled burning, and the thirteen cards received after the 1966 season were not sufficient to enable the preliminary analysis of the 1965 fire card data to be extended. In view of the better spring weather in 1967 more data are expected this year.

Experimental Field Work

A team from the Fire Research Station again visited the New Forest in March 1967, and took rate of spread and thermal measurements at controlled burnings carried out by the Forestry Commission. Substantially more data were collected than in 1966, but the analysis has not yet been completed.

APPENDIX I

Main Experimental Projects and Localities

NURSERY EXPERIMENTS

Benmore Nursery, near Dunoon (Argyll)
Bush Nursery, near Roslin, south of Edinburgh
Fleet Nursery, Gatehouse of Fleet (Kirkcudbrightshire)
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, near Alloa (Clackmannanshire)

AFFORESTATION EXPERIMENTS ON PEAT

Achnashellach Forest (Wester Ross)
Beddgelert Forest (Caernarvonshire)
Clocaenog Forest (Denbighshire and Merioneth)
Inchnacardoch Forest (Inverness-shire)
Kielder Forest (Northumberland)

Naver Forest (Sutherland)
Strathy Forest (Sutherland)
Watten (Caithness)
Wauchope Forest (Roxburghshire)

AFFORESTATION EXPERIMENTS ON HEATHLAND

Allerston Forest, Harwood Dale (Yorkshire)
Clashindarroch Forest (Aberdeenshire)
Inshriach Forest (Inverness-shire)
Land's End Forest, Croft Pascoe (Cornwall)
Millbuie, Black Isle Forest (Easter Ross)

Taliesin Forest (Cardiganshire and Montgomeryshire)
Teindland Forest (Moray)
Wareham Forest (Dorset)

FOREST NUTRITION

Allerston Forest, Broxa (Yorkshire)
Arecleoch Forest (Ayrshire)
Clocaenog Forest (Denbighshire and Merioneth)
Culbin Forest (Moray)
Exeter Forest (Devon)

Inchnacardoch Forest (Inverness-shire)
Selm Muir (Mid and West Lothian)
Shin Forest (Sutherland)
Tarenig Forest (Cardiganshire and Montgomeryshire)
Teindland Forest (Moray)

Wareham Forest (Dorset)
Wilsey Down Forest (Cornwall)

SOIL MOISTURE STUDIES

Aldewood Forest (Suffolk)
Alice Holt Forest (Hampshire and Surrey)
Bernwood Forest (Oxfordshire and Buckinghamshire)
Bramshill Forest (Berkshire and Hampshire)
Inchnacardoch Forest (Inverness-shire)

New Forest (Hampshire)
Queen Elizabeth Forest (Hampshire and Sussex)
Feltwell, Thetford Chase (Norfolk and Suffolk)

PROVENANCE EXPERIMENTS

Scots pine:	Findon, Black Isle Forest (Easter Ross) Thetford Chase (Norfolk and Suffolk)
Corsican pine:	Brighstone Forest (Isle of Wight) Cotswold Forest (Gloucestershire) Thetford Chase (Norfolk and Suffolk) Wareham Forest (Dorset) South Yorkshire Forest
Lodgepole pine:	Achnashellach Forest (Wester Ross) Allerston Forest, Wykeham (Yorkshire) Brendon Forest (Somerset) Ceiriog Forest (Denbighshire) Clocaenog Forest (Denbighshire and Merioneth) Forest of Deer (Aberdeenshire) Glen Trool Forest (Kirkcudbrightshire and Ayrshire) Millbuie, Black Isle Forest (Easter Ross) New Forest (Hampshire) Taliesin Forest (Cardiganshire and Montgomeryshire)
European larch:	Coed y Brenin (Merioneth) Mortimer Forest (Herefordshire and Shropshire) Savernake Forest (Wiltshire and Berkshire)
European and Japanese larches:	Clashindarroch Forest (Aberdeenshire) Drummond Hill Forest (Perthshire) Fetteresso Forest (Kincardineshire) Lael Forest (Wester Ross)
Douglas fir:	Glentress Forest (Peeblesshire) Land's End Forest, St. Clement (Cornwall) Lynn Forest, Shouldham (Norfolk) Mortimer Forest (Herefordshire and Shropshire) Rheidol Forest (Cardiganshire)
Norway and Sitka spruces:	Brendon Forest (Somerset) Cannock Chase (Staffordshire) Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire) Newcastleton Forest (Roxburghshire and Dumfriesshire) The Bin Forest (Aberdeenshire)
Silver fir, Abies alba*:*	Drummond Hill Forest (Perthshire) Lael Forest (Wester Ross) Radnor Forest (Radnor and Herefordshire) Thetford Chase (Norfolk and Suffolk)
Sitka spruce:	Ardgartan Forest (Argyll) Clocaenog Forest (Denbighshire and Merioneth) Coed Morgannwg (Glamorgan) Glendaruel Forest (Argyll)

PROVENANCE EXPERIMENTS—contd.

Sitka spruce—contd.

Glen Trool (Kirkcudbrightshire and Ayrshire)

Kielder Forest (Northumberland)
Mynydd Ddu Forest (Brecon and Herefordshire)
Radnor Forest (Radnor and Herefordshire)
Ratagan Forest (Wester Ross and Inverness-shire)
Taliesin Forest (Cardiganshire and Montgomeryshire)

Wark Forest (Northumberland)
Wilsey Down Forest (Cornwall)

Western hemlock:

Allerston Forest, Wykesham (Yorkshire)
Benmore Forest (Argyll)
Brecon Forest (Brecon)
Brendon Forest (Somerset)
Clocaenog Forest (Denbighshire and Merioneth)

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 (Radnor and Herefordshire)

Thetford Chase (Norfolk and Suffolk)

Beech:

Queen Elizabeth Forest (Hampshire and Sussex)
Savernake Forest (Wiltshire and Berkshire)
Wendover Forest (Buckinghamshire)

Oak:

Forest of Dean, Penyard (Gloucestershire, Herefordshire and Monmouthshire)
Dymock Forest (Gloucestershire and Herefordshire)

CONVERSION OF COPPICE

Alice Holt Forest, Marelands (Hampshire)
Cranborne Chase (Dorset and Wiltshire)
Forest of Dean, Penyard and Flaxley (Gloucestershire, Herefordshire, and Monmouthshire)
Hursley Forest (Hampshire)

PLANTING EXPERIMENTS ON CHALK DOWNLANDS

Friston Forest (Sussex)
Queen Elizabeth Forest (Hampshire and Sussex)

CULTURE OF OAK

Dymock Forest (Gloucestershire and Herefordshire)
Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Micheldever Forest (Hampshire)
Tintern Forest, Crumbland Wood (Monmouthshire)

DRAINAGE EXPERIMENTS

Bernwood Forest (Oxfordshire and Buckinghamshire)
Forest of Ae (Dumfriesshire)
Halwill Forest (Devon and Cornwall)
Hartland Forest (Devon and Cornwall)
Hafren Forest (Montgomeryshire)

Kershope Forest (Cumberland)
Kielder Forest (Northumberland)

DRAINAGE EXPERIMENTS—*contd.*

Lennox Forest (Stirlingshire and Dunbartonshire)
Loch Ard Forest, Flanders Moss (Perthshire and Stirlingshire)
Orlestone Forest (Kent)
Towy Forest (Cardiganshire, Brecon and Carmarthenshire)

POPLAR TRIALS AND SILVICULTURAL EXPERIMENTS

Alice Holt Forest (Hampshire and Surrey)
Bedgebury Forest (Kent and Sussex)
Blandford Forest (Dorset)
Creran Forest (Argyll)
Dyfnant Forest (Montgomeryshire)
Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Greskine Forest (Dumfriesshire)
Lynn Forest, Gaywood (Norfolk)
Quantock Forest (Somerset)
Rogate Forest (Sussex)
South Yorkshire Forest
Stenton Forest (East Lothian and Berwickshire)
Wentwood Forest (Monmouthshire)
Wynyard Forest (Co. Durham)
Yardley Chase (Bedfordshire, Northamptonshire and Buckinghamshire)

ARBORETA

National Pinetum, Bedgebury Forest (Kent)
Westonbirt Arboretum (Gloucestershire)
Whittingehame (East Lothian)

MAJOR COLLECTIONS OF SPECIES PLOTS

Bedgebury Forest (Kent)
Brechfa Forest (Carmarthenshire)
Crarae, Minard Forest (Argyll)
Kilmun, Benmore Forest (Argyll)
Thetford Chase (Norfolk and Suffolk)

SPECIES COMPARISONS IN RELATION TO SPECIAL SITES

Achnashellach Forest (Wester Ross)
Aldewood Forest (Suffolk)
Beddgelert Forest (Caernarvonshire)
Bodmin Forest (Cornwall)
Brendon Forest (Somerset)
Brownmoor Forest (Dumfriesshire)
Caeo Forest (Carmarthenshire)
Cairn Edward Forest (Kirkcudbrightshire)
Clashindarroch Forest (Aberdeenshire)
Coed Morgannwg (Glamorgan)
Dovey Forest (Merioneth and Montgomeryshire)
Forest of Ae (Dumfriesshire)
Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Garadhban Forest (Stirlingshire and Dunbarton)
Glentress Forest (Peeblesshire)
Glen Trool Forest (Kirkcudbrightshire and Ayrshire)
Glen Urquhart Forest (Inverness-shire)
Gwydyr Forest (Caernarvonshire and Denbighshire)
Inchnacardoch Forest (Inverness-shire)
Kielder Forest (Northumberland)

SPECIES COMPARISONS—contd.

Kirroughtree Forest (Kirkcudbrightshire)
Land's End Forest (Cornwall)
Micheldever Forest (Hampshire)
Mynydd Ddu (Brecon and Monmouthshire)
Naver Forest (Sutherland)

New Forest (Hampshire)
Pembrey Forest (Carmarthenshire)
Queen Elizabeth Forest (Hampshire and Sussex)
Rockingham Forest (Northamptonshire)
Rosedale, Allerston Forest (Yorkshire)

Teindland Forest (Moray)
Thetford Chase (Norfolk and Suffolk)
Tintern Forest (Monmouthshire)
Wareham Forest (Dorset)
Wykeham, Allerston Forest (Yorkshire)

RE-AFFORESTATION EXPERIMENTS

Culloden Forest (Inverness-shire and Nairnshire)
Culbin Forest (Moray and Nairnshire)
Drumtochty Forest (Kincardineshire)
Forest of Ae (Dumfriesshire)
Kielder Forest (Northumberland)

Kirkhill (Aberdeenshire)
Lennox Forest (Stirlingshire)
Michaelston, Coed Morgannwg (Glamorgan)
Newcastleton Forest (Roxburghshire)
Radnor Forest (Radnor and Herefordshire)

Redesdale Forest (Northumberland)
Thetford Chase (Norfolk and Suffolk)

WEED CONTROL

Alice Holt Forest (Hampshire and Surrey)
Bramshill Forest (Berkshire and Hampshire)
Brendon Forest (Somerset)
Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
New Forest (Hampshire)

Rogate Forest (Sussex)
Wareham Forest (Dorset)

WIND STUDIES

Hafren Forest (Montgomeryshire)
Myherin Forest (Cardiganshire)
Mynydd Ddu Forest (Brecon and Monmouthshire)
Radnor Forest (Radnor and Herefordshire)
Redesdale (Northumberland)

MENSURATION

The following are experiments in which permanent sample plots are used as assessment units and which are of interest for growth and yield studies. Replicated experiments are marked with an asterisk (*).

SPACING

Scots pine:	Thetford Chase (Norfolk and Suffolk) Roseisle Forest (Moray) Tintern Forest (Monmouthshire) Ebbw Forest (Monmouthshire)
Corsican pine:	Aldewood Forest (Suffolk)

SPACING—contd.

European larch:	Mortimer Forest (Herefordshire and Shropshire) Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire) Radnor Forest (Radnor and Herefordshire) Fleet Forest (Kirkcudbrightshire)
Japanese larch:	Bodmin Forest (Cornwall) Dalbeattie Forest (Kirkcudbrightshire) Drumtochty Forest (Kincardineshire) Rheola, Coed Morgannwg (Glamorgan) Crychan Forest (Brecon and Carmarthenshire) Ebbw Forest (Monmouthshire) Caeo Forest (Carmarthenshire) Brechfa Forest (Carmarthenshire)
Norway spruce:	Monaughty Forest (Moray) Clocaenog Forest (Denbighshire and Merioneth) Kerry Forest (Montgomeryshire, Shropshire and Radnor) Rheola, Coed Morgannwg (Glamorgan)
Sitka spruce:	Allerston Forest (Yorkshire) Brecon Forest (Brecon) Rheola, Coed Morgannwg (Glamorgan) Gwydyr Forest (Caernarvonshire and Denbighshire) Clocaenog Forest (Denbighshire and Merioneth)
Douglas fir:	Allerston Forest (Yorkshire) Ystwyth Forest (Cardiganshire) Brechfa Forest (Carmarthenshire)

THINNING

Scots pine:	Aldewood Forest (Suffolk) Thetford Chase (Norfolk and Suffolk) Swaffham Forest (Norfolk) New Forest (Hampshire) Cannock Chase (Staffordshire) Edensmuir Forest (Fife)* Crown Estates, Fochabers, near Speymouth Forest, (Banffshire and Moray) Millbuie, Black Isle Forest (Easter Ross)
Corsican pine	Aldewood Forest (Suffolk) Thetford Chase (Norfolk and Suffolk) Sherwood Forest (Derbyshire, Yorkshire and Nottinghamshire)* Swaffham Forest (Norfolk) New Forest (Hampshire) Culbin Forest (Moray and Nairnshire) Pembrey Forest (Carmarthenshire)
European larch:	Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire) Murthly Estate (near Strathord Forest, Perthshire)
Japanese larch:	Bodmin Forest (Cornwall) Stourhead Estate (Wiltshire) Glentress Forest (Peeblesshire) Drumtochty Forest (Kincardineshire) Brechfa Forest (Carmarthenshire) Rheola, Coed Morgannwg (Glamorgan)

THINNING—contd.

Norway spruce:	Kershope Forest (Cumberland) Bowmont Forest (Duke of Roxburgh's Estate, Roxburghshire)* Bennan, Cairn Edward Forest (Kirkcudbrightshire) Monaughty Forest, near Elgin (Moray) Tintern Forest (Monmouthshire)
Sitka spruce:	Brendon Forest (Somerset) Dovey Forest (Merioneth and Montgomeryshire)* Forest of Ae (Dumfriesshire)* Ardgartan Forest (Argyll) Loch Eck Forest (Argyll)*
Picea omorica:	Bedgebury Forest (Kent and Sussex)
Douglas fir:	Wensum Forest (Norfolk) Alice Holt Forest (Hampshire and Surrey)* Glentress Forest (Peeblesshire) Mynydd Ddu Forest (Brecon and Monmouthshire) Gwydyr Forest (Caernarvonshire and Denbighshire)
Noble fir:	Dovey Forest (Merioneth and Montgomeryshire)
Beech:	Nettlebed Estate (Buckinghamshire) Hampden Estate (Buckinghamshire)
Oak:	Micheldever Forest (Hampshire) Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire) Wensum Forest (Norfolk) Hazelborough Forest (Buckinghamshire and Northamptonshire)

UNDERPLANTING

European larch, underplanted with various species:	Dymock Forest (Gloucestershire and Herefordshire) Exeter Forest (Devon)
Oak, underplanted with Western hemlock:	Micheldever Forest (Hampshire)
Corsican pine, underplanted with Grand fir:	Thetford Chase (Norfolk and Suffolk)

MIXTURES

Oak/beech:	Tintern Forest (Monmouthshire)
Sitka spruce/Japanese larch *Sitka spruce/Lodgepole pine*	Beddgelert Forest (Caernarvonshire)

GENETICS

PROPAGATION CENTRES

Alice Holt (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 (Witley) Forest (Surrey and Sussex)
Newton Nursery (Moray)
Teindland Forest (Moray)
Wauchope Forest (Roxburghshire)

GENETICS—contd.

SEED ORCHARDS

Alice Holt Forest (Hampshire and Surrey)
Bradon Forest (Wiltshire)
Drumtochty Forest (Kincardineshire)
Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Keillour Forest (Perthshire)

Ledmore Forest (Perthshire)
Lynn Forest (Norfolk)
Newton Nursery (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 (Easter Ross)
Aultmore Forest (Banffshire)
Benmore Forest (Argyll)

Bramshill Forest (Berkshire and Hampshire)
Chillingham Forest (Northumberland)
Clocaenog Forest (Denbighshire and Merioneth)
Coed-y-Brenin Forest (Merioneth)
Coed Sarnau Forest (Radnor)

Devilla Forest (Fife and Clackmannanshire)
Elchies Forest (Moray)
Farigaig Forest (Inverness-shire)
Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Glendaruel Forest (Argyll)

Glenlivet Forest (Banffshire)
Gwydyr Forest (Caernarvonshire and Denbighshire)
Inchnacardoch Forest (Inverness-shire)
Kilmichael Forest (Argyll)
Kilmory Forest (Argyll)

Laurieston Forest (Kirkcudbrightshire)
Saltoun Forest (East and Mid Lothian)
Speymouth Forest (Moray and Banffshire)
Stenton Forest (East Lothian and Berwickshire)
Teindland Forest (Moray)

Thornthwaite Forest (Cumberland)
Torrie Forest (Perthshire)
Westonbirt (Gloucestershire)
Whitrope, Wauchope Forest (Roxburghshire)

PATHOLOGICAL RESEARCH AREAS

ELM DISEASE TRIALS

Alice Holt Forest (Hampshire and Surrey)

TOP DYING OF NORWAY SPRUCE

Knapdale Forest (Argyll)
Coed Morgannwg (Glamorgan)
Wykeham Estate (Yorkshire)

PATHOLOGICAL RESEARCH AREAS—contd.

FOMES ANNOSUS

Bramshill Forest (Berkshire and Hampshire)
Kerry Forest (Montgomeryshire, Shropshire and Radnor)
Lael Forest (Wester Ross)
The Bin Forest (Aberdeenshire and Banffshire)
Thetford Chase (Norfolk and Suffolk)

ARMILLARIA MELLEA

Alice Holt Forest (Hampshire and Surrey)
Bramshill Forest (Berkshire and Hampshire)

POLYPORUS SCHWEINITZII

Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)

BACTERIAL CANKER OF POPLAR

Aldewood Forest, Fen Row Nursery (Suffolk)
Alice Holt Forest (Hampshire and Surrey)
Blandford Forest (Dorset)

DIDYMASCELLA (KEITHIA) THUJINA ON WESTERN RED CEDAR

Alice Holt Forest (Hampshire and Surrey)
Slebech Nursery (Pembrokeshire)

CRUMENULA SORORIA ON PINE

Ringwood Forest (Dorset and Hampshire)

BLUE STAIN IN PINE

Thetford Chase (Norfolk and Suffolk)

ENTOMOLOGY

PINE LOOPER MOTH: BUPALUS PINIARIUS

Cannock Chase (Staffordshire)

LARCH SAWFLY: ANOPLONYX DESTRUCTOR

Drumtochty Forest (Kincardineshire)
Mortimer Forest (Herefordshire and Shropshire)

SPRUCE APHID: ELATOBIUM ABIETINUM

Alice Holt Forest (Hampshire and Surrey)
Bramshill Forest (Berkshire and Hampshire)
Dovey Forest (Merioneth and Montgomeryshire)
Forest of Ae (Dumfriesshire)
Inverliever Forest (Argyll)
New Forest (Hampshire)

PINE SHOOT BEETLE: TOMICUS PINIPERDA

Bramshill Forest (Berkshire and Hampshire)

BLACK PINE BEETLE: HYLASTES SPP.

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)

APPENDIX II

Staff Engaged in Research and Development

As at 31st March, 1967

Staff engaged in Research and Development, apart from outstationed Foresters, are based at the following main centres:

FORESTRY COMMISSION RESEARCH STATION

Alice Holt Lodge,
Wrecclesham,
Farnham, Surrey. Tel. Bentley (Hants) 2255

FORESTRY COMMISSION

Government Buildings,
Bankhead Avenue,
Sighthill,
Edinburgh 11. Tel. Craiglockhart 4010

FORESTRY COMMISSION

25 Savile Row,
London, W.1. Tel. Regent 0221 (01 734 0221)

FORESTRY COMMISSION

Priestley Road,
Basingstoke,
Hampshire. Tel. Basingstoke 3181.

Director	J. R. Thom, B.Sc. (*Alice Holt*)
Conservator	R. F. Wood, B.A., B.Sc. (*Alice Holt*)
Administration and Finance Officer	T. D. H. Morris (*Alice Holt*)
Director's Secretary	Miss O. A. Harman (*Alice Holt*)

SEED (*Alice Holt*)

G. M. Buszewicz, Mgr. Ing., Head of Section

Laboratory: D. C. Wakeman, Miss L. M. McMillan, Mrs. L. S. Elgy
Seed Store: T. A. Waddell
Office: D. T. Baker, E. R. Parratt

SILVICULTURE (SOUTH) (*Alice Holt*)

R. M. G. Semple, B.Sc., Head of Section
J. R. Aldhous, B.A.
R. M. Brown, B.Sc.
A. I. Fraser, B.Sc.
J. Jobling, B.Sc.
A. F. Mitchell, B.A., B.Agric.(For.)
M. Nimmo

Office:

R. G. Harris: Miss E. Burnaby, Miss A. Davidge, F. H. Khawaja

Research Foresters		*Centre*
South East England Region	R. Hendrie	Alice Holt
South East England Area	G. F. Farrimond J. B. H. Gardiner, R. W. Genever, A. J. A. Graver, A. C. Hansford, P. D. Howard, A. C. Swinburn	Alice Holt
Wareham Area	E. E. Fancy, B.E.M. L. A. Howe, A. M. Jenkin, F. S. Smith	Sugar Hill Nursery, Wareham Forest
Bedgebury Area	A. W. Westall R. E. A. Lewis	Bedgebury Pinetum
South West England Region	D. A. Cousins	Bristol
South West England Area	K. F. Baker J. E. J. White	Exeter
Dean and South Wales Area	F. Thompson R. M. Keir, M. L. Pearce	Dean Dean
Westonbirt Area	E. Leyshon D. J. Rice	Westonbirt Arboretum
North Wales Region	G. Pringle	Betws y Coed
North Wales Area	G. A. Bacon C. W. Webber	Betws y Coed 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. R. W. Stevens, H. C. Caistor	Kennington Nr. Oxford
East England Area	R. M. Ure	Santon Downham, Nr. Thetford
	K. Mills, D. J. Williams	Santon Downham, Nr. Thetford

SILVICULTURE (NORTH) (*Edinburgh*)

D. T. Seal, B.Sc., Head of Section
J. Atterson, B.Sc.
R. Lines, B.Sc.
A. J. Low, B.Sc., Ph.D.
S. A. Neustein, B.Sc.
G. G. M. Taylor, B.Sc.

Office:

P. Hunter: T. T. Johnston, A. D. McKenzie, Miss M. E. Grant, Miss E. P. Beattie, Mrs. M. J. Pedder

Research Foresters		*Centre*
North Scotland Region	A. Macdonald	Fort Augustus
North Scotland Area	J. B. McNeill, A. A. Green, D. C. Coutts	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 Newton, Elgin
South East Scotland Area	D. K. Fraser N. Mackell	Bush Nursery, Roslin, Midlothian
Mearns Area	J. C. Keenleyside A. H. Reid	Drumtochty, Laurencekirk, Kincardine
West Scotland Area	A. R. Mair J. E. Kirby, A. B. Lewis	Kilmun, by Dunoon, Argyll
South West Scotland Area	E. Baldwin K. A. S. Gabriel, J. D. McNeill	Mabie, Dumfriesshire
North England Region	J. Weatherell	Wykeham, Scarborough
North East England Area	T. C. Booth M. K. Hollingsworth	Wykeham, Scarborough
Borders Area	G. S. Forbes I. H. Blackmore, D. L. Willmott, J. D. Lindsay	Kielder by Hexham, Northumberland
North West England Area	A. A. Lightly D. S. Coutts	Grizedale, Nr. Hawkshead, Westmorland

ECOLOGIST (*Alice Holt*)

J. M. B. Brown, B.Sc., Dip.For.

Research Foresters: B. G. Howland, P. Marsh

SOILS (*Alice Holt*)

W. O. Binns, M.A., B.Sc., Ph.D., Head of Section
W. H. Hinson, B.Sc., Ph.D.

Research Foresters: D. F. Fourt, A. E. Coates, T. E. Radford
Laboratory: H. M. Gunston, Miss H. J. Pedley, Miss S. Dabek, D. R. Hill
Instrumentation: R. E. Stickland

FOREST GENETICS (*Edinburgh*)

R. Faulkner, B.Sc., Head of Section
A. M. Fletcher, B.Sc., Ph.D.
R. B. Herbert, B.Sc. (Alice Holt)

Research Foresters:

Alice Holt	I. J. M. Dawson, A. S. Gardiner, R. B. Collins, G. Simkins
Bush Nursery, Roslin, Midlothian	C. McLean
Grizedale, Lancs.	A. A. Lightly, D. S. Coutts
Newton, Elgin	M. T. T. Phillips
Westonbirt, Glos.	G. C. Webb

Laboratory: Miss C. Y. Davis
Office: Mrs. D. M. Pearson

FOREST PATHOLOGY (*Alice Holt*)

D. H. Phillips, B.Sc., M.Sc., Ph.D., Head of Section
D. A. Burdekin, B.A., Dip.Ag.Sci.(Cantab.)
S. Batko, D.Ing.

Research Foresters: J. D. Low, C. W. T. Young, B. W. J. Greig, R. G. Strouts, P. J. Webb
Laboratory: Mrs. J. Lord
Office: J. G. Jackman, Mrs. D. Dewé (Typist)

FOREST 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)
J. T. Stoakley, M.A.

Research Foresters: R. C. Kirkland, R. M. Brown, A. R. Barlow, C. H. Hudson, C. J. King, L. A. Tee (Mammals), D. Elgy (Mammals), H. M. Pepper (Mammals)
Laboratory: C. I. Carter, B.Sc., G. Barson, N. R. Maslen, T. G. Winter
Office: Mrs. M. M. Branford

PLANNING AND ECONOMICS (*Alice Holt*)

J. A. Spencer, M.A. Head of Section
R. T. Bradley, M.A.
J. V. St. Crosland, B.Sc. (Edinburgh)
A. J. Grayson, M. A., B.Litt.
G. M. L. Locke, B.Sc.
A. M. Mackenzie (Edinburgh)
D. G. Pyatt, B.Sc. (Edinburgh)
D. Y. M. Robertson, B.Sc.
P. A. Wardle, B.Sc.
W. T. Waters

Foresters: *Based on Alice Holt:* J. Mc.N. Christie, G. Haggett, P. Bond, E. J. Fletcher, I. C. Embry, R. Oakes, M. A. Mitchell, M. Wigzell, M. H. Webb, M. D. Witts, M. D. Whitlock
Based on Edinburgh: J. Armstrong, A. F. Brown, I. M. Parrott, A. Little, A. E. Surnam, G. A. Watson, P. Humphries, J. Meechan

Working Plans and Mensuration:

Field Parties—England and Wales
R. F. E. Bartlett, A. Beardsley, A. C. Miller, D. A. Bell, C. R. Alpe
D. D. C. Davies, A. J. Maisey, K. Shuker, J. B. Kingsmill, R. J. Rogers
A. C. Dover, J. Carter, M. W. Davies, S. Cooper, J. Dickinson
I. D. Mobbs, E. R. Hall
R. N. Smith, G. Harrison, G. J. Jones
E. B. Jury, M. B. Scutt, J. L. Williams

Field Parties—Scotland
J. Straiton, J. L. Davidson, D. A. T. Douglas, I. D. MacDonald, T. M. MacGregor
J. Beaton, J. C. Anderson, P. J. Lodge
J. R. Boyd, J. C. Phillipson
J. B. Smith, R. D. Boyd
A. W. Graham, W. Elger, K. Fryer, P. G. Risby
A. A. J. Rees, A. N. Gordon, L. C. MacCallum
B. Thompson, F. G. O. Thom
J. J. Waddell
C. R. Liversidge

Soil Survey:
D. Harrison, A. S. Ford
G. D. Kearns, F. Webster
J. S. Innes, G. F. Moysey

Office Staff:
Mrs. E. Simpson, Mrs. M. D. Redknap, Miss P. A. M. McCunnin
A. H. Ghori, Miss L. L. H. Grover

WORK STUDY (*Alice Holt*)

L. C. Troup, B.Sc. (Alice Holt) Head of Branch
E. S. B. Chapman, B.Sc. (Edinburgh)
T. W. G. Coulson, B.Sc. (Langholm)
A. A. Cuthbert, B.Sc. (Annan)

N. Dannatt, B.Sc. (Alice Holt)
J. A. Drummond (Kilmun)
D. M. Hughes (Bangor)
J. Laurie-Muir, B.Sc. (Alice Holt)
A. A. Rowan, B.Sc. (Fort Augustus)
A. H. A. Scott, B.Sc. (Lyndhurst)
A. R. Sutton, B.Sc. (Brecon)
A. Whayman (Hawick)
W. O. Wittering (Olney, Beds.)
D. H. Wallace (Dolgellau)

Machinery Research and Development

R. B. Ross, A.M.I.Mech.E. (Alice Holt)
W. S. Mackenzie (Kielder)

Foresters:

St.J. G. D. Bland-Flagg (Yardley), A. C. F. Bowdler (Westerkirk), R. H. Brown (Byrness), R. S. Carlaw (Ae), P. P. Davis (Dolgellau), P. Featherstone (Olney), G. H. Ivison (Byrness), P. W. Lansdown (Lyndhurst), D. J. Morris (Brecon), D. M. Percy (Lyndhurst), I. Pollock (Minard), T. G. Queen (Fort Augustus), A. S. Rawlinson (Fort Augustus), T. R. Sawyer (Haugh), B. D. Symes (Langholm), F. W. R. Platt (Mildenhall), C. E. Allison (New Forest), C. F. Dampney (Lyndhurst), M. J. Day (Brecon), M. J. C. Graham (Langholm), R. J. Reid (Brecon), I. Richardson (Dolgellau), G. O. Smith (Kilmun), W. Trotter (Kilmun), P. Wood (Santon Downham).

Office Staff:

R. D. Duncan, Mrs. E. Butler

ENGINEERING (*Basingstoke*)

A. J. Cole, T.D., A.M.I.Mech.E., A.M.B.I.M.

HARVESTING AND MARKETING (*London*)

B. W. Holtam, B. A. (Marketing)
J. R. Aaron, M.A. (Marketing)

STATISTICS (*Alice Holt*)

J. N. R. Jeffers, F.I.S., Head of Section
R. S. Howell, A.I.S. (Edinburgh)
D. H. Stewart, B.Sc.
Miss J. M. Cowie (Edinburgh)
Mrs. B. E. Witts
D. J. Arthur

Assistants:

C. A. Thorne (Research Forester), Mrs. D. M. Mitchell (Senior Machine Operator), Miss S. Moaby, Mrs. R. J. F. Glynn, Miss E. C. Bridger, Miss R. I. Falkner, Mrs. H. J. Thain (Edinburgh) (Machine Operators).

Office: Miss J. E. Hudson, Mrs. U. Schofield (Typist)

PUBLICATIONS (*London*)

H. L. Edlin, B.Sc., Dip.For., Head of Section
S. H. Sharpley
M. Abrahams

RESEARCH INFORMATION SECTION (*Alice Holt*)

O. N. Blatchford, B.Sc., Head of Section
F. C. Fraass
Miss L. Watson
Mrs. L. D. Birchall (Typist)

PHOTOGRAPHY (*Alice Holt*)

I. A. Anderson, F.I.B.P., Head of Section
Mrs. T. K. Evans, A.R.P.S.
B. J. Lambsdown
A. W. Coram (Illustrator)
Office: Mrs. J. A. Yarney

ADMINISTRATIVE STAFF (*Alice Holt*)

Establishment:	P. H. Hamilton: C. R. Cowles, Mrs. K. Oldham
Finance:	J. J. Richardson: A. R. Taggart, J. Empson, Miss G. B. Hayden
Stores:	L. W. Thomas: B. D. Higgins, D. I. Carlyle
Typists:	Miss M. Hopkin: Mrs. J. G. Anderson, Mrs. E. Allan, Mrs. V. O. C. Lampard, Mrs. J. Richardson, Mrs. P. Ward, Mrs. E. A. Walters.
Telephone Operator:	Mrs. E. A. R. Empson
Messenger:	Mrs. M. Butt
Gardens:	H. Farr
Workshop:	R. H. Butt, T. G. Watts

APPENDIX III

Publications by Staff Members, etc.

Aaron, J. R.	*The Utilisation of Bark.* Res. and Dev. Pap. For. Comm. Lond. No 32, 1966.
Aldhous, J. R.	Bracken Control in Forestry with Dicamba, Picloram and Chlorthiamid. *Proc. 8th British Weed Control Conference*, 1966.
Aldhous, J. R.	*Simazine Residues in Two Forest Nursery Soils.* Research and Development Paper, For. Comm., Lond., No. 31, 1966.
Aldhous, J. R.	Cold Storage of Plants. *Timb. Tr. J. Supplement*, October 1966 (page 20).
Atterson, J.	Fertilizers in Coniferous Forests. *Timb. Tr. J. Supplement*, October 1966 (39–41).
Barlow, A. R.	The Relationship between Resin Pressure and Scolytid Beetle Activity. *For. Rec. For. Comm., Lond.*, No. 57, 1966.
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Binns, W. O., and Grayson, A. J.	Fertilisation of Established Crops: Prospects in Britain. *Scot. For.* 21 (2) 1967 (81–98).
Booth, T. C.	*Plantations on Mediaeval Rigg and Furr Cultivation Strips: A Study in Scoreby Wood, York East Forest.* For. Rec. For. Comm., Lond., No. 62, 1967.
Bradley, R. T.	Production Forecasting and Control. *Paper for the 6th World Forestry Congress, Madrid.* June 1966.
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Brown, J. M. B., and Bevan, D.	*The Great Spruce Bark Beetle, Dendroctonus micans, in North West Europe.* Bull. For. Comm., Lond., No. 38, 1966.

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Crowe, Sylvia *Forestry in the Landscape.* Bookl. For. Comm. Lond. 18, 1966.

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Edlin, H. L. A Modern "Sylva" or "A Discourse of Forest Trees": 18. Sweet Chestnut, *Castanea sativa* L., Walnut, *Juglans regia* L., and Mulberry, *Morus nigra* L., *Quart. J. For.* 60(3) 1966 (193–201).

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Edlin, H. L. A Modern "Sylva" or "A Discourse of Forest Trees": 20. Pines from Overseas, *Pinus* genus. *Quart. J. For.* 61(1) 1967 (32–41).

Edlin, H. L. *Check List of Forestry Commission Publications, 1919–65.* For. Rec. For. Comm., Lond., No. 58, 1966.

Edlin, H. L. *Forestry.* Target for Careers series. Robert Hale, London, 1966. 96 pages, 8 plates.

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Faulkner, R. *Procedures Used for Progeny Testing in Britain, with Special Reference to Nursery Practice.* For. Rec. For. Comm., Lond., No. 60, 1967.

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Henman, D. W. The Case for Wider Spacing. *Timb. Tr. J. Supplement,* April 1966 (page 21).

Holtam, B. W. *Blue Stain.* Leafl. For. Comm., Lond., No. 53, 1966

Jeffers, J. N. R. General Analysis of Non-Orthogonal Experiments. *Res. Note* 9, *Instn. Skoglig Mat. Statist. Skogshögsk., Stockh,* 1966.

Jeffers, J. N. R. Calculation of Life Tables for Insect Populations. *Res. Note* 9, *Instn. Skoglig Mat. Statist. Skogshögsk., Stockh,* 1966.

Jeffers, J. N. R. Association Analysis of Ecological Data. *Res. Note* 9, *Instn. Skoglig Mat. Statist. Skogshögsk., Stockh,* 1966.

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Mitchell, A. F. Dating the "Ancient Oaks". *Quart. J. For.* 60(4) 1966 (271–276).

Neustein, S. A. *Methods of Planting on Single Mouldboard Cuthbertson Ploughing.* Research and Development Paper, For. Comm., Lond., No. 30, 1966.

Phillips, D. H., and Bevan, D. *Forestry Quarantine and its Biological Background.* For. Rec. For. Comm., Lond., No. 63, 1967.

Pyatt, D. G. The Soil and Windthrow Surveys of Newcastleton Forest, Roxburghshire. *Scot. For.* 20(3) 1966 (175–183).

Read, D. J. *Brunchorstia Die-back of Corsican Pine.* For. Rec. For. Comm. Lond. 61. 1967.

Robertson, D. Y. M. Aerial Photography in British Forestry. *Timb. Tr. J. Supplement* October 1966 (15–16).

Wardle, P. A. The Application of Linear Programming to Problems of Truck Transport. *Paper for FAO Study Group on Methods and Organisation of Forest Work.* March 1966.

Wardle, P. A. The Application of Linear Programming to the Solution of Forest Management Problems. *Paper for the 6th World Forestry Congress Madrid,* June 1966.

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

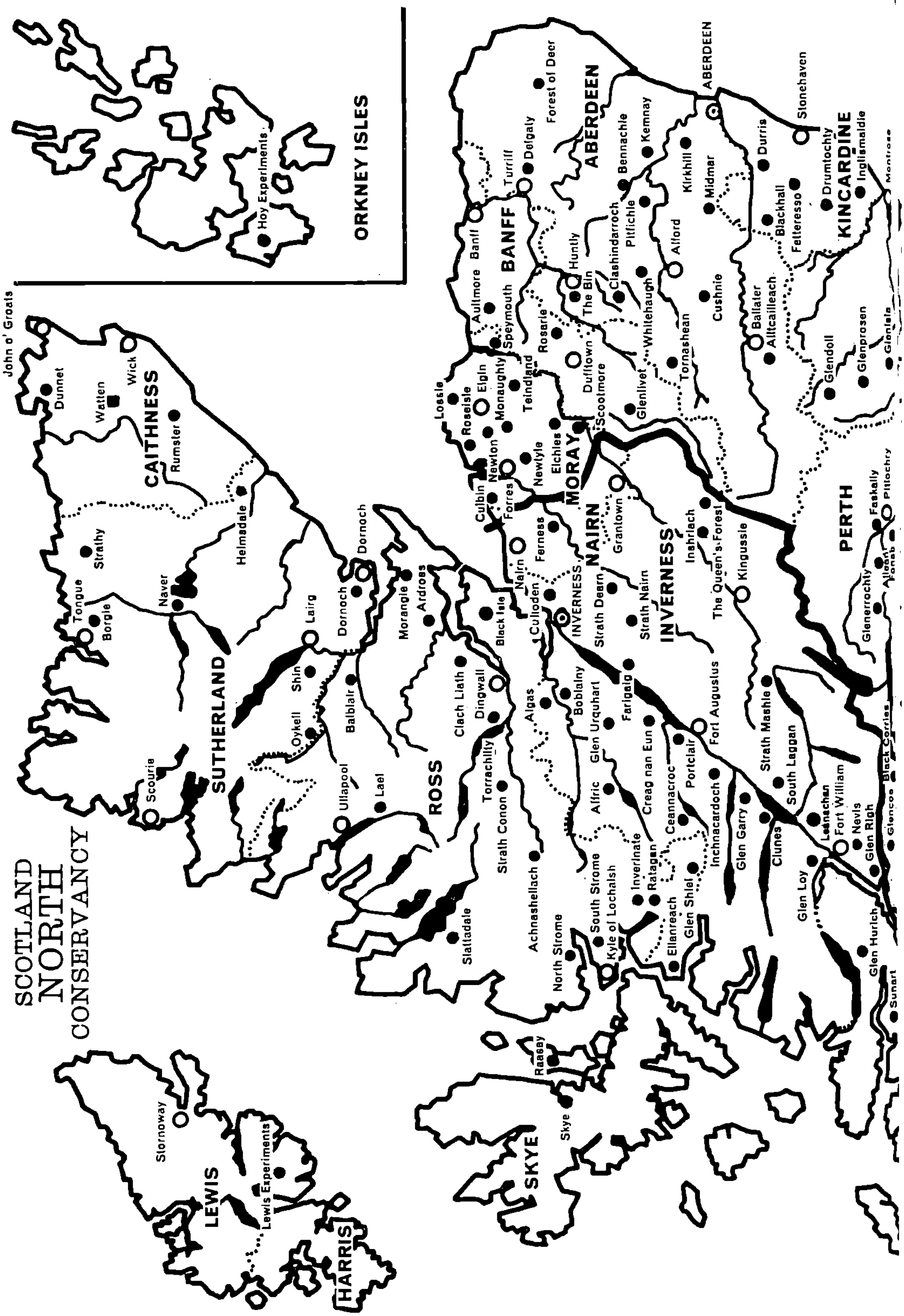
1 pound per gallon (lb/gal)	=0·09978 kilogrammes per litre (kg/l)
1 ounce per bushel (oz/bushel)	=0·7795 grammes per litre (g/l)

Linear Velocity

1 foot per minute (ft/min)	=0·00508 metres per minute (m/min)*

MAPS OF FORESTS AND ESTATES

Listed in Appendix I, etc.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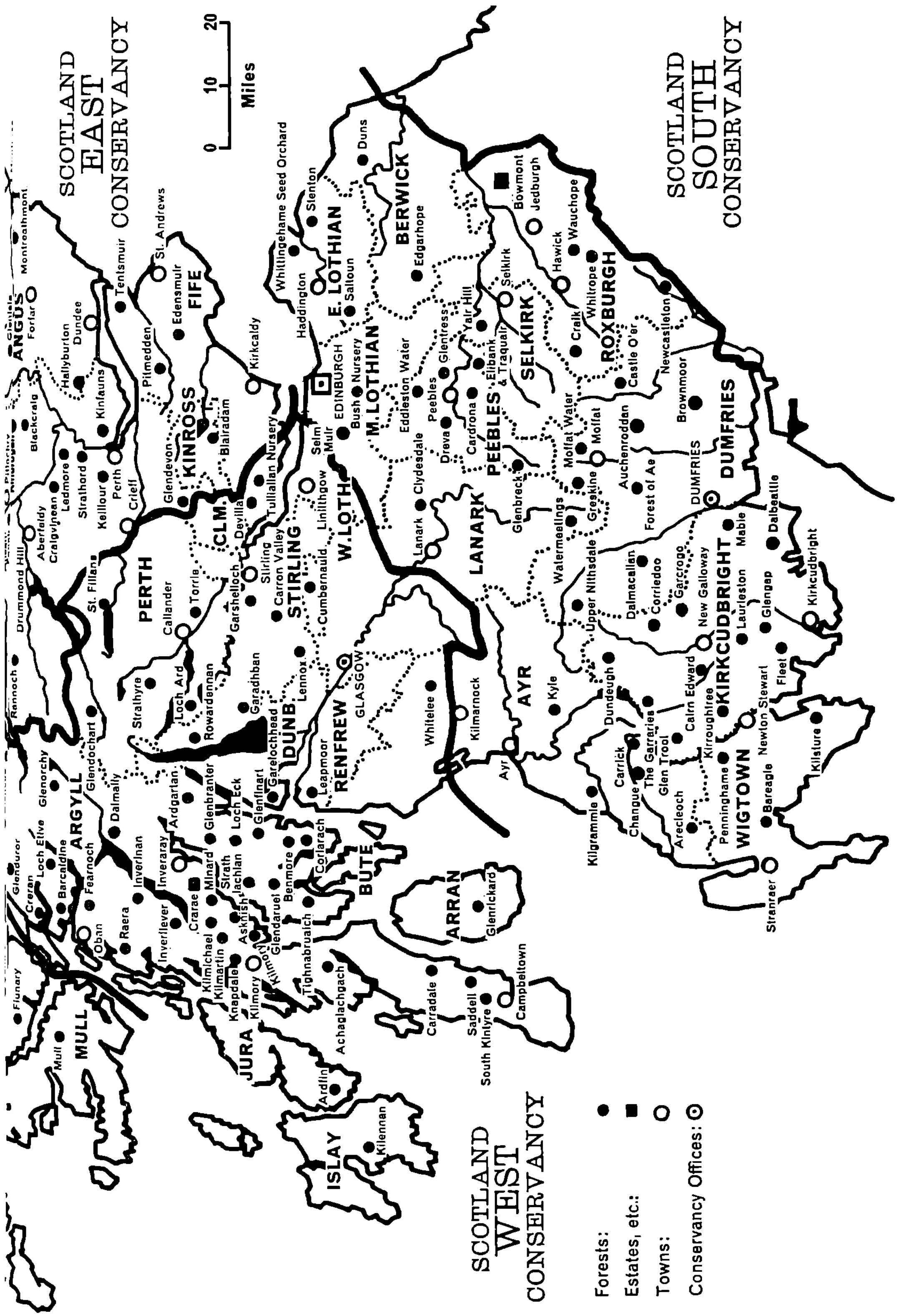
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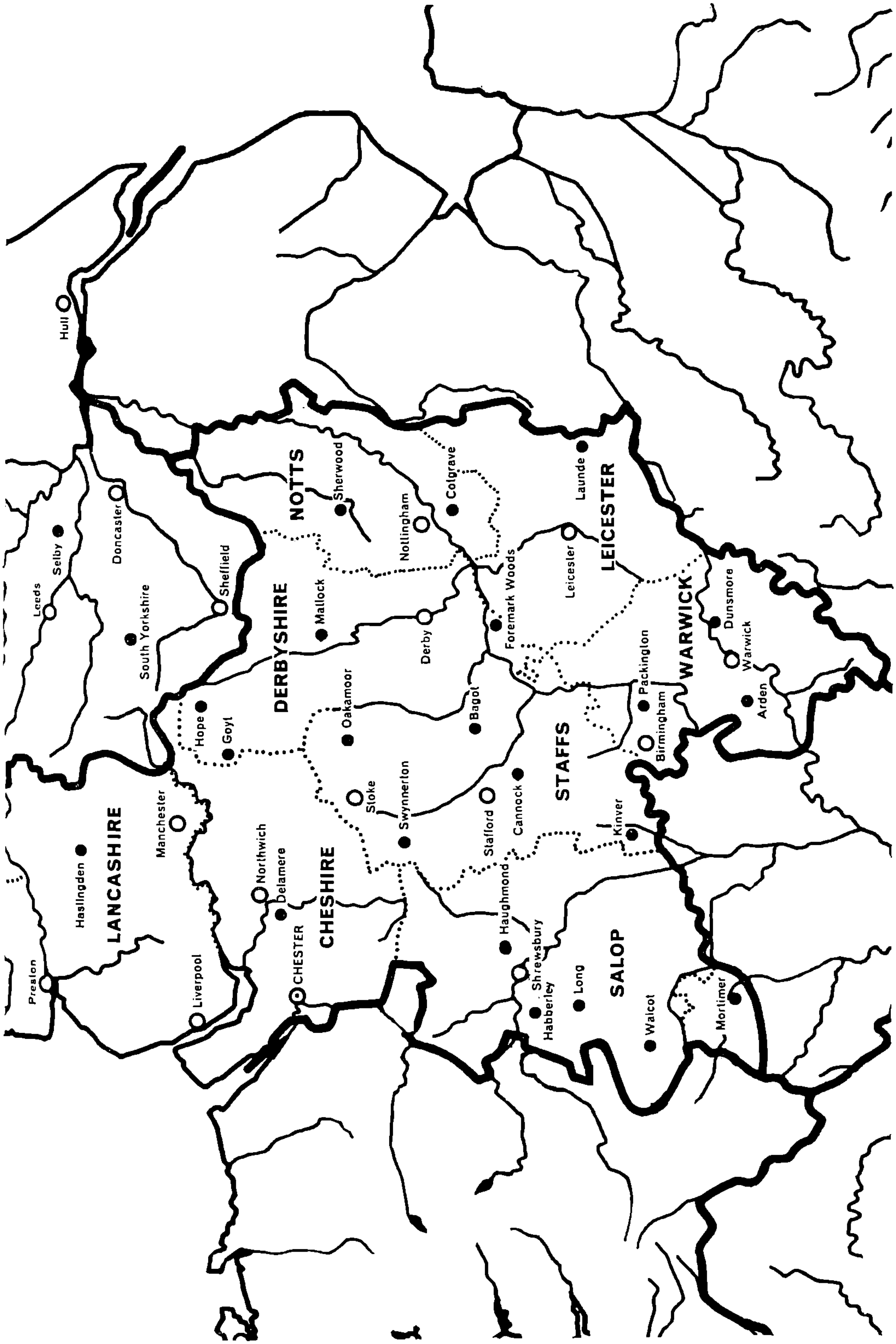
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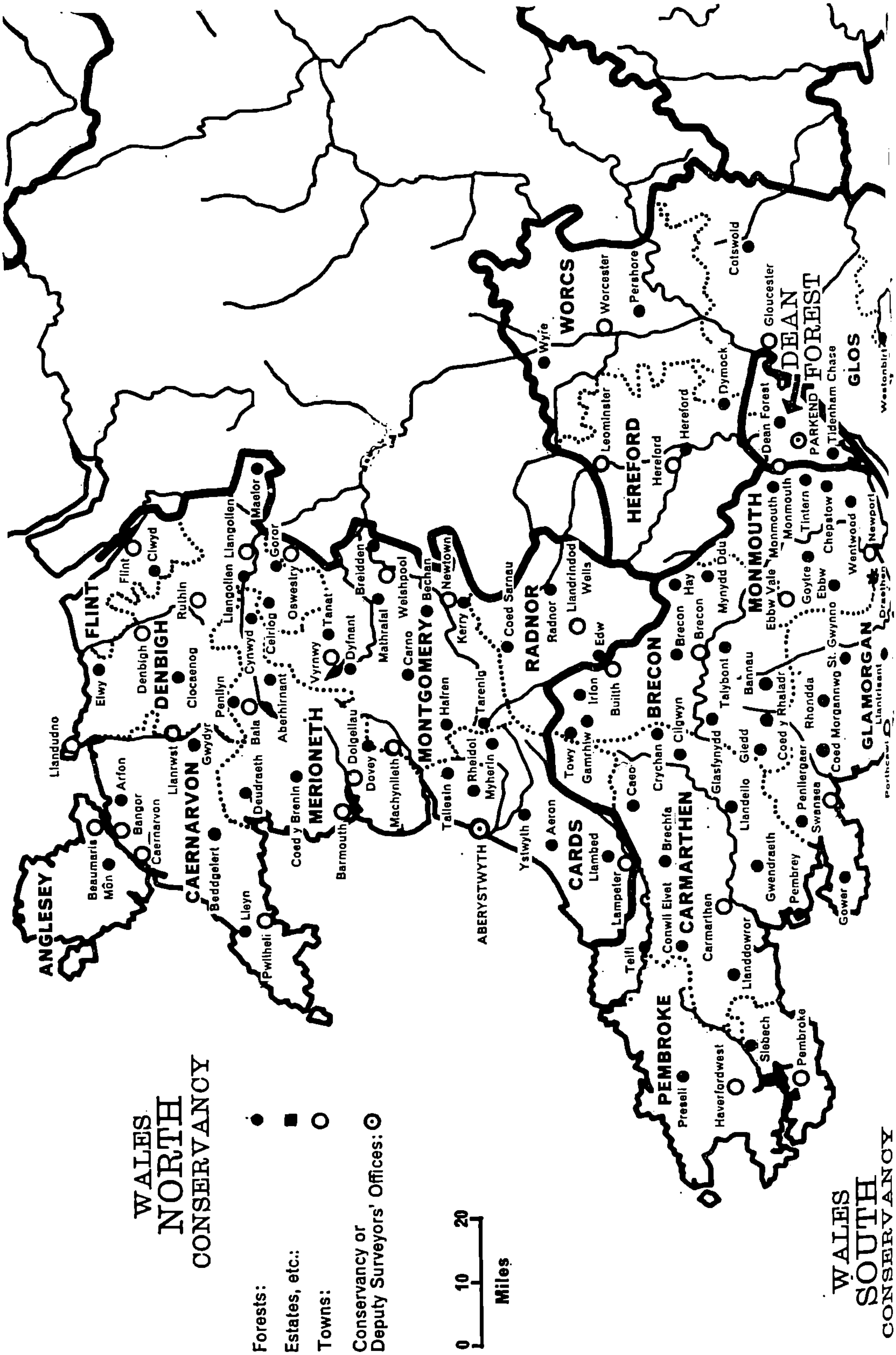
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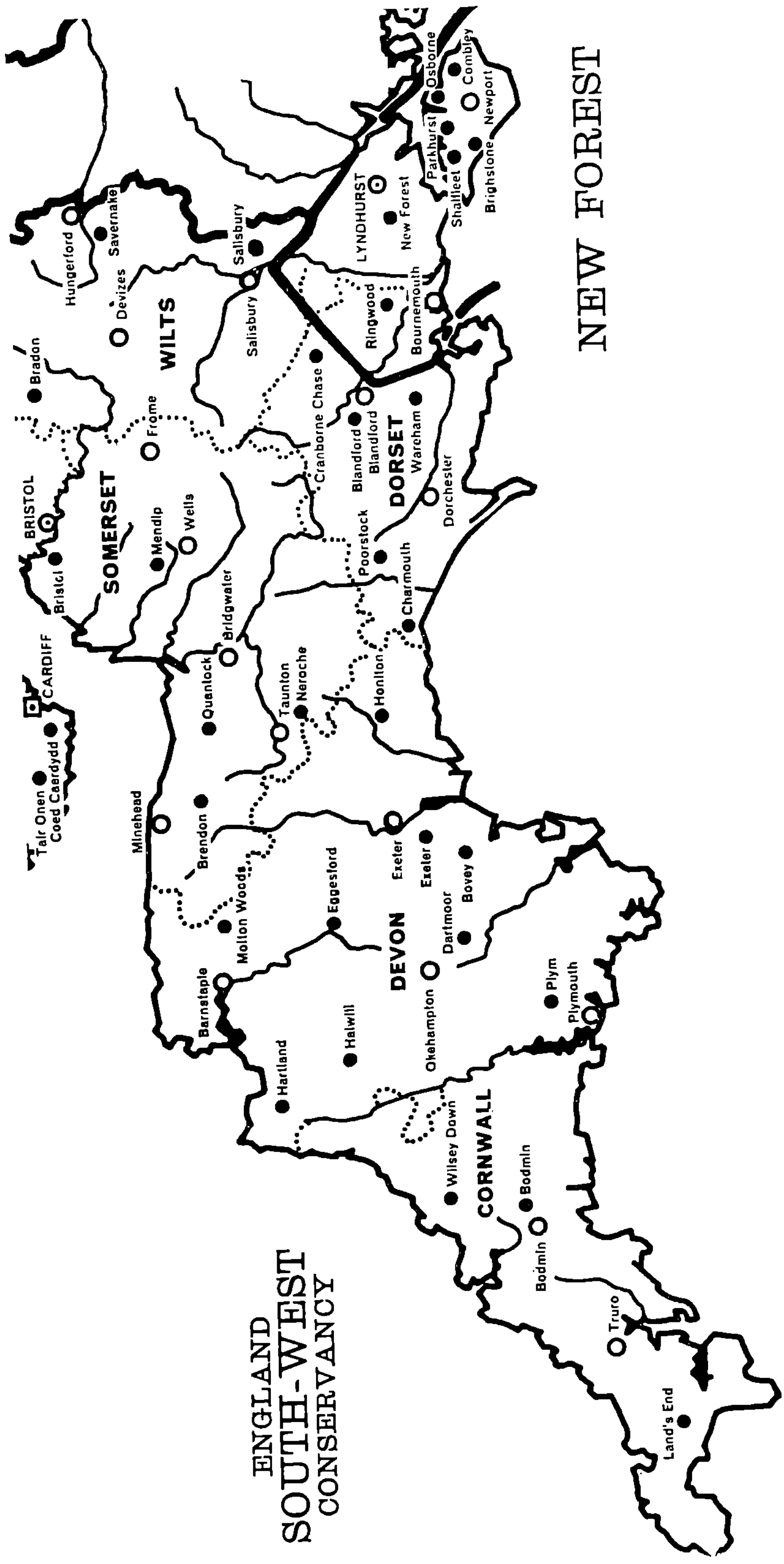

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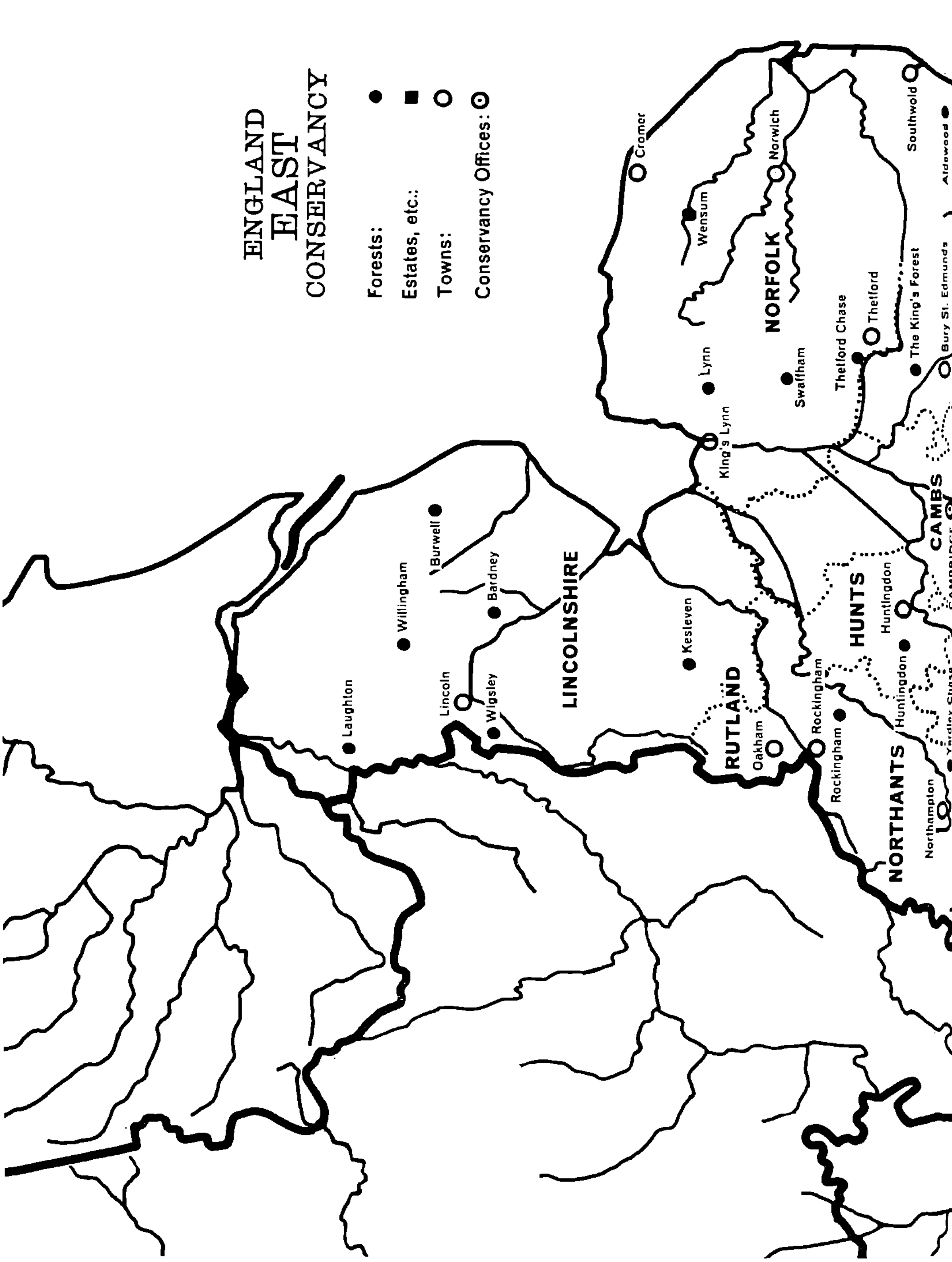
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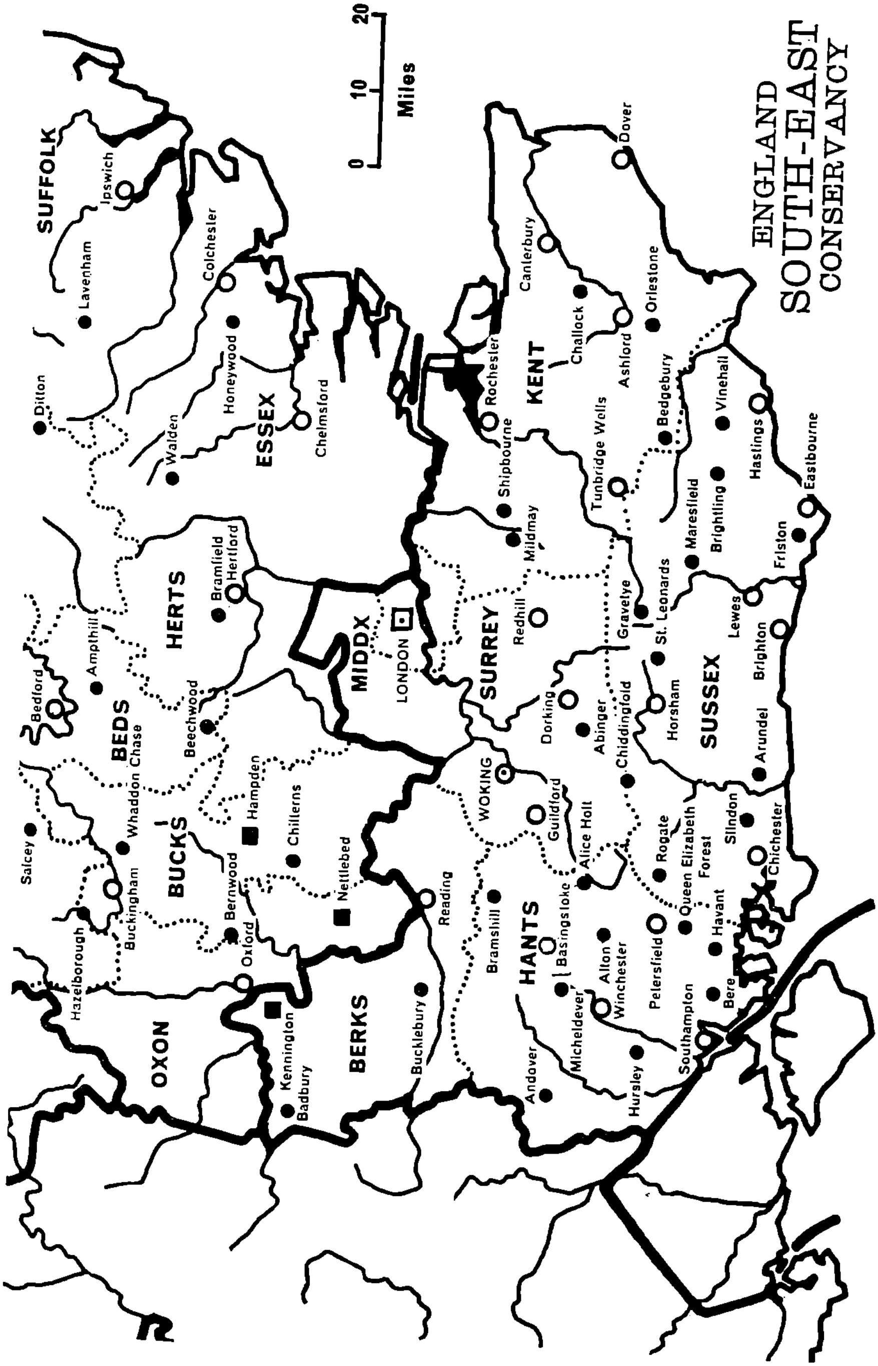
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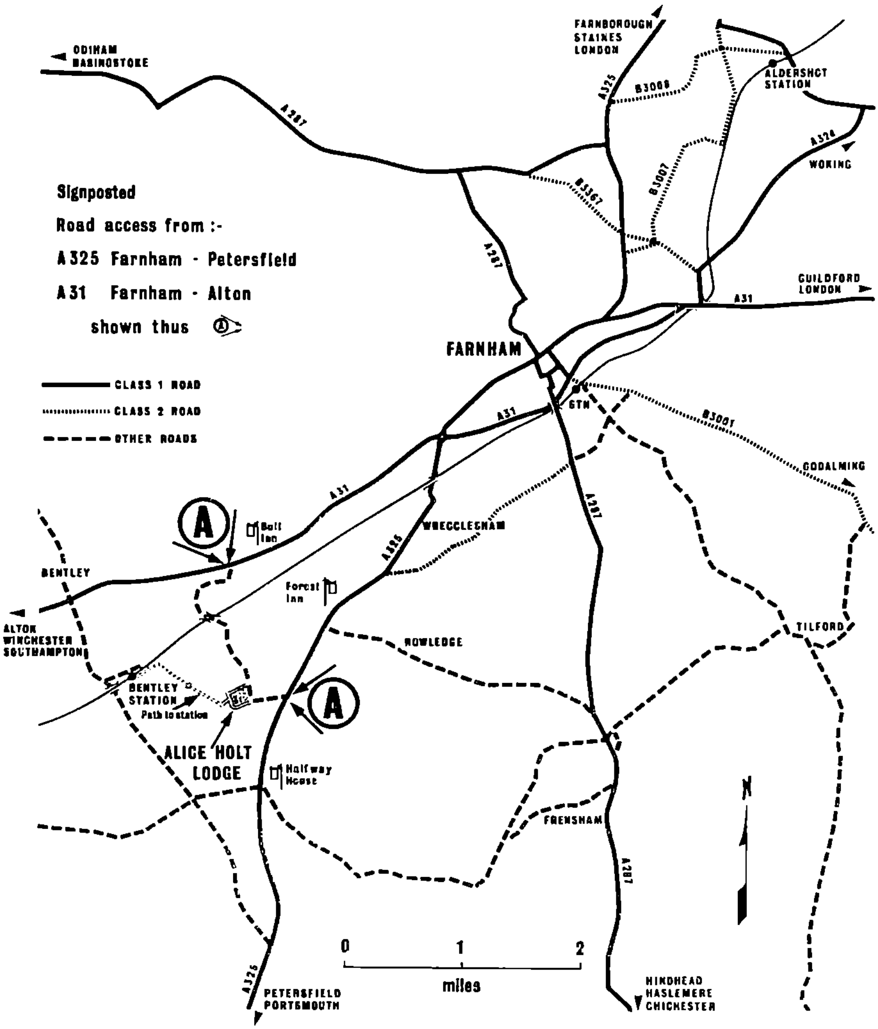

FIGURE 8. Approaches to Alice Holt Research Station, which lies 3½ miles south-west of Farnham, Surrey, between the Farnham-Winchester road, A 31, and the Farnham-Petersfield road, A 325.

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REPORT ON

FOREST RESEARCH

1968

FORESTRY COMMISSION

LONDON

HER MAJESTY'S STATIONERY OFFICE : PRICE £1 0s. 0d. NET

FORESTRY COMMISSION

REPORT ON FOREST RESEARCH

for the year ended March 1968

LONDON
HER MAJESTY'S STATIONERY OFFICE
1968

SBN 11 710107 9

ADVISORY COMMITTEE ON FOREST RESEARCH

Membership as at 31st March 1968

Chairman

SIR FREDERICK BAWDEN, F.R.S.,
Director, Rothamsted Experimental Station, Harpenden, Herts.

Members

Dr. W. P. K. FINDLAY,
Assistant Director, Brewing Industry Research Foundation, Nutfield, Redhill, Surrey.

Professor M. V. LAURIE, O.B.E.,
Professor of Forestry, University of Oxford.

Mr. J. F. LEVY,
Department of Botany, Imperial College of Science and Technology, Kensington, University of London.

Professor J. D. MATTHEWS,
Professor of Forestry, University of Aberdeen.

Dr. N. W. SIMMONDS,
Director, Scottish Plant Breeding Station, Pentlandfield, Roslin, Midlothian.

Professor W. J. THOMAS,
Professor of Agricultural Economics, University of Manchester.

Professor P. F. WAREING,
Professor of Botany, University College of Wales, Aberystwyth.

Secretary

Mr. G. H. BOWERS,
Forest Research Station, Forestry Commission, Alice Holt Lodge, Wrecclesham, Farnham, Surrey (Bentley 2255).

(108111) A 2

The abbreviated title of this Report is *Rep. Forest Res., Lond.*, 1968, as given in the World List of Scientific Periodicals, Butterworths, London, 1963.

CONTENTS

PART II

RESEARCH UNDERTAKEN FOR THE FORESTRY COMMISSION AT UNIVERSITIES AND OTHER INSTITUTIONS

The cover picture, all the photographs, and Figure 5, are by the Forestry Commission's Photographic Section. Figures in the text have all been supplied by the respective authors. Forest maps by Studio Corot, London.

INTRODUCTION

By J. R. THOM

Director of Research

Advisory Committee on Forest Research

The Committee met in London on 1st November 1967, and discussed particularly the arrangements to be made for a Second Visiting Group. This will cover the Pathology and Entomology Sections, both from the point of view of field experimentation and work in the Research Station at Alice Holt.

Following the retirements, in the usual rotation, of Professor E. C. Mobbs and Mr. A. R. Wannop, Mr. J. F. Levy of the Department of Botany, Imperial College of Science and Technology, University of London, Professor J. D. Matthews, Professor of Forestry, University of Aberdeen, and Dr. N. W. Simmonds, Director of the Scottish Plant Breeding Station, Roslin, Midlothian, became members of the Committee.

Natural Environment Research Council

Close contact has been maintained with the Natural Environment Research Council, and the Commission is represented on the Council's Forestry and Woodland Research Committee and its sub-committee on Research Grants and Training Awards. A number of grants to increase the scope of basic research in forestry and forest science in the Universities were made during the year.

Organisation and Staffing

A major task undertaken during the year was the preparation and introduction of the Research Project Register. This has meant a great deal of staff work, but for the first time we now have an orderly numbered sequence of experiments grouped together under Project Heads. Reference is made to Project Plans, priorities indicated, and note made of resources to be employed in carrying out the approved projects. The Register will be given an annual review, which will coincide with the preparation of the annual budget of Research Division. It is confidently expected that this Register will aid project planning, allow an accurate and rapid review of the research programme at any time, and provide a source of information for the Commission's own field Conservators, University Departments of Forestry, the Natural Environment Research Council, and other interested parties on the nature and extent of the Commission Research Programme.

Plans were completed during the year for the building of the new Forest Research Station on the Bush Estate near Edinburgh. This building, scheduled to be completed before the end of 1969, will at long last provide up-to-date accommodation and laboratories for research personnel working in Scotland and the North of England. It will be a great advantage to have the new building on the Bush Estate as this will allow ready contact between its staff and the staffs of other research stations at the Centre. We are grateful to the Edinburgh Centre of Rural Economy for their ready help and advice on the location of our new Station.

Authority was received for the creation at Edinburgh of a new post of Chief Research Officer (North). The new Chief Research Officer will be in charge of the Northern Station and act as deputy to the Director of Research throughout Scotland and the North of England. An additional appointment will be that of Forest Tree Physiologist, to lead a new section based on Edinburgh, but operating over the whole of Great Britain.

During the year, the Research Division said farewell to two long-serving members who had in their own individual ways contributed in no small measure to its work. R. F. Wood retired from his post as Conservator (Research) after some 20 years during which he saw forest research make great advances in many fields. As a research worker, Wood was essentially a silviculturist of the old school, brought up to observe everything in its ecological background and to translate what he saw into precise, well-thought-out experiments. For many years he was associated particularly with the late E. M. Crowther of Rothamsted, and later with Miss B. Benzian in studies in nursery nutrition. The results of this work are apparent in the high standard of nursery work in the Commission's nurseries throughout the United Kingdom.

Wood was an assiduous and painstaking editor of the *Research Annual Report*. He had a high standard of writing and a great gift for the well-chosen word or phrase. Looking back over the many reports he edited one constantly finds his sense of humour intruding into what might have been a rather dry and matter-of-fact recital of experimental data.

He bestowed great care also on the Westonbirt and Bedgebury Arboreta, and did much to raise them to their present position as worthy show places. Our good wishes go with him to the new home and garden that he will establish on the western shores of Argyll.

J. N. R. Jeffers, Principal Statistician, joined the Research Division in 1946 as a Forester in the Sample Plots Section. He soon became interested in the application of mathematics and statistics to problems of forest research and management. He became a Fellow of the Institute of Statisticians and acquired an international reputation in his own field. He built up the Statistics Section of the Research Division, applying his knowledge to the statistical design and analysis of forest experiments, and working particularly on the applications of multivariate analysis and the uses of mathematical models in forest research. His appointment as Director of the Merlewood Research Station of the Nature Conservancy came as no surprise to his many friends and colleagues at Alice Holt, and our best wishes go with him.

Information and Communications

The *Library Review*, published thrice annually, has been overhauled and its publication speeded up. This ensures that all publications issued by the Forestry Commission are immediately listed, and are then available on demand to all enquirers. More use has been made of the Research and Development Paper series, which is available on a limited specialised circulation.

The bi-annual refresher courses for field staff have been continued, and the exchange of ideas is mutually advantageous. Likewise the annual visits of forestry students from the various University Forestry Departments allow the Research Division to make contact with the next generation of foresters.

Close co-operation has been maintained with the Timber Growers' Organisation in England and Wales and the Scottish Woodland Owners' Association, both in the field and in the exchange of information through various publications.

Visitors

We were again glad to be able to welcome many visitors during the year. About 300 individuals came to Alice Holt, besides about 400 in 23 parties from the Universities, Private Woodlands Associations, institutes and other research stations. Among our distinguished visitors were Dr. N. A. Osaga, Director of the Forestry Division of F.A.O.; Mr. I. Mahama, Commissioner for Forestry in Ghana; Dr. D. A. N. Cromer, Director of the Forest Research Institute, Canberra, Australia; Professor Tsunahide Shidei, from Kyoto University, Japan; Mr. Bent Gerdes from the Manning Seed Company, U.S.A.; and Mr. J. T. E. Gilbert of New Zealand, who was travelling through Europe as a Winston Churchill Fellow. Other visitors came from such diverse countries as Brazil, Bulgaria, Czechoslovakia, Canada, Colombia, Denmark, Finland, Iran, Israel, Malaya, Malawi, Norway, Nigeria, Rhodesia, South Africa and Sweden.

Staff Visits Abroad

In May, E. G. Richards and G. D. Rouse visited Norway and Sweden with members of the Home Timber Merchants Association of Scotland and staff of the Forest Products Research Laboratory, Ministry of Technology, to see methods of sawmilling and harvesting.

Also in May, J. R. Aldous spent two days in Denmark at the Danish Tree Improvement Station, discussing plans for collection of seed of Lodgepole pine.

In June, R. Lines went to Iceland on a tour of Icelandic forests, kindly arranged for him by the Icelandic Forest Service.

W. O. Binns visited North Finland in August to see the Nisula roll method of transplant production.

A. J. Grayson was in India from October to December to assist in the initiation of work in forest economics at the Gokhale Institute of Politics and Economics, Poona, under the scheme for Commonwealth Educational Cooperation.

Conferences

The major conference of the year was the 14th I.U.F.R.O. Congress, held at Munich in September 1967. D. H. Phillips, W. O. Binns and S. A. Neustein attended as official delegates, and J. M. B. Brown, J. N. R. Jeffers, J. R. Aldhous, R. Lines, and A. S. Gardiner were also present. R. T. Bradley and P. A. Wardle of the Planning and Economics Section of the Commission's Headquarters also attended.

S. A. Neustein of Research Division and J. A. Spencer and A. J. Grayson of the Planning and Economics Section attended the Commonwealth Forestry Conference held in India in January 1968.

In April 1967, the second meeting of the British Forest Pathology Group, held in Thetford Forest, was organised and attended by D. H. Phillips, D. A. Burdekin, B. J. W. Greig, J. D. Low and C. W. T. Young.

W. O. Binns attended the Colloquium on Forest Fertilisation, held in August 1967 at Jyväskylä, Finland.

In September 1967, D. H. Phillips visited the Phytopathology Laboratory of the Institut Agronomique, L'Université Catholique de Louvain, Heverlee, Belgium, to attend a meeting of a working group on Root Rots of Woody Plants.

J. M. B. Brown went to the Winter Meeting of the British Ecological Society at Cambridge in January 1968.

J. A. Spencer was present at the Seventh Session of the F.A.O./E.C.E. Joint Working Party on Forest and Forest Products Statistics in Geneva in March 1968.

The symposium on Wind, arranged by the Society of Foresters of Great Britain, and held in March 1968 in Edinburgh, was attended by W. O. Binns, J. M. B. Brown, J. E. Everard, A. I. Fraser, R. Lines, and S. A. Neustein.

Staff Changes and Promotions

D. H. Phillips (Principal Pathologist) took over from R. F. Wood as Chief Research Officer (South) on promotion to Senior Principal Scientific Officer. He was succeeded as Principal Pathologist by D. A. Burdekin.

R. S. Howell, on promotion to Principal Scientific Officer, became Principal Statistician in place of J. N. R. Jeffers. W. H. Hinson (Soils) and Miss J. M. Davies (Entomology) were also promoted to Principal Scientific Officer, and Mrs. J. Lord (Pathology) became an Assistant Experimental Officer. Mrs. B. Witts (Experimental Officer) left Statistics Section on resigning from the Commission.

J. V. St. L. Crosland left Planning and Economics Section for Work Study on promotion to Assistant Conservator.

The following were promoted to District Officer, Grade I: J. Atterson (Silviculturist, North); A. I. Fraser (Silviculturist, South); R. B. Herbert (Genetics); J. T. Stoakley (Entomology); R. T. Bradley and D. G. Pyatt (Planning and Economics); and A. A. Cuthbert, A. H. A. Scott, D. M. Hughes and D. H. Wallace (Work Study). A. I. Fraser began two years' Sabbatical leave at Edinburgh University, where he will study climatic and physical elements of the atmosphere and their effects on tree growth.

P. Hunter (Edinburgh) was promoted to Higher Executive Officer.

J. G. Grevatt and W. T. Waters (District Officers) left Planning and Economics Section for Organisation and Methods Section, London, and East England Conservancy, respectively.

New staff appointed during the year were: J. E. Everard (District Officer, Silviculturist, South), G. P. Moffatt (Scientific Officer, Soils), D. K. Lindley (Scientific Officer, Statistics), J. F. Morgan (District Officer, Planning and Economics), K. T. Davidson (Civil Engineer, Work Study), W. D. Wardrop (Higher Executive Officer, Deputy Administration and Finance Officer), and P. A. Mayne (Executive Officer, Publications Section). Mr. S. H. Sharpley (Executive Officer, Research Information Section) moved to Alice Holt from Publications Section. Miss L. M. McMillan (Senior Scientific Assistant, Seed Section) resigned from the Commission in January 1968.

In October 1967, E. E. Fancy (Head Forester of the Research Nursery, Wareham) retired after over 40 years' service with the Commission. This time, except for the war years, he spent wholly at Wareham Forest. Joining as a young man in 1927 he rose steadily to become Head Forester, though he had no forestry school training, and his success was due to innate ability and persistence coupled with a personality that combined integrity, kindness and complete sincerity.

He joined Research Division in 1945, and for some years carried out the field work of the late Dr. M. C. Rayner in one part of the nursery and that of the late Dr. E. M. Crowther in another, and to satisfy these two critical "Masters" called for an extraordinary degree of tact and judgment.

The precision and quality of his work became a byword, and his friendly and helpful approach made a visit to his nursery at Sugar Hill always a pleasure. Unfortunately he has not enjoyed good health recently, and we hope that he will soon be better and enjoy some well-earned relaxation.

Awards

Two Veitch Memorial Medals were awarded by the Royal Horticultural Society to members of the Forestry Commission staff. A. F. Mitchell received a gold medal for work on conifers, and E. Leyshon was given a silver medal for work on the rehabilitation of Westonbirt Arboretum. The Forestry Commission was also awarded the Lindley silver medal for its exhibit of cones and foliage at the Society's Autumn Show.

(108111) B

REVIEW OF THE YEAR'S WORK

By D. H. PHILLIPS

Chief Research Officer (South)

PART I

Forest Tree Seed

Seed crops at home this year were disappointing and cost of collection was high. Most conifer seed collected in Britain was from registered stands, however, though about 56 hectares in the registered stands in Scotland were lost in the gale of January 1968.

A reserve of three years' supply of all conifers except Hybrid larch and *Abies* species is still maintained. Efforts are being made to increase the proportion of genetically superior seed in the store.

Most of the Seed Section's resources are still absorbed by service functions, and this year 80 per cent of the laboratory time was taken up by seed testing. The seed store continued to act as the main supply centre for the whole country. For the first time it divided dispatches of seed of Lodgepole pine into five provenance groups.

Some research was done to support the service work. In some nurseries, seedling production remains low when compared with numbers of viable seeds sown, and because of this, studies have been started to compare laboratory germination capacity tests with the production figures obtained with the tested seeds in a range of nurseries. Other work was done in collaboration with the International Seed Testing Association to investigate problems in the testing of forest seed.

Nursery Investigations

The greater part of the nursery programme was again occupied with nutritional work, particularly on the slow-release fertiliser "Enmag". This is a commercial material based on magnesium ammonium phosphate with the addition of either potassium chloride or potassium sulphate. It was compared with standard fertiliser regimes using potassium metaphosphate or potassium superphosphate. Results were conflicting. In some Scottish experiments, plant growth was rather better in plots treated with "Enmag" than in those treated with other fertilisers. In a series of experiments in Southern England, however, though "Enmag" gave promising results in the earlier part of the season, its advantage over other fertilisers was not always maintained in seedbeds to the end of the season, and differences in transplant lines were small.

When late top-dressings were given to seedbeds at the end of August or in September it was again found that the plants often, though not always, took up nitrogen applied at this time. They took up less potash than nitrogen, however, and if both these elements were applied, little potassium was absorbed at all. When similar top-dressings were given to transplant lines, flushing was affected in the following year, those given nitrogen flushing first and those with no fertiliser coming last into leaf. In some nurseries in which plants were damaged by frost, the plants treated with potassium were less damaged than the others.

In further work to find a satisfactory alternative seed dressing to the red lead commonly applied to help in sowing, comparisons were made between red lead, Lithofar red and Auramine yellow. Lithofar red made the seed more conspicuous than did the other colorants, and allowed satisfactory germination, whereas red lead reduced the germination of larch species, and Auramine yellow lowered the height of Douglas fir at one nursery.

An effective and safe post-emergence weed killer is still needed for use in seedbeds. Trials with propazine showed that this material used at 0·56 kg/ha (½ lb/acre) applied six weeks after emergence gave good weed control without ill effects to Scots pine or Sitka spruce.

Further work was done on the production and use of tubed planting stock. Some production difficulties were experienced, partly because of the high temperatures reached in the summer in the frames in which the plants were raised, but preliminary field experiments with tubed seedlings gave encouraging results.

Afforestation of Difficult Sites

Much of the work on difficult sites has been on the measurement of wind in high exposed sites in Scotland and Wales, using tatter flags and anemometers. On the Welsh sites, rate of flag tatter has been high, but growth of Sitka spruce has been good at all sites except Hafren, where that of Lodgepole pine and Noble fir has also been disappointing, and Japanese larch and several minor species have failed altogether.

Small-scale experimental work still arises from time to time from enquiries on the restoration of industrial sites.

Cultivation and Drainage

The experiment planted in 1962 at Inshriach Forest (Inverness-shire) was assessed after six growing seasons. At this site, on a *Calluna* heath on a humus iron podzol, cultivation greatly improved growth, and the results helped to reinforce the argument that complete cultivation of certain heathland sites may be well worth while.

It has become clear that in peaty gleys adequate drainage may lead to erosion and damage to culverts if the latter are not built to anticipate this.

Nearly all the current drainage experiments initiated in 1964 for gley soils in England and Wales to examine the effects of drain depth and spacing and the effect of fertilisers in the presence or absence of drains have now been set up. Results so far show that after winter rain the soil water level still rises nearly to the soil surface, but falls much more rapidly after drainage.

Soil analyses of peat from deep blanket bog in Caithness, typical of large areas regarded as unplantable, suggest that the problems here are physical rather than nutritional.

Nutrition of Forest Crops

In experiments on the manuring of young Lodgepole pine on peat soils, it was found that unground Gafsa phosphate produced the same effect as the ground material. There is evidence that fertilisers containing calcium improve the take-up of nitrogen in deep acid peats, though the increased growth produced may be only temporary. Further experiments to test this have been laid down. Results of other experiments show that in these deep peats nitrogen supply may also be increased by draining. On these soils, Lodgepole pine may show small response to added phosphorus, but its growth may be greatly improved when potassium and nitrogen are also added.

The growth of checked crops on mineral soils often improves if phosphorus is supplied, or competing weeds are removed. In a recent trial in checked Sitka spruce on Dartmoor, however, responses to fertilisers were obtained in only part of the treated area. Further fertiliser and herbicide treatments gave an initial growth improvement, and a good kill of *Calluna*, but the trees soon fell back into check. Additional work on this problem is clearly needed.

Site Classification

A small project on site relationships of Corsican pine, begun in collaboration with Mr. D. G. M. Donald, of Stellenbosch University, South Africa, was continued, a principal component analysis of much of the data being made. Of the various site and crop variables examined, the most important included winter temperature, growing season sunshine, longitude and latitude, soil clay and stone content, depth of free water, soil depth and humus type, total phosphorus and soil pH. Further study of the data will be made, and the methods used will later be applied to other species.

A special study of the secondary forest species—Western hemlock, Western red cedar, Grand fir and Noble fir, is being carried out to compare them with the present major species—Sitka spruce, Douglas fir, Corsican pine, Norway spruce, Scots pine and Japanese larch. Among the factors being considered are seed origin, establishment, growth, yield, resistance to *Fomes annosus* root rot and to exposure, and likely market trends.

Regeneration of Tree Stands

Natural regeneration of Sitka spruce was further studied at the Forest of Ae (Dumfriesshire), and the main losses were found to be caused by drought, aphid infestation, browsing animals, and competition from vegetation. Some direct sowing experiments with Sitka spruce have been carried out in Border forests, and the third-year survivals were 6 to 9 per cent for seeds sown respectively on uncultivated and cultivated surfaces, and 20 per cent on plots netted against mice and birds (see also Forest Ecology, page 94).

In underplanting experiments under larch and Scots pine it was often found necessary to use herbicides to control weeds by the second season when the overwood density was less than about 600 stems/ha (240 stems/acre). Survival and growth of a wide range of species under cover in Thetford Forest, East England, have continued to be generally good.

Arboreta, Forest Plots and Species Trials

Improvements were again made in most of the main arboreta, though the Scottish tree collections at Kilmun and Crarae were badly damaged by the gale of 14th to 15th January 1968.

Assessments were made in the 1951, 1952 and 1953 sections of the miscellaneous species trial at Kielder (Northumberland). In the 1951 and 1952 sections, pure plots were planted: Inland Lodgepole pine and Hybrid larch did well in both years, while other species were variable. Few except Scots pine showed promise in 1951, and Scots pine, Sitka spruce, Grand fir, *Picea omorika*, and the Japanese birch, *Betula ermannii*, grew well in the 1952 section. The 1953 plots were mixtures with Norway and Sitka spruce, and the species tested (and the spruces also) appeared to benefit from the 3 row – 3 row mixture layout used. The best growth was given by Hybrid larch, and Japanese larch, Douglas fir, and most species except Western red cedar did quite well.

Northern cypress, *Chamaecyparis nootkatensis*, in species trials in deep infertile peats in Scotland and Northern England did not confirm the promise it showed in pre-war trials on a similar soil.

Provenance

In work on Lodgepole pine, it appeared from an analysis of data on one-year seedlings from one new major experiment that fairly good discrimination of provenance groups is possible by combining data for seed weight, seedling height and autumn needle colour.

Results from many experiments suggest that the most vigorous provenances of Lodgepole pine are those from the coast of Washington and Oregon, and that those from Queen Charlotte Island also do well, while inland provenances are generally poor.

Preliminary conclusions from experiments with provenances of Sitka spruce are that those from Washington are consistently the best. Queen Charlotte Island provenances may do well in the North (but not better than those from Washington), and there is no advantage in using seed from Alaska. Further information is still needed on later growth and timber qualities, however.

Experiments with Norway spruce are showing that there are large differences in provenances of this tree, and they are big enough to warrant careful choice of seed origin. The best seed sources are in Roumania and Poland.

Results after the first 12 years from the first large-scale trial of Douglas fir provenances are now available from plots in England and Wales. So far they show that the best growth with least of the precocious needle shedding that occurred on one site was given by provenances from the West coast of Washington. In Scotland, the inland variety *caesia* grew well at first, but then became affected by the needle fungus *Rhabdocline pseudotsugae*, and its rate of growth then fell off.

Weed Control in the Forest

Overall sprays with 2,4,5-T in water gave better control of *Rhododendron* than did basal bark sprays with the same chemical in diesel oil.

Dicamba markedly decreased the height and percentage cover of bracken, and applications by mistblower generally gave results as good as normal high volume applications. Scots pine planted only two weeks after the land was treated with dicamba were unharmed, and Corsican pine also appeared to be tolerant to the chemical, but some species (notably Western hemlock) were damaged even when eight weeks was left between treatment and planting. In other experiments, dicamba gave promising results against the willow-herb *Epilobium angustifolium* and the rush *Juncus squarrosus*.

Chlorthiamid ("Prefix") again caused damage to some species, though the extent of the damage was less than in some earlier experiments, perhaps because the high May rainfall dispersed the chemical.

Atrazine and Ametryne, two triazine compounds allied to simazine, were given a preliminary trial and showed promise against mixed herbaceous weeds.

Tree Stability

A notable feature of the year was the hurricane of 14th to 15th January 1968, which did severe damage to forests across the central Lowlands of Scotland and particularly in the Clyde-Forth valleys. A survey of the damage is being made, with particular reference to the effects of topography.

Some preliminary results are now available from the aerodynamic study at Redesdale Forest in Northumberland, where anemometers measure the wind at various heights at points within and outside the forest. The results show that even when strong winds blow outside the forest, the wind speed in the tree tops is only about one-tenth of that at the same height outside.

In an experiment to examine the effect of the size of felling areas on subsequent windblow, fewer trees were blown around 2·0 ha (5-acre) clearings than round smaller ones measuring 0·4 ha (1-acre) and 0·12 ha (0·3-acre), but these smaller-sized clearings differed little in this respect.

Trees on forest margins were treated experimentally to restrict extension of wind damage by cutting off their tops, high-pruning them to the fourth live whorl, or killing them with ammonium sulphamate; no treatment gave consistent success.

Mixtures

A special survey of Lodgepole pine/Sitka spruce nursing mixtures shows that the spruce rarely benefited from planting in mixture in this way, and it was decided that it was not worth while to set up any further mixture experiments of this kind.

Miscellaneous Investigations in Plantations

More observations were made in four areas to see if the Green spruce aphid, *Elatobium abietinum*, plays any important part in reducing the growth of pole-stage Sitka spruce, comparisons being made between untreated plots and others sprayed with malathion. In the first area, in which observations have been made over several years, no differences have ever been found between sprayed and unsprayed crops. In the other areas, in which studies as yet cover only one season, aphid attack significantly reduced increment in the unsprayed plots in one area but not in the other two. The investigations will continue.

The review of the northern spacing experiments was completed, the main factors considered being the effects of spacing on branch size and stem taper. At 30 years, it was found that branch size increased considerably with initial spacing, but even at 20 ft maximum branch size was unlikely to exceed 1½ in. (*c.* 4 cm) in diameter. Stem taper also increased with initial spacing, but this effect was confined mainly to the lower stem.

Poplars and Elms

Further evidence was collected showing the great vigour of *Populus trichocarpa* and its hybrids, which also tolerate a wider range of site conditions than other poplars. If it were not for their susceptibility to bacterial canker, selected balsam poplars could be grown commercially, and would considerably improve productivity.

In pruning experiments on poplars, it was found that increasing severity of pruning from a quarter and half total height to three-quarters total height appreciably lowered the rate of radial growth.

When softwood cuttings of elms were raised by mist propagation, mean annual survival of clones of English, Huntingdon, Dutch and Smooth-leaved elms was respectively 33, 57, 59 and 69 per cent. In establishment studies, it was found that large softwood cuttings of elm survived better after transplanting than did smaller ones.

Forest Ecology

In a two-year study of young Black pines kept under different degrees of shade it was found that shading had a much greater effect on diameter increment than on current height, and that it affected stoutness and weight of leaves, dry weight of tops, number and size of buds, and root production.

Preliminary investigations on periodicity of root growth of young Corsican pines showed that root extension began in mid-March or earlier, and almost ceased about mid-May, but was resumed late in July after the cessation of shoot growth, and then continued until early December.

In unprotected plots sown with seed of Corsican pine, and containing naturally occurring Scots pine seed, most of the seeds and seedlings were destroyed, mainly by mice, but very large yields of seedlings of both species were obtained in plots from which mice were excluded (see also Regeneration of Tree Stands, page 57).

Soil Moisture, Climate and Tree Growth

Studies showed that in a sandy soil rate of drainage after artificial wetting fell rapidly to a very low level, and it is therefore correct to assume the absence of appreciable percolation loss in the water balance equation for such a soil.

Forest Genetics

Cone and fruit crops of all species were again generally light, though Sitka spruce, Douglas fir and beech produced an abundant yield in some places.

The search for Plus trees was once more centred mainly on Sitka spruce. Some selection of Corsican pine continued, but that of Scots pine was suspended, and will be resumed only when F_1 material in progeny-test plots is mature enough to allow further breeding material to be chosen. Work on progeny-testing of the Plus trees is gathering momentum, and about one-fifth of the Plus trees chosen are now represented in progeny trials. Glasshouse studies to speed up progeny-testing of Sitka spruce and European larch gave promising results, and answers were found to some of the difficulties encountered in the earlier stages of this work.

In continued investigations on grafting, Douglas fir again gave good results, but growth and survival of scions of Sitka spruce was poor.

Further work was done with staff of the Forestry Department, University of Aberdeen, on problems of fertilisation, seed development and pre-harvest conelet drop in Scots pine. In a pilot trial, conelet development was advanced when trees were enclosed in a polythene structure.

Results of experiments on flower induction suggest that it may be profitable to girdle trees in old stands of good quality European larch in early spring in the year before felling to provide a large seed crop at reasonable cost. The trees should be given a complete girdle, divided into two overlapping halves. In good seed years, girdling also increases the yield of seed of Douglas fir.

Spoilage of stored Douglas fir pollen by moulds led to drying experiments, and it was found that the condition of the stored pollen was improved by vacuum drying followed by exposure over silica gel.

Forest Pathology

Root- and butt-rot fungi may cause heavy decay losses, and work has therefore continued on *Fomes annosus*, *Armillaria mellea* and *Polyporus schweinitzii*. Sodium nitrite is now the chief chemical used to control *F. annosus*, though disodium octoborate and urea are also used over small areas, but recent trials show that ammonium sulphamate, diquat and paraquat are also very promising. Biological control of *F. annosus* by means of *Peniophora gigantea* is now used in pine forests, and fungi that may prove effective in the same way in Sitka spruce plantings have now been isolated for testing.

Additional information was obtained on the biology of *Didymascella* (*Keithia*) *thujina*, the cause of needle blight of Western red cedar. The formulation of cycloheximide known to control needle blight is now being withdrawn from commercial sale, but tests with an alternative formulation also gave satisfactory results.

Work on stem crack was extended to species other than Grand fir, and showed that in Noble fir and Sitka spruce, cracks (though small ones) might occur without external scars, while in Douglas fir bark scars were not associated with cracks within the stem.

The climate of these islands again had much to do with the pattern of enquiries for advice on pathological disorders, damage being caused not only by living organisms, but also by frost, waterlogging and lightning, and by wind, particularly in January 1968, when a severe gale caused much destruction in Scotland.

Forest Entomology

The annual pupal census of the Pine Looper moth, *Bupalus piniarius*, shows a large increase in the population in many forests, and suggested that an infestation large enough to cause some defoliation was likely in Cannock Chase Forest, Staffordshire, in 1968. Work on control of the Douglas fir seed wasp (*Megastigmus spermotrophus*) is being reduced, but some seed trapping will continue for a few years, and some further chemical control experiments will be carried out to confirm the effectiveness of malathion.

The Pine bark moth, *Laspeyresia coniferana*, has made locally heavy attacks on Corsican pine in Anglesey, N. Wales, and a study of its biology has therefore been made. The larvae occur mainly in brashing wounds and slash marks, and all stages of larvae and the pupa may overwinter.

Work continued on the Green spruce aphid, *Elatobium abietinum*, to investigate its general biology, the losses it causes, and host plant susceptibility. Suction trap data showed that the peak in activity of alate viviparae in Southern England runs from late April to the end of June. The suction trap also provided further information on the times of flight of other aphids, bark beetles and other insects. To assist with the identification of trapped specimens, keys and descriptions of winged forms of the adelgid species found in Britain have now been made.

It is now possible to recommend BHC to replace Aldrin for the control of cutworms in nurseries.

Mammals and Birds

Work on control of Grey squirrels was again carried out in collaboration with the Infestation Control Laboratory of the Ministry of Agriculture, Fisheries and Food. Experiments once more showed how vital it is to concentrate protective trapping in the period from late April to June, and how quickly squirrels can re-colonise a cleared area.

Six chemical repellents tested against fallow deer were ineffective, but the Dutch repellent "Aaprotect" reduced browsing of Norway spruce by roe deer.

A study of fencing led to the development of a fence using high tensile spring steel wire and woodwork treated with standard preservatives. This type of fencing offers a large saving in materials and labour.

Work on starlings (*Sturnus vulgaris*) has also shown that time and labour can be saved when dispersing woodland roosts if traditional methods are replaced by the combined use of an amplified distress call apparatus and bird-scaring cartridges.

Planning and Economics

This Section and that of Work Study are both parts of the Management Services Division of the Headquarters organisation, but publish accounts of their researches in this *Report*.

Working Plans

Progress has been made with Soil survey work, and a site classification guide to the soils on the Cambrian, Ordovician, Silurian and Devonian slates of Wales and the Welsh borderland will soon be published. Similar work on the Old Red Sandstone areas of north and east Scotland is well advanced, and results so far suggest that on the difficult heathland soils of much of this region, impeded vertical drainage is the main problem. If this can be dealt with, the land should support species giving a much higher yield than the traditional Scots pine.

Scots pine is also the species commonly grown in the North York Moors, where another survey is in progress, and here again results suggest that higher yielding species could be grown in large parts of the region.

A special study of the dune forest of Tentsmuir (Fife) has supported the view that planting of Sitka spruce to replace Scots pine could safely be extended there over soils with a high water table.

Economics

During the year, the results were published of a study of the financial effects of initial spacing. Continued work on roading indicated that where roading costs are high or yields low, roading (and the start of thinning) should be postponed. Other studies suggested that line thinning methods could facilitate felling and extraction, and reduce the cost of brashing and harvesting.

Work Study

As part of its duties this Headquarters Section has now taken over the responsibilities for Machinery Research and Development.

Work on shortwood extraction systems was continued and the Robur timber-carrying unit was found to give good results on suitable land with relatively gentle slopes, and attempts are being made to improve performance on wet "green" rides. Tests are being made with a fairly cheap timber carrier built up from Fordson Major equipment.

Studies on tree-length extraction systems were concentrated mainly on frame-steered tractors. The Holder tractor is proving well suited to early thinnings, and the larger Hough Paylogger and similar large machines will be valuable for extracting larger thinnings and clear fellings.

Though further work is needed, the major problems in the development of a system incorporating the Lokomo plough now seem to have been solved. Working in North Wales, the plough with its associated equipment has produced up to 60 chains of deep drain in one day at an estimated cost of 10 shillings per chain.

Timber Utilisation Development

The programme of work on home-grown timber, carried out jointly with the Forest Products Research Laboratory (Ministry of Technology), entered its tenth year.

In work with the continuous laminating machine it was found that distorted timber could be made successfully into laminated beams that remained stable during changing conditions of atmospheric humidity.

Experiments on the making of woodwool/cement building slabs showed that these could be made satisfactorily with most of the common home-grown softwoods, provided decayed timber was excluded.

In continued bark-composting experiments in Thetford Chase, disappointingly low temperatures were reached in the compost heaps, and it was concluded that bark from the mechanical peeler needed to be further shredded or ground before composting was attempted.

Design and Analysis of Experiments

The Statistics Section was again handicapped by staff shortages, but its equipment was improved by additions that included a second 7,000-word I.C.T. Sirius computer, an English Electric Lector document reader, an 8-track paper-tape Teletype machine, and a card-to-tape converter. The Section continued to provide advisory, analytical and computing services to Research and Management Services Divisions and to others.

Experimental Workshop

The Workshop again designed and made a large range of equipment for the use of other sections.

Photography

The photographic collection now contains more than 38,000 items, and so presents an increasingly difficult problem of retrieval. More and more requests for audio-visual aid material are being received, and during the year several wild-life recordings on tape were made.

Publications

Nine new publications were issued through Her Majesty's Stationery Office, and ten priced publications sold by the Stationery Office were revised and reprinted. Additions were made to the Research and Development Paper series, which is designed to provide for limited, primarily internal circulation of specialised material. Thirty-one of these papers were issued during the year, and 18 other unpriced publications were also revised and reprinted.

Research Information

The Research Liaison Officer is responsible for the library and general information services, and makes arrangements for visitors to the Station. He also does much to maintain our contacts with the field and with other research stations and the universities. This year the library issued a revised list of Forestry Commission translations, and further translations were made. A trial index of Forestry Commission literature was made and issued for comment, and if it is favourably received will be further developed.

PART II

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

In a short extract from the *Report of Rothamsted Experimental Station for 1967*, Miss B. Benzian and Mr. S. C. R. Freeman deal with work on the slow-acting nitrogen fertiliser isobutylidene diurea (IBDU). When this, in two grades, one fine, the other coarse, was compared with formalised casein and "Nitro-chalk", the latter generally gave the best results.

Mr. H. G. Miller and Dr. B. L. Williams, of the *Macaulay Institute, Aberdeen*, have continued their studies on forest soils and tree nutrition. Most of their work has been on nitrogen, and in one experiment in mature Scots pine at Alltcailleach Forest, Aberdeenshire, they have found evidence that the trees may respond to a single nitrogen application for up to eight years, and that some of the nitrogen may be stored for later use. Results of work in a pole-stage Corsican pine crop at Culbin, Moray, showed that after heavy nitrogen applications part of the nitrogen was retained in the organic layers of the soil, but part was stored within the tree crop. Work on cation-exchange capacity, moisture retention and other characteristics of peat may eventually lead to improved methods for the assessment of the actual or potential capacity of a peat soil to support tree growth.

Dr. D. J. Read, of the *Department of Botany, University of Sheffield*, comments on the preliminary results of his investigations on the Estuarine Clays of North Yorkshire. Results so far suggest that riggs, that is, ridges of soil, may produce a drier and deeper rooting zone, but in these soils drains appear to have little effect on water balance.

Mr. P. G. Biddle and Dr. T. W. Tinsley of the *Commonwealth Forestry Institute, University of Oxford*, have continued their work on Poplar mosaic virus, and have begun to extend their studies to cover our important conifer species. They have found a virus in Sitka spruce that causes shortening and chlorosis of the needles, and often a subsequent leaf fall.

Mr. A. Manap Ahmed and Dr. A. J. Hayes of the *Department of Forestry and Natural Resources, University of Edinburgh*, report on further work on the fungus *Crumenula sororia*, which is associated with cankers on pines. They have found the fungus on cankers on all above-ground parts of the tree, and obtained evidence that it enters through needle scars and wounds. Aspect has a highly significant effect on successful infection, most cankers appearing on the more north-easterly sections of the stems.

Mr. J. S. Murray and Dr. C. S. Millar of the *Forestry Department, University of Aberdeen*, discuss a randomly based survey of the incidence of the pine blister rust *Peridermium pini*, which is common on Scots pine in North-east Scotland. The disease was found in more than 25 per cent of the plots sampled. Incidence was low in the younger crops but rose and remained steady from the age of thirty onwards, with no marked falling off in the later age classes.

In a second extract from the *Report of the Rothamsted Experimental Station for 1967*, Dr. G. A. Salt gives an account of work on the pathology of conifer seedlings. *Phytophthora cactorum*, species of *Cylindrocarpon* and *Pythium*, and *Rhizoctonia solani* were isolated from seedlings of various species. Further evidence was obtained that the "psychrophilic" endophytic seed fungus previously found on seed of Sitka spruce can greatly reduce emergence in early sowings, and has no effect on later ones, when soil temperatures are higher. Thiram again effectively prevented its attack.

Dr. J. F. Longworth, of the *Commonwealth Forestry Institute, University of Oxford*, summarises work on viruses isolated from forest insects. A number of new viruses have been discovered, while studies of a group of seven cytoplasmic polyhedral viruses isolated from widely different Lepidoptera showed them to be indistinguishable from one another.

In a paper from the *Department of Forestry and Natural Resources, University of Edinburgh*, Mr. D. H. Mills reports further work on fish populations in the Glentress Burn, Peeblesshire, in which he found that only 0·16 per cent of salmon fry survived to the end of the summer, though when sections of streams were cleared of trout, they were over-colonised and were at their former population level a year after clearance.

Dr. Myles Crooke, of the *Forestry Department, University of Aberdeen*, contributes a report on his studies on the relationship between the population of coal tits and that of the Pine looper moth in Culbin Forest, Moray. Provision of nest boxes in one of the study plots has not raised the breeding density there above that elsewhere, but winter feeding seems to have resulted in large numbers of tits wintering in the favoured plot.

Mr. W. H. Parry, of the same *Department*, gives an account of studies on the population dynamics of the Green spruce aphid, *Elatobium abietinum*, at Forest of Deer, Aberdeenshire, and Fetteresso Forest, Kincardineshire. Data was collected on numbers and types of aphids, of predators, and of parasitised aphids. Aphid numbers tended to increase from April to the end of June, and then to decline rapidly. There was evidence that variations in the sizes of summer peak numbers of aphids are due to differences in the size of the over-wintering population. Predators were found, but were too low in numbers to have much effect on the aphid population. In heavily infested plantations, needle loss was up to 75 per cent.

Dr. W. A. Fairbairn, of the *Department of Forestry and Natural Resources, University of Edinburgh*, has concluded his experiment on light relations of tree species and the results are being analysed in readiness for future publication.

Dr. D. C. Malcolm, of the same *Department*, has continued to gather data for his study on environmental factors and the growth of Sitka spruce. The most interesting general relationship emerging so far is a strong one between productivity (as measured by height growth) and altitude, which itself affects other factors of climate and soil.

Mr. A. J. M. Heselden and Mr. M. J. Woolliscroft, of the *Joint Fire Research Organisation, Boreham Wood, Herts*, again summarise their work on fires in forest and heathland fuels. They have studied controlled burnings in the New Forest, and found that rate of spread of head fires was usually controlled by radiation from the flames. Further data from controlled burnings is being collected for analysis.

PART I

Work carried out by Forestry Commission Research and Development Staff

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FOREST TREE SEED

As in previous years the Seed Section continued to be the central unit of seed procurement, extraction, processing, storage, testing and distribution for the Forestry Commission and a large section of the commercial nurseries and private forests. This service continued to take priority and research work was organised as permitted by the heavy load of service commitments.

Register of Seed Sources

The registered seed sources were decreased by 62·2 ha (153·7 acres) of which the greater part, 56·3 ha (139·2 acres), was lost in South West Scotland due to the gale in January 1968. Three new seed orchards were planted (one Scots pine and two Lodgepole pine) comprising 7·48 ha (18·5 acres). In connection with the substantial decreases in seed usage in latter years it is now considered that the number of registered stands should also be decreased.

The main changes in the Register are as follows:—

Areas gained:	*Number*	*Hectares*	*(Acres)*
New seed orchards	3	7·48	(18·5)
Areas lost. Total:	22	*69·68	(172·2)
Stands lost by windthrow	18	*56·33	(139·2)
Stands felled	3	2·83	(7·0)
Reduction of area	1	10·52	(26·0)
Stands thinned:	9	39·25	(97·0)

* Area includes parts of stands.

Seed Certification

The certification scheme for seed origin is operated by the Forest Seed Association, of which the Commission is a member of the Management Committee with the responsibility of maintaining the Register of Seed Sources. During the year under review the scheme was revised to conform to the requirements of the international certification scheme as being organised by O.E.C.D. (the Organisation for Economic Co-operation and Development). The O.E.C.D. scheme is expected to come into operation during the next year.

Seed Procurement (Table 1)

The seed crops at home were disappointing and altogether only 371·4 kg (817·3 lb) were collected, of which 128·6 kg (283·3 lb) were conifer seed. This collection was the lowest of the last ten years. Almost all conifer seeds were collected from registered sources. The collection costs were very high and therefore some steps were made to make collection less expensive in the future.

TABLE 1

SEED PROCURED IN FOREST YEAR 1968

Species	Home-collected Weight in kilograms (pounds)			Imported Weight in kilograms (pounds)			Grand Total
	General	Regis-tered	Total	General	Regis-tered	Total	
Scots pine	—	45·5 (100·1)	45·5 (100·1)	—	—	—	45·5 (100·1)
Corsican pine	—	—	—	—	—	—	—
Lodgepole pine	—	4·36 (9·6)	4·36 (9·6)	24·95 (55·0)	—	24·95 (55·0)	29·31 (64·6)
Norway spruce	—	—	—	—	—	—	—
Sitka spruce	5·26 (11·6)	2·84 (4·5)	7·3 (16·1)	—	—	—	7·3 (16·1)
Douglas fir	—	38·6 (85·1)	38·6 (85·1)	25·54 (56·3)	—	25·54 (56·3)	64·14 (141·4)
European larch	·63 (1·4)	1·18 (2·6)	1·81 (4·0)	—	—	—	1·81 (4·0)
Japanese larch	—	27·72 (61·1)	27·72 (61·1)	443·16 (977·0)	—	443·16 (977·0)	470·88 (1038·1)
Hybrid larch	·32 (0·7)	2·99 (6·6)	3·31 (7·3)	—	2·0 (4·4)	2·0 (4·4)	5·31 (11·7)
Western hemlock	—	—	—	—	—	—	—
Western red cedar	—	—	—	—	—	— —	—
Noble fir	—	—	—	(28·85 (64·2)	28·3 (61·8)	57·15 (126·0)	57·15 (126·0)
Grand fir	—	—	—	—	—	—	—
Lawson cypress	—	—	—	·91 (2·0)	—	·91 (2·0)	·91 (2·0)
Other conifers	—	—	—	42·18 (93·0)	—	42·18 (93·0)	42·18 (93·0)
Total conifers	6·21 (13·7)	122·39 (269·6)	128·6 (283·3)	565·59 (1247·5)	30·3 (66·2)	595·89 (1313·7)	724·49 (1597·0)
Oak	—	—	—	256·28 (565·0)	—	256·28 (565·0)	256·28 (565·0)
Beech	111·9 (246·0)*	—	111·9 (246·0)	—	—	—	111·9 (24·6)
Other hardwoods	130·9 (288·0)*	—	130·9 (288·0)	2·9 (6·4)	—	2·9 (6·4)	133·8 (294·4)
Total hardwoods	242·8 (534·0)	—	242·8 (534·0)	259·18 (571·4)	—	259·18 (571·4)	501·98 (1105·4)
Total conifer and hard-woods	249·01 (547·7)	122·39 (269·6)	371·4 (817·3)	824·77 (1818·9)	30·3 (66·2)	855·07 (1885·1)	1226·47 (2702·4)

* Conservancy collections for direct use only.

Due to the continued shortage of seed from home sources the import of some species was necessary and altogether 855·07 kg (1,885·1 lb) were purchased from abroad of which 595·89 kg (1,313·7 lb) were conifer seed. As is usual this was done in close consultation with the Silviculturists (provenance) in order to ensure that the imported seeds originate from the most desirable provenances. The import was also one of the lowest of the last ten years.

A special import of 25·54 kg (56·3 lb) of Douglas fir seed for provenance experiments was obtained through the international seed pool organised by I.U.F.R.O., located in Denmark. Altogether there were 96 lots covering the whole natural distribution range of this species in Northern America. During the next year a similar collection of Lodgepole pine seed is expected.

Seed Extraction (Table 2)

Due to extremely poor crops (see above) the seed extraction was concentrated in two of the four Forestry Commission extractories. The volumes of the processed cones are listed in Table 2.

TABLE 2

CONES COLLECTED AND PROCESSED IN THE EXTRACTION PLANTS

Species	England and Wales	Scotland	Great Britain
	Alice Holt	Millbuie	Total
	Volume in hectolitres (bushels)	Volume in hectolitres (bushels)	Volume in hectolitres (bushels)
Scots pine	*41·82 (115)	32·37 (89)	74·19 (204)
Lodgepole pine (M)	—	8·73 (24)	8·73 (24)
Sitka spruce	2·55 (7)	6·90 (19)	9·45 (26)
Japanese larch	*28·00 (77)	—	28·00 (77)
European larch	0·36 (1)	2·55 (7)	2·91 (8)
Hybrid larch	2·91 (8)	6·18 (17)	9·09 (25)
Douglas fir	50·91 (140)	—	50·91 (140)
Total	126·55 (348)	56·73 (156)	183·28 (504)

* Including Scottish collections sent to Alice Holt.

Seed Store (Table 3)

Table 3 shows the amount of seed in hand after the completion of the spring 1968 sowings. As compared with last year the stocks were decreased by 2,497 kg (5,548 lb). As planned, there is sufficient stock for three years of the majority of species with the exception of Hybrid larch and *Abies* species. The lack of Hybrid larch seed is due to shortages in the older cone-bearing sources. However, it is expected that the seed should be produced in larger amounts as the new seed orchards mature. As regards *Abies* species it was recently decided not to build up large stocks due to some risks involved in the long-term storage. Crops of these species occur quite frequently and there is no danger that one year we may be left without seed.

TABLE 3

SEED STOCK IN HAND

Weight in kilograms (pounds)

Species	Amounts held from General and Registered Sources			Total
	General	Registered Stand	Seed Orchard	
Scots pine	889·72 (1,961·5)	114·49 (252·4)	22·72 (50·1)	1,026·93 (2,264·0)
Corsican pine	490·74 (1,081·9)	479·08 (1,055·7)	—	969·82 (2,138·1)
Lodgepole pine	1,835·05 (4,045·6)	—	—	1,835·05 (4,045·6)
Norway spruce	778·05 (1,715·3)	—	—	778·05 (1,715·3)
Sitka spruce	1,689·45 (3,724·6)	—	—	1,689·45 (3,724·6)
Douglas fir	1,016·86 (2,241·8)	610·81 (1,346·6)	—	1,627·67 (3,588·4)
European larch	11·02 (24·3)	324·18 (714·7)	0·23 (0·5)	335·43 (739·5)
Japanese larch	937·03 (2,065·8)	31·52 (69·5)	—	968·55 (2,135·3)
Hybrid larch	0·32 (0·7)	5·67 (12·5)	0·41 (0·9)	6·40 (14·1)
Western hemlock	163·97 (361·5)	—	—	163·97 (361·5)
Western Red cedar	175·59 (387·1)	1·72 (3·8)	—	177·31 (390·9)
Noble fir	32·61 (71·9)	28·03 (61·8)	—	60·64 (133·7)
Grand fir	152·32 (335·8)	—	—	152·32 (335·8)
Lawson cypress	0·91 (2·0)	1·95 (4·3)	—	2·86 (6·3)
Other conifers	101·47 (223·7)	—	—	101·47 (223·7)
Total conifers	8,275·11 (18,243·5)	1,597·45 (3,521·8)	23·36 (61·5)	9,895·92 (21,816·8)
Oak	—	—	—	—
Beech	—	—	—	—
Other hardwoods	6·94 (15·3)	—	—	6·94 (15·3)
Total hardwoods	6·94 (15·3)	—	—	6·94 (15·3)
Grand Total	8,282·05 (18,258·8)	1,597·45 (3,521·8)	23·36 (61·5)	9,902·86 (21,832·1)

The seed stocks, although generally sufficient in volume, do not contain enough genetically superior seed and efforts are being continued to procure more seed from these sources.

Seed Testing

The major part of the work of the Seed Testing Laboratory continued to be routine testing of the Commission's seed stocks. This service function took up about 80 per cent of the available laboratory time. During the year under review 773 seed samples were tested in accordance with the Seed Act (1920) requirements. This number includes 17 samples for private forestry and 22 samples for the Commonwealth Forestry Institute as a part of its seed distribution scheme for the developing Commonwealth countries. The research programme required 274 samples to be tested.

On these samples 3,306 different tests were performed as specified in Table 4. As compared with last year the service work required 98 more tests and the research programme 395 fewer.

TABLE 4

TESTS PERFORMED ON SEED

Test	Service	Research	Total	Total of previous year
Purity	529	38	567	516
Seed size determination	612	48	660	567
Germination	974	364	1,338	1,688
Tetrazolium	14	9	23	37
X-Ray	5	—	5	11
Cutting test	2	1	3	140
Moisture content	583	109	692	607
Cone test	1	17	18	37
Total	2,720	586	3,306	3,603

Seed Supply (Table 5)

The Commission's central store at Alice Holt continued to be the main seed supply centre for the whole country, and during the year under review altogether 3,285·77 kg (7,243·9 lb) were issued of which only 245·4 kg (541·0 lb) were hardwood seed. As regards conifer seed the Commission took 67·53 kg (148·9 lb) more than the private sector, and this was contrary to the previous year when it required 1,535 lb less than the private sector. The amount of seed listed under Export, Research, Gifts, etc., increased by over three times as compared with the last year, and this happened mainly due to the increased export of our surplus stock of Lodgepole pine of inland provenances.

For the first time Lodgepole pine seed dispatches were sub-divided in five provenance groups as recently introduced into the Commission practice. These provenances are indicated by letters as follows:

(L) = North Coastal (British Columbia, Alaska)
(M) = South Coastal (Washington and Oregon, U.S.A.)
(N) = Skeena River basin, B.C.
(O) = North and Central Interior, B.C.
(P) = Southern Interior, B.C.

TABLE 5

SEED SUPPLIED FROM THE CENTRAL SEED STORE FOR SOWING SPRING 1968

Species	Weight in kilograms (pounds) Amounts Supplied from General and Registered Sources to: Forestry Commission			Private Forestry			Exports Research Gifts etc.	Grand Total
	General	Registered	Total	General	Registered	Total		
Scots pine	12·93 (28·5)	31·70 (69·9)	44·63 (98·4)	31·75 (70·0)	46·95 (103·5)	78·70 (173·5)	46·81 (103·2)	170·14 (375·1)
Corsican pine	0·18 (0·4)	152·63 (336·5)	152·81 (336·9)	31·30 (69·0)	76·66 (169·0)	107·96 (238·0)	20·96 (46·2)	281·73 (621·1)
Lodgepole pine (L)	19·37 (42·7)		19·37 (42·7)					
(M)	59·83 (131·9)		59·83 (131·9)	40·96 (90·3)		40·96 (90·3)		
(N)	29·90 (65·9)		29·90 (65·9)	4·08 (9·0)		4·08 (9·0)	99·79 (220·0)	280·69 (618·8)
(O)	3·49 (7·7)		3·49 (7·7)	9·75 (21·5)		9·75 (21·5)		
(P)	6·26 (13·8)		6·26 (13·8)	7·26 (16·0)		7·26 (16·0)		
Norway spruce	79·24 (174·7)		79·24 (174·7)	169·42 (373·5)		169·42 (373·5)	99·47 (219·3)	348·13 (767·5)
Sitka spruce	465·75 (1,026·8)		465·75 (1,026·8)	276·46 (609·5)		276·46 (609·5)	12·07 (26·6)	754·28 (1,662·9)
Douglas fir	40·41 (89·1)	19·46 (42·9)	59·87 (132·0)	85·28 (188·0)	76·20 (168·0)	161·48 (356·0)	3·63 (8·0)	224·98 (496·0)
European larch	1·41 (3·1)	9·30 (20·5)	10·71 (23·6)	12·25 (27·0)	57·24 (126·2)	69·49 (153·2)	1·59 (3·5)	81·79 (180·3)
Japanese larch	73·66 (162·4)	0·14 (0·3)	73·80 (162·7)	175·54 (387·0)		175·54 (387·0)	2·22 (4·9)	251·56 (554·6)
Hybrid larch	25·40 (56·0)	22·63 (49·9)	48·03 (105·9)	9·75 (21·5)		9·75 (21·5)	1·68 (3·7)	59·46 (131·1)

TABLE 5 (*contd.*)

Species	Weight in kilograms (pounds) Amounts Supplied from General and Registered Sources to:						Exports Research Gifts etc.	Grand Total
	Forestry Commission			Private Forestry				
	General	Registered	Total	General	Registered	Total		
Western hemlock	25·49 (56·2)	0·91 (2·0)	26·40 (58·2)	26·31 (58·0)		26·31 (58·0)	1·54 (3·4)	54·25 (119·6)
Western red cedar	1·72 (3·8)		1·72 (3·8)	17·69 (39·0)		17·69 (39·0)	0·68 (1·5)	20·09 (44·3)
Noble fir	121·97 (268·9)		121·97 (268·9)	13·09 (29·0)	30·00 (66·0)	43·09 (95·0)	4·22 (9·3)	169·28 (373·2)
Grand fir	132·58 (292·3)		132·58 (292·3)	107·95 (238·0)		107·95 (238·0)	47·99 (105·8)	288·52 (636·1)
Lawson cypress	1·31 (2·9)	2·36 (5·2)	3·67 (8·1)				0·27 (0·6)	3·94 (8·7)
Other conifers	36·38 (80·2)		36·38 (80·2)	2·99 (6·6)		2·99 (6·6)	12·16 (26·8)	51·53 (113·6)
Total conifers	1,137·28 (2,507·3)	239·13 (527·2)	1,376·41 (3,034·5)	1,021·83 (2,252·9)	287·05 (632·7)	1,308·88 (2,885·6)	355·08 (782·8)	3,040·37 (6,702·9)
Oak	229·52 (506·0)		229·52 (506)				11·79 (26·0)	241·31 (532·0)
Beech	—	—	—	—	—	—	—	—
Other hardwoods	3·36 (7·4)		3·36 (7·4)	0·23 (0·5)		0·23 (0·5)	0·50 (1·1)	4·09 (9·0)
Total hardwoods	232·88 (513·4)		232·88 (513·4)	0·23 (0·5)		0·23 (0·5)	12·29 (27·1)	245·40 (541·0)
Total conifers and hardwoods	1,370·16 (3,020·7)	239·13 (527·2)	1,609·29 (3,547·9)	1,022·06 (2,253·4)	287·05 (632·7)	1,309·11 (2,886·1)	367·37 (809·9)	3,285·77 (7,243·9)

The statistics in Table 5 do not include the dispatches of seed stored for people and institutions outside the Commission, which amounted to about 227 kg (500 lb). The majority of these dispatches were carried out on behalf of the Commonwealth Forestry Institute and were directed to many Commonwealth countries.

In addition to the main programme of seed dispatches some 5,000 measured and packeted lots of seed were prepared for use in Research Division nurseries. Moreover the Seed Section was processing, storing and preparing for distribution the seed collected in the Commission's arboreta as a part of the seed exchange scheme run by the Silviculturist South. This work amounted to 8 kg (17 lb) of seed distributed in 414 samples.

Research

The current research programme consists of 22 projects which cover the main aspects of our activities with a view to improving our service efficiency. Unfortunately the progress in these projects is rather slow because a heavy load of service duties is impairing the capacity for carrying out research.

Germination capacity is the main factor of seed quality and therefore it continues to be one of the most important subjects for our research. Testing to determine the correct viability for some lots of seed continues to be difficult. As would be expected the seed analyst has no trouble in determining the germination of highly viable seed which present no problem with dormancy or abnormal sprouts. Likewise little difficulty is experienced in testing seed lots which are of very poor viability. Most of our troubles are to be found with lots of questionable germination, especially those with sprouts on the border-line of normal and abnormal. There is also not enough information on the productivity of such questionable lots in the field. Seed dormancy is, of course, a vast problem on its own and complicates the issue still further.

In connection with the above, work started on the examination and analysing of all seed sowings throughout the Commission nurseries in relation to seed test results reported from the laboratory. Given such statistics each year a clearer picture should be obtained of the relative productivity of different nurseries and different quality seed lots. In several nurseries actual total seedling production remains low in relation to viable seeds sown, and although in recent years quite a substantial improvement in seed economy has been recorded there still exists considerable scope for further improvements.

Close co-operation with the International Seed Testing Association was continued, and here our Seed Testing Laboratory took an active part in several international investigations aiming towards better standardisation of seed testing methods and equipment. The main items are summarised below:—

Special Investigations

Germination

Experimental work was devoted to referee testing between ten countries in Scots pine and Norway spruce samples. As the result of this investigation a revised test prescription was proposed which shortened the test duration from 21 to 14 days.

Standardisation of Seedling Evaluation

Experience has shown that the standardisation of germination test methods cannot progress further without improved definition of abnormal germination. Here the work amounts to growing-on tests of abnormally germinated seed and accumulating a collection of photographs for analysis and publication.

Moisture Content Determination

Long-term storage for seed of many tree species is becoming a routine necessity, and in connection with this the reliable determination of moisture content is quite an important issue in the international seed trade. In view of the above the international rules were revised in order to improve standards.

Another important project in our agenda is finding a reasonably quick method for identification of seed origin as a safety check for our imported seed. Experience is showing that many imported seed lots have not originated from the declared places, and so long as we are dependent on foreign sources there must be some safeguard against purchasing and using unsuitable provenances. The prospects of making progress are quite good, partly through morphological tests (seed size, shape, colour etc.) and partly through physiological tests. At present the investigation is confined to Lodgepole pine seed for which the application of proper provenance is especially important in this country.

As regards seed storage our main attention is concentrated on the efficiency of our routine long-term storage. The methods employed have been in use for the last ten years, and although by and large the seed is retaining its quality quite well there are some individual cases of quicker deterioration than expected. This is quite an important problem because the current value of the seed stock is over £150,000.

There are plans to analyse the behaviour of all lots of the major species which were kept in the store for three years and over, and work has started on *Abies* species which generally give indications of the most erratic behaviour. Work was continued on some other storage investigations:

Abies procera

The ten years' storage experiment covering a range of temperatures and moisture content comes to its conclusion in 1969. The interim report after five years' storage was made in 1965.

Elm Seed

Infrequent seed crops and limited storage life of home-produced seed present difficulties in supplying this seed to our nurseries. Small-scale storage trials are being continued with some encouraging results.

Neem Seed (Azadirachta indica)

This investigation was carried out on behalf of the Nigerian Forestry Services and with the help of a Nigerian Forestry Officer who was attending a refresher course at Oxford. Neem tree is one of the important timber producing trees in Nigeria, and the main aim of this investigation was to find out a suitable method for storing this seed for at least six months, i.e. from the time of collection to sowing.

Four consignments of seed were received but only one lot had retained any viability when it arrived at our laboratory, and unfortunately all efforts failed in keeping alive this seed for more than two months. The experiment will be continued with the next seed crop.

Seed Dressed with Waxoline Type Dyes

As indicated in last year's *Report* this seed colorant is being tested as a substitute for the red lead dressing now used. It is assumed that this dressing could eventually be carried out centrally on all seed lots before storage, and therefore it was decided to carry out some long-term storage trials in order to discover the influence of this dressing on the seed's life-span. Two experiments are being carried out for the second year and the results are promising. More details will be reported after three years' storage.

As mentioned above, this year's cone crop was extremely poor and therefore no proper experimenting with the seed extraction was possible. However, the work on the development of a new seed de-winging machine was continued and it is in its last stages of completion.

G. BUSZEWICZ

REFERENCE

Forest Seed Association Members' Handbook, published by F.S.A., Farnham, 1968. 31 pages.

PUBLICATIONS BY STAFF MEMBERS

BUSZEWICZ, G. Better seeds mean better forests. *Suppl. Timb. Trades J.* April 1967, 35–7.

NURSERY INVESTIGATIONS

In 1967, research concentrated on fertiliser regimes and in particular the use of less soluble commercial formulations based on magnesium ammonium phosphate. The nurseries in which experiments were laid down were:—

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

Wales: Crumbland, between Chepstow and Monmouth

Scotland: Newton, Moray
Tulliallan, Clackmannanshire
Devilla, Clackmannanshire
Benmore, Argyll
Glenfinart, Argyll
Fleet, Kirkcudbrightshire

In addition to the experiments described here, joint work was undertaken under the leadership of Miss B. Benzian of the Chemistry Department, Rothamsted Experimental Station. Also, several lots of plants for provenance and species trials were raised.

SEED DRESSINGS

Auramine yellow and Lithofar red used as colorant seed dressings were tested in experiments to find a satisfactory alternative to red lead. The trials were carried out at Alice Holt, Kennington and Wareham nurseries, on four species at each nursery.

An unexpected result from these experiments was the depressing effect of red lead dressings on all larch species. At Alice Holt red lead significantly reduced the number of European larch seedlings at the five per cent level compared with Lithofar red; at Kennington it significantly reduced mean height of hybrid larch at the one per cent level; and at Wareham it significantly reduced the numbers of Japanese larch at the five per cent level.

Tables 6 and 7 give the mean numbers (mid-season counts) and the end of season mean heights for the larch species included in these experiments.

TABLE 6

MEAN NUMBER OF LARCH SEEDLINGS PER SQUARE YARD—SEED DRESSING EXPERIMENT

From mid-season germination counts

Nursery	Species	Red Lead	Auramine Yellow	Lithofar Red	Standard Error
Alice Holt	European larch	363	388	425	±12·5*
Kennington	Hybrid larch	999	1,004	921	±23·8
Wareham	Japanese larch	510	580	578	±20·1*

*See notes on opposite page.

TABLE 7

END-OF-SEASON MEAN HEIGHT OF LARCH SEEDLINGS—SEED DRESSING EXPERIMENT

cm (inches)

Nursery	Species	Red Lead	Auramine Yellow	Lithofar Red	Standard Error
Alice Holt	European larch	19·6 (7·7)	19·8 (7·8)	19·6 (7·7)	±0·63 (0·25)
Kennington	Hybrid larch	5·6 (2·2)	6·1 (2·4)	6·4 (2·5)	±0·13 (0·05)**
Wareham	Japanese larch	11·7 (4·7)	16·0 (6·4)	13·5 (5·4)	±1·35 (0·54)

*Notes:**, **: Differences significant at 5 per cent and 1 per cent level respectively.

At Wareham, Japanese larch appeared to germinate satisfactorily, but subsequently many of the newly emerged seedlings turned yellow, and a number died.

Auramine yellow also caused a significant reduction in the mean height of Douglas fir at Kennington nursery compared with Lithofar red.

Generally it was agreed at all three nurseries that seed treated with Lithofar red stood out against the soil slightly better than seed treated with other colorants.

DATE OF SOWING

Comparison of Two Provenances of Sitka Spruce

For the sixth successive year Sitka spruce seed from Queen Charlotte Islands, British Columbia, and from the west coast of Washington, U.S.A., was sown at six dates between late February and early/mid-May (at approximately two-week intervals). The experiment was carried out at Alice Holt, Kennington and Wareham.

The same general trend was noted as in previous years, for the earliest sowing dates produced the tallest seedlings, though at Kennington seed sown in late April germinated at the same time or even a little after seed sown two weeks later.

The difference in height between Queen Charlotte Islands seedlings and Washington seedlings was most marked, Washington seedlings averaging 15 per cent taller (range 7–64 per cent) than those from Queen Charlotte Islands seed.

FERTILISERS

Late Season Top-Dressings on Seedbeds

Experiments were again repeated at Alice Holt, Kennington and Wareham in which seedbeds of ten conifer species were given top-dressings of 54 kg/ha (=48 lb/acre) of nitrogen (N), or 108 kg/ha (=96 lb/acre) of potassium (K), or both, in late August/September.

The objects were: *firstly* to confirm that seedlings are capable of absorbing nutrients when added late in the season without necessarily increasing in size; *secondly* to observe the effect of any higher nutrient status on the plants' performance in the transplant lines in the subsequent year.

Generally, the experiments confirmed the results obtained in 1966 that seedlings of most species often, but not always, take up N from such top-dressings; all species at Alice Holt and Kennington did so, though foliar analysis of seedlings at Wareham showed no increases, or only insignificant increases. Plants which had received both N and K at Wareham generally had a lower concentration of N than those which had received N top-dressings only.

Less K was taken up than N. The best effects were observed at Alice Holt where all species, except Lodgepole pine, had much higher foliar concentrations of K after receiving K top-dressings alone, but when both N and K were applied, differences in nutrient concentration between plants on control plots (no late top-dressings) and on NK plots were much smaller. There was also evidence from Kennington and Wareham that the addition of both nutrients as top-dressings reduced the foliar concentration of K, but at both these nurseries, responses to late applications of K were small.

Extension of Late Top-Dressed Seedlings (1966) into Transplant Lines

To determine whether late top-dressings of N, K, or both, have any effect on growth the subsequent year, seedlings which had received these treatments in 1966 were lined out in the same experimental layout, for observations during 1967.

Initially, treatments affected the date of flushing; plants which had received N flushed first, K next, and controls (no late top-dressings) last. At Wareham, where the progress of flushing was closely followed, N plots were sometimes two weeks in advance of control plots.

Severe frosts were experienced in early May at all the nurseries, with resultant damage to some species. At Alice Holt, only Japanese larch was severely damaged by frost, and assessment shortly afterwards showed that, compared with controls, trees on K plots had significantly less damage at one per cent level, and that trees on N plots were also slightly less damaged (but not significantly so). At Wareham, Sitka spruce and European larch were frost damaged, but although on K plots Sitka spruce were the least damaged and on N plots the most damaged, differences were small. At Kennington no plants were damaged by frost.

By the end of the growing season there were no differences in growth or survival on any species except Sitka spruce at Kennington, where plants that had received N late top-dressings were significantly taller.

Slow Release Fertilisers including "Enmag"

The largest part of the nursery research programme has been taken up by experiments into the use of relatively insoluble ("Slow-release") fertilisers, and in particular magnesium ammonium phosphate mixed with potassium chloride or potassium sulphate, as formulated commercially by Scottish Agricultural Industries under the name "Enmag".

Forms of "Enmag"

Experiments at Newton, Devilla, Glenfinart and Fleet nurseries compared "Enmag" made with potassium chloride with "Enmag" made with potassium sulphate in 1967, and also "Enmag"/chloride made in 1967. The 1966 material had only one-third of its total nitrogen content insoluble in water, whereas the 1967 material had two-thirds insoluble.

There were no consistent differences in Lodgepole pine and Sitka spruce numbers and heights at the end of the season, as between plots treated with the types of "Enmag". "Enmag" slightly reduced seedling numbers in proportion to the rate of application, compared with controls which received no fertilisers.

At the end of the season, seedlings were taller on plots treated at the higher rates, although the differences were small.

Forms of "Enmag" in relation to "Scorch" of Transplants

Damage to transplants, mainly of *Abies* species and Norway spruce, has been associated with the use of potassic superphosphate and has been attributed mainly to the chloride content of the fertiliser. The two forms of "Enmag" were included in experiments to test the possibility that the formulation containing chloride might give rise to more damage than that containing sulphate.

At Alice Holt, Kennington, Crumbland and Wareham, fertiliser regimes based on "Enmag", made with either potassium chloride or potassium sulphate, were compared with regimes based on potassium metaphosphate or potassic superphosphate.

At Kennington, typical damage ("scorch") was noticed on *Abies procera* receiving potassic superphosphate, and a few plants died. However, at no nursery was there any significant difference in the survival of any species under any of the fertiliser regimes.

Late April and May was a very wet period for all southern nurseries and this, as in the previous year, was probably the reason why there was so little damage clearly attributable to high concentrations of fertiliser salts.

Damage associated with excess fertiliser did occur, however, in two other series of experiments—the "long-term experiment" series in Scotland, started in 1967, and in a series of English experiments comparing fertiliser regimes. Both occurrences are detailed below.

Effect of Repeated Use of "Enmag"

The long-term experiment (5/66) at Fleet, which was reported in 1966, was continued in 1967 and was sown with Lodgepole pine, Grand fir, and Japanese larch. Some results are given in Table 8. Analyses of soil samples collected in February 1968 show that the soil pH value was somewhat higher in 1967 in "Enmag"-treated plots than in any other treatment, although the increase was not related to the rate of application of "Enmag". There was a marked reduction in pH on plots where "Enmag" was omitted in 1967 and top-dressings with "Kay-nitro" applied instead. The very marked drop in Mg per cent in the soil following this treatment, indicates that a high magnesium residue from "Enmag" in the soil, if found to be detrimental, could well be reduced substantially in only one year by omitting "Enmag" and top-dressing with "Kay-nitro" instead. The soil phosphate content in the plot that was given the highest rate of "Enmag" two years running is now higher than after one year's dressing, but no damage has occurred to the plants.

Wherever any fertiliser had been applied in the spring, there were slightly fewer seedlings of all species than on plots where only top-dressing had been applied. The best growth has still been on plots with repeated "Enmag", but even "Enmag" in 1966 followed by "Kay-nitro" in 1967 has produced taller seedlings than potassic superphosphate plus "Nitrochalk".*

Similar long-term experiments to those described above were established in 1967 at Newton, Tulliallan and Benmore in transplant lines of Lodgepole pine,

* Mean height as one-year-old seedlings was poorest with repeated "Kay-nitro", even poorer than the control with no fertilizer at all. This was probably due to the plant nutrition being out of balance as only nitrogen and potash were applied.

Sitka spruce, Western hemlock and Grand fir. Grand fir failed to survive so well as other species. Table 9 shows the contrast between survival of Lodgepole pine and Grand fir. Neither species was adversely affected by "Enmag", but while the pine was almost insensitive to high applications of potassic superphosphate applied before lining out, the fir was severely damaged by similar dressings at Newton, less so at Tulliallan and not at all at Benmore. At Benmore the soil texture is heavy and rainfall high; at Tulliallan the soil is just as heavy but the rainfall is only one-third that at Benmore, while at Newton the soil is much lighter and the rainfall is 20 per cent less than at Tulliallan. The lighter the soil and lower the rainfall, the more liable Grand fir appears to be to burning by excess fertiliser.*

TABLE 8

PLANT AND SOIL DATA FROM EXPERIMENT 5/66 EXTENSION 1967, FLEET NURSERY, KIRKCUDBRIGHTSHIRE

Fertilisers applied		Soil Analyses					Grand fir 1+0	Japanese larch 1+0
in 1966	in 1967	pH value	Chemical CaO%	% oven-dry weight			Total number per sq m (sq yd)	Mean height cm (in)
				MgO	P	K		
"Enmag"	"Enmag"	5·3	0·068	0·053	0·025	0·013	250 (209)	12·1 (4·7)
"Enmag"	"Kay-nitro"*	4·6	0·044	0·004	0·011	0·010	254 (212)	10·0 (3·9)
"Enmag"	No fertilisers	5·0	0·038	0·012	0·010	0·007	247 (206)	7·1 (2·8)
"Kay-nitro"*	"Kay-nitro"*	4·6	0·021	0·003	0·005	0·009	332 (278)	2·8 (1·1)
Fisons 48 + "Nitrochalk"*	Fisons 48 + "Nitrochalk"*	4·9	0·063	0·002	0·010	0·006	228 (190)	7·5 (3·0)
No fertilisers applied	No fertilisers applied	4·8	0·026	0·002	0·004	0·004	340 (284)	4·3 (1·7)
Satisfactory values		4·5—5·5	0·080	0·006	0·005	0·009	1,200 (1,000) viable seeds sown	5·0 (2·0)

Note: * These fertilisers were applied as two top-dressings in mid-July and mid-August. The other fertilisers were applied about two weeks before sowing.

"Enmag" and Potassium Metaphosphate

A new series of experiments was started at Alice Holt, Kennington and Wareham nurseries comparing fertiliser regimes based on "Enmag", or potassium metaphosphate, or potassium superphosphate. Nitrogen was supplied either in highly soluble form as "Nitrochalk", or in the slowly soluble form as formalised casein. All regimes were tried with, and also without, late top-dressings of nitrogen and potassium. Fourteen species were tested in seedbeds, and sixteen in transplant lines.

The regimes selected were based on the information available on plant responses to the fertiliser in question.

Results both on seedbeds and transplants were satisfactory in that there were few outright failures under any regime. Plants on "Enmag" plots in mid-season usually looked healthier than others, and at Alice Holt maintained their lead over other plants given other treatments. At Wareham this was only true for hemlock, while at Kennington plants on "Enmag" had lost any early advantage by the end of the season.

* *Note* also from Table 9 that the insoluble "Enmag", although applied at twice the rate (in weight of fertiliser) of the potassic superphosphate, has caused little reduction in survival.

TABLE 9

SURVIVAL OF 1 + 1 TRANSPLANTS

per cent

Nursery	Species	Basal Fertiliser	Rate of Application*				
			0	½	1	2	3
Newton, Moray	Lodgepole pine	"Enmag"	93	91	90	88	86
		Potassic superphosphate		88	88	86	85
	Grand fir	"Enmag"	96	95	94	94	89
		Potassic superphosphate		95	83	58	22
Tulliallan, Clackmannanshire	Lodgepole pine	"Enmag"	93	97	97	95	94
		Potassic superphosphate		99	93	98	96
	Grand fir	"Enmag"	95	96	97	97	96
		Potassic superphosphate		95	95	94	80
Benmore, Argyll	Lodgepole pine	"Enmag"	96	96	87	90	92
		Potassic superphosphate		82	91	97	83
	Grand fir	"Enmag"	98	98	98	97	96
		Potassic superphosphate		98	98	96	97

Note: *Rate 1 is equivalent to 140 kg per ha (125 lb per acre) of potassium in each fertiliser.

Transplants showed fewer differences than seedlings. At Kennington, on plots given potassic superphosphate, Grand and Noble fir both showed signs of fertiliser damage in July and a number of plants died.

WEED CONTROL

Simazine on Transplants

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

At Wareham, none of the seven conifer species were affected at any of the rates. At Kennington only Corsican pine of the seven species showed any adverse effect from simazine applications, the 2·24 kg (2 lb) rate reducing the mean height of Corsican pine transplants to an extent significant at the 5 per cent level. Since the higher rates of 4·48 and 8·95 kg (4 and 8 lb) showed no such effect on Corsican pine, this result is anomalous.

Weed control was generally excellent at 4·48 and 8·95 kg (4 and 8 lb) rates, adequate at the 2·24 kg (2 lb) rate, but somewhat erratic at the 1·12 kg (1 lb) rate.

Herbicides on Seedbeds

Continuing the search for a safe and more effective post-emergence weed-killer on seedbeds, propazine at 0·56, 1·12 and 2·24 kg active ingredient per hectare (½, 1 and 2 lb per acre) and a new proprietary herbicide from the Shell Company, named SD. 11381, at 0·28, 0·56 and 0·84 active ingredient per hectare (¼, ½ and ¾ lb per acre), were sprayed in 674 litres of water per hectare (60 gallons per acre) on to seedbeds at intervals of from one to six weeks after emergence of the seedlings.

Both propazine and Shell SD. 11381 killed plants on many plots and reduced the mean height of survivors. Generally the effects were the more severe the higher the rate per hectare, and the sooner after emergence the herbicide was applied. At Alice Holt, Scots pine was less affected by propazine than Japanese larch, numbers of pine seedlings being reduced by up to 8–15 per cent, compared with 16–50 per cent for larch. At Kennington Sitka spruce was less affected than Western hemlock. Yield and growth of spruce seedlings treated at 0·56 kg of propazine per hectare (½ lb per acre) six weeks after emergence, was similar to that on control plots; but on corresponding plots the number of hemlock seedlings was 30 per cent less than on untreated plots.

The results with Shell SD. 11381 paralleled those with propazine. Sitka spruce and Scots pine were more resistant than Japanese larch and Western hemlock, the spruce again being unaffected in yield or growth by sprays at 0·28 kg per hectare (¼ lb per acre) applied six weeks after the first crop seedlings had emerged.

The effects of propazine and SD. 11381 on the time needed to weed plots are shown in Table 10.

TABLE 10

HAND WEEDING TIMES ON HERBICIDE-TREATED PLOTS EXPRESSED AS A PERCENTAGE OF WEEDING TIMES ON CONTROL PLOTS, KENNINGTON, 1967

Time and Rate of Herbicide Application	One week after Emergence			Three weeks after Emergence			Six weeks after Emergence		
	0·56 P *or* 0·28 S (½ P *or* ¼ S)	1·12 P *or* 0·56 S (1 P *or* ½ S)	2·24 P *or* 0·84 S (2 P *or* ¾ S)	0·56 P *or* 0·28 S (½ P *or* ¼ S)	1·12 P *or* 0·56 S (1 P *or* ½ S)	2·24 P *or* 0·84 S (2 P *or* ¾ S)	0·56 P *or* 0·28 S (½ P *or* ¼ S)	1·12 P *or* 0·56 S (1 P *or* ½ S)	2·24 P *or* 0·84 S (2 P *or* ¾ S)
Propazine	66	42	15	40	25	19	54	44	20
Shell SD.11381	70	53	27	80	55	41	89	75	88

Notes: (1) 0·28, 0·56, 0·84, 1·12 and 2·24 are rates of herbicides applied per hectare in kg active ingredient.
(2) P = Propazine; S = Shell SD. 11381.

Weeding times from Kennington (Table 10) showed propazine to have been more effective than SD. 11381.

At Alice Holt no pre-emergence sprays had been used on plots to be treated with propazine or SD. 11381, and weeds, especially the grass *Poa annua*, were so big when the spraying dates came round that they presented an unusually severe test for the herbicides. However, good control of weeds was obtained with higher rates of propazine.

It is clear that 1·12–2·24 kg of propazine per hectare (1–2 lb per acre) and 0·56–0·84 kg Shell SD. 11381 per hectare (½–¾ lb per acre) did substantial damage to conifer seedlings. However, the lowest rate of propazine—0·56 kg per hectare (½ lb per acre), applied six weeks after emergence, markedly reduced hand weeding times and had no measurable ill-effect on Scots pine and Sitka spruce seedlings.

NEW TYPES OF PLANTING STOCK

Production of Tubed Planting Stock

During the summer months experimental work was started on the raising of conifer seedlings in small plastic tubes for use as planting stock. In Canada such tubed seedlings, raised under intensive conditions and planted out when only a few weeks old, have been used on a large scale for spring and summer planting during recent years. It is felt that tubed seedlings could well have an important place in British forestry practice, and the purpose of the present experiments is to develop suitable methods for their large-scale production in Britain.

Heated "Twinlight" frames at two research nurseries (Bush and Newton) were used to provide partial environmental control for the experiments, which were designed to study the influence of such factors as soil medium for filling the tubes, level of fertilisation, depth of seed cover, and tube dimensions, on the germination and early growth of Lodgepole pine and Sitka spruce seedlings. For these purposes, and for the production of stock to be used in the associated forest experiments, a "standard" technique was adopted, based on Canadian practice. Thin-walled polystyrene tubes were used, 7·6 cm long and × 1·6 cm internal diameter (3 in. × ½ in.), slit down one side, and filled with a mixture of equal parts by volume of horticultural peat and medium sand, to which the slow-release compound fertiliser "Enmag" had been added at a rate of 1·5 kg/m^3 (1½ oz/ft^3). One seed was sown in each tube and covered with a 3 mm (⅛ in.) layer of medium sand. Other soil mixes, tube sizes, etc. were then compared with the "standard" treatment. In all, eleven experiments were carried out between May and September.

Germination in the experiments was variable and often very low, particularly in the case of Lodgepole pine. Some experiments were resown with pine seed of higher germinative capacity, and this resulted in a marked improvement in germination, but even with this the germination figures for both species were frequently less than 50 per cent. Growth of the seedlings was also variable and somewhat disappointing, as they appeared to pass through a period of semi-check three to four weeks after germination. Subsequently, normal growth was resumed, and at eight weeks from sowing the average heights for pine and spruce were respectively 2·5 cm and 2 cm (1 in. and ¾ in.). It is thought that both germination and growth were affected by unfavourable growing conditions in the frames used. In particular, it was difficult to avoid undesirably high temperatures during sunny weather, despite regular watering and the use of shading.

Because of the growth problems outlined above, the results of individual experiments must be inconclusive, and it is not proposed to discuss these further. However, taking the experiments as a whole, there was little evidence to suggest that any of the other treatments gave better results than the "standard" one. This will therefore continue to be used as a standard until evidence indicates that modifications will give improved results.

During 1968 it is planned to carry out a more comprehensive experimental programme on the various aspects of tubed seedling production. For this work, polythene-covered and conventional glazed greenhouses will be used in place of the frames used during 1967. It is hoped that the better environmental control obtainable will lead to better and more uniform germination and growth of seedlings.

Forest Use of Tubed Planting Stock

Experiments were begun on the use of tubed seedlings as planting stock. For the present it has been decided to concentrate on their potential use in the large afforestation programmes now being undertaken on poor land in North and West Scotland. The advantages offered by tubed stock would be of greatest benefit there.

For the initial work, two sites were chosen in North Scotland—at Glengarry Forest (Inverness-shire) on wet heathland, and at Naver Forest (Sutherland) on deep infertile peat. Both sites are considerably exposed and should provide testing conditions for the seedlings. Because of difficulties with the nursery research programme, seedlings were not available for planting until the beginning of August. However, between August and October six small experiments were established, three at each site, to obtain preliminary information on the influence on seedling survival and growth of such factors as date of planting, age at planting, animal damage and type of ploughing. Both Lodgepole pine and Sitka spruce seedlings were used, planted into normal plough ridges by means of a dibble.

First reports of survival in these experiments have been encouraging, although some frost-lift has occurred at Glengarry. It will be of interest to see how well the seedlings grow during the coming growing season—their first full season in the field.

During 1968 it is planned to carry out a considerably larger experimental programme at the two sites used in 1967, and at a site in West Scotland. Planting will take place between May and October, and will investigate a wide range of factors thought likely to influence the behaviour of tubed seedlings in the forest.

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AFFORESTATION OF DIFFICULT SITES

Planting on High and Exposed Sites in the North and Outlying Islands

One new trial plantation at Helmsdale (Sutherland) has been planted, and an above-standard level of nutrition supplied. An adjacent experiment will compare a range of nutritional inputs. Results from this experiment will be used to determine future nutrition of the trial plantation.

Three small plots of Leyland cypress have been planted at South Kintyre (Argyll), Carrick and Glentrool (Kirkcudbrightshire) in exposed situations where its ability to withstand exposure will be compared with Sitka spruce.

In co-operation with the Zetland Education Department, a new trial plantation is being planted at Voxter in the Shetland Islands, where it will form a shelter belt at the new Crofters' Training School and will provide an opportunity to test a larger block of recommended provenances than are represented in the older plantations. Assessment of exposure by tatter flags will be serviced by the Crofter Training School.

Two trial plantations have been selected on North Uist, and following approval by the local owners, tenants and Crofters Commission, acquisition is proceeding. These will be established with the aid of Forestry Commission staff stationed on the Isle of Lewis.

Plantations at High Elevations in Wales

No new work has been undertaken during the year at the five sites in mid-Wales. Tatter flags, changed at monthly intervals, were maintained from early May to the beginning of December. The mean daily tatter rate continues to be high, varying from 25·7 cm^2 (3·98 in.^{2}) at Hafren Forest (elevation 732 m, 2,400 ft) to 17·4 cm^2 (2·71 in.^{2}) at Myherin Forest (elevation 533 m, 1,750 ft). Anemometers were read throughout the year, but the winter measurements are somewhat unreliable due to the build-up of ice. For the period mentioned above the mean wind speed recorded was 27·0 km/h (16·8 mile/h) at Hafren, and 20·3 km/h (12·6 mile/h) at Myherin.

The growth of Sitka spruce continues to be quite good at all sites except Hafren. At Radnor Forest (elevation 610 m, 2,000 ft) the mean height is 82·5 cm (2·75 ft) at six years, whilst at the highest plot Mynydd Ddu (elevation 777m, 2,550 ft) the mean height is 55·2 cm (1·81 ft) after seven years.

At Hafren the survival and growth of Lodgepole pine and Noble fir is very disappointing, whilst a small trial of Japanese larch and numerous minor species has been a complete failure.

The small trial using potted plants and individual shelters, mentioned in last year's *Report*, is to be repeated on a larger scale in 1968. The use of corrugated iron shelters is to be discontinued, however, as the sheltered plants appear to be starved of light. Also it is thought that zinc toxicity from the galvanised iron sheeting may be harming the plants.

Industrial Sites

Liaison has been maintained with the Livingston New Town Development Corporation and associated county councils. In small-scale planting trials, first-year survival of all species planted in three seasons in 1967 has been good, pot-planted trees being particularly successful. Only those plants which were flushed before planting have failed. It is, however, premature to consider the trials successful until they have been carried on in other seasons and continuing health and growth is assured. Further planting will be carried out in 1968.

Meetings have again taken place in the South with representatives of industry and local governments, and it is expected that the discussions will lead to small trials being undertaken. Though a wide range of problems has been reviewed, one of the major sources of concern at the moment appears to be the restoration of filled gravel pits. While many of the materials dumped in pits seem capable of supporting adequate tree growth, the increased rate of tipping of household refuse may lead to difficulties due to decomposition and settlement.

Wind-loosening of Lodgepole Pine

Windsway in vigorous coastal provenances continues to cause concern, and a small experiment attempting to influence the root/shoot ratio by means of a growth regulator was completed. N-dimethylaminosuccinamic acid, commercially known as B-9, was tested at five rates and three dates of application as foliar sprays using concentrations of 200–7,200 parts per million. No visible reaction to any treatment was apparent after the first year nor in the second, in spite of subsequent weekly application at a heavy rate.

Estimation of Exposure by Flag Tatter

In an intensive study of air flow, 43 flags have now had two years' consecutive exposure in an area of approximately 81 hectares (200 acres) on the Whitrope beat of Wauchope Forest (Roxburghshire).

At each flag station of known elevation, exposure was assessed in three ways viz:—

(1) By measuring the angle to the horizon in 16 compass directions by means of an Abney level. (Howell and Neustein, 1966.)

(2) By a subjective exposure score of 1 to 10, estimated by an experienced forester.

(3) At the same time as the above overall subjective exposure was scored, the forester estimated exposure in each of eight compass directions using a score of 1 to 5.

The object of these assessments was to find a parameter, or combination of parameters, which could be used in future as a means of assessing exposure or supplementing tatter-flag data. The amount of variation of tatter which could be explained by these three exposure assessments was 57 per cent, 60 per cent and 51 per cent respectively. An additional 8–18 per cent was covered by including elevation in the calculation.

It appears therefore that, under the prevailing circumstances, skyline-angle assessment has some potential, and current investigations are concerned with investigating methods of weighting particular compass directions.

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Cultivation of Heathland

Experiment 2 planted in 1962 at Inshriach Forest (Inverness-shire) has now been assessed after six growing seasons. The experiment was established on *Calluna* heath on a typical fluvio-glacial terrace in the Spey valley. The soil may be described as a Humus Iron Podzol, derived from deep deposits of mixed sands and gravels. There are occasional traces of a weak ironpan, but there are no signs of induration in the subsoil. At the time of planting (1962), ploughing was not considered, by the local field staff, to be essential for successful establishment.

The experiment compares Scots pine and Lodgepole pine, with and without phosphate, on three forms of soil treatment. The experiment design involves split plots, in randomised blocks, with three complete replications of each treatment. The main results at six years are summarised in Table 11.

TABLE 11

INSHRIACH EXPERIMENT 2, PLANTED 1962
CULTIVATION, MEAN HEIGHTS WITH AND WITHOUT PHOSPHATE

cm (ft)

Cultivation Treatment	Scots pine		Lodgepole pine	
	With phosphate	Without phosphate	With phosphate	Without phosphate
No ploughing	26·21 (0·86)	27·43 (0·90)	26·52 (0·87)	27·43 (0·90)
Tine, spaced furrow ploughing	48·77 (1·60)	45·11 (1·48)	48·16 (1·58)	49·38 (1·62)
Tine, complete ploughing	59·13 (1·94)	52·73 (1·73)	65·84 (2·16)	63·40 (2·08)
Standard Error (±)	1·40 (0·046)		1·65 (0·054)	

The differences due to phosphate treatment were not significant, but the differences due to cultivation treatments were very highly significant. Total height growth to date has been limited by heavy cropping by the large game bird known as Black grouse (*Lyurus tetrix britannicus*). Local reports indicate that the plants in the "complete ploughing" plots have suffered most, due to their emergence from winter snow cover while most other plants in the experiment were still protected. The mean heights do not represent the true growth differences between the cultivation treatments, since the weight or volume of the aerial part of each tree on "complete cultivation" is perhaps ten times greater than those on the unploughed control plots.

These results reinforce the arguments advanced last year (*Report* for 1967, page 44) that *complete* cultivation of certain heathland sites may be a profitable form of site treatment.

During the year a number of exploratory surveys were carried out in co-operation with the Soil Survey Section of the Planning and Economics Branch. The information gained confirms that the Ironpan Soil, once believed to be the typical problem soil of the upland heaths, does in fact occur in a wide variety of climatic situations. In upland Wales, for example, this type and related soils are now known to be of major importance. The impression gained from these surveys suggests that improvements in cultivation technique are required to exploit the full potential of such soils.

An important result of recent soil survey work in north-east Scotland has been the recognition of the extent of occurrence of indurated gley soils in this region. Research work has been in hand for a number of years on what was believed to be a relatively minor local problem. The new information available indicates that much greater emphasis is required, to obtain an early answer to the cultivation and drainage problems posed by these soils. (See also page 118).

Drainage

Surface Water Gleys and Peaty Gleys

The drainage experiment at Rosedale, Allerston Forest (Yorkshire), on a surface water gley, continues to attract interest, and detailed studies of the soil moisture regime have continued. New tensiometer equipment was tested by Dr. D. J. Read of Sheffield University and its field reliability established, and further instrumentation is planned for 1968. Foliage analysis confirms a suspected shortage of phosphate on this site, but also disclosed an unexpected shortage of potassium; remedial manuring will be carried out during 1968.

Advisory services continued to be in demand during the year, including several requests for assistance from the private woodlands sector. A problem resulting from the success of well-aligned drainage patterns has been the erosion factor in main drains intended to carry off the resulting run-off loads. This problem arose in an acute form in the pole-stage draining experiment in a peaty gley at Kershope Forest (Cumberland), with severe damage to existing culverts on watercourses carrying additional flood loads.

With increasing application of the recommended drainage patterns (*Research Branch Paper* No. 26), greatly increased peak run-off levels must be anticipated, particularly in the early years following drainage. Where drainage patterns can be led directly to large existing watercourses, this problem need not be unduly severe. However, where drainage water requires to be led through existing roadworks via small streams or by forest ditches, the suitability of existing culverts for the changed conditions requires to be checked in advance.

The current series of experiments in Southern England and Wales is now almost complete. Initiated in 1964, the objectives can be summarised as:—

(1) To investigate the effect of two drain depths, 0·6 metres (2 ft) and 0·9 metres (3 ft), and three drain spacings, 15 metres (50 ft), 30 metres (100 ft) and 45 metres (150 ft) on:
  - (*a*) the soil moisture regime
  - (*b*) the root development and stability
  - (*c*) crop volume production;

(2) To assess the most economical and effective combination of drain depth and spacing;

(3) To assess the effect of fertiliser in the presence and absence of drainage.

Crop types varying from newly planted to first thinning stage are represented, but the species Sitka spruce is common throughout. Apart from the one experiment at Halwill Forest, the series is in Wales, there being one each at Clocaenog Forest and Hafren Forest and two at Towy Forest. Initial work on the last "repeat" at Crychan Forest will continue through the summer of 1968.

The soil moisture regime is being investigated by measuring at weekly intervals the level of water in bore-holes. The weekly accumulated rainfall is measured at the same interval, and self-recording rain gauges are also being used. The data obtained from these weekly measurements is processed by computer and graphs are automatically plotted on a graph-plotter. Part of one of these graphs is shown as Figure 1. This shows the results obtained from the closest-spaced drains, i.e. 15 metres (50 ft), and as can be expected, the differences in water depth with the various drain depths are greater than with 30 metres (100 ft) spacing and 45 metres (150 ft) spacing. The closeness of the lines in the pre-drainage period suggests that the randomly sited replications have accounted for any variation in the site water table. In the first winter after drainage quite large differences in water depth have occurred. Although the water level does rise to within a few inches of the soil surface, this quickly falls again, whereas in the pre-draining period levels fall only slowly.

In other experiments in the series the plotted graphs suggest that the number of bore-holes is insufficient to account for site variations, and so further bore-holes are to be installed. Also it would seem that some of the 24-inch bore-holes have penetrated an impermeable layer and so these must by replaced by shallow ones.

Deep Peats

Early growth of Sitka spruce and Lodgepole pine is promising at the large experiment at Clocaenog Forest, particularly so where the cultivation was by single mouldboard ploughing, and where a high level of PK fertiliser was applied. Hand maintenance of the deep main drains is proving an expensive operation, which in certain instances is required annually.

At Rumster Forest (Caithness), work started on a new drainage experiment upon an area of very deep blanket bog. The bog ranges in depth from 2·7 m to 5·8 m (9 ft to 19 ft) and is typical of extensive tracts in north Scotland at present considered to be unplantable, mainly due to the problem of securing adequate drainage. Despite severe and sometimes spectacular tractor-bogging troubles, most of the planned drainage treatments were achieved, and the experiment is now ready for planting.

Laboratory analysis of peat samples from this bog suggests that the peat is no more deficient in major nutrients than many lowland raised-bogs, which are at present considered to be plantable. The physical problems posed for the operation of mechanical equipment upon deep peat deposits have not as yet been fully solved.

In the drainage experiment at Flanders Moss, Achray Forest (Stirlingshire), deepening of the main drains was carried out by hand labour in the absence of suitable mechanical plant. Bore-hole studies indicate that the watertable response to drain deepening was relatively rapid, but it will be some years before a detectable response by the tree crop can be expected.

After three growing seasons, the best growth of Lodgepole pine has been upon plough ridges produced by the single-mouldboard turfing plough. This accords

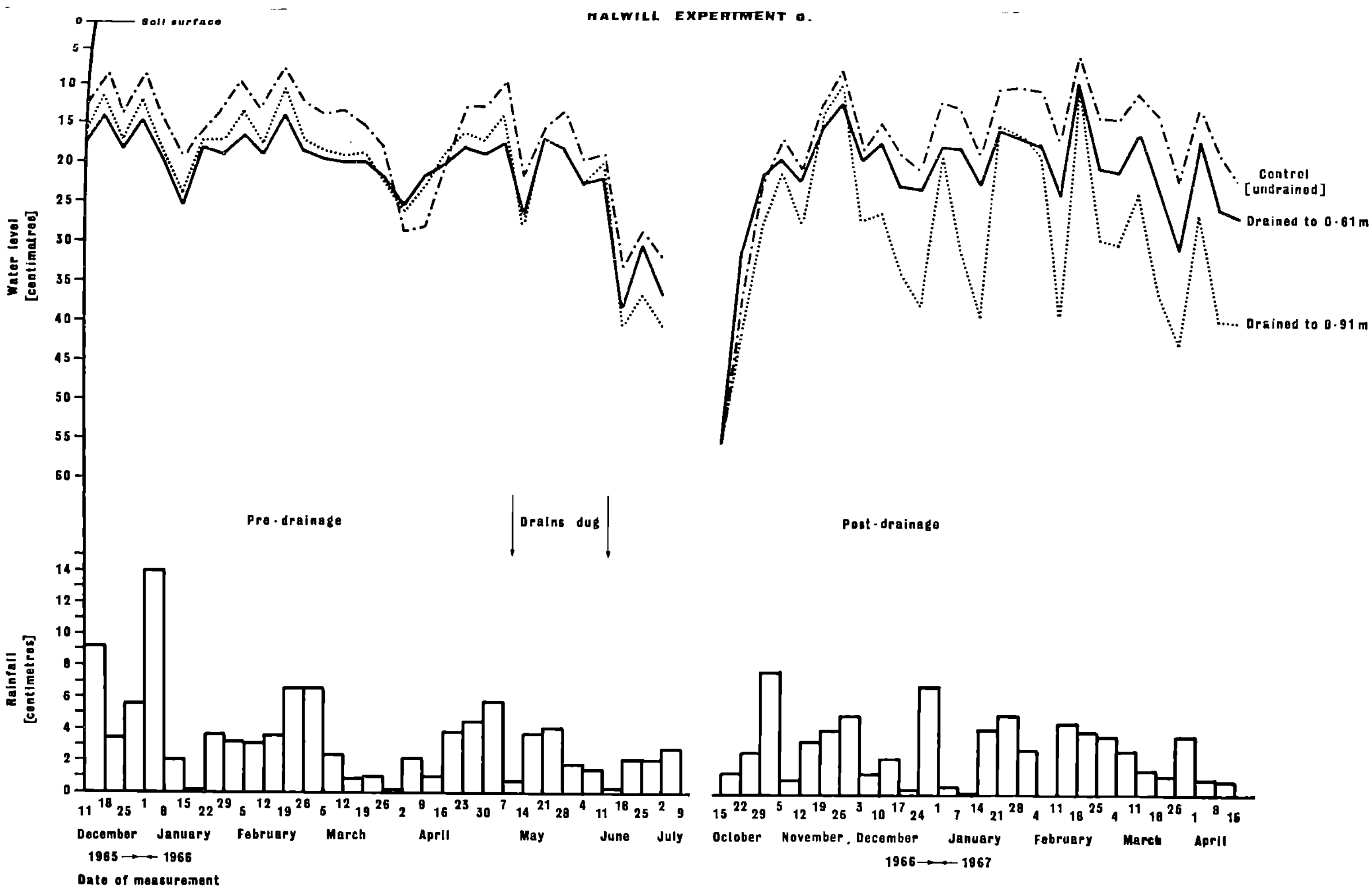

FIGURE 1: Drainage of gleyed soils, Halwill Forest. The mean level of water in bore-holes during the winter before drainage and during the subsequent winter. Drain depths are 0·61 metres (2 ft) and 0·91 metres (3 ft), at a spacing of 15 metres (50 ft). Also shown is the undrained control. Rainfall is indicated at foot of diagram.

with previous experience and was attributed (Binns, 1962) to improved mineralisa- of nitrogen (accentuated by phosphate addition) under the thicker turf produced by this type of plough, as compared with the double-mouldboard turfing plough.

In this experiment, various forms of ploughing are compared, single-mould-board and double mouldboard, both pure and mixed, and Glenamoy tunnel ploughing, the latter producing a smaller ridge of turf than either of the standard plough types. Height growth at three years is clearly correlated with the size of turf ridge, and does not appear to be directly correlated with drainage effects at this stage.

Foliage analysis suggests a possible mechanism for the levelling-off of growth on single- and double-mouldboard ploughing after ten years, as previously reported (Lines and Neustein, 1966). At this stage, the larger plants on single-mouldboard ridges have greater needle weights and higher nitrogen contents than plants on other forms of ploughing, but have lower needle concentrations of phosphate and potassium. If phosphate and potassium supplies on the site are allowed to become deficient, then the effect would be experienced first by the larger plants, allowing the smaller plants which are less deficient to catch up.

If, however, repeat fertilisation with phosphate and potassium according to need is accepted as standard practice, the initial advantage gained by plants upon large turf ridges may be a lasting effect. Developments in this experiment will be observed with interest, since the results could affect the design of future ploughing equipment.

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NUTRITION OF FOREST CROPS

Manuring of Young Crops on Peat Soils

Four more experiments comparing types of rock phosphate similar to the one at Shin Forest, Sutherland, described in the 1967 *Report* were laid down during the past year. Foliage samples collected for chemical analysis from the South Coastal Lodgepole pine in the Shin experiment at the end of September, 1967, i.e. at the end of the second growing season, indicate that so far the types of rock phosphate have had similar effects on the needle weight, and the concentrations of nitrogen, phosphorus and potassium on the needles, and from this the only interesting significant effect was an interaction on needle nitrogen concentration between rates and methods of application. Increasing the rate broadcast increased the nitrogen percentage while the opposite happened with spot application (see Table 12). The reason for the heavier spot-applied rates having a lower nitrogen percentage is probably because the methods of application differed. At the two heavier rates the phosphate was applied in two or four spots near the plants and not thrown at them as were the two lighter rates: hence more nitrogen would be mineralised near the plants given the lighter rates. The important conclusion from these analyses is that unground Gafsa phosphate appears to be having a similar effect to ground Gafsa phosphate.

Also at Shin Forest, another experiment on South Coastal Lodgepole pine compares ground rock phosphate with potassic superphosphate (Fisons 48) broadcast at planting. This experiment is identical with the one at Racks Moss, Mabie Forest, Dumfries-shire, described on page 49 of the 1967 *Report*. It is interesting to note that, at three years from planting, the trees at Racks Moss were 30 cm (1 ft) taller than those at Shin where blast damage has been noted. Nutrient concentrations in the needles from both sites did not differ markedly.

TABLE 12

NITROGEN CONCENTRATION IN YOUNG LODGEPOLE PINE IN SHIN FOREST, EXPERIMENT 8 P.66

(Per cent Oven-dry Weight)

Method of Application	Rate of Application kg P/ha (lb/acre)			
	17(15)	34(30*)	67(60)	134(120)
Broadcast	1·78	1·81	2·07	2·17
Spot	2·00	2·11	1·92	1·88

* 30 lb P is equivalent to 2 cwt Gafsa rock phosphate

Last year (*Report* for 1967, page 49) we described how the calcium in phosphorus fertilisers is apparently responsible for increasing the N concentration in the needles of trees on deep peat, perhaps by raising the level of microbiological activity. This effect has only been noticed in the last few years, since a PK fertiliser containing no calcium, namely potassium metaphosphate, has been used. While fundamental studies will be necessary to find out why this happens, a new trial is now being established at Borgie Forest, Sutherland, to compare rates and types of calcium compounds, and to compare calcium and magnesium compounds on deep acid peat. The latter comparison is included to determine whether the calcium is required as a nutrient by micro-organisms, or whether it only acts by locally raising the pH value of the peat substrate.

This effect of N on deep peats has often been noticed where conventional Ca-containing fertilisers, such as potassic superphosphate, have been used in Sitka spruce in check, but the improvement is often only temporary. It seems that periodic additions of N will be needed to maintain growth on deep acid peats, such as those at Arecleoch, Ayrshire, and Selm Muir, Midlothian. Improved nitrogen supply may also be provided by placing fresh peat on the ground surface, and this is shown by the results from an experiment at Castle O'er Forest, Dumfries-shire (Twiglees Experiment 5/52 Extension 63). Fertilisers were put on in 1963 when the trees were about 1·5 m (5 ft) tall and the area was ploughed with deep cross-drains in 1964. The trees growing adjacent to the ridge turned out by the deep drainer plough have been assessed separately. Table 13 gives the results of shoot growth assessments and of foliage analysis from this experiment and shows the remarkable improvement in growth caused by the deep-drainer ridge. From the foliage analysis done three years after the draining it is obvious that the improvement is due to an increase in nitrogen. It is also interesting to note the low nitrogen percentages in the PK and NPK treatments only four years after fertilising was done indicating that a further nitrogen application is now required if reasonable growth is to be maintained.

TABLE 13

FOLIAGE ANALYSIS DATA AND ANNUAL SHOOT GROWTH OF SITKA SPRUCE IN CASTLE O'ER FOREST, EXPERIMENT TWIGLEES 5/52, EXTENSION 63

Treatment	Nutrients applied kg per ha			Foliage Analysis–Sept. 1966				Annual Shoot Growth cm	
				Needle Wt. mg	% oven-dry weight				
	N	P	K		N	P	K	1962	1966
No fertilisers									
—not drainside	0	0	0	5·6	0·85	0·18	0·54	7·0	11·0
—drainside*	0	0	0	6·2	1·34	0·19	0·57	6·7	26·8
PK									
—not drainside	0	96	94	5·3	0·98	0·25	0·82	5·8	20·1
—drainside*	0	96	94	—	—	—	—	5·8	23·5
NPK									
—not drainside	102	97	90	5·3	0·92	0·22	0·78	4·3	29·9
—drainside*	102	97	90	—	—	—	—	6·4	38·7

* "Drainside" means trees adjacent to deep-drained ridge.

On a very poor, deep, raised bog at Eddleston Forest, Midlothian, four nitrogen compounds were compared as top-dressings on Lodgepole pine planted in 1959, the top-dressings being applied in June, 1966. At the end of 1966, ammonium nitrate produced the highest nitrogen concentration in the needles, but at the end of 1967, urea has produced the highest nitrogen concentration. Ammonium nitrate has produced the longest mean shoot length in 1967, but there is no significant difference between the shoot lengths for ammonium nitrate and urea (see Table 14). This indicates that urea, which is being used in large-scale trials, is likely to be no poorer than "Nitram" (ammonium nitrate) on the acid peats.

TABLE 14

FOLIAGE ANALYSIS DATA AND SHOOT LENGTH OF LODGEPOLE PINE IN EDDLESTON FOREST, EXPERIMENT 5/66

Treatment	Needle Wt. (mg)	Nitrogen (% oven-dry weight)	Shoot Length (cm)
Ammonium sulphate	14·7	1·50	32
Ammonium nitrate ("Nitram")	13·3	1·46	35
Calcium nitrate	13·5	1·44	29
Urea	17·1	1·65	32
No nitrogen applied	14·0	1·34	26

Another example of the effect of nitrogen on Lodgepole pine on poor, acid peat is on Cardross Moss, Achray Forest, Stirlingshire, where NPK, PK and P fertilisers were applied to 6- and 10-year-old Lodgepole pine in late May, 1966 (Experiment 4/66). Table 15 gives some of the results from this experiment, and shows that "phosphorus only" is barely better than the control, "phosphorus plus potassium" has produced a marked improvement, while with the addition of nitrogen the improvement is even more marked. Notice the marked drop in 1967 in needle N concentration in the NPK treatment, which is partly due to dilution in the larger needles produced in 1967; the figures for content per needle make this clear. It will, however, be a few years yet before we can say whether the addition of nitrogen is worthwhile on a crop such as this.

TABLE 15

FOLIAGE ANALYSIS DATA, SHOOT GROWTH AND STEM DIAMETER OF LODGEPOLE PINE IN ACHRAY FOREST, EXPERIMENT 4/66

Treatment	Needle Wt. (mg)		N (% oven-dry Wt.)		N (mg/1,000 needles) end 1967	Shoot growth 1967 (cm)	Stem diameter increment 1967 (mm)
	end 1966	end 1967	end 1966	end 1967			
NPK	14·6	20·8	1·77	1·39	289	50·2	11·4
PK	12·4	14·9	1·36	1·25	186	44·7	8·1
P	9·0	13·7	1·00	1·09	149	30·8	5·6
O	8·7	10·6	0·98	1·08	114	26·2	4·6

Checked Crops

Little new work has been done in the last few years on checked crops on mineral soils, since growth can often be improved by supplying phosphorus, or by cutting back competing weeds. However, it is not always easy to deal with check in Sitka spruce where this is associated with dense *Calluna*, as is shown by an experiment on Dartmoor.

In May 1961 a large area of Soussons block, Dartmoor Forest, Devon, was top-dressed with 77 kg P/ha (69 lb P/acre) as triple superphosphate. The crops responded over most of the area, but in one part there was virtually no effect.

Analysis of the foliage at the end of 1963 showed reasonable P concentrations in the needles, but low N (0·68 to 0·86 per cent). It was noticed that dwarf gorse (*Ulex gallii*) was virtually absent from this area, though common over most of Soussons.

A factorial trial of two rates of nitrogen (112 and 224 N kg/ha, or 100 and 200 lb/ acre, as "Nitrochalk") and two herbicides, was laid down in 1964, and to begin with the results were encouraging. The N treatments gave a good boost to growth, and the herbicides gave a good kill of *Calluna*. Foliage analysis, however, showed that the fertiliser effect wore off rapidly, and by 1967 hopes that the herbicides would produce a lasting N effect were also dispelled. The main effects of the treatments on foliage nitrogen are shown in Table 16 together with the levels in the untreated plots.

TABLE 16

EFFECT OF NITROGEN AND HERBICIDES ON THE NITROGEN STATUS OF CHECKED SITKA SPRUCE

Treatments	Main Effects of Treatments on N% of Foliage			
	1964	1965	1966	1967
112 kg N/ha	+0·44	0	−0·02	−0·01
224 kg N/ha	+0·87	+0·05	−0·06	−0·07
2,4-D	+0·02	+0·18	+0·13	+0·08
Paraquat	−0·01	+0·30	+0·18	+0·07
Increase for Significance at 5%	0·10	0·08	not calculated	not calculated
Absolute Control—actual concentration	0·89	0·73	0·89	0·70

The nitrogen treatments are to be re-applied in 1968. However, there seems no easy way of speeding up the rate of growth. The untreated trees are growing about 8 cm (3 inches) in height a year, and the best growth achieved, by the 224 kg/ha N treatment, was about 35 cm (14 inches) in 1965. All treatments were virtually back in check by 1968.

Manuring of Pole-stage Crops

The three recent pole-stage manuring experiments on Scots pine in Scotland all show responses in basal area increment, and this is paralleled by an increase in needle weight and needle nitrogen concentration. Phosphorus and potassium increased initially at Inchnacardoch, and potassium is still significantly higher in the treated trees at Devilla, where the trees are growing on soil formed from Millstone Grit (see Table 17).

In the Speymouth experiment, light intensity beneath the canopy was measured, and a cone assessment was made. The results of these are given in Table 18, which shows quite definitely that fertilising on this gravel plain stimulates the crown to such an extent that light intensity beneath it is noticeably reduced. It also increases coning.

120 ha (300 acres) of checked, semi-checked and pole-stage Sitka and Norway spruce were top-dressed with prilled urea by helicopter in Achray Forest, Stirlingshire, in June 1967, as a field-scale trial. The completely checked areas were also top-dressed with unground Gafsa rock phosphate, again by helicopter. It is hoped that stem analyses done in a few years' time will show if a response has been obtained.

TABLE 17

1967 FOLIAGE ANALYSIS DATA FROM POLE-STAGE MANURING EXPERIMENTS

Treatment kg nutrients/ha (lb/acre)			Site							
			Speymouth 7/64				Devilla 19/65			
			Needle Wt. (mg)	% O.D. Wt.			Needle Wt. (mg)	% O.D. Wt.		
N	P	K		N	P	K		N	P	K
0	0	0	16·9	1·55	0·23	0·83	22·3	1·61	0·18	0·53
134 (120)	60 (50)	112 (100)	20·4	1·95	0·24	0·86	26·2	1·69	0·18	0·69
268 (240)	120 (100)	224 (200)	20·7	2·23	0·24	0·78	24·3	1·98	0·18	0·82
Statistical significance			* (linear)	*** (linear)	ns	ns	ns	* (linear)	ns	* (linear)

TABLE 18

CROWN AND CONE ASSESSMENTS IN EXPERIMENT 7/64, SPEYMOUTH FOREST, MORAY

Treatment (Rates as in Table 17)	Visual Score of Crown Density	Light Intensity (lumens per ft²)	No. of Cones per Tree
No fertiliser	2·2	3·76	68
NPK low rate	4·4	3·02	127
NPK high rate	4·8	2·84	143

Notes:

(1) *Crown Density*—assessed in March, 1966, by visual scoring taking

1 = open crown, easy to see through.

5 = dense crown, impossible to see through.

(2) *Light Intensity*—Assessed in August, 1966, using a photo-electric light meter.

(3) *Cone Assessment*—done in July 1967, by counting the number of cones visible on one side of the tree and multiplying this number by three. Ten trees per 0·04 ha (0·1 acre) assessment plot were assessed.

Eight experiments remain from the ten in the 2^5 series laid down in 1959 and 1960, and seven of these were due for remeasurement last winter (see *Reports* for 1965, page 25, and 1967, page 51, for earlier results). Results are only available so far for four of them, three of which had shown significant responses to N or P in the past. The course of the response during the nine years, in three-and two-year periods, is shown in Table 19.

TABLE 19

RESPONSE OF POLE-STAGE CROPS TO 168 KG N OR 99 KG P/HA

Forest	Species	Yield Class	Age at Treatment	Nutrient	Per cent increase in basal area increment for four consecutive periods of years after treatment			
					1–3	4–5	6–7	8–9
Brecon, Breconshire	Sitka spruce	180	24	P	2	10*	8	4·5
Glasfynydd, Breconshire	Sitka spruce	160	30	P	22**	23**	15	15
Pembrey, Carmarthenshire	Corsican pine	80	23	N	37***	40**	31*	10

* Increase significant at 5 per cent
** Increase significant at 1 per cent
*** Increase significant at 0·1 per cent

These results suggest that the marked effect at Pembrey, having lasted well for seven years, had probably disappeared by the end of the ninth year. The increase at Glasfynydd seems to have been well maintained, though the 5 per cent significance level is not quite reached, while at Brecon, the highest yielding crop in the series, the small effect seems to have almost gone.

Demonstrations of Nutrient Deficiencies

The "deficiency garden" (mentioned in last year's *Report*) which was established on deep peat at Eddleston Forest, Midlothian, in Spring, 1967, produced some interesting differences between treatments by the end of the first growing season. With Sitka spruce where *either* N, P or K was omitted, the plants had the typical appearance of this species after one growing season after planting, i.e. yellow with short leaders and needles. However, where all three major nutrients were applied, the plants produced good healthy needles and good leaders. This is the first time such a marked response to nitrogen or potassium has been obtained in the first growing season after planting. Similar, but less marked, effects occurred with the Lodgepole pine in this demonstration, and in addition pines not given magnesium developed magnesium deficiency symptoms, i.e. very pale yellow needle tips. Also survival was noticeably lower in pine plots which did not receive magnesium, which is difficult to explain as the deficiency did not seem severe enough to cause death.

The deficiency garden at Wareham Forest, Dorset, started in 1960, continues to show the effect of unbalanced fertilising by colour rather than growth, except at the most exposed end of the block, where some trees are severely affected by K deficiency. The only real exception to this is the "minus P" treatment, where a light treatment of P has been necessary to keep the trees alive. Symptoms of N, P, K, and Mg deficiency can be seen at certain times of the year, for all species—Scots, Corsican and Monterey pines, Sitka spruce, Douglas fir and Western hemlock.

The most striking growth feature, however, has been the contortion of Douglas fir. This at first was thought to be due to regular frosting, but the marked resemblance of the trees to those shown to be copper deficient in Holland (e.g. Oldenkamp and Smilde, 1966), prompted treatment with foliage sprays of copper sulphate in fully manured plots. This had little effect, and in 1967 a heavy ground application of copper sulphate, at 75 kg Cu/ha (67 lb Cu/acre) was added. At the end of 1967 it seemed that the copper had reduced the distortion, but not as effectively as withholding nitrogen! In the fully manured plots without copper, half of the trees had slight to severe distortion. The scores are shown in Table 20.

TABLE 20

EFFECT OF COPPER SULPHATE ON DISTORTION OF DOUGLAS FIR

Fertiliser Treatment	*Mean Score for Distortion*
Complete (NPK Ca Mg annually)	1·7
Complete + Cu	0·8
−N (PK Ca Mg annually)	0·1

Note: 0 = no distortion
6 = very severe distortion

Permanent Foliage Sampling Plots

The 1967 foliage analysis data from the permanent sampling plots in Scotland and North England are given in Table 21. Compared with 1966, the needle weights are similar, but almost all nutrient concentrations are higher. The only concentration to fall was that of phosphorus in the good Sitka spruce.

Analysis of Foliage and Soils

Foliage

Nearly 2,200 samples were received at Alice Holt during autumn and winter, and the analyses were nearly all completed by the end of March. A new system of storage, in glass tubes which are stacked in perforated wall racks, has cut down—indeed virtually eliminated—the space needed. Two racks together hold over 3,000 samples, and there is a convenient space for another, so the storage problem has been solved for the time being. The change to glass tubes (from polythene bags) was long overdue, a further advantage being that stored samples can be dried off in their tubes before weighing out for analysis.

There have been no major changes in analytical techniques during the year, only minor improvements in handling.

TABLE 21

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)	*7·8* 6·0—10·7	*1·50* 1·00—1·73	*0·20* 0·17—0·30	*1·23* 0·89—1·54	*0·34* 0·29—0·42	*0·17* 0·11—0·20	7½ : 1 : 6¼
Sitka spruce (in partial check)	*5·2* 4·2—6·3	*1·10* 0·84—1·67	*0·15* 0·07—0·20	*0·79* 0·54—1·11	*0·33* 0·07—0·47	*0·13* 0·10—0·17	7¼ : 1 : 5¼
Lodgepole pine (Washington Coastal Provenance)	*16·0* 8·8—21·8	*1·43* 1·14—1·60	*0·18* 0·13—0·22	*0·06* 0·40—0·78	*0·13* 0·08—0·24	*0·10* 0·08—0·12	8 : 1 : 3½

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

Mineral Soils

In recent years the Alice Holt Laboratory has done relatively little soil analysis, and most of that has been for working plan soil surveys. However, soils from the Corsican pine site classification study (see page 55) were dealt with during the year, and a large programme of analysis is in hand for the Minor Species Project (page 55).

Peat Soils

At the end of 1966 approximately 100 peat sites were sampled in Scotland and North England, the samples being analysed by the Soil Chemistry Department of the Edinburgh University School of Agriculture. Included in the sampling was an investigation to determine the variability of nutrients in samples taken, using the peat sampler mentioned in the 1966 *Report*. This was done by taking eight individual cores at random within an area 20 metres square, and from a neighbouring similar area, giving a total of 16 cores which were 45 cm long and divided into three equal sections of 15 cm for analysis. This investigation was done at four locations which were Bad-a-Cheo, Rumster Forest, Caithness; Balblair Forest, Ross and Cromarty; Easter Dean, Eddleston Forest, Midlothian; and Lochar Moss (Black Grain Section), Mabie Forest, Dumfriesshire. Percentage standard errors were calculated for the means of the eight cores, for each horizon, and means of these are given in Table 22. The results indicate that eight cores give a remarkably good estimate of the dry matter, ash and major nutrients in deep acid peat, considering the visible surface variability in vegetation on such peats. The number of cores would have to be reduced to two before the standard errors doubled, so that our present method of sampling, which is to take six cores from any particular site, seems to give results which are sufficiently reliable for our purposes. It is interesting to note that nitrogen is the least, and potassium the most, variable of the nutrients.

TABLE 22

PERCENTAGE STANDARD ERRORS OF PEAT ANALYSIS DATA

Means for Rumster, Balblair, Eddleston and Mabie Forests

	Dry Matter	Ash	N	P	K	Ca	Mg
A	6·1	6·9	3·8	6·2	11·9	5·7	5·5
B	4·9	6·3	4·8	6·4	7·6	5·5	4·7
C	3·2	5·0	4·2	5·8	10·6	5·6	4·0

Notes: (1) Dry matter was estimated as per cent fresh weight, but the others as per cent oven-dry weight

(2) A, B & C are horizons 0–15 cm, 16–30 cm, and 31–45 cm respectively.

Peat samples collected from large raised bogs currently being afforested, in places as far apart as Caithness and Dumfriesshire, indicate remarkable similarities in their chemical constituents, whether expressed as percentage oven-dry weight or as weight per unit area. Table 23 compares peat analyses from three raised bogs, and for comparative purposes a typical blanket peat and a very rich basin peat are included. Note that the blanket and basin peats contain twice as much nitrogen per acre as do the raised peats, and also that the basin peat has a very high ash content due to the deposition of mineral matter caused by periodic flooding. Even though the phosphorus content of the blanket and basin peats is more than four times that of the raised peats, phosphate fertiliser is still required on both these types. Potassium contents of these three types also differ considerably, and it is noteworthy that on the raised peats potassium is required at planting, and within six years of planting on the blanket peat, but so far has not been necessary on the basin peat. The peat analysis data reflects these differences.

TABLE 23

PEAT ANALYSES FROM SELECTED SITES IN SCOTLAND

15–45 cm (6–18 in.) deep layer

Site	Peat Type	Nitrogen (% O.D. organic matter)	% Oven-dry weight			kg/ha (lb per acre) (approx.)		
			Ash	P	K	N	P	K
Bad-a-Cheo, Rumster Forest, Caithness	raised bog	1·6	1·8	0·021	0·010	3,600 (3,200)	49 (44)	22 (20)
Cardross Moss, Achray Forest, Stirlingshire	raised bog	1·6	1·7	0·022	0·008	3,500 (3,100)	48 (43)	17 (15)
Racks Moss, Mabie Forest, Dumfriesshire	raised bog	1·4	2·2	0·021	0·008	3,400 (3,000)	50 (45)	19 (17)
Inchnacardoch Forest, Inverness-shire	blanket peat	2·1	4·1	0·053	0·015	7,800 (7,000)	204 (183)	58 (52)
Skiall (Pilot Plot), Caithness	basin peat	2·7	22·5	0·047	0·041	8,100 (7,200	186 (166)	159 (142)

Several forests in Wales have now been sampled, and the analysis will be done by the agency handling the Scottish samples. A comparison with results in Scotland may show why Sitka spruce on Welsh peats takes up so much more nitrogen than Sitka spruce on Scottish peats. Microbiological studies may however be needed for a full explanation of this striking difference.

Nitrogen may well turn out to be the key element on many deep peats; we need to find out not only whether high-yielding species can be grown in the first rotation, but also whether the nitrogen-supplying power of the peat will change over long periods.

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SITE CLASSIFICATION

Corsican Pine

Last year we reported a small project on the site relationships of Corsican pine, in which thirty stands, covering the Southern part of England, East Anglia and touching the Midlands and South Wales, were studied (*Report* for 1967, page 54).

Considerable progress has now been made with the statistical analysis of the large amount of data amassed. The 50 site and crop variables have been examined in four groups;

(*a*) Climate and Physiography (15)

(*b*) Soil Physics (13)

(*c*) Soil and Foliage Chemical (16)

(*d*) Tree Growth (6).

A multivariate analysis was run on the groups, using the method of principal components, and the relations between those groups of variables forming important components were then calculated. The significant relationships can be set out diagrammatically.

The first Climate and Physiography component included measures of evaporation, rainfall, altitude and exposure, but apparently contributed little or nothing to tree growth, while the second, covering winter temperature, growing season sunshine, longitude and latitude was of considerable significance.

The first Soil Physics component also contributed little, being made up of a measure of available soil water and the depth to gley mottle. The second and third components, in contrast, had significant associations with growth; these components included factors for clay and stone content, depth to free water in winter, soil depth and humus type.

Both first and second Soil and Foliage Chemical components contributed valuable factors. In the first were measures of total phosphorus and soil pH, and the second combined needle weight and percentage needle magnesium with girth and height of the sample tree.

Further statistical treatment is envisaged, but it is already possible to gain some understanding of those site factors which are (or are not) correlated with the growth of Corsican pine. The make-up of the components, and their interrelation, has revealed much of interest, and the statistical technique of principal component analysis seems to offer special advantages in these studies. There is of course much that could be done to improve the study: many site variables are inadequately expressed (particularly aspect), and too many values have been estimated rather than measured precisely. However, the experience has been very stimulating, and the practice in gathering and handling data should be useful for future, wider studies.

It is hoped in due course to publish a full report, to be written in collaboration with Dr. D. G. M. Donald of Stellenbosch University, South Africa.

Minor Species

The performance and potential of Western hemlock, Western red cedar, Grand fir and Noble fir is being compared as far as possible with growth of current "major" species, namely Sitka spruce, Douglas fir, Corsican pine, Norway spruce, Scots pine and Japanese larch.

The principal lines of approach to the investigation are:—

(*a*) to locate stands of any given minor species, and to compare the growth and predicted yield with that of adjacent major species. As the validity of the comparison depends on the site being similar, site and soil characteristics are being assessed for each site;

(*b*) to evaluate the role of the fungus *Fomes annosus* as a factor influencing timber production. *F. annosus* is known to be particularly important in hemlock stands, and studies are planned which will provide figures of the impact of this fungus on timber production of all species in this study;

(*c*) to evaluate the limits imposed by exposure on performance of species, particularly *Abies grandis;*

(*d*) to evaluate (i) establishment techniques likely to influence early survival and growth, (ii) the role of seed origin on early growth, and (iii) the response to fertilisers or improved drainage;

(*e*) to forecast market trends and relate these to the timber properties of the species in this study.

In autumn 1967 almost all the recorded minor species stands over 27 years in age were inspected—in all about 600 stands. From these about 240 have been selected for the more detailed studies outlined above.

It is hoped this study will be completed by the end of 1968.

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REGENERATION OF TREE STANDS

Estimates of Seedfall

Two experiments at Newcastleton (Roxburghshire) and Farigaig (Inverness-shire) were begun with the aim of confirming the results of the previous study at Glenbranter in 1964/65, i.e. to estimate the duration and intensity and quantity of seed fall. The germination capacity of the seeds obtained is being assessed by X-ray photography.

Natural Regeneration of Sitka Spruce

Survival of naturally regenerated Sitka spruce, which is being monitored at the Forest of Ae, has fallen by 9 per cent overall in the first year. Drought, aphid infestation, damage by browsing animals and competition from vegetation have been the main hazards, with twice as many deaths under cover as in the open. Assessment continues and contact is being maintained with a post-graduate student of Edinburgh University investigating the moisture status of the seedling population, in areas adjacent to the experiment.

Erosion following Clearfelling of Spruce

Clearfelled plots on a steep slope at Benmore Forest (Argyll) have been at risk for thirteen months, during which time rainfall intensity has been recorded, surface contours assessed periodically and soil erosion trapped. The results have not yet been analysed, but it appears that soil movement is very small. A particular difficulty was to obtain a good junction between the soil and the reservoir in which the soil wash was trapped. Spraying the junction with paint from an aerosol sprayer solved this problem.

Underplanting of Larch and Pine

Four underplanting experiments established in recent years in the North have now passed through the weeding phase, and the amount of vegetation suppression provided by the overwood is of interest. Under an overwood of Japanese larch at Drumtochty (Kincardineshire) and Allerston (Yorkshire) no weeding was required in the first year, but at the former the grass growth in the second and third year justified removal. The intensity of weeding was little affected by overwood densities of less than 593 stems/ha (240 stems/acre). At Allerston, where the site was treated overall with paraquat before felling, second year weeding will probably not be necessary. A previous adjacent experiment at Allerston showed that, without herbicide, second-year weeding was required.

Similarly, under Scots pine overwoods in experiments at Culloden and Culbin, first-year weeding was not required, but second-year weeding was not markedly reduced under overwood densities below 618 stems/ha (250 stems/acre).

It is therefore concluded that herbicide is to be recommended on susceptible grass species at a rate which must be effective for at least two years, unless overwood densities exceed the above levels.

Light measurement has been repeated in this series of experiments, and a reflecting densiometer is being tried as an alternative to the instantaneous photometers, which are somewhat fickle instruments and very sensitive to the weather.

Weeding again proved necessary in all plots at Radnor Forest and in selected plots at Michaelston, Coed Morgannwg (Glamorgan), where a range of species is being established under an overwood of larch thinned to different densities, as well as in clearfelled blocks. Light measurements were taken in both experiments during the growing season.

The joint nursery experiment, with Dr. W.A. Fairbairn of Edinburgh University, investigating the light demands of six species, has been concluded and its results will be published. (See also p. 162.)

Regeneration of Scots Pine

At Tentsmuir (Fife), following the completion of a soil map, an experiment was designed to assess the potential of species more demanding and more productive than the existing Scots pine. However, the wind damage of January 1968 has made it necessary to postpone this project.

At Thetford, the experiment planted in 1967, on two contrasting soil types, to examine the survival and early growth of Corsican pine and Grand fir in clearfelled strips and under different densities of overwood cover, an assessment at the end of the first season of the survival of the newly planted crops suggests that, so far, none of the deaths are directly attributable to the absence or presence of an overwood. Failure appears to have been due to insect attack and, in the case of Corsican pine, to the use of some comparatively poor plants.

In the earlier planted experiment at Thetford (1964), in which 18 species were planted on three soil types under an overwood of pine thinned to 495 stems/ha (200 stems/acre), the growth of several species on both the deep acid sand and on the complex Methwold/Worlington soil type has continued to be very satisfactory. At these two better sites, the overwood will be clearfelled in plots of *Nothofagus* and of the nine most vigorous conifer species, and thinned to 124 stems/ha (50 stems/acre) in plots of beech and Red oak in the autumn. On the thin alkaline soil (Newmarket series) growth has been much less vigorous, and one or two species are now exhibiting symptoms of chlorosis. At this site the present overwood stocking is being retained for a further period. At the three sites the overwood is being retained in all plots of the five fir (*Abies*) species because of their slower establishment.

Regeneration of Scots Pine in Native Woods

Research Division experience since the 1930's, and Nature Conservancy experience from the 1950's, confirms that there is no easy key to the natural regeneration of the remnants of the native Scots pine woods. A variety of factors combines to make these sites of little value in the furthering of normal regeneration research. However, it is important to maintain the natural gene pool and this is being most economically perpetuated by the Conservancies involved by replanting with stock raised from general local collections, and by tree banks. Amenity is served by the retention of the old pine for the maximum duration, and replanting the intervening groups.

The Research Division continues to maintain an undisturbed enclosure of native pine at Rannoch (Perthshire), and the ecological developments of this relatively balanced woodland system remain of interest and deserve deeper study of both flora and fauna. Past subjective multistate assessments of vegetation at 10-year intervals have been very difficult to evaluate, and it is proposed to re-classify the vegetation on an objective basis, compatible with the use of the computer in its analysis.

Direct Sowing of Sitka Spruce

Since 1964 eight experiments in Border forests have been established in areas clearfelled of spruce, and where the ground was free of vegetation and presumably low in rodent populations—two important factors which have led to the failure of direct seeding trials in afforestation work.

Seeds of known viability were scattered on the untouched surface, on raked, and on mattock-screefed ground. Phosphate was applied to part of each surface treatment in some experiments. In addition some blocks were netted against mice and birds.

First-year germination and survival ranged from 3 per cent to 45 per cent with means of 11 per cent, 15 per cent and 19 per cent for uncultivated surface, cultivated surfaces, and netted treatments respectively. Phosphate did not improve survival significantly, but cultivation and netting did.

Third-year survival ranged from 3 per cent to 31 per cent. Later germinants were not differentiated from originals, and mean survival of 6 per cent, 9 per cent and 20 per cent corresponded to the treatments above. There were still no important phosphate responses by the third year.

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ARBORETA, FOREST PLOTS AND SPECIES TRIALS

Arboreta and Forest Plots

In Kilmun Arboretum (Benmore Forest, Argyll) plots of *Larix occidentalis* and *Picea* x *lutzii* were planted in 1967. Specimen tree groups of *Chamaecyparis thyoides*, *Pinus parviflora* and *Fraxinus pennsylvanica* were also added to the collection. A short guide to the arboretum and forest plots was prepared and is now in process of publication by H.M. Stationery Office. The arboretum unfortunately suffered badly from the gale which affected west and central Scotland on 14–15th January 1968. Damage was particularly severe in parts of the older sections and some of the best plots were almost completely destroyed. Surprisingly, the *Eucalyptus* collection suffered remarkably little damage considering that heights of up to 18 m (60 ft) occur in the older plots. A start has been made on clearing up the damage, and replacement of the plots destroyed will commence in 1969.

Crarae Forest Garden (near Minard Forest, Argyll) was also badly damaged by the January gale and, as at Kilmun, a number of the best plots were destroyed.

At Westonbirt, further lengths of the north-eastern shelter-belt were regenerated and overgrown areas and encroached rides were cleared, notably Morley Ride, Wigmore and along Willesley Drive. Replacement of species lost by senility or wind-blow was continued, with the addition of new species, particularly of the genera *Betula* and *Sorbus*, and a number of Mexican species of conifer. Much thought has gone into planning the extension of the developed arboretum into some of the woodland areas of Silk Wood. A new path to the entrance has been surfaced and stock-fenced, and improvements to the approach road completed. The text of a new guide with coloured illustrations has been prepared and will be published shortly by H.M. Stationery Office.

At Bedgebury, 93 plants of 53 coniferous species and varieties, and a collection of nine of the ten clones of Leyland cypress, were planted. Attention has been paid to improving the drainage in large areas where it has been poor. A programme of spraying some Silver fir species against damage from *Adelges* insects seems to promise good results. A new Short Guide and a fully revised Main Guide are being prepared to incorporate changes in the point of entry and best route to take around the arboretum, since the new car-park has been opened.

Species Trials

Kielder Species Trial

Assessments were completed in the large species trial at Kielder (Northumberland) established between 1951 and 1954. In this experiment species which were thought likely to show reasonable survival and growth were planted in unreplicated 0·2 ha (0·5 acre) plots; species about which less was known were planted in 100-plant plots replicated three times. Pure plots were used except in the 0·2 ha plots of the 1953 section; these were planted, using a 3 row:3 row mixture of the main species with either Norway or Sitka spruce. The three older sections were laid out on fairly typical peaty gley soils with *Molinia* vegetation, whereas the 1954 section was sited mainly on an atypical flat area in a stream valley, with variable soils and vegetation.

TABLE 24

MEAN HEIGHTS FOR SPECIES IN 1951 AND 1952 SECTIONS OF KIELDER TRIAL ASSESSED AT AGES OF 17 YEARS AND 16 YEARS RESPECTIVELY

metres (feet)

Species	Experiment section and age at assessment: 1951 17 years	Experiment section and age at assessment: 1952 16 years	Comments
Scots pine	5·7 (18·7)	4·8 (15·7)	Form very poor in 1952 section
Lodgepole pine (inland)	7·1 (23·3)	5·5 (18·0)	Form poorer in 1952 section
Sitka spruce	2·6 (8·7)	5·0 (16·6)	Low vigour in 1951 section
Norway spruce	2·0 (6·6)	3·3 (11·0)	Stocking poor in 1951 section, but good in 1952 section
Japanese larch	4·0 (13·3)	4·9 (16·0)	Poor stocking and form in both sections.
Hybrid larch	5·7 (18·7)	7·3 (23·9)	
Douglas fir	3·6 (11·7)	3·2 (10·7)	Poor stocking in 1951 section
Western hemlock	2·0 (6·0)	3·4 (11·1)	
Western red cedar	failed at 11 years*	1·7 (5·5)	Few survivors in 1952 section
Lawson cypress	1·8 (5·8)	2·6 (8·5)	
Grand fir	2·2 (7·4)	3·7 (12·2)	
Noble fir	—	1·8 (5·8)	
Abies concolor	0·7 (2·3)*	—	Very poor stocking
A. nordmanniana	failed at 11 years*	—	
Picea engelmanni	—	3·1 (10·3)*	
P. omorika	2·1 (6·8)	3·5 (11·6)	
P. orientalis	—	1·9 (6·2)*	
P. pungens	—	failed at 16 years*	
P. rubens	—	1·8 (6·0)*	
Sessile oak	failed at 11 years*	—	
Sycamore	failed at 11 years*	—	
Alnus cordata	—	failed at 2 years*	
Alnus incana	3·5 (11·5)	—	Some branch dieback
Betula ermannii	—	4·4 (14·6)*	Very good stocking, vigorous
B. lenta	—	failed at 2 years*	
Quercus rubra	—	failed at 7 years*	

Note: *indicates data from replicated 100-plant plots; remaining data from 0·2 ha unreplicated plots.

Height assessment data are summarised in Table 24, for the 1951 and 1952 sections, and in Table 25, for the 1953 section which contains the mixed plots. Data for the 1954 section have not been presented because survival and growth have been very poor as a result of repeated frost and deer damage; it has in fact been decided to abandon the section.

Overall, survival and growth in the 1951 section have been poorer than in the other two sections. It is probable that this is due, at least in part, to the former having been turf-planted, whereas the other two were planted on single mould-board Cuthbertson ploughing. In the 1951 section, an Inland Lodgepole pine origin (Roseisle Forest *ex* Hat Creek, British Columbia) is easily the most vigorous species (see Table 24) and forms a very striking plot. It is followed, surprisingly, by Scots pine (of North-east England origin) and by Hybrid larch. Both Norway and Sitka spruces show low vigour and none of the other species has grown particularly well.

In the 1952 section the overall picture is considerably better, with higher stocking and more vigorous growth. Hybrid larch is the most vigorous species followed by Inland Lodgepole pine (origin Western Montana, U.S.A.) and Sitka spruce. Scots pine, of the same origin as in the 1951 section, has again grown fairly vigorously, but form is very poor. Of the remaining conifer species, Grand fir and *Picea omorika* show most promise, both exceeding Norway spruce in height. Of the hardwood species, only one remains and this, the little known Japanese species *Betula ermannii*, forms an attractive, well stocked, vigorous plot.

Table 25 indicates that in the large mixture plots of the 1953 section only Western red cedar has not grown at least moderately well. Comparison of the height data with those for the 1952 section (Table 24) suggests that most species have benefited from being in 3 row:3 row mixture with either Norway or Sitka spruce. As in the 1952 section, Hybrid larch is the most vigorous species to date, followed by Japanese larch and Douglas fir, the latter having no doubt responded to the sheltering effect of the spruce bands. It is of considerable interest to note that both spruces appear to have grown better in mixture than in pure crops, the improvement being particularly noticeable when the mixture is with larch. In the spruce/larch mixtures, however, the relative vigour of the larches is beginning to result in some suppression of adjacent spruce rows, and relatively drastic early tending measures will soon be required if the mixtures are to be maintained. This problem has not arisen in the remaining mixtures where the growth rates have so far not differed markedly.

Nootka Cypress Trials

Nootka cypress (*Chamaecyparis nootkatensis*) showed some promise on poor acid peat in a pre-1940 experiment at Achnashellach Forest (Ross and Cromarty), and in order to follow this up small unreplicated trials were planted in 1961 on infertile deep peat sites at Inchnacardoch (Inverness-shire), Glen Coe (Argyll), Naver (Sutherland) and Wark (Northumberland). After two years the Wark experiment had to be written off as a result of very high losses following hare browsing, but observations continued at the remaining experiments and a six-year height assessment was recently carried out.

The results to date have not been encouraging. Trees in all three experiments have suffered repeatedly from shoot dieback, due mainly to frost damage, and are consequently of very bushy habit. At Inchnacardoch, where trees from five Scottish sources and one Canadian (Prince Albert, British Columbia) origin

TABLE 25

MEAN HEIGHTS AT 15 YEARS FOR MIXED AND PURE PLOTS IN 1953
SECTION OF KIELDER TRIAL

metres (feet)

Species	15-year height	Comments
Half-acre plots		
Hybrid larch/	7·4 (24·3)	
Sitka spruce	4·7 (15·6)	Very wavy stems
Douglas fir/	4·7 (15·6)	
Sitka spruce	4·3 (14·2)	
Grand fir/	3·7 (12·2)	
Sitka spruce	4·6 (15·0)	
Pure Sitka spruce	3·6 (11·8)	Good form and colour, but less vigorous than in mixed plots.
Sitka spruce/	4·1 (13·5)	
Norway spruce	3·9 (12·8)	
Scots pine/	4·3 (14·1)	
Norway spruce	4·0 (13·4)	
Japanese larch/	5·9 (19·4)	Better form than hybrid larch
Norway spruce	4·3 (14·2)	
Hybrid larch/	7·8 (25·6)	Very wavy stems
Norway spruce	4·7 (15·4)	
Douglas fir/	4·4 (14·5)	
Norway spruce	3·9 (12·9)	
Western red cedar/	1·7 (5·7)	Low current survival
Norway spruce	3·4 (11·2)	
Lawson cypress/	3·5 (11·4)	Bushy form with multiple leaders
Norway spruce	3·8 (12·6)	
Grand fir/	3·8 (12·6)	
Norway spruce	3·9 (12·9)	
Pure Norway spruce	3·6 (11·7)	Good form and colour, but less vigorous than in mixed plots.
100-plant plots		
Picea albertiana	1·9 (6·2)	Early growth very poor, but now improving.
P. glauca	2·9 (9·6)	Started poorly, but now growing fairly well
P. rubens	2·6 (8·5)	(as above)
Pinus rigida	failed at 6 years	
P. strobus	failed at 6 years	

were planted, the six-year heights ranged from 43 cm to 64 cm (1·4 ft to 2·1 ft) and in most cases are less than the heights at three years. The two Scottish origins planted at Naver currently have heights of 49 cm (1·6 ft) and 40 cm (1·3 ft) while the single Scottish origin at Glen Coe has reached 42 cm (1·4 ft); in both these experiments there has been a small increase in height since the three-year-old assessment. Survival at Inchnacardoch and Glen Coe has been fairly good, but at Naver one-third of the trees are now dead.

It is doubtful if this species has a future on such poor testing sites without a higher degree of site amelioration than at present practised, and the experiments will be reviewed for closure at the time of the ten-year-old assessment. In the meantime, the Inchnacardoch and Naver experiments have been top-dressed with potassic superphosphate at 560 kg/ha (4½ cwt/acre) to see if this will produce any worthwhile growth response.

Nothofagus Species

The survey of these species, referred to in the *Report* for 1967, has now been completed and written up. The findings will probably be published later in a paper covering such aspects as establishment problems, growth, yield and financial prospects, comparison of the two main species, climatic stem canker, etc.

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PUBLICATIONS BY STAFF MEMBERS

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PROVENANCE

Lodgepole Pine

A major new provenance experiment with 85 seed lots is planned for sowing in 1968 at four nurseries. These provenances became available following the visit of Messrs. Maxwell and Aldhous to western North America in 1965. Twenty-six lots selected from this collection were sown at Newton Nursery, Moray, in 1967. At the end of the year, differences in height, survival and needle colour were all highly significant. For height the provenances from the Washington and Oregon coast, and one from Vancouver Island, were best, followed by those from south interior British Columbia. With the exception of Skagway, the Alaskan provenances were generally superior to those from the Skeena and Bulkley rivers, and from central interior British Columbia. There was a significant regression of seedling height on seed weight, and when these data were plotted graphically, distinct provenance groupings were evident. Differences in needle colour in autumn were also very highly significant. Combining the data for seed weight, seedling height and autumn needle colour, would allow a fairly precise discrimination of provenance groupings. This goes some way towards the ideal of being able to classify an unknown or doubtful provenance into its correct group within one year. Full statistical tests will be made on the much larger collection sown this year.

Fifteen of this same collection of provenances, selected for areas of origin with low rainfall and high pH soils, some of them from areas of limestone mountains, were sown in the south in 1967. These may prove useful in the afforestation of high limestone areas in the Lake District, Craven district of Yorkshire, Pennines of Northern England, and thin soils over chalk in the south-east of England, including Thetford.

Lodgepole pine is used on such a wide variety of sites that it is difficult to provide enough experiments to indicate which provenances are likely to be best for all the major regions and types of site. The following is a summary of experiments laid down in recent years and their results to date.

In 1961 three experiments were planted which had the improvement of our cover of site types as one of the main objectives, the other being to evaluate new or little-known provenances. The sites were a *Calluna/Eriophorum* peat, 427 m (1,400 ft) above sea level at Wark, Northumberland; a fairly deep *Eriophorum* peat 350 m (1,150 ft) at Selm Muir, Midlothian; and a deep *Calluna/Trichophorum* peat at 305 m (1,000 ft) on Rannoch Moor (Glencoe Forest). Thirteen provenances (see Table 26) were planted, most of which had been included in the Forest of Deer experiment noted in the 1967 *Report*. The "unknown" provenances were Skagway, Bellakula and Cypress Hills.

All three experiments suffered somewhat from the severe winter of 1962–1963 and only at Glencoe can the growth be considered satisfactory. This experiment is within the Black Mount trial plantation, where the exposure has been estimated by the exposure flag method. This indicated only moderate exposure, but the Wark and Selm Muir sites were almost certainly more exposed. Wind exposure, however, was probably less important than nutrition in limiting growth. At Selm Muir, in an attempt to prevent basal bowing of the vigorous south coastal origins, no fertiliser was supplied after planting; in May 1964, ground mineral phosphate was applied. Clear symptoms of potash deficiency became evident in the autumn of 1964 and there were large differences in colour

TABLE 26

MEAN HEIGHT OF LODGEPOLE PINE PROVENANCES AT WARK, NORTHUMBERLAND; GLENCOE, ARGYLL; AND SELM MUIR, MIDLOTHIAN

Provenance	Mean height in metres (feet) at 6 years		
	Wark	Glencoe	Selm Muir
Skagway, Alaska	0·536 (1·76)	1·155 (3·79)	0·454 (1·49)
Kirroughtree Forest, Kirkcudbright Expt. 1 (*ex* Queen Charlotte Islands)	0·667 (2·19)	1·247 (4·09)	0·613 (2·01)
Ladysmith, Vancouver Island	0·719 (2·36)	1·372 (4·50)	0·744 (2·44)
Long Beach, Washington coast	0·963 (3·16)	1·679 (5·51)	0·777 (2·55)
Keyport, Washington coast	0·832 (2·73)	—	0·756 (2·48)
Newport, Oregon coast	0·908 (2·98)	1·554 (5·10)	0·826 (2·71)
Tidewater, Oregon coast	0·981 (3·22)	—	0·820 (2·69)
North Bend, Oregon coast	0·960 (3·15)	1·628 (5·34)	0·872 (2·86)
Fort Fraser, central interior British Columbia	0·527 (1·73)	1·195 (3·92)	0·594 (1·95)
Bellakula (?), north coast of British Columbia	0·555 (1·82)	1·271 (4·17)	0·564 (1·85)
Cypress Hills, Saskatchewan	0·600 (1·97)	—	0·606 (1·99)
Oakridge, Oregon Cascade Mts.	0·597 (1·96)	—	0·649 (2·13)
Cascadia, Oregon Cascade Mts.	0·561 (1·84)	1·189 (3·90)	0·558 (1·83)
Standard error ±	0·027 (0·09)	0·037 (0·12)	0·015 (0·05)

between the provenances, the south coastal ones remaining fairly green, whereas the inland ones were a bright yellow. Top-dressing with potassic superphosphate was done in 1967. The Wark site also proved to be deficient in both potash and phosphate and was treated similarly. From Table 26 it is clear that the most vigorous provenances are those from the coast of Washington and Oregon, with Ladysmith not significantly poorer. Of the northern coastal provenances, the seed lot originally from Queen Charlotte Island was significantly taller than that from Skagway. The inland provenances from Fort Fraser, Cypress Hills, Cascadia and Oakridge were all poor, while the Bellakula provenance was indistinguishable in appearance or performance from these inland origins. It seems certain that this seed was incorrectly named by the supplying seed merchant. The Ladysmith provenance is very similar to Sooke in the earlier experiments.

In 1964 a small trial designed to test the ability of a few provenances to withstand extreme maritime exposure was laid out on sand-dunes at Newborough, Môn Forest, Anglesey. The provenances were the most promising available from each of six regions—Central Interior British Columbia; Southern Interior B.C.; transitional Inland/Coastal B.C.; Northern Cascades, Washington; northern Oregon coast and mid-Oregon coast. A second experiment with the same provenances was planted on shallow lowland peat in the New Forest to compare their performance in better conditions.

At Newborough two blocks were on a plateau of stabilised dune and four were in a trough between stabilised dunes. The upper blocks suffered sand-blasting in the first winter, when the survival of mid-Oregon coastal (Reedsport) and Southern Interior B.C. (Revelstoke) provenances was significantly better than the remainder. During the second year, a breeding colony of Herring gull (*Larus argentatus*) largely destroyed these two blocks, but the Central Interior B.C. provenance (Fort Fraser) and one from Langley near the mouth of the Fraser river, were very significantly less damaged. The lower blocks were, by the end of 1967, just as badly affected by sand-blast and hare damage, but the same two provenances had survival percentages more than twice those of any others. This experiment is to be closed.

In the New Forest, however, growth during 1966 and 1967 was very vigorous, the outstanding provenance being the northern coastal Oregon (Newport), some trees growing 0·9 to 1·2 m (3 to 4 ft) in each of these two years. The best trees from Newport were 3 m (10 ft) tall and the plots are full and a deep blackish green. Basal bowing is becoming marked on a small proportion. Mid-coastal Oregon (Reedsport) was the next most vigorous, the best trees being 2·4 m (8 ft) tall, but basal bowing was slightly more prevalent. Northern Cascades (Concrete) yielded less uniform plots, with best trees 1·5 m (5 ft) tall. The Northern coastal, Central and Southern inland B.C. plots (Bellakula, Fort Fraser and Revelstoke) were poor, yellowish in colour, irregular and small. Their shoots are mainly bi-nodal, in contrast to the uni-nodal growth of the southern origins here.

In 1965 a small experiment was designed to compare the performance of an intermediate (Inland/Coastal) provenance from Skeena River, of which Seed Orchards were planned, with representative provenances from the other main coastal and inland regions. The plots were on three sites, on high elevation deep peat in central Wales, middle elevation deep peat in North-east Wales, and high elevation shallow peat in South-west England. There was no significant difference in survival at any of the sites. After two years' growth, the U.S.A. coastal provenances, Long Beach, South Washington, and Reedsport, mid-Oregon, were outstandingly the most healthy, vigorous and tall on all sites, Long Beach being well ahead of Reedsport. Vancouver Island (Nanaimo) was the next best, also on all sites. The Skeena River plots retained their needles better than other northern ones, and were only moderately vigorous, but this smaller vigour allowed them to retain a straight stem, whilst some of the Long Beach trees showed basal bend.

Sitka Spruce (See Table 27)

The widespread series of plots comparing Alaskan provenances (Cordova or Juneau) with the Queen Charlotte Island, British Columbia, provenance, which was described in the *Report* for 1964, was assessed at six years of age. In all but one comparison the Queen Charlotte Island provenance was taller by 25 to 50 per cent. There was a suggestion that the Alaskan seed origins were the first to flush and they had hardly any Lammas growth. These phenological differences do not seem to have influenced frost damage; the form of the Alaskan provenances was frequently better, while the Queen Charlotte Island one showed more forked stems and a general bushiness. Both provenances were attacked by Green spruce aphis, *Elatobium abietinum*. Needle colour was often distinctly bluer-green on the Alaskan lots.

Two earlier series of experiment were designed to test Alaskan provenances. In 1954, one from Hollis, Prince of Wales Island, was compared with a Queen

Charlotte Island and a Scottish seed lot, namely, Stonefield, Argyll (believed to have come originally from Washington), on sites at Kielder, Northumberland and Strathy, Sutherland. At both sites all provenances suffered early frost damage. The faster rate of growth of the Stonefield origin soon enabled it to grow out of the frost zone, so that at ten years of age it was significantly taller than the other two. Trees from Queen Charlotte Island were barely significantly taller than those from Hollis, which is less than two degrees of latitude further north.

In 1959 three other Alaskan provenances (Cordova, and seed from two Norwegian stands, originally from Killisnoo and Sitka), were compared with Queen Charlotte Island and Inverliever, Argyll, seed lots. The Inverliever stand is thought to be derived from Washington seed. The main experiment was at Watermeetings, Lanarkshire, on an exposed hilltop at 457 m (1,500 ft) above sea level. Unreplicated plots were planted at Naver, Sutherland, and Ratagan, Wester Ross. The severely exposed and infertile site at Watermeetings provides a real test of hardiness and it is noteworthy that survival exceeds 90 per cent in all provenances. There were no significant height differences at six years between the three Alaskan lots, which were all significantly poorer in height than the one from Queen Charlotte Island, which, in turn, was significantly less tall than the Inverliever (ex Washington) provenance. It might be thought that the longer period of shoot growth normally characteristic of southern provenances might result in autumn shoot die-back from early frosts on this site, but there is no evidence for this and the Inverliever trees showed hardly any Lammas growth. At the other two sites, which are relatively sheltered and fertile, growth has been twice as fast; the Alaskan provenances again ranked as the slowest growing, but in this case Queen Charlotte Island proved to be the tallest provenance.

Further comparisons of Alaskan provenances, this time with a representative range of provenances from as far south as South Oregon (43°N), are provided by the major series of experiments planted in 1960–1961. These cover 13 sites in Britain, varying in latitude from 50½°N in Cornwall to 58°N in Sutherland, and also Rathnew and Killarney Forests in the Republic of Ireland. The sites vary in fertility and exposure, those in Wales and south-west England being typical of the more rigorous sites to which Sitka is now being extended, mostly on peats of varying depths and at high altitudes relative to the localities. Bannau in South Wales (Taf Fawr Forest) was specially selected for bad air-drainage and the incidence of late frost. The more northerly sites are generally at lower elevations, but are less fertile and some are very exposed.

Results after six years' growth are presented in Table 27, as percentages of the mean height of the tallest provenance at each site; the mean height of the latter is given as an indicator of the growth at each site, and, as a standard of comparison from site to site, the mean height of one provenance from Queen Charlotte Island. In the south, Alaskan provenances, even on the sites prone to late frosts, showed no superior survival. At Wark and Glentrool there were serious losses in the southern provenances due to winter frost-drying during 1962/63 (see Lines, 1966), whereas the Alaskan ones were unharmed. Elsewhere, survival figures were nearly all high and show no significant differences. In growth, no Alaskan provenance was tallest on any site, and current leader growth shows that the Alaskan provenances will fall further behind at each assessment. The mainland British Columbian provenance of Terrace nowhere achieved 90 per cent of the tallest and was very like, or inferior to, the Alaskan provenances in growth. Queen Charlotte Island, though only 1½° further south, yielded plants which were among the tallest at the two most northerly sites and were usually above 80 per cent of the height of the tallest elsewhere. The two provenances from Vancouver Island (Sooke, with moderate rainfall, San Juan, with relatively high rainfall) much further south, showed a marked difference in their performance. Plants from Sooke showed a great resistance to exposure and strong leader growth, and have done best of all provenances on the frost-site at Bannau (Taf Fawr Forest) as well as at Ratagan and in Killarney, Ireland, despite these being areas of high rainfall.

The Washington provenances showed the most consistently vigorous growth of any in these trials, and those from Oregon were little inferior. On the evidence of the first six years nothing is to be gained, and much production is lost, by the use of Alaskan provenances on any sites on which Sitka is the selected species. Queen Charlotte Island provenance may give good results in the north, but not significantly better than those from Washington. From this series of experiments it seems that Washington or Oregon provenances are the best choice for the majority of Sitka sites all over Britain. This conclusion must be viewed with caution until there is more evidence on later growth, and about the timber quality of various provenances.

Norway Spruce

The only British experiment in the I.U.F.R.O. series of 1938 was planted in 1942 at the Bin Forest, Aberdeenshire. Early growth and site conditions were described in the *Report* for 1959 (pages 170–178). Because of *Calluna* check on parts of the experiment, growth was very variable and it is only in recent years that the poorer plots have come out of check and begun to grow at a normal rate. There are five replications but one block was so variable that it was omitted after assessment. A height and girth assessment of the dominant trees in the centre of each plot was carried out in 1967.

Despite the variable site there were significant provenance differences in both height and girth. There was a range of 2·1 m (7 ft) (equal to about two Yield Classes) between the best and worst provenances. If provenances are grouped together it is clear that the Polish and Rumanian group is distinctly superior in height and just superior in girth to the other groups. Nevertheless there are big variations between individual provenances within all groups. The most surprising result is that the single provenance with the greatest mean height was Drängsered, South Sweden. It was noted earlier that plots of this provenance chanced to fall on the better vegetation types and this is the most likely explanation, as the tallest plot (Crucea, Rumania) in the whole experiment is on a grassy site. Despite wide difference between Drängsered and the north Scandinavian provenances, cross-pollination of the Drängsered stand from adjacent stands of imported spruce seems unlikely; the indumentum score from the earlier assessment placed it convincingly in the Scandinavian group.

It can be concluded that the provenance differences in Norway spruce are large enough to merit careful choice of seed origin, the best being from Rumania and Poland. Now that this experiment is largely through the phase of early check, later assessments will be of increasing value as they reflect the inherent characteristics of the provenances.

An experiment to compare 25 provenances of Norway spruce was planted in March 1968 at Halwill, Cornwall, and the Forest of Dean, Gloucestershire.

TABLE 27

MEAN HEIGHT AS A PERCENTAGE OF THE TALLEST PROVENANCE OF SITKA SPRUCE AT SIX YEARS ON 14 SITES
SITE OF EXPERIMENT (NORTH TO SOUTH)

Provenance	Site	1	2	3	4	5	6	7	8	9	10	11	12	13	14
	°N.	58	57½	57¼	56	55	55	53	52½	52¼	52½	52	51¾	51½	50½
Cordova, Alaska	60½	95	83	49	(62)	(86)	67	78	49	63	77	58	66	55	71
Lawing, Alaska	60	86	85	60	(71)	68	59	—	58	44	70	—	56	49	—
Seward, Alaska	60	(87)	(77)	(79)	—	(83)	—	—	—	—	—	—	—	—	59
Juneau, Alaska	58¼	84	85	67	—	83	77	—	—	—	—	—	—	—	59
Sitka, Alaska	57	73	81	64	(78)	—	70	—	56	67	72	63	62	62	73
Terrace, B.C.	54½	76	77	69	—	64	69	87	67	65	78	67	61	63	79
Skidegate B.C. (Q.C.I.)	53	*100*	*100*	81	92	72	91	96	83	82	92	80	75	88	87
San Juan R, B.C. } Vancouver Island	48½	99	86	77	85	67	89	80	85	85	85	84	82	82	83
Sooke, B.C. } Vancouver Island	48¼	88	87	*100*	88	89	83	94	94	84	95	*100*	*100*	87	94
Forks, Wash.	48	92	82	89	91	—	86	80	85	82	98	96	70	82	96
Hoquiam, Wash.	47	91	99	93	—	69	*100*	85	89	*100*=	88	94	86	81	91
Jutland, ex Wash.	—	—	90	—	*100*	—	—	*100*	85	*100*=	*100*	—	66	*100*	*100*
Jewell, Ore.	46	75	94	84	91	*100*	99	98	93	63	94	86	82	89	99
North Bend, Ore.	43	87	85	93	83	73	96	93	*100*	93	87	86	68	82	91
Top Ht. at Site = 100% m (ft)		0·97 (3·2)	1·46 (4·8)	1·80 (5·9)	1·55 (5·1)	1·10 (3·6)	1·25 (4·1)	1·19 (3·9)	1·10 (3·6)	1·10 (3·6)	1·28 (4·2)	2·29 (7·5)	0·70 (2·3)	1·52 (5·0)	1·83 (6·0)
Mean Ht. Skidegate m (ft)		0·97 (3·2)	1·46 (4·8)	1·46 (4·8)	1·43 (4·7)	0·79 (2·6)	1·13 (3·7)	1·16 (3·8)	0·97 (3·2)	0·91 (3·0)	1·16 (3·8)	1·83 (6·0)	0·55 (1·8)	1·34 (4·4)	1·61 (5·3)
Significance of Diff.		NS	NS	xxx	NS	x	xxx	—	—	xxx	xxx	xx	—	—	—

Key to Sites

1. Shin, Sutherland
2. Deer, Aberdeen
3. Ratagan, W. Ross
4. Loch Goil, Argyll
5. Glentrool, Kirkcudbright
6. Wark, Northumberland
7. Clocaenog, Denbighshire
8. Taliesin, Cardiganshire
9. Tarenig, Cardiganshire
10. Myherin, Cardiganshire
11. Killarney, Kerry (Ireland)
12. (F) Bannau, Breconshire
13. Rheola, Glamorgan
14. Wilsey Down, Cornwall

Notes:—(1) Figures in parentheses are from incompletely replicated, or unreplicated plots
(2) Significances: NS = Not significant x = S.D. at 5% xx = S.D. at 1% xxx = S.D. at 0·1%

The provenances are nearly all from selected seed-stands, twelve in Rumania, two in Bulgaria, three in Switzerland, five in France and one in Britain. There is also a seed-lot from a stand in New York State. The control is the normally imported seed from Lower Austria. The number of provenances being an exact square (25), a very efficient analysis is possible from a partially balanced triple lattice design.

This experiment was projected and sown two years before the invitation was received and accepted to join a very large-scale trial of this species being organised in Sweden, and will be a very useful addition to it, the more valuable because of the unusual design of the Swedish experiment.

Dr. O. Langlet had assembled sufficient seed from 1,100 exact localities covering the entire range of Norway spruce in Europe, to enable him to offer plants of all provenances to other countries. Nineteen countries have accepted them. The 1,100 provenances are sent out in sets of eleven blocks of 100 provenances each, each provenance represented by twenty-five plants. The composition of each block is a stratified random sample from all 1,100, so that each shall contain a different set and each set will contain a proportion from each main region. Each block of 100 provenances is mixed and randomised on the site as planting proceeds, so that each provenance has all twenty-five plants as single-plant plots in one block; plant positions are mapped immediately after planting. It is a disadvantage that there is no single provenance in common with any other block, and the relation of one block to another in analysis is done by the regions which are represented by various provenances in all blocks. The precision is thus not high and, being single-plant plots, the duration of the experiment must be short. This is where the previous small experiment mentioned has its value.

The plants for this international experiment were received in mid-March 1968 and are planted in Grovely Wood, Salisbury Forest, where they occupy twenty-five acres.

In Scotland four sets of Dr. Langlet's plants (each of 100 provenances) were planted at two contrasting sites. Two hundred were used at Minard on the coast of Argyll, a site strongly influenced by oceanic conditions. Another two hundred were planted at Drummond Hill, Perthshire, which is remote from maritime influence and tends towards a more continental climate. The same standard provenance was used at both sites, randomly arranged in twenty-two plots in each of the four blocks. A response surface for each block will be constructed from the performance of this standard and the performance of the test provenances adjusted by computer.

Engelmann Spruce

This species has a minor interest as a possible "second string" to Sitka spruce. As it has a considerable latitudinal and elevational range it seems likely that we have not used the best provenance for British conditions in the past. A preliminary experiment with five provenances from British Columbia, and one from Washington, was planted at Shin, Sutherland, this year. If any of these provenances prove outstanding a further experiment may be planned.

Douglas Fir (See Table 28)

The English and Welsh plots of the first large-scale experiment, planted in 1954, have been thinned and assessed at the end of twelve years' growth, but the Scottish plots are not yet tall enough to thin, so cannot be assessed.

The provenances were special collections by the Manning Seed Company, from selected stands, and cover only the State of Washington in any detail. The survival and early growth figures showed few differences among the provenances, and the heights at the end of ten years at Glentress, Peeblesshire, also lack significant differences.

The differences among the plots in England and Wales after twelve years, in both height and girth, are becoming significant. They are given in Table 28. The origins are grouped in their climatic regions to facilitate comparisons.

The sites of the plots are:

Rheidol, Cardiganshire (107 m, 350 ft). Near west coast. Old hardwood scrub.

Mortimer, Herefordshire (198–229 m, 650–750 ft). Exposed to North. Old hardwood coppice area.

Shouldham, Lynn Forest, Norfolk (6–15 m, 20–50 ft). Open. Abandoned grazing. Bracken.

St. Clement, Lands End Forest, Cornwall (46–61 m, 150–200 ft). Steep, east-facing slope. Old scrub-oak.

In summary, the provenances from the west coast and the northern Cascades of Washington are giving the biggest trees. If Sequim, on the north-eastern point of the Olympic Peninsula, be regarded as "West Coast", this applies to all four various sites. The plots from Elma are everywhere remarkably uniform, and this is, all round, the best provenance so far. Plots from Hoquiam usually contain the biggest trees, but on some sites they are markedly irregular in size.

There is an important point to note, however. The plots at St. Clement, near Truro, have suffered in the last few years from precocious needle-shedding, without apparent pathological agent; many are seriously thin in the crown, and this must affect future increments. The "west coast of Washington" provenances are almost free from this, so may force ahead further, while the "southern Cascades" and Oregon are worst affected.

It is of interest also, that a provenance from Interior British Columbia (Shuswap) was included in the Scottish experiments. This is the geographical variety *caesia*. It grew very well for the first ten years and was the tallest at some sites, but since then it has suffered from *Rhabdocline* and has fallen behind. It also differed in having consistently more acute angles of branching.

To follow up this general experiment, and to extend it to a wider range of provenances, 15 provenances were planted out in March 1968 at the New Forest and the Forest of Dean as full experiments, with a smaller series of plots at Halwill, Cornwall. The provenances include two from Vancouver Island, and four selected Washington Coast origins including two from Elma to compare with the earlier experiment; the rest are from along the Pacific Coast to the southern parts of Oregon.

In 1967, 98 provenances were ordered through I.U.F.R.O. and specially collected. These cover all the western parts of the range of Douglas fir and their exact origins are known. They are being used by Genetics Section for "gene-banks" and seed-orchards. Twenty-nine provenances have been sown in a replicated experiment for later use in provenance trials in the south.

Abies grandis

There is increasing interest in this species for second rotation crops. Evidence is accumulating from French provenance experiments, reinforced by chance comparisons in Scottish species trials, that seed from the Cascade mountains,

TABLE 28

HEIGHT AND GIRTH OF DOUGLAS FIR PROVENANCES AFTER TWELVE YEARS' GROWTH

Region	*Provenance*			*Experiment*						m (ft)	
	Locality	Elevation m (ft)	Precipitation mm (in)	Rheidol		Mortimer		Shouldham		St. Clement	
				Ht	Girth	Ht	Girth	Ht	Girth	Ht	Girth
Washington	Forks	122 (400)	2,921 (115)	6·19 (20·3)	3·69 (12·1)	6·34 (20·8)	3·14 (10·3)	4·57 (15·0)	2·90 (9·5)	9·42 (30·9)	4·21 (13·8)
West	Hoquiam	91 (300)	1,778 (70)	6·06 (19·9)	3·75 (12·3)	6·67 (21·9)	3·44 *(11·3)*	4·36 (14·3)	2·96 (9·7)	10·03 *(32·9)*	4·45 *(14·6)*
Coast	Elma	152 (500)	1,575 (62)	6·43 (21·1)	3·75 (12·3)	6·92 *(22·7)*	3·41 (11·2)	4·85 *(15·9)*	3·11 (10·2)	9·45 (31·0)	4·42 (14·5)
Puget Sound	Lovella	427 (1,400)	1,194 (47)	6·34 (20·8)	3·84 (12·6)	5·79 (19·0)	3·20 (10·5)	4·30 (14·1)	2·93 (9·6)	8·66 (28·4)	4·33 (14·2)
and	Sequim	457 (1,500)	1,524 (60)	6·55 *(21·5)*	3·84 *(12·6)*	5·64 (18·5)	3·11 (10·2)	4·02 (13·2)	2·77 (9·1)	8·11 (26·6)	4·14 (13·6)
Central Dry	Tenino	91 (300)	1,270 (50)	6·19 (20·3)	3·69 (12·1)	5·85 (19·2)	3·11 (10·2)	4·30 (14·1)	2·83 (9·3)	8·35 (27·4)	4·05 (13·3)
Belt	Castle Rock	152 (500)	1,346 (53)	6·19 (20·3)	3·81 (12·5)	6·40 (21·0)	3·32 (10·9)	4·39 (14·4)	2·99 (9·8)	8·47 (27·8)	4·21 (13·8)
	Lopez I.	61 (200)	737 (29)	6·40 (21·0)	3·75 (12·3)	— —	— —	4·02 (13·2)	2·96 (8·7)	7·68 (25·2)	3·99 (13·1)
Washington	Darrington	152 (500)	1,930 (76)	6·43 (21·1)	3·78 (12·4)	5·70 (18·7)	3·08 (10·1)	4·60 (15·1)	3·11 (10·2)	8·59 (28·2)	4·21 (13·8)
Cascades	Enumclaw (High)	457 (1,500)	1,524 (60)	6·37 (20·9)	3·66 (12·0)	6·12 (20·1)	3·23 (10·6)	4·39 (14·4)	2·86 (9·4)	9·08 (29·8)	4·39 (14·4)
	Enumclaw (Low)	152 (500)	1,346 (53)	6·25 (20·5)	3·66 (12·0)	6·58 (21·6)	3·41 (11·2)	4·42 (14·5)	3·05 (10·0)	8·87 (29·1)	4·14 (13·6)
	Ashford	457 (1,500)	1,930 (76)	6·37 (20·9)	3·84 (12·6)	6·31 (20·7)	3·29 (10·8)	4·33 (14·2)	2·83 (9·3)	9·08 (29·8)	4·30 (14·1)
	Graham	183 (600)	1,905 (75)	6·06 (19·9)	3·57 (11·7)	5·79 (19·0)	3·14 (10·3)	4·05 (13·3)	2·65 (8·7)	8·79 (28·8)	4·27 (14·0)
	Wind River	457 (1,500)	2,210 (87)	6·16 (20·2)	3·75 (12·3)	5·61 (18·4)	3·14 (10·3)	4·14 (13·6)	2·74 (9·0)	8·50 (27·9)	4·45 *(14·6)*
Oregon Coast	Vernonia	244 (800)	1,270 (50)	5·91 (19·4)	3·60 (11·8)	6·19 (20·3)	3·32 (10·9)	4·51 (14·8)	3·14 *(10·3)*	9·05 (29·7)	4·33 (14·2)
Oregon Cascades	Upper Santiam R.	457 (1,500)	1,778 (70)	6·06 (19·9)	3·75 (12·3)	5·30 (17·4)	3·08 (10·1)	3·84 (12·6)	2·93 (9·6)	8·75 (28·7)	4·33 (14·2)
Significance of Differences						xxx	xxx	xx	NS		

Note:—Significances: NS = Not significant, x = S.D. at 5%, xx = S.D. at 1%, xxx = S.D. at 0·1%

which has hitherto been our main seed source, produces less vigorous plants than that from the coastal lowlands, especially Vancouver Island. A small trial, using the same Vancouver Island and Washington provenances planted last year at Honiton, was planted this year at Alice Holt and Brendon in the South, and in the North at Drumtochty, Kincardineshire, in a heavily-thinned hybrid larch crop. It is adjacent to a trial with *Abies alba* provenances and other *Abies* species.

Abies concolor variety lowiana

The large series from Oregon to the middle of the Sierra Nevada, covering the variation from *A. grandis* to *A. concolor* has produced excellent plants showing differences in the numbers of stomata on the upper side of the leaf, which broadly increase with more southerly latitudes of origin. Full trials have been planted out at Alice Holt, Mortimer (Hereford), Wilsey Down (Cornwall) and Honiton (Devon).

Abies procera

A small trial of home-collected provenances, two Danish and one from Oregon, has been planted at Radnor and Thetford Forests.

Scots Pine

An interesting little collection of provenances from Spain, Turkey, Poland, Scotland and Sweden, nine in all, was planted at Wareham and at Thetford.

Sequoia sempervirens

An extension of the 1965 demonstrations at Alice Holt and Plym, which cover the range from the extreme north (Oregon) to the extreme south, was planted at Weston Common, Alton (Hants). This includes mostly repeat sowings and some different single-tree collections. At Alice Holt, the most northerly origin is strikingly ahead of all the others, but more southerly ones are next in the order of height. At Plym, growth has been slow due to frost and rabbit-damage.

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WEED CONTROL IN THE FOREST*

Rhododendron, Rhododendron ponticum

Experiments 1964–66

The results of experiments between 1964 and early 1966 have been published elsewhere (Aldhous and Hendrie, 1966), and were referred to in the 1967 *Report*.

Since these publications, the three experiments carried out in 1965/66 have been re-assessed for the health of the crop and the kill of *Rhododendron*. In these experiments 2,4,5-T was applied (*a*) overall at the rates of 35 and 45 lb per 100 gallons of water (3·5 and 4·5 kg per 100 litres), and (*b*) as a basal bark spray at the rates of 20 and 30 lb per 100 gallons (2 and 3 kg per 100 litres) of diesel oil. Volumes of spray per square yard of *Rhododendron* varied mostly between 250 and 400 ml (250 to 400 gallons per acre or 2,800 to 4,480 litres per hectare). Tree crops were present at the time of spraying, which was October 1965, or March 1966.

Table 29 shows the mean health scores of the tree crop assessed during the period September to December 1967.

TABLE 29

MEAN HEALTH SCORES OF CROP TREES IN 1965/66 RHODODENDRON CONTROL EXPERIMENTS SEPTEMBER TO DECEMBER 1967

Site	Species	Control	October Applications				March Application			
			Overall		Basal Bark Spray		Overall		Basal Bark Spray	
		0	35 lb/ water	45 lb/ water	20 lb/ oil	30 lb/ oil	35 lb/ water	45 lb/ water	20 lb/ oil	30 lb/ oil
Bedgebury	Corsican pine	1·0	1·0	1·2	1·1	1·0	1·0	1·0	2·0	1·7
Bramshill	Western hemlock	1·0***	1·9	2·0	1·9	1·8	2·0	2·0	1·9	1·9
Wareham	Pinus radiata	1·0	1·2	1·0	1·0	1·0	1·0	1·2	1·0	1·0

Notes:

Trees were scored for health on the basis of 1 = completely healthy,
5 = dead.

*** Control significantly more healthy than all treatments at 0·1 per cent level.

At Bedgebury and Wareham, Corsican pine and *Pinus radiata* obviously tolerated the high concentrations of 2,4,5-T within the plantation with negligible damage. The poorer health scores for March basal bark treatments with oil at Bedgebury were thought to have been at least partly due to the use of a faulty knapsack sprayer.

* Full details of the names, formulae and properties of the chemicals mentioned in this section can be found in the 4th Edition *Weed Control Handbook*, ed. E. K. Woodford, publ. Blackwell, Oxford.

Brand names of weedkillers which are currently marketed can be found in the *Agricultural Chemicals Approval Scheme, List of Approved Products* (Ministry of Agriculture).

At Bramshill, however, Western hemlock seems to have been damaged by the high concentration of 2,4,5-T within the plantation, even though applications were made in its dormant season.

Rhododendron health was scored in a similar way (1 = fully healthy to 5 = dead) during the period September to December 1967, the results being presented in Table 30.

TABLE 30

MEAN HEALTH SCORES OF RHODODENDRON—SEPTEMBER TO DECEMBER 1967

Site	Control	October Applications				March Applications			
		Overall		Basal Bark		Overall		Basal Bark	
	0	35 lb/ water	45 lb/ water	20 lb/ oil	30 lb/ oil	35 lb/ water	45 lb/ water	20 lb/ oil	30 lb/ oil
Bedgebury, Kent	1·0	4·3	4·9	4·4	5·0	4·9	4·5	3·3	3·0
Bramshill, Hants	1·0	5·0	5·0	5·0	4·8	4·9	4·8	5·0	5·0
Wareham, Dorset	1·0	4·1	4·1	2·2	1·8	4·7	4·8	2·2	2·3

At Wareham, with both dates of application, and at Bedgebury with March applications, basal bark treatments in oil have given markedly inferior control compared with overall treatments in water. Health scores of between 4 and 5 indicate in almost all cases that weak regrowth has occurred from a stool previously killed right back.

In another experiment at Bramshill in 1965/66 the same 2,4,5-T treatments as were used in the above experiments were applied to (*a*) four-year-old regrowth and (*b*) freshly-cut stumps, in October 1965, and also in March 1966.

October treatments received very high volumes of spray solution—800–1,500 gallons per acre of *Rhododendron.* Volumes applied in March treatments were reduced to between 200 and 500 gallons per acre.

Health assessments at September 1967 showed virtually complete kill of freshly cut *Rhododendron* stumps, and also of March-treated four-year-old regrowth. Kill was also exceptionally good on October-treated four-year-old regrowth, but some weak resprouting had occurred.

It seems clear that the amount of 2,4,5-T applied in this experiment was in excess of that required to give adequate control.

Experiments 1966/7

At Abinger Forest, Surrey, concentrations of 15, 25 and 35 lb of 2,4,5-T in 100 gallons (1·5, 2·5 and 3·5 kg in 100 litres) of water were applied to one-year-old *Rhododendron* regrowth at a rate of 220 gallons per acre (2,464 litres per hectare) of *Rhododendron.* Applications were made in August 1966, November 1966, February 1967 and May 1967. "Natrosol" (sodium ethylhydroxycellulose) was added to some treatments to see if increasing the viscosity of the spray solution improved the retention of spray on *Rhododendron* leaves, and the subsequent kill.

Early assessments, at three and six months after spraying, indicated that the initial control was good, but that lower concentrations, especially the 15 lb per

100 gallons (1·5 kg per 100 litres), were either slow in taking effect or provided inadequate control. At this stage there seems to be no advantage from the addition of "Natrosol".

Bracken, Pteridium aquilinum

Two series of experiments were started in south England and Wales in the Spring of 1967 using dicamba to control bracken.

First Series of Experiments

In one series, dicamba was applied at 3 and 4 lb per acre (3·4 and 4·5 kg/ha) overall by mistblower, and 4 and 6 lb per acre (4·5 and 7·2 kg/ha) to three-foot strips to coincide with the tree row spacing, using a knapsack sprayer. Applications were made in May 1967 in preparation for planting the following winter.

The object of this series of experiments was to confirm that the rates suggested from previous experiments (Aldhous, 1966) were satisfactory, and that mistblower applications were effective. Crops were not expected to be damaged, but this would be confirmed.

Tables 31 and 32 show the average height of bracken and the percentage cover of bracken respectively at the end of the first year following spraying.

TABLE 31
MEAN HEIGHTS OF BRACKEN AT SEPTEMBER/OCTOBER 1967

cm (in)

Site	Un-treated Control	Treated (overall mean)	Treatments					
			Overall M.	Overall K.	Rates within M.		Rates within K.	
					3M	4M	4K	6K
Forest of Dean	129·0 (50·8)	50·1 (19·7)	50·1 (19·7)	50·1 (19·7)	58·4 (23·0)	41·4 (16·3)	56·7 (22·3)	43·2 (17·0)
Ebbw, Monmouth	140·9 (55·5)	50·8 (20·0)	50·1 (20·1)	50·8 (20·0)	51·6 (21·3)	47·7 (18·8)	52·1 (20·5)	49·6 (19·5)
New Forest	72·1 (28·4)	10·2 (4·0)	20·3 (5·3)	7·1 (2·8)	16·5 (6·5)	10·2 (4·0)	8·1 (3·2)	5·9 (2·3)
St. Leonards, Sussex	95·3 (37·5)	37·0 (14·6)	35·3 (13·9)	38·7 (15·2)	43·2 (17·0)	27·4 (10·8)	47·6 (18·8)	29·8 (11·8)
Neroche, Somerset	97·1 (38·3)	53·3 (21·0)	not included	53·3 (21·0)	not included		58·2 (22·9)	48·3 (19·0)

K = applied by knapsack sprayer; M = applied by mistblower. See Notes to Table 32.

Without exception, all applications of dicamba significantly reduced the height and percentage cover of bracken compared with untreated controls, at the 0·1 per cent level.

Differences between treatments were more erratic. Generally mistblower applications produced as good results as knapsack applications, in spite of the slightly lower rates.

Higher rates of dicamba were more effective in reducing bracken height and cover, both as mistblower and knapsack treatments. At the Forest of Dean, the 4 lb per acre (5·3 kg/ha) rate from a mistblower significantly reduced bracken height (at the 1 per cent level) and cover (at the 5 per cent level) as compared with the 3 lb per acre (3·4 kg/ha) rate. At the same forest, the 6 lb per acre

(6·8 kg/ha) rate from a knapsack significantly reduced bracken height compared with the 4 lb per acre (5 kg/ha) rate at the 5 per cent level.

Generally, control in the first year following dicamba applications has been consistently good. The persistence of this control in subsequent years will be important.

TABLE 32

PERCENTAGE GROUND COVER OF LIVE BRACKEN AT SEPTEMBER/OCTOBER 1967

Site	Untreated Control	Treated (overall mean)	Treatments					
			Overall M.	Overall K.	Rates within M.		Rates within K.	
					3M	4M	4K	6K
Forest of Dean	78·8	23·2	22·1	24·1	27·1	17·1	25·7	22·8
Ebbw, Monmouth	68·6	13·3	13·3	13·3	15·5	11·0	15·0	11·5
New Forest	61·4	1·3	1·7	1·0	1·8	1·5	1·1	0·8
St. Leonards, Sussex	80·8	9·2	10·7	8·2	14·0	7·3	11·8	4·5
Neroche, Somerset	93·7	16·1	not included	16·1	not included		19·2	13·0

Notes for Tables 31 and 32

3, 4 and 6 represent lb of dicamba per acre

M = Mistblower

K = Knapsack sprayer

Second Series of Experiments; Test at Interval between Treatment and Planting

The second series of experiments was carried out at three sites to test how soon planting could take place after dicamba treatments.

Dicamba at 1½, 3 and 4½ lb per acre (1·7, 3·4 and 5·1 kg/ha) was applied in March and May 1967, either as a 10 per cent granule or spray, and then various coniferous species were planted at 0, 1, 2, 4 and 8 weeks after application. As planting dates occurred from March to July, all plants were cold-stored until required.

Cold storage had an unfortunate effect, since nearly all species suffered from cold storage, because they were generally put into store too late. The adverse effects of storage on Grand fir and Western hemlock at Ceiriog, North Wales, Grand fir and Douglas fir at Forest of Dean, and Japanese larch at St. Leonards, Sussex, was so devastating that it is expected that these species will be of little use in assessing dicamba residues. It is, of course, possible that dicamba residues had a much greater effect because the trees were already unhealthy.

End-of-season assessments on the other species (Corsican pine, Scots pine, Norway spruce, Western hemlock, Sitka spruce) showed that damage from dicamba residues was generally directly related to the rate of application, and inversely related to the period between application and planting.

Corsican pine and Scots pine seem to be more tolerant of dicamba residues than the other two species, and the damage attributable to dicamba application at the four- and eight-week planting dates was negligible. Scots pine seemed free from damage even when planted two weeks after applications. Norway spruce appeared to require the full eight weeks interval before damage became very slight. Western hemlock planted eight weeks after dicamba treatment was still showing considerable damage at the end of the season, although it is difficult to differentiate this from cold storage effects. Full data is not available yet for Sitka spruce.

Five experiments were established in 1967 in Scotland and Northern England to compare knapsack mistblower and knapsack pressure sprayer application of dicamba on bracken. At one site, Glentress Forest, Peeblesshire, paraquat was mixed with the dicamba as there was a strong grass understorey to the bracken. Preliminary results were good at most sites, but it will be the coming year (1968) before the real effect of the treatments can be assessed.

Herbaceous Weed Control

"Prefix" (Chlorthiamid)

Forestry Commission experiments with "Prefix" up to 1967 have been summarised by J. R. Aldhous, Forestry Commission *Research and Development Paper* No. 49, 1967.

Three further experiments were started during 1967, at Thetford, Alice Holt and Gwydyr Forests.

At Thetford, "Prefix" at 4 lb per acre (5 kg/ha) was compared with paraquat at 2 lb per acre, applications being made at four dates from November 1966 to March 1967. Corsican pine was planted six weeks after each application.

Preliminary reports indicate little damage attributable to "Prefix" on the Corsican pine, and generally good weed control in the first year.

At Alice Holt, "Prefix" was applied at 3 and 4 lb per acre (3·4 and 5 kg/ha), two and four weeks after planting a range of 20 species, including 16 coniferous species and four broadleaved species.

End-of-season assessments for 1967 on shoot growth revealed no significant reduction on growth, attributable to "Prefix".

Health assessments showed also that "Prefix" had not damaged the majority of the species. However, adverse effects were observed on Western hemlock (significant at the 5 per cent level), Grand fir and Leyland cypress (both significant at the 1 per cent level). Damage was also more severe on Douglas fir treated at 4 lb per acre (5 kg/ha) than at 3 lb per acre (3·4 kg/ha), but the combined mean health score for both rates was not significantly different from that of the control.

At the end of 1967, "Prefix" had not caused any noticeable damage to Corsican pine, Scots pine, Lodgepole pine, Sitka spruce, Norway spruce, Japanese larch, European larch, Hybrid larch, Noble fir, *Abies lowiana*, Red cedar, Lawson cypress, beech, Pedunculate oak and Sessile oak.

This lack of damage is not in keeping with the effect of "Prefix" on crop trees in experiments over the last few years, and suggests that the very high May rainfall may have helped to disperse the chemical in the soil.

At Gwydyr Forest, North Wales, chlorthiamid at 3 and 4 lb per acre (3·4 and 5 kg/ha) was applied to Sitka spruce and Scots pine, planted in Forest Year 1964, at two dates, mid-March and early April.

End-of-season assessments showed no significant differences had resulted in the mean 1967 shoot growth on either species, but as Table 33 shows, the health of both species was affected.

TABLE 33

MEAN HEALTH SCORES FOR SITKA SPRUCE AND SCOTS PINE AFTER TREATMENT WITH "PREFIX"

Species	Treatments					Standard Error
	Control	3M	3A	4M	4A	
Scots pine	1·04	1·37	1·25	1·56	1·66	0·18*
Sitka spruce	1·00	1·16	1·10	1·66	1·29	0·14*

Notes

(1) Health scores were assessed 1 to 5 as shown:—

1 = Healthy
2 = Slightly affected
3 = Moderately affected
4 = Severely affected
5 = Dead

(2) 3M, 3A, 4M, 4A indicate 3 or 4 lb per acre of " Prefix " active ingredient applied in March or April.

(3) *differences significant at 5 per cent level.

The more chlorthiamid applied, the greater the damage observed. However, date of application had no consistent effect on damage.

Triazines

Following reports from U.S.A. (Newton, 1964) that Atrazine gave good herbaceous weed control in new plantations without damage to the crop, a preliminary experiment was carried out at Orlestone Forest, Kent, with Atrazine and Ametryne, two triazine compounds closely related to simazine, but which differ by having considerable contact phytotoxicity, as well as acting through the roots.

Both herbicides were applied at 5, 10 and 15 lb per acre in 60 gallons of water to square yard plots round Corsican pine planted in 1964. The trees were protected from the direct spray. Assessments in October 1967 showed all trees to be completely undamaged, and that the mixed herbaceous weeds (grasses and broadleaves) had been well controlled:—

Percentage live cover of controls . . . 78 per cent
Percentage live cover of sprayed plots . 10 to 21 per cent

There was little difference between the rates of herbicides. Further experiments are being carried out in 1968 at rates of application giving costs similar to the currently recommended rates of paraquat and dalapon.

Before-planting Treatment with Dicamba

The willow-herb *Epilobium anfustifolium* can be a troublesome weed in localised areas, particularly rich sheltered valleys where it can grow to seven feet (2 m). Dicamba was applied to such an area in the Carfin Section of Clydesdale Forest, Lanarkshire, in 1967 at 4 and 8 lb active ingredient per acre (5 and 10 kg/ha) in 8 gallons (36 litres) water, using a mistblower. The 1967 result was complete suppression of the *Epilobium* at both rates, but it will be 1968 before the amount of complete kill of the underground stems will be known. It was also noted in this trial that dicamba gave a good first year control of the rush *Juncus squarrosus.*

TABLE 34

MEAN HEALTH SCORE OF OAK AT FOREST OF DEAN—JUNE 1967

Control	Diesel Oil		Paraffin		Water		Water/Diesel		Water/Paraffin	
0	15	25	15	25	15	25	15	25	15	25
1·02	1·85	2·70	2·75	3·00	1·02	1·08	1·52	1·80	2·32	2·88

TABLE 35

PERCENTAGE CROWN REDUCTION OF HAZEL COPPICE AT ALICE HOLT—JUNE 1967

Control	Diesel Oil		Paraffin		Water		Water/Diesel		Water/Paraffin	
0	15	25	15	25	15	25	15	25	15	25
1·4	50·0	78·0	50·5	69·8	18·0	26·8	52·1	62·2	32·1	44·9

Notes on Tables 34 and 35

(1) Health scores 1 to 5:—

1 = Healthy
2 = Slightly affected
3 = Moderately affected
4 = Severely affected
5 = Dead

Pre-Planting Control of Grass under Larch and Pine Stands

The mistblower paraquat trial done in 1966 at Port Clair Forest, Inverness-shire, showed that on that site where the main grass species is *Holcus mollis* (Creeping soft grass), paraquat does not give satisfactory control for two growing seasons and hence is not a treatment to be recommended for such areas.

In the two experiments comparing pre-planting paraquat treatments on grass under larch, done at Drummond Hill in 1965 and 1966, it is now obvious that grass control varies from 1 to 2½ years depending on the grass species. (See a similar note in the section on "Underplanting of Larch and Pine", page 57.) As the cost of a paraquat treatment compares with the cost of 1–1½ hand weedings, it certainly seems justifiable to apply paraquat to non-rhizomatous grass species prior to planting, or to apply it post-planting using an "Arbogard". The use of paraquat through a mistblower cannot be recommended at present. Some research is being done to reduce or eliminate the fine droplets produced by a mistblower to make it safer to use paraquat both with regard to the operator and to neighbouring crop trees or plants under windy conditions.

Woody Weeds

Trials were laid down at Alice Holt, Hampshire, and Forest of Dean to test the efficiency of 2,4,5-T as a basal bark application to hazel coppice and oak, using different diluents. Table 34 shows the mid-season assessments for the health of the trees at Forest of Dean, and Table 35 the percentage reduction in crowns of trees at Alice Holt.

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TREE STABILITY

Windthrow Survey—Scottish Windblow of 1968

The outstanding event of the year was the hurricane of 14/15th January 1968 which caused extensive damage to woodlands in the Clyde–Forth valley and adjacent districts. Approximately 1·4 million m^3 (40 million h ft) were windthrown.

Three features of the wind are noteworthy:—

(1) The long period during which the mean speed exceeded 74·2 km/h (40 knots) namely, six hours.

(2) The relatively low value of gusts; only about 50 per cent above the mean, whereas about 80 per cent is more common.

(3) The relatively constant direction, just south of west throughout the storm.

These features, especially the last, were considered to make an investigation of the effect of topography on the occurrence of damage particularly opportune. A preliminary survey of damage, concentrating particularly on the direction of fall, has been arranged, and using a helicopter, aerial photographs of the main areas will be utilised in attempting to rationalise the topographic factor.

Records of Windthrow

By the end of March 300 cards had been received for the above Scottish hurricane alone, almost twice the average annual total for the Forestry Commission.

Analysis of the windthrow returns made during the period 1961–67 is almost complete, and the results will be published, probably as a Research and Development Paper. The breakdown of the various characteristics is already available, but without supporting statistics false interpretation is likely. In all 1,200 notification cards were received, giving details of about 970 hectares (2,400 acres) of windthrow. Almost half of this acreage is accounted for by Sitka spruce, the leading species in the region affected, followed by Norway spruce and Douglas fir, each of which totalled about 80 hectares (200 acres). The returns make almost no mention of hardwoods. There were, however, few hardwood plantations at risk, though many open-grown trees are known to have been blown down. Sixty per cent of the crops blown were aged between 31 and 40 years and in 80 per cent of the area top height was between 9·5 and 18·25 metres (31–60 ft).

Tree-Pulling Investigations

No field studies using the tree-pulling technique were carried out during the last year. However, due to the increasing demand for this type of work, two Foresters from Silviculture (North) were trained, and they will carry out investigations in the north. Work in the south will continue and the emphasis will move from Sitka spruce to the lesser-used species, particularly Douglas fir and Norway spruce.

Aerodynamic Studies

The experiment at Redesdale (Northumberland), where wind velocity profiles are being measured above an unthinned Sitka spruce stand, is beginning to yield some interesting and useful results.

Records over a long period when some very high winds were experienced were missed because of the Foot and Mouth disease restrictions, but a good range of general wind speeds has been measured during the year.

The large quantity of data collected on the Automatic data-logger needs careful analysis, and it will be some time before a complete assessment of the results can be made. However, some interim and rather general conclusions are worthy of note.

There are two pairs of masts in the forest, one pair near an exposed south-west edge, and one pair some 10 tree heights in from the edge. Comparisons of wind velocities between the two masts, at the same distance from the forest edge, show good agreement over a range of wind speeds and directions (Table 36).

The tree crop near the edges of the forest has a mean height of 10·4 m, and a top height of 11·2 m, whereas the crop around the innermost masts has a mean height of 11·3 m and a top height of 12·8 m. The table indicates that, even when there are strong winds blowing outside the forest, the wind speeds among the tops of the trees is only about one-tenth of that at the same height outside the forest. The wind speeds given are averaged over an hour, so that gusts will be 50–80 per cent above the values given.

The winds are accelerated slightly over the edge of the forest, but the region where the air moves faster is between 17 m and 25 m above the ground, well above the tops of the trees (Table 36).

The experiment is being extended to provide more detailed information on the tree growth, and climatic factors in addition to wind.

Felling Area Sizes in Sitka Spruce

The second experiment in this series at Redesdale Forest (Northumberland) has now been subject to two years' gales. It compares the windthrow consequent on felling area sizes of 0·12, 0·40 and 2·0 hectares (0·3, 1·0 and 5·0 acres), and up to the end of January 1968 a total of approximately 2,400 trees have been thrown on the crop margins by nine gales.

As in the preceding experiment (*Report* for 1964) the predominant sector of damaging winds was north-westerly to south-westerly, and the resulting damage was on the opposing windward faces. Windrun within clearings was assessed and showed a similar reduction in windrun with decreasing size of clearing as at the Forest of Ae. Centrally-sited anemometers gave the highest readings, and those near the eastern margin gave higher readings than the more sheltered westerly instruments.

The number of trees thrown per hectare felled, up to January 1964, is lowest in the largest clearing size, but there is little difference between the 0·4 hectare (1 acre) and 0·12 hectare (0·3 acre) clearings, i.e. although previous results are not contradicted they are not as yet wholly confirmed.

In co-operation with the Soils Officer of the Planning and Economics Section, the possibility of forecasting the rate of windthrow extension from the distribution of current damage is being investigated. Periodic re-survey data is available from the above experiments and several Border forests.

Restriction of Windthrow

In 1963 and 1964 comparative lengths of margins of windthrow areas were treated in three ways in order to restrict the extension of damage. All treatments

TABLE 36

WIND VELOCITY IN KM/H (KNOTS), IN RELATION TO HEIGHT ABOVE GROUND, AND POSITION IN FOREST, FOR A RANGE OF GENERAL WIND SPEEDS

(See p. 84, fourth para, for height of crop.) km/h (knots)

Location	Height Above Ground, metres (feet)	Wind Velocities in km/h (knots) for a Range of General Wind Speeds							
		Light Wind from South West		Mod. Wind from South West		Mod. Wind from North East		High Wind from South West	
		Mast 1		Mast 1		Mast 1		Mast 1	
Mast in Open Ground	10 (33)	15·2	(8·2)	26·3	(14·2)	17·0	(9·2)	46·1	(24·9)
	13 (43)	15·7	(8·5)	27·1	(14·6)	18·3	(9·9)	47·8	(25·8)
	17 (56)	15·7	(8·5)	28·2	(15·2)	18·7	(10·1)	48·5	(26·2)
	21 (69)	19·1	(10·3)	30·4	(16·4)	23·3	(12·6)	53·0	(28·6)
	25 (82)	19·5	(10·5)	30·9	(16·7)	22·6	(12·2)	52·6	(28·4)
		Mast 2	Mast 4	Mast 2	Mast 4	Mast 2	Mast 4	Mast 2	Mast 4
Masts distant by 1 Tree Ht into Forest from Edge	10 (33)	0·18 (0·1)		1·1 (0·6)	0·0	4·8 (2·6)	8·1 (4·4)	9·3 (5·0)	0·7 (0·4)
	13 (43)	13·7 (7·4)	15·2 (8·2)	20·6 (11·1)	22·2 (12·0)	20·4 (11·0)	17·6 (9·5)	43·7 (23·6)	41·3 (22·3)
	17 (56)	16·7 (9·0)	18·0 (9·7)	26·1 (14·1)	27·6 (14·9)	24·5 (13·2)	23·7 (12·8)	51·3 (27·7)	50·0 (27·0)
	21 (69)	19·5 (10·5)	20·2 (10·9)	28·7 (15·5)	30·0 (16·2)	28·2 (15·2)	26·3 (14·2)	55·2 (29·8)	50·8 (27·4)
	25 (82)	21·1 (11·4)	20·7 (11·2)	31·3 (16·9)	31·1 (16·8)	30·6 (16·5)	30·0 (16·2)	56·7 (30·6)	52·3 (28·2)
		Mast 3	Mast 5	Mast 3	Mast 5	Mast 3	Mast 5	Mast 3	Mast 5
Masts distant by 10 Tree Hts into Forest from Edge	10 (33)	0·0	0·0	0·0	0·9 (0·5)	0·0	1·1 (0·6)	0·6 (0·3)	5·9 (3·2)
	13 (43)	0·18 (0·1)	2·6 (1·4)	9·8 (5·3)	11·1 (6·0)	18·0 (9·7)	19·1 (10·3)	15·4 (8·3)	22·0 (11·9)
	17 (56)	6·5 (3·5)	10·9 (5·9)	16·5 (8·9)	20·0 (10·8)	23·5 (12·7)	23·9 (12·9)	28·0 (15·1)	33·5 (18·1)
	21 (69)	13·0 (7·0)	14·8 (8·0)	21·1 (11·4)	24·1 (13·0)	25·4 (13·7)	25·0 (13·5)	37·1 (20·0)	41·9 (22·6)
	25 (82)	16·5 (8·9)	19·1 (10·3)	24·6 (13·3)	28·5 (15·4)	26·5 (14·3)	27·8 (15·0)	44·8 (24·2)	49·3 (26·6)

were designed to reduce the "sail" area of the edge trees by (*a*) removing the top 25 per cent of the tree but retaining a minimum of three live whorls, (*b*) ultra-high pruning to the fourth live whorl, and (*c*) killing the trees with ammonium sulphamate. The effectiveness of each treatment was compared with untreated control lengths of crop margin. It was impossible to achieve strictly comparable conditions of aspect, soil and tree height at each site, but the overall result of these trials was that no treatment was consistently successful. Tree topping of a wider band of trees has been shown to be effective in Germany in recent years, but it is thought that on very windthrow-susceptible soils in Britain the occurrence and extension of sporadic damage within the stand being protected, renders expensive margin treatment inappropriate in most situations.

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MIXTURES

Lodgepole Pine and Sitka Spruce

Before considering the need and form of further experimentation on the likely benefits of Lodgepole pine/Sitka spruce nursing mixtures, an extensive survey of such mixtures was undertaken. This topic was one which several Conservators had previously suggested as important. The *Report* for 1967 briefly described the form of the survey and drew some tentative conclusions which can now be expanded.

Of 91 mixtures none was obviously successful, 52 were clearly unsuccessful, and the remaining 39 were only possibly successful. There was some suggestion that the chances of successful nursing were greater on the more fertile sites and that intimate mixtures (i.e. in which each spruce or pair of spruces is surrounded by pine) tended to produce taller spruce than band or group mixtures, but the long-term needs and costs of maintenance could not be investigated. Phosphate and ploughing encouraged the relative success of spruce, but here it should be noted that applying manure only to the spruce, and not to the pine, has proved unsuccessful in previous experiments.

The overall result of the survey indicated that worthwhile nursing of Sitka spruce is not spectacular or frequent and hardly justifies the large areas which have been planted with mixtures. In the present stage of knowledge one cannot be certain whether the weak nursing capacity of Lodgepole pine will produce a successful spruce crop on a given site type. The current silvicultural trend is towards cheaper mechanical application of increasingly efficient herbicides and aerial applications of fertilisers, which argues against amelioration treatments applicable to only one constituent of a mixed crop. For this reason, and because experimentation would have to be complex, long-term (at least into the crop phase) and cover a wide range of soil vegetation and exposure types, it has been concluded that it is no longer appropriate to establish new nursing experiments.

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MISCELLANEOUS INVESTIGATIONS IN PLANTATIONS

Growth Problems in Pole-stage Sitka Spruce

As was indicated in the 1967 *Report*, three new experiments were established at the beginning of 1967 in north-east Scotland to continue the investigation into the effect of defoliation by the Green spruce aphis *Elatobium abietinum* on the increment of pole-stage Sitka spruce crops. Each experiment was sited in a young well-stocked crop of top height 9–12 m (30–40 ft), in which a first thinning had recently been, or was about to be, carried out. Six pairs of plots were laid out at the Forest of Deer (Aberdeenshire) and at Rosarie Forest (Banffshire); three pairs were laid out at Fetteresso Forest (Kincardineshire).

During the subsequent spring and summer, relatively high levels of *Elatobium* infestation were common throughout north-east Scotland and a considerable amount of spruce defoliation resulted. At both the Forest of Deer (Aberdeenshire) and Rosarie Forest (Banffshire) high population levels were recorded within the experiments. Malathion spraying in April and June gave effective control of the aphids and, by autumn, treated plots could be visibly distinguished from untreated plots because of the much lower canopy density in the latter following the loss of aphis-attacked needles. At Fetteresso Forest (Kincardineshire), on the other hand, the aphis population remained relatively low throughout the season within the experiment, despite the occurrence of high levels of infestation in adjacent stands, and little defoliation was observed in unsprayed plots.

When the experiments were assessed at the end of the growing season, it was found that at both Deer and Rosarie the average basal area increment was distinctly higher in the sprayed than in the unsprayed plots. In the Deer experiment, where the differences between the six pairs of plots were consistently in favour of the sprayed plots, the average difference amounted to 0·58 m^2/ha (2·1 ft^2 qg/acre) or 18·4 per cent of the increment in the unsprayed control plots and was very highly significant. Differences between plot pairs were less consistent at Rosarie, where in two cases the unsprayed plot showed a slightly higher increment; on average the increment in the sprayed plots was 0·20 m^2/ha (0·7 ft^2 qg/acre) or 9·2 per cent higher than in the unsprayed, but this difference was not significant. It is probable that these inconsistencies at Rosarie may have arisen because thinnings which should have been felled in April, and which were therefore not measured when setting up the experiment, were in fact left standing until August. Their late removal undoubtedly took away an appreciable part of the season's increment and the proportion so taken may well have varied to some extent between plots. At Fetteresso, there was no difference in increment between sprayed and unsprayed plots.

The data from Deer and, to a lesser extent, those from Rosarie, suggest that *Elatobium* damage can cause an appreciable loss of increment in affected stands. Confirmation of this will have to await the occurrence of further years with high population levels in the experiments.

In the older experiment at the Forest of Ae (Dumfriesshire) a relatively high level of aphis infestation was also observed, but as in previous years there was no significant difference in increment between sprayed and unsprayed plots. Because of inadequate replication (only three pairs of plots), and increasing difficulty of obtaining effective spray treatment in the 15 m (50 ft) high crop, it was decided to close this experiment, which has served as a prototype for the three new experiments.

Spacing in Plantations

The review of the Northern spacing experiments previously reported (*Report* for 1967, page 78), has been completed. The violent storm of 14/15th January 1968 caused considerable damage in many of these experiments and some have had to be closed. The remaining experiments considered to be likely to yield useful information will in future be managed by the Mensuration Section of the Planning and Economics Branch, who already deal with the Southern experiments in this series.

The main factors considered in the review were the effects of spacing upon branch size and stem taper, in consideration of possible effects upon timber quality. Branch size assessments were based on the mean diameter of the two largest branches in the whorls nearest 10 ft and 20 ft. Typical values for Sitka spruced thinned to a C/D grade throughout are presented in Table 37.

TABLE 37

SPACING EXPERIMENTS IN SITKA SPRUCE

Mean Values for Crop Height and Mean Branch Diameter of 2 Largest Branches at 10 ft and 20 ft in four Experiments at 30 years

Spacing (ft)	Mean Height (ft)	Mean Branch diameter, at 10ft	2 largest branches (in), at 20 ft
3×3	57·0	0·73	0·88
4½×4½	56·6	0·82	1·00
6×6	58·2	1·05	1·20
8×8	59·0	1·20	1·32

At 30 years, most of the branches at 10 feet were dead, and the results quoted suggested that total branch development at this height was limited by competition effects, even at the widest spacing used. The progressive increase in branch size with the increase in initial spacing is quite marked, but the maximum branch size even at 20 ft is unlikely to exceed 1½ in. diameter at the widest spacing used.

The effect of initial spacing on branch size to 20 ft appears to have been unaffected by any of the thinning regimes practised. These were: "no thinning", low thinning of C/D grade, and low thinning designed to maintain the same relative number of stems per acre in each spacing plot, using C/D grade thinning of the 4½ ft spacing as a control. The latter regime involved thinning the 3-ft spacing plots very lightly, and thinning the 6-ft and 8-ft plots at progressively heavier intensities.

The data on the effect of spacing on stem taper have still to be analysed, but the following points may be made. Stem taper increased sharply with increased initial spacing in the range examined, but effect was largely confined to the lower part of the stem. The effect appeared to occur early in the life of the tree and there was little evidence of any large subsequent effect due to thinning.

Planting Methods

Assistance in experimental design and assessment has been given to the Work Study Section in investigation of planting methods. In preliminary trials, first-year survival and shoot growth of Lodgepole pine and Sitka spruce planted at three forests in five different ways, all in common use, were very similar. Work content, therefore, may be the main criterion of choice between them.

Review of Old Experiments

At Allerston (Yorkshire) a major review of experiments was completed, and resulted in the proposed closure of some 35 experiments in the experimental areas of Wykeham, Harwood Dale and Broxa. This will result in a considerable reduction in the maintenance load falling on local research staff. The commonest reasons for closure were obsolete treatments, small size of plots and inadequate design. Likewise the series of experiments based on spaced group planting ("Anderson Groups") is being summarised and will be concluded with the assistance of students from Aberdeen University.

A. J. LOW

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POPLARS AND ELMS

Poplar Varietal Studies

Varietal Trial Plots

Assessments were again confined to selected plots of commercial cultivars and of important trial clones. Data of special interest were collected in plots planted in 1950 at Quantock Forest, Somerset, that have proved at previous assessments to be the fastest growing in any trial. An indication of their vigour can be gained from the computed data in Table 38. It is worth recording that although only 18 years old, two trees in these plots have reached a height of 30 m (100 ft) and several others are more than 29 m (95 ft) tall. All are specimens of *Populus* "Androscoggin" and *P. trichocarpa*. The plots were planted with 16 trees at a spacing of 5·5 × 5·5 m, 18 × 18 ft (54 stems per ha, 134 per acre), but a few early deaths and demands for sample trees for timber testing have reduced plot stocking by varying amounts. *P.* "Androscoggin" and *P.* "Oxford" are artificial hybrids bred in the United States; the slower growing *P.* "Robusta" and *P.* "Heidemij" are natural crosses of *P.* x *euramericana*.

TABLE 38

VARIETAL TRIAL PLOTS—QUANTOCK FOREST, SOMERSET
HEIGHT, GIRTH AND VOLUME AT 18 YEARS

Clone	No. of trees per acre	Mean ht (ft)	Mean breast height girth (in)	Basal area per acre (ft^2 qg.)	Main crop vol. per acre (h ft O.B.)	Thinning vol. per acre (h ft O.B.)	Total vol. production per acre (h ft O.B.)
Androscoggin	109	93	46½	102·588	3,498	395	3,893
Trichocarpa	109	94	49	114·210	3,507	381	3,888
Oxford	118	76	43	94·706	2,562	198	2,760
Robusta (PH)	109	86	39½	74·745	2,151	459	2,610
Robusta (AE)	92	81	40½	62·058	1,913	641	2,554
Heidemij	126	77	36	70·168	2,151	—	2,151

The data provide further evidence of the improvement in productivity that can be achieved by the use of selected balsam poplars. They also tolerate a wider range of site conditions than other poplars, and it is unfortunate that none of them can be grown on a commercial scale due to the risk of bacterial infection. Their yield compares favourably with poplar Yield Class 160 allowing for differences in stocking.

Populetum

Seventeen clones were planted during the winter, bringing the total now included to 318.

Spacing of Poplars

At Alice Holt Forest, plots of a vigorous clone of *P. trichocarpa* were measured at 11 years of age, in an experiment designed to examine the production of pulpwood at close spacings. The data, from four plots of each spacing, are summarised in Table 39.

TABLE 39

HEIGHT, GIRTH AND VOLUME OF POPULUS TRICHOCARPA AT 11 YEARS

Spacing (feet)	No. of trees per acre	Mean height (feet)	Mean girth (inches)	Basal area per acre (ft² qg)	Volume per acre over bark (Hoppus feet)
9×9	538	45·9	20·6	97·7	1,842
12×12	302	47·5	25·6	86·1	1,539
15×15	194	46·4	27·9	64·0	1,116

Though height growth has not been affected by spacing, the rate of radial growth has decreased as competition at the two closer spacings has increased, and volume production has not improved proportionate to the stocking. It is hoped to discuss these relationships more fully in a separate paper. For purposes of comparison the volume per acre of poplar Yield Class 160 at 11 years is nearly 27 m^3 (750 h ft) at a spacing of 7·3 m, 24 ft (30 trees per ha, 75 per acre).

At Lynn Forest, Norfolk, plots with trees initially spaced at 4·3 m (14 ft) were thinned for the first time, and plots planted at 2·4 m (8 ft) were thinned for the second time, in an experiment planted in 1953–54 to compare the production of veneer logs at four different spacings.

Pruning of Poplars

At Cannock Chase, Staffordshire, where the effects of nine pruning regimes are being studied in a long-term experiment, assessments carried out at the end of the sixth year show that the rate of radial growth is appreciably lowered by increasing the severity of pruning from one-quarter and one-half total height to three-quarters total height. There is also some evidence that when pruning is taken to one-half and three-quarters total height, the rate of growth is lowered more by annual pruning than by bi-annual and tri-annual pruning.

Distribution of Poplar Cuttings

More than 12,000 9-in. cuttings of the approved clones were distributed to trade nurseries and private estates during the winter. A further 800 cuttings were sent to research workers in Great Britain and Germany.

Bacterial Canker Investigations on Poplars

The testing of both new and well-known clones continued at a heavily infected site at Blandford Forest, Dorset. Nearly 500 plants of 31 clones were planted in trials there during the winter. Work on bacterial canker is briefly summarised in the chapter "Forest Pathology" on page 108.

Elm Clonal Collection

The number of home selected clones under review was increased during the year to a total of 69, following the introduction of further selections of English and Dutch elm from south-west England.

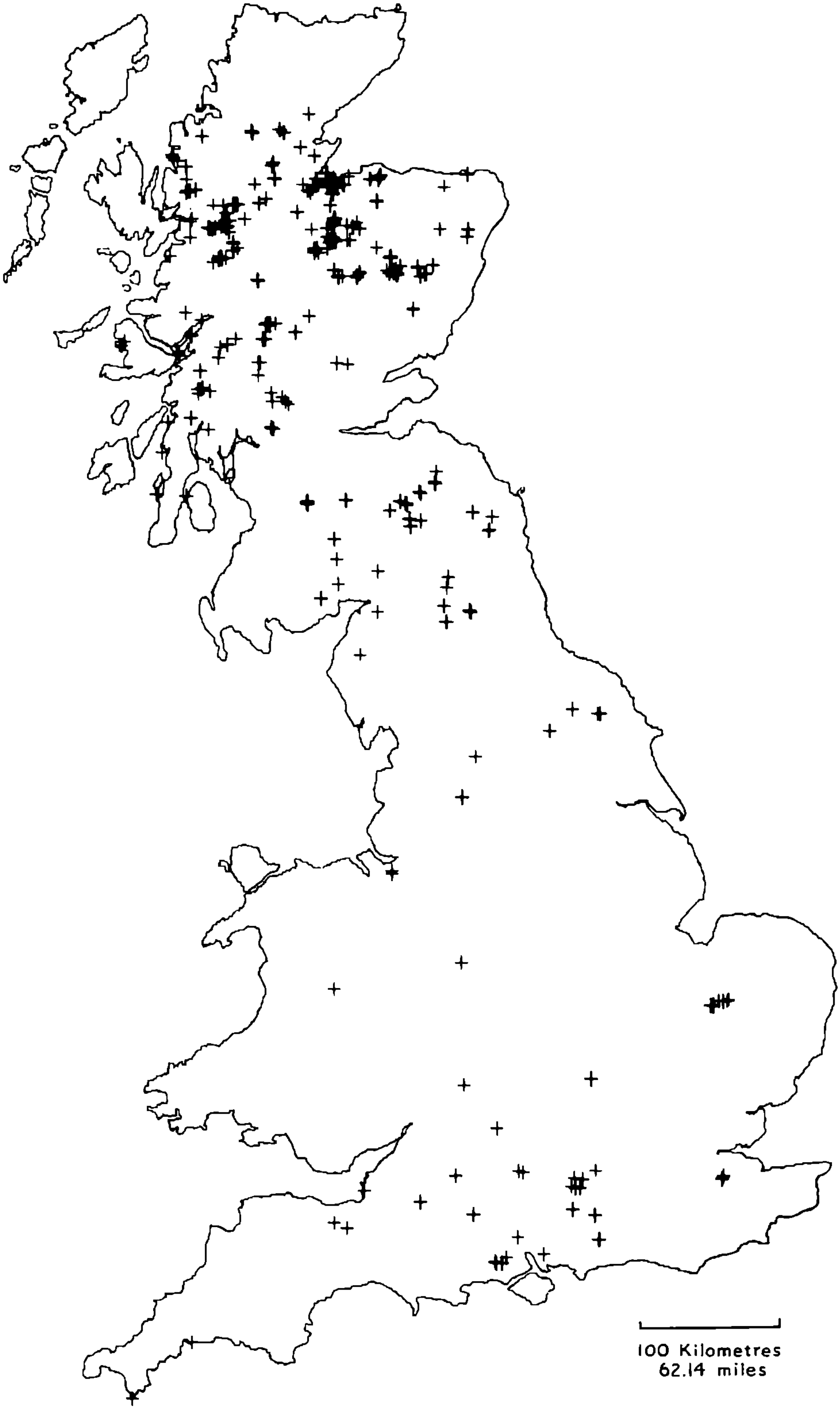


PLATE 1: Genetics (p. 101)

Distribution Map of Scots Pine Plus Trees prepared by the Research Station Computer at Alice Holt. Bold crosses represent more than one tree.

(108111)

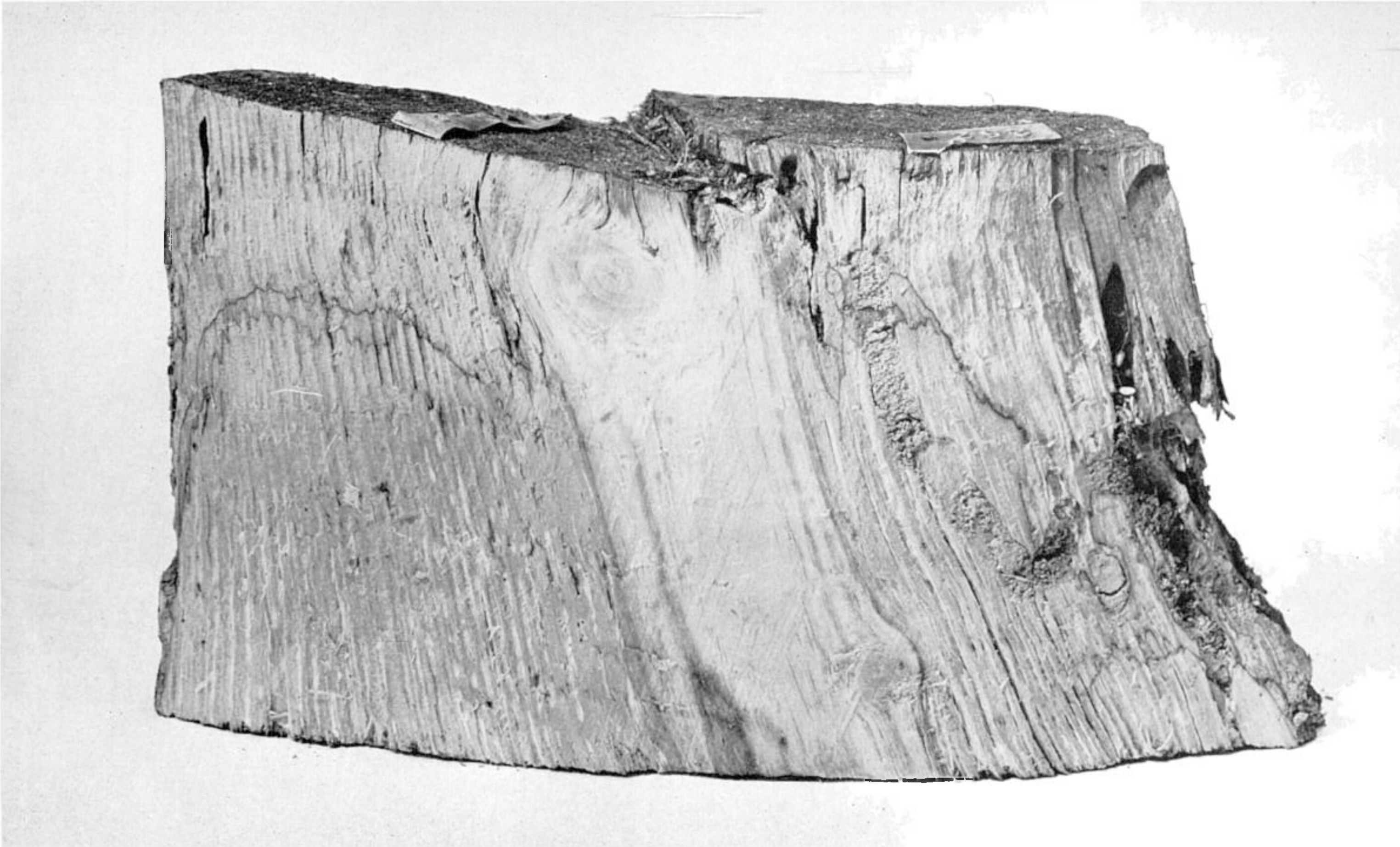


Plate 2: Forest Pathology (p. 108)

Longitudinal section through a Scots pine stump (felled five years ago) previously infected with *Fomes annosus* and subsequently treated with "Polybor". *Fomes* decay (white pocket rot) has advanced up as far as the black zone lines because other fungal competitors were excluded by "Polybor". Age of tree when felled was about 32 years. (Two-thirds natural size.)

PLATE 3: Forest Pathology (p. 108)

Sporophores of *Peniophora gigantea* on a Scots pine stump two years after inoculation with this fungus. ($\times \frac{1}{2}$.)

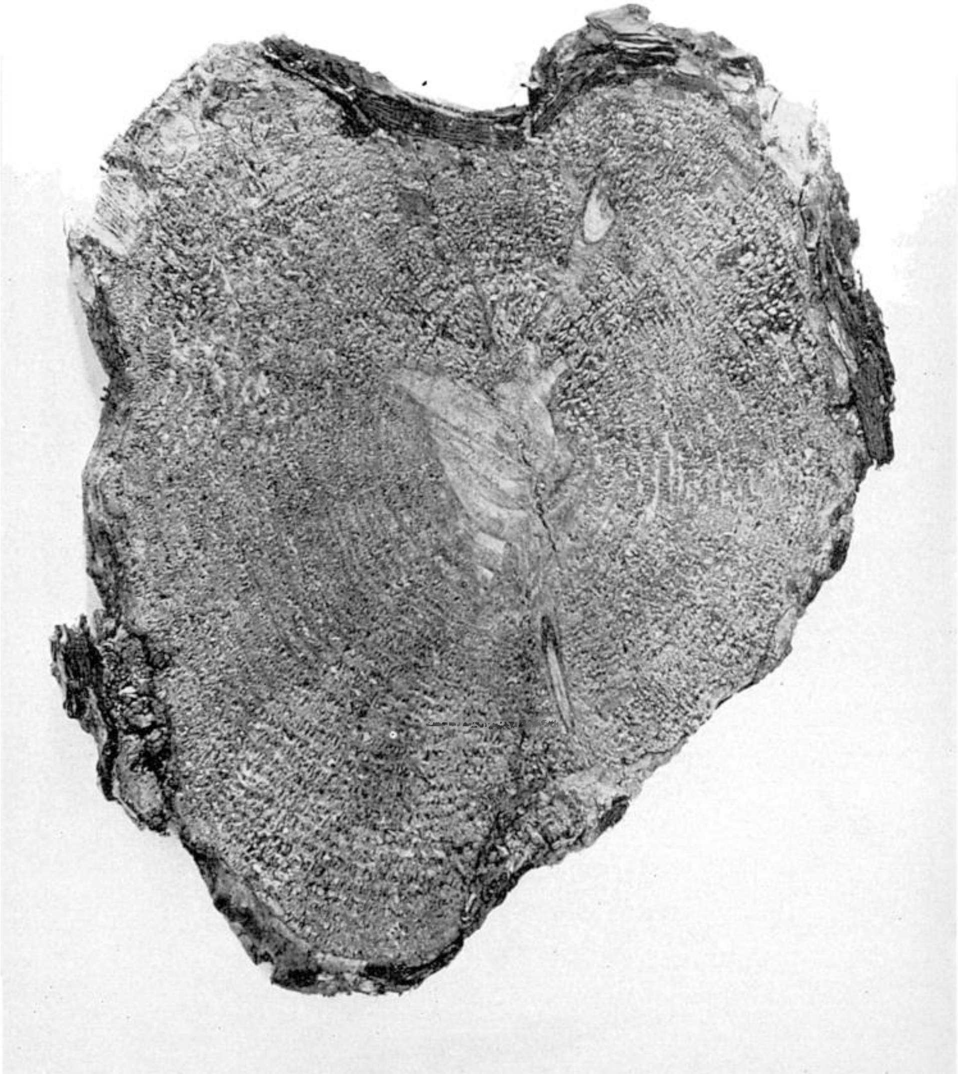


PLATE 4: See facing page.

PLATES 4 and 5: Forest Pathology (p. 108).

Cross-sections through Scots pine stumps (felled five years ago) showing results of stump treatment on previously infected stumps. Age of trees when felled was about 32 years.

Left, Plate 4:—Treatment with "Polybor" has allowed almost complete colonization by *Fomes annosus* to occur.

Above, Plate 5:— Treatment with *Peniophora gigantea*. *Fomes annosus* has been confined to the small, central area (outlined in black) and the majority of the remaining area has been colonized by *Peniophora gigantea*. (× ⅓.)

PLATE 6: Genetics (p. 105)

1·5 to 1·8 m (5 to 6 ft) tall two-year-old Sitka spruce plants raised under glass. Characters such as vigour, stem form and branching habit, which may be inherited and typical of progenies of specific clones, are readily discernible at this stage.

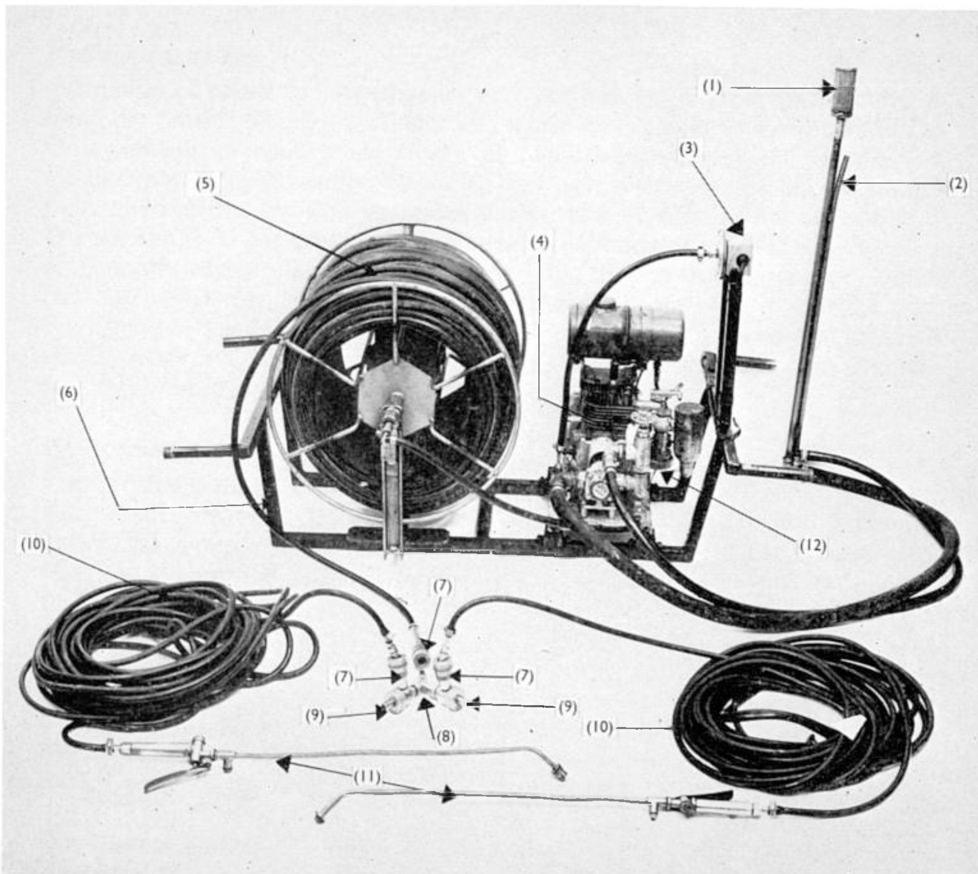


PLATE 7: Work Study (p. 127)

"Pharos" Portable Sprayer for Chemical Weed Control

Key

(1) 5·1 cm (2 in.) diam. Suction Filter.
(2) By-Pass Line.
(3) Suction cut-out switch.
(4) Pump Unit. (Allman's Midget Sprayer.)
(5) Live reel with 152·4 m × 0·79 cm diam. hose (500 ft × $\frac{5}{16}$ in. diam.)
(6) Hollow Section Metal Frame 2·54 cm (1 in. × 1 in.).
(7) Self-sealing Couplings.
(8) "Y" piece.
(9) Pressure Regulator. Cooper-Pegler "Polychair".
(10) Side hose. 24·38 m × 0·65 cm diam. (80 ft × $\frac{1}{4}$ in. diam.)
(11) Hand Lances.
(12) Main Line Pressure Regulator.

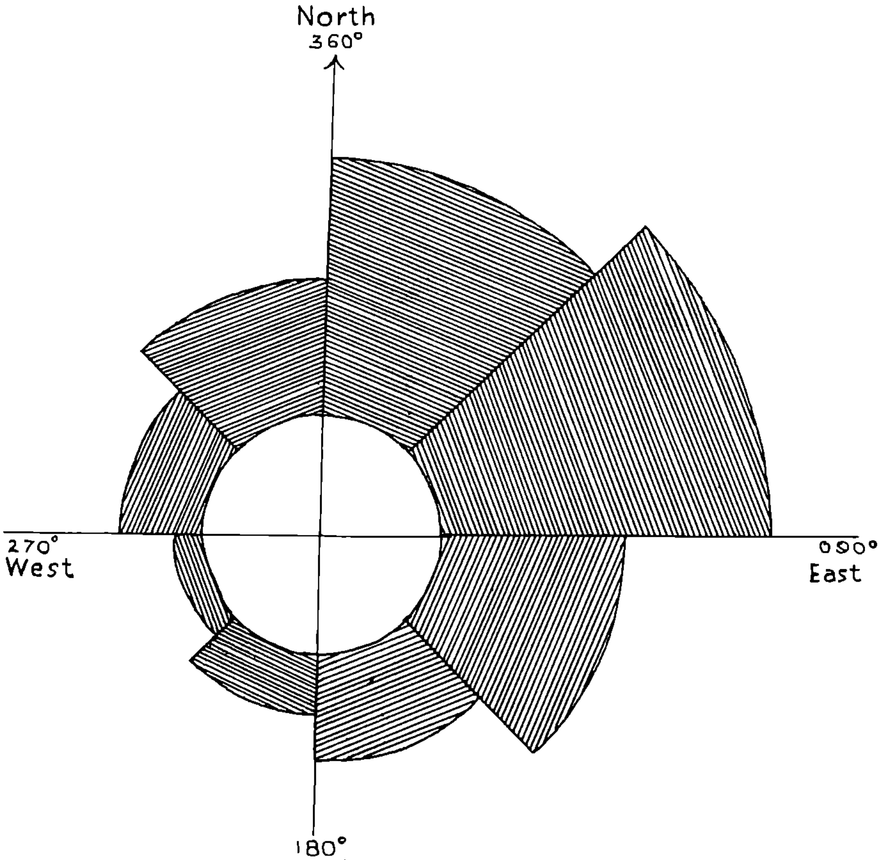


PLATE 8: Ahmed and Hayes: Biology of Crumenula sororia (p. 152).
Relationship between cankers and aspect.

Propagation of Elm

Supplies of plants for experiments were again raised from softwood cuttings using the "mist" technique. Clones of English elm (*Ulmus procera*) proved the most difficult to root, while clones of Smooth-leaved elm (*U. carpinifolia*) usually rooted most readily. Records, kept over a five-year period, of cutting survival in mist show that the mean annual rate of survival for all clones of English elm is 33 per cent, while the mean annual rate of survival for all clones of Smooth-leaved elm is 69 per cent. The figures for clones of Dutch (*U. hollandica* var. *hollandica*) and Huntingdon elm (*U. hollandica* var. *vegeta*) are 59 per cent and 57 per cent respectively. During the current season a special study will be undertaken at Kennington Nursery, Oxford, to examine methods of improving the rooting of English elm cuttings.

Elm Establishment Studies

Experiments planted at Alice Holt Forest between 1962 and 1964 have shown that rooted softwood cuttings lined out for one year may be expected to survive better and grow faster than other age-types of plant in the early years after planting. Preliminary results also suggest, in the case of one-year transplants, that a close relationship exists between height of plant and rate of survival. In a single experiment, laid down in 1964, plants nearly 0·9 m (3 ft) tall at planting had a rate of survival of almost 90 per cent after four seasons, while plants 0·6 m (2 ft) tall had a survival rate of about 60 per cent, and plants 0·3 m (1 ft) tall had a survival rate of only 30 per cent. The unstable habit of rooted softwood cuttings continues to be a major problem after planting, and a study has been started on methods of improving stability other than by mounding and staking.

Elm Disease Testing

Nine recently selected clones were planted in the Elm disease trial at Alice Holt during the winter, and will be inoculated with the causal organism, *Ceratocystis ulmi*, as soon as established. Attempts are being made to assess the susceptibility of clones that have been under trial for three or four years.

J. JOBLING

FOREST ECOLOGY

The Weather of the Year 1967 (See Table 40)

Monthly values of the main climatic elements for Alice Holt Lodge, Hampshire (115 m), are given in Table 40 for the year 1967. In Britain as a whole the year was distinguished first by the very mild winter, with temperatures in the south at the end of January breaking a long record for the time of year. Although April was somewhat cold and lacked sunshine, the spring was rather early and a noteworthy frost on 3rd May (Alice Holt minima: −3·5, grass −8·5°C) led to many reports of damage to young trees in the New Forest and other lowland forests in the south: in the north and east, and the uplands generally, growth of trees was not advanced enough for material damage then.

May led also to trouble of a different sort. Rainfall was far above the average, in England especially, and the waterlogging of active roots in nurseries and young plantations caused dieback or death of trees in several localities. July was mostly dry, warm and sunny, except in the north-west and, for the country generally, the summer months showed a small excess of sunshine and deficiency of rain, but the wet May ensured sufficient soil moisture for satisfactory growth. With abundant rainfall in spring and again in early autumn, and soils warmed by midsummer sun, weeds were unusually aggressive.

The stormiest month of 1967 was February, when, during the second half, damage was caused to forests over a wide area, but no forest was severely struck and no individual gale stood out for violence. Gales continued to occur in Scotland through most of March, when the south became quieter until the predominantly cyclonic weather of May. The wet month of October was also stormy and, in the following winter, the south had a curious record in that gales were all very early (October) or very late (March). But on 14/15th January 1968, a storm comparable with that of 31st January 1953 (mainly in East Scotland), or 16th September 1961 (Northern Ireland and western fringe of Scotland), struck the Clyde-Forth valley and adjacent counties with gusts reaching 185 km/h (100 knots) causing severe damage to buildings and forests. The effects on silviculture and forest planning were well ventilated at a symposium on Wind in Edinburgh, which had been previously arranged by the Society of Foresters for the middle of March. Everyone who attended that discussion, and every forester in the path of the storm, now fully grasps the powerful impact of the wind on upland forestry practice and the importance of current research on all aspects of the problem of creating wind-firm stands.

In the warmer, drier summer, 1967, fungal infections of needles and leaves were less prevalent than for several years past. On the other hand reduced increment and consequential top dying of Norway spruce, previously connected with mild winter weather, were more evident. Widespread small increases in *Bupalus piniarius* pupal counts may possibly be linked with greater summer warmth: but the mild winter was not reflected by abnormal defoliation of Sitka spruce by the aphis *Elatobium abietinum.*

Although the 1966, or even the 1965, weather is more relevant, this is perhaps the place to mention that mature tree seeds were in short supply in autumn 1967. Useful quantities of spruce seed were obtained from some forests; but the promise of a locally plentiful beech mast was not realised, for reasons not well understood.

TABLE 40

MONTHLY WEATHER RECORDS, ALICE HOLT LODGE, HAMPSHIRE (115 M) FOR THE YEAR 1967

Month	1 Jan	2 Feb	3 Mar	4 Apr	5 May	6 Jun	7 Jul	8 Aug	9 Sep	10 Oct	11 Nov	12 Dec	Yearly means	Yearly totals
Air temperature (screen) (°C)														
Mean daily maximum	6·6	8·6	10·7	12·3	14·6	19·4	22·3	19·4	17·1	13·9	8·6	6·5	13·3	
Mean daily minimum	1·7	1·9	3·1	3·5	6·6	8·9	11·9	11·2	10·2	8·0	2·0	0·8	5·8	
Monthly extreme grass minimum	−11·6	−7·8	−4·4	−8·9	−8·3	−1·1	1·1	2·2	0	−2·2	−7·8	−18·9		
Soil temperature (°C)														
Mean at 10 cm under bare soil	3·0	3·7	5·2	7·6	11·6	16·7	19·2	16·6	13·6	10·2	4·6	3·6	9·6	
Mean at 20 cm under bare soil	3·6	5·1	5·8	7·6	11·0	15·6	18·4	16·5	13·9	11·1	5·7	4·4	9·9	
Mean at 60 cm under short grass	4·9	5·8	7·0	8·5	9·6	15·2	17·6	17·2	15·6	13·2	8·3	6·1	10·75	
Precipitation mm	83·1	90·9	70·6	46·5	143·3	39·6	25·9	61·7	75·2	165·4	50·3	69·0		922·0
Total hours bright sunshine	61·0	88·4	173·0	140·0	186·0	209·3	234·0	175·0	115·0	104·6	78·5	61·0		1,626·0
Mean daily run of wind (miles)	38·3	73·1	41·7	47·2	54·6	25·0	25·5	30·0	34·6	61·5	31·4	60·0		

Pinus nigra Regeneration Studies

Shade and Growth of Young Black Pines

Three-year-old plants of several geographic origins were set out in March 1966 under graded shade treatments in a disused nursery in Alice Holt Forest. Approximate percentages of natural daylight received by the plants under the five treatments were: 100, 55, 37, 18, 9, these shades being referred to here as light, medium, strong and severe. The plots were cleared for final assessment in March 1968. Interim measurements in October 1966 showed, as expected, an insignificant influence of shade on current height, but a pronounced influence on diameter increment: there were also significant effects on stoutness and weight of leaves, on dry weight of tops and on number and size of buds. The final data have not been worked up, but we observed, when digging up the five-year-old, thrice moved, plants that those in full light had much more extensive roots (pioneer roots sometimes 120 cm out from the stem), easily surpassing those under light and medium shade.

Regeneration of Pine by Planting in Thetford Forest

The shade tolerance of young Corsican pines and possible alternative species is important for reforestation under shade, the subject of several current silvicultural experiments. Protection against frost in the growing season is the main advantage of this method, and the survey of minimum temperatures in contrasted situations, which was begun in 1964, was continued in 1967 with a modified lay-out to embrace new experiments. Growth in East Anglia was not advanced enough to suffer in the frost of 3rd May, which destroyed much in the southern counties; but a more local frost on 9th June caused considerable damage to Corsican pine and other species. Measurements of light intensity have been continued in the silvicultural underplantings.

Influence of Month of Planting

Some variation in the season of planting has been tried in practice and in experiments, but the results have been inconclusive, though late summer planting is finding increasing favour in Scotland. A month-of-planting experiment of Corsican pine to run for three years (thus smoothing the main effects of weather vagaries) will be started in Thetford and in Wareham Forest, Dorset, in September 1968. In relation to this, preliminary observations were made in 1967 on the periodicity of root growth in this tree. There are indications of a threshold temperature of 7°C, or a little less: in 1967 root extension began early, in mid-March, sporadically even earlier. After the buds broke and shoot growth began to exhaust the tree's reserves (about mid-May), root extension almost ceased, to be resumed in July after completion of shoot growth, and continued until early December.

Natural Regeneration

In the *Report* for 1966 reference was made to the evidence of catastrophic losses of seeds and young seedlings, even in years of abundant mast, and to plans for some detective work. The experiment set out in the West Tofts section of Thetford Forest in the early months of 1967 comprised three degrees of protection against mammals and birds and five types of vegetative cover. One thousand seeds with germinative capacity of 80 per cent were sown on 15th April in each plot of 2 × 1 m, and three counts of seedlings were made between the beginning of germination in mid-May and 1st September. Keeping mice out proved (as was predicted) the main key to survival and germination of Corsican pine (and Scots pine) seeds in the environment of this experiment. Thus, in the bare fallow treatment under light Scots pine canopy, fully protected plots yielded 500–600 newly germinated Corsican pine, with more than 1,000 volunteer (self-sown) Scots pine seedlings: unprotected plots alongside yielded only about 20 and 40 respectively. Mousetraps placed in a variety of situations caught mostly the common wood mouse, *Apodemus silvaticus;* but there were also some short-tailed voles, *Microtus agrestis.* The investigations were much hampered by the difficulty of telling the two pines apart in the seedling stage.

It is intended that the evidence of this experiment will offer some guidance whenever experiments in the direct sowing of pines in the forests are undertaken.

J. M. B. BROWN

PUBLICATIONS BY STAFF MEMBERS

BROWN, J. M. B. The Corsican pine in Britain. *Suppl. Timb. Trades J.* April 1967, 31–33.

BROWN, J. M. B. Frost and the forest. *Memo. Dep. Geogr. Univ. Coll. Aberystwyth* **10,** 1967.

SOIL MOISTURE, CLIMATE AND TREE GROWTH

Soil Moisture Studies

Deep Percolation in Sandy Soil

The study of soil moisture in relation to the growth of selected tree stands has been continued for some years, and the general scope and methods of investigation have been detailed in previous *Reports*, especially those for 1965 and 1966. An important aspect of this work has been the estimation of water use from measurements of changes in soil storage. In making such estimates, any loss of water due to deep percolation continuing into the period of the deficit is usually assumed to be small, though it is sometimes suggested that this is an unwarranted assumption. As the neutron moisture gauge has enabled us to consider use during short periods, it has become vital to examine the drainage characteristics of the profiles in detail. Accordingly the sites of the moisture gauge access tubes at Bramshill Forest were heavily watered in January 1968 and covered with tarpaulins to prevent further accession. The subsequent changes in storage have been recorded for two months, at a time when the transpiration is low. We have thereby been able to confirm that the rate of drainage rapidly falls to a very low value; under the conditions of the test the total losses do not significantly exceed the rate of estimated evapotranspiration for February and March.

The use of this simple technique of covering an access tube when the profile is in about the wettest possible condition, will be a valuable tool for the investigation of sites in need of artificial drainage or cultivation. At Bramshill, as well as confirming the absence of appreciable percolation loss in the water balance equation, it has shown that the lower part of the profile may retain a few centimetres of extra storage as a result of the high infiltration rate under the experimental conditions.

Studies on Chalk Soils

The *Report* for 1964 described studies of the soil moisture regimes under stands of Corsican pine and grass at Feltwell, Thetford Chase, and under beech and grass on the South Downs near Buriton (Hants). This work has continued, and confirmed and amplified the earlier conclusions, which contrasted the moisture régimes of the chalk soils with those seen on porous loamy profiles. The results of four year's measurements on these sites are currently being assessed and summarised.

As in 1964, it is concluded that there is a consistent and substantial difference between drying patterns under trees and grass, and that the high conductivity of the chalk allows water abstraction to extend throughout the profile, beyond the root range, without the gradient with depth characteristic of loamy soils.

Instrumentation and Techniques

Neutron Soil Moisture Gauge

Routine field readings with the neutron moisture gauge have continued, although some inconvenience has been caused by the failure of boron trifluoride counting tubes. Of the replacement tubes used at least one had a counting efficiency which differed from that of the original tube, and when using it a scaling factor had to be applied to the existing calibration curve. Plotting the characteristics of spare tubes now held in stock has shown, however, that these are sufficiently similar to be interchangeable. This procedure also serves as a check on the consistency of performance of any given tube.

To study the shape of the moisture calibration curve of the instrument, "moisture standards" were made up in 180 litre (40 gallon) drums, consisting of mixtures of washed sand and pebbles flooded with water to produce stable systems. These drum standards, however, are not a substitute for field calibration which, due to the complex effects of neutron absorbers and moderators in the soil, remains the simplest way of interpreting the readings from a particular site.

A large Veihmeyer-type sampler, developed at Alice Holt and capable of extracting soil cores five cm in diameter down to a depth of two metres, greatly assists in field calibration, and a smaller sampler of a similar type is used at present to sample the top 30 cm of the profile.

Automatic Charging Set

The techniques of recording wind velocity profiles over a forest stand at Redesdale are discussed on page 83. The Westinghouse data-logger and associated equipment has been powered by two banks of batteries which have been changed at weekly intervals for charging. During the year a special battery charger and control system has been constructed to allow the batteries to be charged *in situ* from a small diesel generator set. The charger has 24 and 48 volt outputs and control gear to meet the following requirements:—

(1) The dual outputs shall cut out independently with precise voltage adjustment so that they can be set to avoid excessive gassing and loss of water.

(2) The generator must run for as short a total time as possible but long enough on each occasion thoroughly to heat up the engine, to reduce maintenance.

This requires that the charging periods keep in step and that either battery can cause the charging to be initiated when the voltage (under load) falls to a critical value.

Garnier Gauge Records

As in other years, records from the two similar Garnier Gauges have been maintained in 1967, at Alice Holt Lodge, as part of a network of stations. In Table 41 results are shown for the Alice Holt installation for 1967, with the relevant local rainfall and sunshine records. For comparison, Penman-type calculations of evaporation made by the Meteorological Office are also shown, from data collected at South Farnborough, Hants. The rainfall figures are presented in centimetres for the first time.

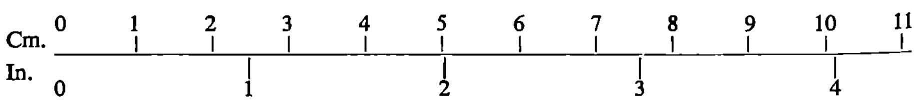
The weather in 1967 was highly variable, with a rather mild winter, and warm summer. The dull, very wet May was followed by a sunny and warm June and July. Amounts of snow were small, and unlikely to have influenced the lysimeter measurements. There were only seven occasions when dew or rain were absent from the grass surround at nine a.m., so oasis effects will have been small. The consistent differences between the gauges noted in other years are persisting, and also the differences between gauge estimates and calculated evaporation values.

TABLE 41

EVAPORATION RECORDS—ALICE HOLT LODGE 1967

Month	Potential evaporation (cm) (E_t)			Penman Formula Estimates (cm) (Met. Office) Average 1962–66		Rainfall at Alice Holt 1967 (cm)	Sunshine daily mean hours	
	Lysimeters		Calculated Value*				Normal from tables	Actual 1967
	A	B		E_t	E_0			
January	—0·51	0·48	0·63	0·46	0·76	8·30		1·95
February	2·21	3·38	1·02	1·35	2·24	9·10		3·15
March	2·59	3·61	2·54	3·07	4·39	7·06		5·55
April	3·96	4·22	4·75	5·04	7·18	4·65	5·05	4·65
May	5·92	6·58	7·62	8·13	10·16	14·32	6·20	6·00
June	7·87	6·55	9·20	9·12	11·42	3·96	6·90	7·00
July	10·90	9·35	10·30	8·69	10·85	2·59	6·50	7·55
August	9·00	6·91	7·32	7·73	9·65	6·17	6·30	5·65
September	6·37	4·80	3·81	4·80	6·86	7·52	4·60	3·80
October	2·06	3·25	1·65	1·90	2·72	16·52		3·35
November	0·10	0·71	0·51	0·79	1·31	5·03		2·60
December	0·63	2·16	0·38	0·28	0·46	6·98		1·95
Totals	51·10	52·00	49·73	51·36	68·00	92·20	—	—
Summer months	44·02	38·41	43·00	43·51	56·12	39·21	5·93	5·77

* See Technical Bulletin No. 4 Ministry of Agriculture, 1954 "The Calculation of Irrigation Need".



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FOREST GENETICS

Seed Crops

Cone and fruit crops of all species were generally light in 1967, although locally abundant crops of Sitka spruce occurred throughout Scotland. Douglas fir and beech produced heavy crops in parts of Argyll, central Perthshire and south and west England. Japanese larch flowered moderately heavily in certain eastern and southern districts of Scotland, but severe late frosts caused widespread damage and the final harvests were generally poor. Scots pine produced light to moderate crops throughout Britain for the second season in succession.

Advantage was taken of the substantial cone crops of Douglas fir at Tavistock, Devon, and Sitka spruce at South Laggan Forest, Inverness-shire, to obtain data on the costs of collections by climbing and from felled selected seed trees respectively.

Survey of Plus Trees

Organised surveys for additional Sitka spruce Plus trees continued in north and west Scotland, the Scottish Borders, south Wales and south-west England. Surveys were also made in Corsican pine areas at Culbin and in Tentsmuir Forest in east Scotland. Very few Plus trees of other species were selected and registered during the year. Table 42 contains an abstract of the total numbers of home selected and foreign Plus trees registered before the end of March.

Scots pine selection work has been suspended and will not be resumed until the F_1 material in progeny-test plots is sufficiently mature for the purpose of selecting further breeding material. Plate 1 presents a distribution map of Scots pine Plus trees prepared by the Forest Research Station computer at Alice Holt. Both the outline and the points were plotted by computer techniques.

TABLE 42

NUMBERS OF PLUS TREES OF THE MORE IMPORTANT SPECIES REGISTERED BEFORE 31ST MARCH 1968

Species	Number of Plus Trees
Scots pine	924
Corsican pine	127
Lodgepole pine	372
Sitka spruce	638
European larch	434
Japanese larch	144
Douglas fir	501
Western hemlock	46
Western red cedar	59
Oak	173
Beech	118
Total	3,536

Progeny Testing

The programme of progeny-testing each Plus tree is now gaining momentum. During spring 1968, progenies from 100 Scots pine, 16 Douglas fir and 22 Sitka spruce Plus trees were planted out in replicated blocks on up to five forest sites in the main planting regions for the species concerned. In addition 134 other progenies are in nursery-stage tests; these will provide planting material for 1969. The pine and Douglas fir progenies have been derived from both controlled and wind-pollinated flowers on the parent trees, or from clones established in either tree banks or seed orchards. The Sitka spruce, Western red cedar and beech material is entirely derived from wind-pollinated flowers on the parent trees, whereas the larches are all from controlled pollinations.

Table 43 gives details of the number of Plus trees with progenies in nursery or forest stages of testing at the end of 1967.

TABLE 43

NUMBERS OF PLUS TREES BY SPECIES REPRESENTED IN PROGENY TESTS

Species	Number of Plus trees represented in Progeny Trials
Scots pine	412
Corsican pine	45
Lodgepole pine	43
Sitka spruce	49
European larch	41
Japanese larch	27
Douglas fir	55
Western hemlock	Nil
Western red cedar	27
Oak	Nil
Beech	19
Total	718

Vegetative Propagation

In the 1964 *Report* reference was made to the success of grafting scions of Douglas fir onto large well-established rootstocks on a seed orchard site. This work was followed up in April 1967 in a field-scale trial at Drumtochty, East Scotland, in which grafts of Douglas fir and Sitka spruce were made on rootstocks of the respective species, planted in 1964. The rootstocks had an average height of 1·8 m (5·9 ft) at the time of grafting. All the Sitka spruce scions were collected directly from Plus trees, whereas many of the Douglas fir scions were collected from young grafts.

The early results are again promising for Douglas fir, which flushed early and produced extension growth on the scions averaging 12 cm (4·7 in.). On the other hand, the development of the Sitka spruce scions has been poor. None of the scions flushed until eight to ten weeks after grafting and many failed to develop normally before the end of the growing season. The survival at the end of the first growing season was 86 per cent and 45 per cent for Douglas fir and Sitka spruce respectively.

Controlled Pollination

As described in the previous *Report*, difficulties have been encountered in obtaining high yields of viable seed from artificially pollinated Scots pine flowers. In 1967 the Genetics Section and staff from Aberdeen University Forestry Department again co-operated in a programme of experiments which aims to elucidate some of the factors connected with the problems of fertilisation, seed development and pre-harvest conelet-drop. The work was undertaken in the National Tree Bank at Newton and in seed orchards at Ledmore, both in East Scotland.

Several of the 1966 experiments were repeated, including that of single applications of pollen during three different stages of female flower development. Also repeated was an experiment to determine the effect on seed yield of removing the isolation tubes at various intervals after pollination. In the past there have been high losses of conelets, which are suspected to have been caused by the abrasion of developing flowers inside the isolation tubes during periods of high winds, and coinciding with the time when the conelets begin to bend over following pollination.

In addition new experiments were designed to investigate whether ovules show selectivity in accepting live pollen grains in preference to dead (artificially killed) grains into the pollen chamber. The percentage of live pollen in the five treatments under test varied from 100 per cent live to all completely dead. A further experiment was designed to confirm or disprove the hypothesis that auxins in recently killed pollen may affect ovule development. This involves the study of conelet development following pollinations using live pollen, pollen killed by heat treatment and chemically killed pollen.

Routine Scots pine flower isolations in recent years have been effected using either 5·5 cm long × 1·5 cm – 2·0 cm (2·2 in. × 0·6 in. – 0·8 in.) diameter celluloid tubes or 38 cm × 23 cm (15 in. × 9 in.) "Terylene" bags. In the 1967 series of experiments the "standard" celluloid tubes were used in comparison with larger 22–28 cm × 7 cm (8·7–11·0 in. × 2·8 in.) celluloid tubes, 7 cm × 2 cm (2·8 in. × 0·8 in.) cellulose acetate tubes (these proved to be harmful to the flowers), and 6·2 cm × 1·6 cm (2·4 in. × 0·6 in.) cellulose acetate butyrate tubes of Swedish manufacture. The yield of viable seed per pollinated flower will be used as the criterion of the efficacy of each method of isolation. A separate "look-see" trial was carried out to demonstrate the effects on flower and conelet development of a large 12 m × 7·2 m × 3·6 m (39·4 ft × 23·6 ft × 11·8 ft) (high) semi-circular (in section) polythene covered structure. The "house" was erected over two or three 3 m (9·8 ft) tall ramets of three clones, approximately 28 days before the flowers would have been receptive under outdoor conditions. Female and male flowering was advanced, by 14 and 18 days respectively, in comparison with flowers on ramets of the same clones growing outside the "house". The female flowers in the polythene house were otherwise unprotected, and male strobili were removed as they developed; when in a receptive condition the female flowers were pollinated with a pollen mixture. The rate of conelet development following pollination was extremely rapid, and all conelets hardened and turned downwards before any of the flowers outside were receptive.

The polythene " house " will be left in position for twelve months to determine whether the conelet development and maturity is further advanced. Observations will be made of any differences in growth and flower production which occur in 1968, and to see what effect, if any, the isolation treatment has had on the yield of seed per cone.

Phenological observations on flower development and pollen shedding, at two-day intervals, were made on 152 clones at Newton and 110 clones at Ledmore. This data will supplement previous records and will be used when matching clones for use in the second generation of clonal seed orchards.

Regular inspections of developing flowers on 26 clones were carried out by a member of the Entomology Section. These produced no evidence to suggest that insects are responsible for serious damage or losses to flowers or conelets. Selected flowers were, however, sprayed with a colloidal suspension of DDT (60 per cent) diluted to 0·2 per cent strength in water to provide check material.

The programme of experiments, together with routine artificial pollinations at both Newton and Ledmore, involved the isolation of some 20,000 flowers. The majority of the pollinations used a mixture of 10 pollens, although at Ledmore a "four-tester" crossing programme using 12 clones as females and four clones as males was completed.

Flower Induction

Following a review of all flower induction experiments (see *Report* for 1965) a further series of experiments was started in 1964. The first was on an 80-year-old European larch stand at Farigaig in Inverness-shire (Expt. 2/64) which was due for felling in 1969 or 1970. The following four treatments and controls were applied.

O—Control. No girdling.

G1—Partial girdling of the stem by removing a 2·5 cm (1 in.) deep band of bark, phloem and cambium for three-quarters of the girth of the tree.

G2—As above but the girdle divided into three separate quarters.

G3—As above but the girdle was a complete one, divided into two slightly overlapping "halves" and spaced vertically 15 cm (5·9 in.) apart.

R—Severing the largest roots on the downhill side of the tree.

O—No root severing.

All the girdling treatments were applied at a height of 60 cm (23·6 in.) above the ground. The experimental design took the form of a 4 (girdling) × 2 (root severing) factorial, replicated five times in each of three years. The treatments were all applied 18 months before the cone crop was harvested from the felled trees.

In 1965 the crop was harvested, the seed extracted and the data analysed by a straightforward analysis of variance. This showed that girdling had an effect on cone production but root severing had not. In 1966 and 1967 assessments were also made of previous flowering on the individual trees as well as the current-year cone counts; this can be done relatively easily on European larch which retains its cones for several years. This further independent variable allowed an analysis of covariance to be employed which reduced the error by 50 per cent and showed significant ($p=0·5$) differences between the girdling treatments.

Assuming that block and treatment effects are multiplicative, and that a log transformation is appropriate, the estimated cone crop increments for the various treatments were:—

Treatment	*1965*	*1966*	*1967*	*Overall*
G1	+ 40	+350	− 30	+190
G2	+200	− 50	+10	+220
G3	+500	+150	+210	+840

In none of the years were there any significant differences due to root severing. In the light of these results it can be recommended that complete girdling (G3) can be profitably employed in old stands of good quality European larch in early spring of the year before felling takes place, in order to provide large quantities of seed at reasonable cost.

A second experiment which involved three girdling treatments and a "control" was begun in a mature stand of Douglas fir at Benmore Forest, Argyll (Expt. 11/64) also in 1964. The girdles were freshened up in each of the following years and cone crops were estimated by visual counts made every autumn during the period 1965–67. The experiment confirmed earlier observations that, in normal flowering years, the "between tree" variation in flowering on Douglas fir is often greater than the "between treatment" variation. However, in good seed years (and 1967 was a case in point), great increases in seed production can be expected from complete girdling treatments.

Glasshouse Investigations

The development of early-test procedures for screening progenies of Plus trees under partially controlled environmental conditions was continued with Sitka spruce and European larch in the glasshouse at Alice Holt.

The trial of over-wintering treatments described in the *Report* for 1966 showed that the most reliable means of achieving adequate winter-chilling in Sitka spruce is to place the plants in uncovered nursery plunge beds for a period of 12 weeks. For European larch the method and degree of chilling appears to be less critical.

The growth of both species under glass during the second season was extremely vigorous. The mean height of the Sitka spruce plants which had been selected for greatest vigour at the end of the first growing season was 137 cm (54 in.) and the height of the tallest individual plant was 182 cm (71·6 in.), whereas the mean of those plants selected for least vigour at the end of the first year was 104 cm (40·9 in.). The average height of the two-year-old European larch seedlings which were selected for similarity of height after the first growing season was 146 cm (57·5 in.).

Two-year-old plants raised under glass clearly show differences in vigour, stem straightness and branching habit (see Plate 6, central inset).

A further important result of this trial was that glasshouse-raised Sitka spruce plants, when grown-on during the second growing season without artificial heating or extended daylength, were found to produce as much shoot growth as plants grown-on in a heated environment and with a daylength extended to 15 hours during the early part of the growing season.

The main trial in 1967 was concerned with the routine testing of 20 progenies derived from open-pollinated Plus trees of Sitka spruce. Each progeny was represented by 56 plants, in eight replications of seven-plant plots. Owing to a temporary shortage of glasshouse space the sowings were delayed until 12th April, and in order to extend the growing period, artificial heating (15·5°C, 60°F) and lighting (15-hour photo-period) were given until the end of November. Following this treatment the plants were hardened-off, by terminating the extended photo-period and by gradually reducing the air temperature over a period of one month; they were then transferred to plunge beds in the open nursery for a 12-week period of winter-chilling. It is intended to extend the trial for a further growing season.

The mean height of the progenies at the end of the first growing season ranged from 9·9 cm to 26·3 cm (3·9 in. to 10·4 in.); other characters associated with vigour, stem straightness and branching habit were also assessed; the results will be reported elsewhere.

Two important factors, which will assist in improving techniques for future trials, have emerged from the 1967 work. Firstly, the comparison of growth data obtained from sowings of the previous two years has indicated that the optimum time for sowing Sitka spruce under glasshouse conditions is during the latter half of February. Secondly, if trials are to be continued for a second growing season, any artificial extension of the photo-period should be terminated not later than the end of October of the first year. This is because growth in Sitka spruce continues for several weeks after an extended photo-period is discontinued even when the inside air temperature has been reduced to cold glasshouse conditions. A one-month period of hardening-off, before the application of winter-chilling, has proved to be inadequate after an artificial extension of the growing season. Investigations into the duration of extended photo-period to give optimum results, will be conducted during the course of glasshouse progeny trials in 1968.

Pollen Handling

In 1965, large quantities of Douglas fir pollen, collected in the same year and subjected to the standard drying technique, namely storage over silica gell for two months at +2°C (35·6 °F) prior to long-term storage, were spoilt by moulds. On closer examination it was found that only the surface layers of pollen within the bottles had been thoroughly dried, and that the lower layers had coagulated due to the inefficiency of the drying methods. In consequence, an experiment was conducted to examine the possibility of achieving more rapid and thorough drying of Douglas fir pollen by vacuum methods without lowering the viability of the pollen.

Pollen lots from three trees were selected at random from ten lots collected in April 1967. The treatments, applied to each, were: drying under vacuum until all turbulence ceased; drying over silica-gel; drying under vacuum followed by prolonged exposure to silica-gel.

Each treatment was replicated three times, each replication consisting of a storage bottle containing sixty grammes of pollen.

Results showed that vacuum drying followed by exposure to silica-gel considerably shortens the period necessary for drying, and that the viability of the pollen is well maintained in comparison with drying by silica-gel alone.

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FOREST PATHOLOGY

Death and Decay caused by Fomes annosus

Work on *Fomes annosus* during the past year has mainly concentrated on various aspects of stump protection. Sodium nitrite, which has replaced creosote as the recommended stump protectant in Forestry Commission plantations, is a toxic chemical, and objections to its use have been raised in certain areas. Alternative materials may sometimes be required, for example in water-catchment areas, and in areas from which livestock cannot be excluded. Good results in the past have been obtained with various chemicals and this year a trial was set up to compare a number of these substances. Final results are not yet available, but early indications are that the boron compound "Polybor", ammonium sulphamate, and the herbicides paraquat and diquat may give results comparable with those of sodium nitrite.

Biological control of *F. annosus* on pine, using the fungus *Peniophora gigantea,* has continued to give satisfactory results. *P. gigantea* is now the standard stump protectant used in 70,000 acres of pine forests mainly in East England. Tablets of *P. gigantea* are now available commercially. The advantages of *P. gigantea* over most "passive" chemical protectants have been demonstrated by the examination of pine stumps in an infected area. In one experiment the average amount of *F. annosus* in stumps treated with "Polybor" after five years was 61 per cent, while in stumps inoculated with *P. gigantea* the percentage was 26 per cent. Plates 2 to 5 show pine stumps which have been treated with *P. gigantea* and "Polybor". (See central inset.)

P. gigantea can be used only on pine, and there is great potential for a fungus that could be used for the biological control of *F. annosus* on Sitka spruce. Sampling of the fungal air flora at various sites in different parts of the country has produced a number of promising fungi, which have been tested in the laboratory. A selection of these will be tested in field trials during the coming year.

Investigations into the susceptibility of Grand fir, Western hemlock and Western red cedar to butt rot by *F. annosus* are being jointly conducted by the Pathology and Silviculture (South) Sections.

Armillaria mellea

A long-term experiment to study the invasion of Norway spruce stumps by *Armillaria mellea* and other fungi was set up during the year in collaboration with Dr. M. J. Swift of Birkbeck College, London. The role of conifer stumps in maintaining and spreading *Armillaria* infection has not previously been studied. With many conifer crops now being clear felled, the problem of whether losses in the replanted crop are likely may well depend upon the ability of *Armillaria* to colonise the conifer stumps. Stump treatment with sodium nitrite against spore infection by *Fomes annosus* may affect the activity of *Armillaria,* and this factor is also being studied in the experiment. Data collected during the year has indicated that there may be differences between species with regard to killing of young trees by *Armillaria.* The pines and spruces appear to be susceptible and Douglas fir and the Silver firs more resistant.

Polyporus schweinitzii

This fungus causes severe butt rot in Sitka spruce, Douglas fir and pines, and frequently leads to wind-snap of the trunk. A long-term trial to test the susceptibility of a range of conifer species to infection by *P. schweinitzii* was laid down on an infected site in the Forest of Dean.

Studies of the excavated root systems of young Sitka spruce have shown that infection by *P. schweinitzii* can occur when the trees are 10 to 15 years old. Field trials and pot experiments to learn more of the means of infection have been laid down.

Needle Blight of Western Red Cedar caused by Didymascella thujina

Work on this disease has continued along two main lines; further spray trials have been laid down and spore traps have been set out to elucidate the biology of the fungus.

A spray trial was carried out in South Wales to determine whether three spray applications with cycloheximide were needed to give satisfactory control. The results of this experiment (laid down at Slebech Nursery, Pembrokeshire) confirmed those of last year (see *Report* for 1967) and showed that a single spray application gave good control.

The formulation of cycloheximide, Actispray, which has been used successfully in the past to control *Didymascella thujina*, has now been withdrawn by the manufacturers. An alternative formulation has been produced and a preliminary trial indicated that it also gave good control. An experiment to test whether "Captan", sprayed at fortnightly intervals from March to September, could control this disease, gave a negative result.

Three spore traps were run during the season at Alice Holt; one, a millipore filter suction trap, gave daily spore counts and two others, designed at Alice Holt, gave hourly counts. An automatic rainfall gauge and surface wetness recorder were established alongside the spore traps.

A preliminary examination of the data shows that there are two peaks of spore production, one in June-July and the other in September-October. These two peaks occurred later than last year (see *Report* for 1967) possibly because June was a dry month. Spore release appeared to be closely related to rainfall.

An examination of the spore counts from the hourly spore traps on those days when the millipore filter spore counts were high, showed at least in some cases that spores were released immediately after rain started to fall.

Bacterial Canker of Poplar caused by Aplanobacterium populi

The new standard method of screening poplar clones (see *Report* for 1967) has now been introduced. The first results indicate that very few of the clones tested show a high degree of resistance to Bacterial canker. The most promising clones are from the species *Populus trichocarpa* but it has not yet been established whether the timber from these clones is suitable for match production.

Screening tests have indicated that many of the *Populus* × 'Euramericana' hybrids which are grown commercially in this country are not resistant to Bacterial canker. Field observations on the natural infection of certain clones, for example *P.* 'Robusta', have confirmed the results of artificial inoculations. Continuing efforts are being made to find new sources of potentially resistant clones.

Top Dying of Norway Spruce

The onset of this disorder is preceded by sharp growth reductions in seasons immediately following mild winters. Following the mild winter of 1966–67, a number of stands were examined, and sharp reductions were observed in some.

Whether trees subsequently deteriorate is largely dependent on the degree of air circulation in their crowns; where this is already high or is markedly increased by operations such as thinning, Top dying is likely to ensue.

Growth measurements of healthy and affected trees were made in several areas, and these measurements provided further evidence of the association of the disorder with mild winters.

During the winter of 1967–68 a greenhouse experiment was started to study the effects of various winter temperature regimes on vegetatively propagated plants of apparently resistant and susceptible clones.

Effect of Low Temperatures on the Establishment of Corsican Pine

Daily records of the minimum temperatures during the three months April, May and June in Thetford Chase were continued in conjunction with G. W. Hurst of the Meteorological Office, although on a reduced scale this year. After three relatively frost-free years since this work began, there were at least two severe frosts in the spring of 1967, on the nights of 2nd May and 8th June. In one area at Thetford where a temperature of −5°C (21°F) was recorded on the 8th June, severe damage was caused to the young Corsican pine crop and only 25 per cent of the plants are likely to survive. The advantages of bare soil areas compared with grassy areas were again demonstrated by temperature records, and by differences in height growth on the two types of site. Some of the results from this work have been reported by Hurst (1967).

Stem Crack in Conifers

The work on stem crack in Grand fir (see *Reports* for 1964, 1965 and 1966) was extended to other conifer species. Preliminary studies on Noble fir and Sitka spruce indicated that, in contrast to Grand fir, internal cracks can occur in the absence of external scarring, although such cracks are invariably small in length and depth. Also in Noble fir and Sitka spruce, the length of the cracks is not closely related to scar length as in the case of Grand fir. A study of bark scars on Douglas fir indicated that this is a different condition to that reported on above, as Douglas fir bark scars are not associated with internal cracks.

Advisory Work

A total of 386 enquiries were dealt with during the year; 105 from Commission staff and 281 from others. Three hundred and thirty-six of these enquiries were dealt with at Alice Holt and 54 of them by the new Pathology staff of two foresters in Scotland. Eighty-five visits were paid as a result of these queries.

There were approximately equal numbers of enquiries classified as parasitic and non-parasitic. The most frequent parasitic disorders were *Armillaria mellea*, *Marssonina salicicola* and *Didymascella thujina*. The most commonly reported non-parasitic disorders were caused by cold damage, particularly early-season frosts.

The weather records for 1967 showed a number of interesting phenomena related to disease incidence.

It was unusually wet in parts of south-eastern England in April, and over most of Britain in May. In England and Wales it was the wettest May since 1773. In some places on heavy soils there was severe root damage on young Grand fir, Lodgepole pine, beech and Lawson cypress, either by waterlogging or by *Phytophthora* root rot, which is favoured by wet conditions.

Judging by subsequent queries, the rainy weather may also have favoured *Gnomonia tiliae*, a fungus causing premature defoliation of lime.

May started with widespread and damaging frosts. Oak was the most conspicuously damaged tree species, and in many places the blackened foliage of hedgerow trees delineated the distribution and depth of frost layers. This damage was soon masked by a second crop of leaves. Spruce and Douglas fir shoots were also damaged, but the severest injury to conifers was not revealed until later in the season, when deaths in young Western red cedar were reported from several places. In these instances severe frost damage to bark and cambium was found. Douglas fir and Western hemlock were also affected in this way, but to a lesser degree.

Thunder-storms were frequent in May, and there was an unusual amount of lightning damage in the form of group deaths in conifers.

Later on in the season, Weeping willows showed marked recovery from *Marssonina salicicola*, a fungus which causes leaf-spot, shoot-canker and die-back, This disease has been rampant for several years now, and in the earlier, wetter part of the season severe attacks had developed. Corsican pine appears to have benefited as well; for the first time in several years we have had no queries about death of current year's needles.

In January 1968 a severe gale caused serious windblow and windsnap in Scotland. Although fungal attacks on fallen timber develop slowly, a leaflet was prepared in collaboration with the Entomologist giving advice on protective measures which may be needed against pests and diseases. This leaflet was distributed to all interested parties in affected areas.

Two fungal diseases, previously unknown in this country, were found in 1967; *Fusicoccum noxium* (imperfect stage of *Dothidea noxia* Ruhl.) on *Quercus robur* and *Pyrenochaeta pubescens* Rostr. on *Tilia europea* var. *pallida.*

General

Mr. W. M. French of Brunel University worked with the Section for six months mainly on the spore trapping of *Didymascella thujina.*

Mr. G. J. de Brit of the Forestry Division of the Irish Department of Lands visited the Section to study experimental methods for applying stump treatments against *Fomes annosus.*

Mr. D. R. Douglas, a post-graduate student at the Commonwealth Forestry Institute, Oxford, visited the Section to discuss matters concerned with his thesis on economic losses caused by *Fomes annosus* in East England.

The second meeting of the British Forest Pathology Working Group was held at Thetford Chase in April 1967. Field excursions were arranged by members of the Section to demonstrate current research on *Fomes annosus* and spring frosts.

During the year a revised edition of the leaflet on *Grey Mould (Botrytis cinerea) in Forest Nurseries* was prepared and revisions of those on *Fomes annosus* (Forestry Commission Leaflet No. 5, H.M.S.O., 2s. 0d.) and *Keithia Disease of Western Red Cedar* (Forestry Commission Leaflet No. 43) were published. Also published was a revised edition of Forestry Commission Leaflet No. 53, *Blue Stain of Coniferous Wood*, by B. W. Holtam (H.M.S.O., 6d.).

D. A. BURDEKIN

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FOREST ENTOMOLOGY

Pine Looper Moth, Bupalus piniarius

Populations of pupae in 43 out of the 47 forests sampled in the winter 1967–68 show an increase of population. A greater number, 20, than in any previous survey contain an overall forest mean of one or more pupae per square yard. Values for the two quantities, overall forest mean and highest compartment mean, both expressed in pupae per square yard, for the four forests with highest populations, are as follows:—

Forest	Overall Forest Mean	Highest Compartment Mean
Sherwood III	5·2	12·8
Cannock Chase	5·0	20·4
Tentsmuir	3·0	6·0
Delamere	2·8	6·8

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

The rate of increase in population density recorded between the two winter assessments 1966/67 and 1967/68 has been large in many forests. The rate of increase at Cannock has been of the same order as that in the years prior to the 1963 infestation and this fact, taken with some high individual compartment mean counts, suggests that a third infestation, following those of 1953 and 1963, is a strong possiblity. Failing a collapse in the population due to natural causes, a degree of visible defoliation is to be expected in 1968.

Douglas Fir Seed Wasp, Megastigmus spermotrophus

Work on this project is now being run down. Regular sampling of cones over the past five years has given satisfactory evidence of an association between low percentage infestations and good seed crops, and sampling, having served its purpose, will be discontinued. Seed trapping is a convenient method of obtaining information about seed production, which is of interest to Silviculture, and about seed wasp populations, and will be carried on for at least a further three years.

A few sites had bumper seed crops in 1967, and cut-tests on cone samples from 11 trees in a seed stand at the Tavistock Estate, South Devon, showed eight trees with under 10 per cent infestation while the other three had 12·4, 27·5 and 74·1 per cent infestation. A tree in the New Forest had 52·8 potentially sound seeds per cone, by far the largest number found during the investigation.

An experiment was done at Monaughty Forest, East Scotland, to test and compare the reduction of infestation obtained by repeated application of Malathion and a Malathion/BHC mixture during the period of oviposition. Sprays were applied to 30 trees by means of sprinklers attached to each tree. This method is only effective under virtually still air conditions such as occur when a high-pressure weather system predominates. Unfortunately there were almost continuous westerly winds during the oviposition period, and in consequence only single applications of Malathion and Malathion/BHC mixture were made. The occurrence of sufficient trees bearing cones to make this replicated experiment possible was associated, almost inevitably, with a sizeable cone crop; and the percentage infestation was consequently rather low. The range for the 10 untreated trees was from 4·5 to 52·4 per cent, with six trees having less than 20 per cent of potentially sound seed infested. This meant that treatments would have to give a high degree of control to show a significant difference. In fact the treatments applied resulted in no significant reduction in infestation.

It is planned that future control experiments will be confined to confirming the effectiveness of Malathion, shown in an earlier experiment, a further test of BHC, and to determining the number of applications necessary. These experiments will be done only where and when suitable circumstances arise.

Pine Bark Moth, Laspeyresia coniferana

This tortricid has long been associated on the Continent with resinous cankers caused by fungi. Apparently primary attacks of the species have for some years been recorded in this country on the economically unimportant host *Pinus ponderosa*. High populations have also been noted on occasion to coincide with a characteristic bottle-shaped swelling of the lower metre of the tree stem. However, locally very heavy attacks have appeared on Corsican pine at Newborough Heath in Môn Forest, Anglesey, North Wales, and an investigation is therefore being carried out on the species' biology and significance.

An annual life-cycle appears to be predominant although a great deal of overlap both in stages and generations is evident. The adults emerge in the period mid-June to early August and oviposition follows. However, all stages of larvae and the pupa may overwinter. The larvae burrow irregular short tunnels in the bark but never reach the live cambium. Most are found in brashing wounds and slash marks, where resin is plentiful.

Control of the Bark Beetles, Hylobius abietis and Hylastes species

An experiment planted 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, and incidentally to check the effectiveness of the treatment against *Hylobius*, was assessed in the summer and again in the autumn. The treatment generally proved very satisfactory against both species. At one site the autumn assessment showed a considerable number of treated trees with light damage due to *Hylobius*, but few with heavy damage, whereas a significant proportion of the untreated trees had heavy damage. It is therefore considered that the light damage represents successful repulse of a heavy attack rather than a breakdown of control. A further assessment will be done in Summer 1968.

Large-scale user trials of 1·6 per cent Gammacol, notably at Thetford, gave satisfactory control in their first season.

Green spruce aphis, Elatobium abietinum

Defoliation/Increment Loss

The loss in increment associated with severe defoliation is being investigated by comparing growth patterns in attacked and unattacked forest. Neighbouring pairs of plots, consisting of one each of both categories of forests, have been sampled and increment data recorded. Four such pairs, from Ae, Clashindarroch, Knapdale and Deer, all in Scotland, were selected for their locally recorded history of severe defoliation. The data has not yet been completely analysed.

Host Plant Susceptibility

Satisfactory xylem sap samples are now being obtained by suction applied to cut branch samples by high vacuum pump. Initial chromotographic analyses have shown that at least six amino-acids may be present, threonine, aspartic acid, glumatic acid, and serine being common in at least spring-taken samples. Both quantitative and qualitative determinations of tree-to-tree, within-tree and seasonal variations in amino-acids present are being made. Methods of storage of material for later analysis are being investigated.

Flight

The suction trap, operated at Alice Holt, again showed a single peak in activity of alate viviparae, commencing on 24th April and ending on 30th June. Trap data and accumulated observation indicate that the peaks in flight and in the density of population of both alatae and apterae, occur characteristically early in the year in the southern half of Britain. This is not always the case in the north, and a shift in the peak into other seasons is not uncommon with increasing latitude or altitude.

Suction Trap Collections

Details of the apparatus developed at Alice Holt have now been described by Stickland (1967). The advantages over other traps run on similar principles are that flying insects are sucked directly into a liquid, and that separate consecutive samples can be obtained over a period of a few days. Ethylene glycol has proved to be a suitable liquid for general use in the trap.

The main bark beetle flight again occurred early in the season, 70 per cent of the total catch being recorded during the months of May and June. Of the 13 species captured, *Leperesinus fraxini* was most numerous and accounted for a quarter of the total catch.

Progress has been made with the identification of the winged morphis of conifer-feeding aphids, particularly the *Cinarininae*. In 1967 the commonest species caught were *Schizolachnus pineti* and *Cinara pinicola*, in that order, and both had flight peaks in June and July. Information on the occurrence of the seasonal forms, and hence the overwintering state of these little-known species, is being obtained.

Studies on Adelgids

Morphological keys and descriptions have been made of the winged forms of the adelgid species occurring in Britain. Prior to this it has been impossible to identify the migrating individuals captured in the suction trap. Only in the cases of *Adelges viridis* and *A. abietis* gallicolae, and *Pineus orientalis* and *P. pini sexuparae*, is it still necessary to depend upon life-cycle information for separation down to species. Information on seasonal flight activity of most species is now being acquired. Further transfer experiments have been carried out to check host alternation patterns in the alatae of certain species. Another species, *Adelges (Cholodkovskya) viridana*, not previously recognised in Britain, has been found to be widely distributed on Japanese and hybrid larch.

Control of Cutworms

The experiment at Kennington Nursery, described under "Nursery Investigations" in the 1967 *Report*, to find an alternative to Aldrin for cutworm control, was repeated during the summer of 1967. Satisfactory control was achieved by Aldrin, BHC and DDT with no statistically significant differences between them. Carbaryl proved to be less effective. Two applications of Aldrin, BHC or DDT gave no better results than single applications. No further experiments are planned, and we shall in future recommend the use of BHC at 1 kg active ingredient (= 4·5 litres of 20 per cent concentrate) in 1,000 litres of water per hectare, or 1 lb (= 4 pints of 20 per cent concentrate) in 100 gal of water per acre, at the time damage is first observed; if further damage occurs a second application could of course be made.

Enquiries

There were 56 enquiries from southern, and 10 from northern Forestry Commission units, as well as 92 and 10 from southern and northern private sources.

D. BEVAN

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MAMMALS AND BIRDS

Grey Squirrels

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

No further field trials of warfarin in Scotland were carried out. However, a submission to the Minister of Agriculture for permission to carry out field trials on Crown Lands in England and Wales was granted in March 1968. Trials of warfarin against grey squirrels will take place during the period 1968–70 in order to provide the basis for firm recommendations for the use of this poison as a method of control specifically for squirrels and safe for other wildlife.

Protection trapping of a vulnerable crop in non-isolated woodland by cage-trapping in and around it just prior to the damage period has continued. The results emphasize the rapid rate of recolonisation at this time of year and the importance of concentrating control in the period late April to July.

Deer

Work has continued on methods of ageing deer. Various methods of assessing the condition of bone marrow as an indicator of roe deer condition are being investigated. The tagging of red deer calves in Galloway, South Scotland, has continued; a total of 89 calves has been marked in three seasons of which 28 have been culled or found dead. The results of single applications of nitro-chalk, basic slag and an NPK fertiliser to natural vegetation in a red deer wintering area are being compared both for their effects on the vegetation and their attractiveness to deer.

Starling (Sturnus vulgaris) Roost Dispersal

A woodland starling roost dispersal technique has been developed. Two woodland roosts, in Kesteven Forest, Lincolnshire, and Bodmin Forest, Cornwall, were dispersed by combining the use of the amplified distress call apparatus with bird-scaring cartridges. The whole operation took four evenings on each site; a considerable saving of time and labour over traditional methods. The technique depends on having reasonable mobility of the distress call apparatus and siting the guns firing the bird-scaring cartridges in the starling flight paths. These cartridges are also used to protect outlying blocks which might be used as an alternative roost site.

Chemical Repellents in the Forest

Six chemical repellents were tested against fallow deer browsing in the New Forest and found to be ineffective. The Dutch repellent Aaprotect successfully reduced roe deer browsing on Norway spruce in a trial at Cranborne Chase Forest, Wiltshire.

Fencing

A major advance in forest fencing has been made by combining the advantages of using spring steel wire with woodwork treated either with creosote or other recognised preservative. The main saving in materials and labour derives from the fact that fewer straining posts and intermediate stakes are required.

An investigation of the advantages and disadvantages of the variety of types of wire netting in common use has begun.

Damage

An investigation of the effects of various types of damage by mammals and birds has been initiated.

Squirrel Questionnaire

The annual questionnaire on red and grey squirrels for the year ending September 1967 showed that grey squirrel damage had slightly increased. Practically no change was observed in the relative distribution of red and grey squirrels.

JUDITH J. ROWE

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PLANNING AND ECONOMICS

Planning and Economics is a Branch of the Management Services Division of the Headquarters organisation. Work has continued in the four sections, Working Plans, Census, Mensuration and Economics, and particular attention has been paid to production forecasting and the development of planning at the regional level.

J. A. SPENCER

WORKING PLANS SOIL SURVEY

Soil survey has continued at an increased rate, with four two-man survey teams operating in different parts of the country. The main effort of each team has been concentrated in a defined (usually geological) "soil region", where the normal progress of soil survey may henceforth be seen as consisting of two successive phases. Phase 1 comprises the mapping of soils within the soil region in a sample of forests sufficient to allow the preparation of a comprehensive site classification. The results are then published in the form of a guide to the recognition, properties and silvicultural use of the site types of the region. At this stage detailed field instruction on the use of the site classification outlined in the guide is given to local forest staff. Phase 2 comprises the extension of routine soil mapping throughout the region.

To date, the most advanced stage reached in a regional survey is the end of Phase 1, now achieved by the team working in Wales. This survey covers the areas of the *slaty* type of rock of Cambrian, Ordovician, Silurian and Devonian ages in Wales and the Welsh borderland. Over a period of about 2½ years an area of 21,500 ha (53,000 acres) of forest has been mapped, out of a soil region of some 111,000 ha (275,000 acres) of existing forest. A site classification guide has been prepared and discussed in detail with local forest staff. It is intended for publication in 1968.

This guide will contain introductory sections dealing with the physical basis of the classification used, followed by tables showing the basic properties of each site type, data of use in the assessment of windthrow hazard and information on silvicultural properties, to assist in choosing the best techniques for such important operations as cultivation and drainage, choice of species, fertilisation and thinning.

Another regional survey covers the Old Red Sandstone areas in North and East Scotland where Phase 1 is well under way. This is a region of some 36,000 ha (90,000 acres) of existing forest, of which 7,700 ha (19,000 acres) have been mapped to date. The region contains a preponderance of ex-heathland soils which are widely acknowledged to possess extremely difficult physical conditions, namely severe compaction and stoniness, often with a thin ironpan. The soil survey has shown that impeded vertical drainage due to the dense subsoil is the major limitation to tree growth, and that greater attention to drainage, rather than to surface cultivation as practised up to the present, is likely to yield a better crop response. This relatively lowland region not only possesses a climate suitable for the growth of much higher-yielding species than the traditional Scots pine, but in addition the gentleness of the terrain and the region's geographic situation make it a particularly favourable prospect from the harvesting and marketing viewpoint. This area provides an excellent opportunity to use soil survey as the initial stage of what must be a relatively long-term effort aimed at the progressive improvement of forest productivity in the region. Succeeding stages of this project may involve Research Division in more intensive studies of soil physical conditions and the development of effective drainage and other techniques for the establishment of replacement species.

Survey is also in progress in the North York Moors region, which hold 23,000 ha (56,000 acres) of forest also established on ex-heathland soils derived from varied Jurassic sedimentary rocks. Scots pine has again been the traditional choice of species and, while yield has generally been satisfactory for the species, it is now apparent that climatic factors do not limit either the choice of species or rates of growth to the rather low levels that have been achieved with pine. Deeply rootable soils of the brown earth or humus-iron podzol types are capable of supporting stands of spruce, Douglas fir and other species to maturity, with yield classes approximately double those of the average crop of pine. Ironpan soils and peaty gleys constitute the major difficult soils and these appear to require respectively deep cultivation and drainage before the potential of high yielding species can be realised. There are also substantial areas of shallow soils overlying limestone and on these severe chlorosis in pines has occurred. Survey is showing, however, that soils on limestone vary appreciably in depth and that those deeper than about 18 in. not only produce healthy pine, but are in fact capable of producing good crops of Sitka and Norway spruces. Such areas will therefore repay detailed mapping.

During the period of this *Report*, a fourth survey team has carried out a special survey of Tentsmuir Forest, Fife, which is situated on coastal sand dunes and consists largely of Scots pine with a mean yield class of 100 hoppus ft per acre per annum (about nine cubic metres per ha per annum). The object of the soil survey was to discover how far Sitka spruce or other more productive species could be used to replace Scots pine in the second rotation. So far Sitka spruce has been planted on only a few sites where the ground-water table is high and has there produced a mean yield class of 135 hoppus ft per acre per annum (about 12 cubic metres per ha per annum). Soils of this type cover 540 ha (1,300 acres) or 37 per cent of the forest area and it would appear that planting of spruce could be safely extended over them. Experimental work is being planned by Research Division to find the best methods to use when replacing pine with spruce or other species on this soil type and on other soils in which the ground-water table lies at progressively deeper levels. In fact there is an increasing weight of evidence from this country and abroad (Brown & Bevan, 1966) that, providing there is sufficient rooting depth, Sitka spruce and other high-yielding species may be grown to maturity at rapid rates of growth on very coarse-textured and quite impoverished soils in rainfalls as low as 630 mm/an (25 in./an), although some deaths due to unseasonable frosts or drought must be expected in the establishment phase. How far the immediate results of the Tentsmuir survey are applicable to the other coastal sand dune forests is not known because the existence of a high ground-water table has not hitherto been regarded as typical of such areas. However, there are some 8,000 ha (20,000 acres) of these forests in which pine predominates and the matter will clearly repay further investigation.

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D. G. Pyatt

ECONOMICS

Investment Studies

During the year a study was published on the effect on expenditure and returns of varying the initial spacing in plantations. This work, based on material compiled by Research Division and Mensuration Section, forms part of a re-appraisal of spacings to be adopted in the establishment of Forestry Commission plantations. Work has continued on the relationship between investment in roading and the cost of harvesting operations, and has been extended to consider the effect of varying the timing of roading on road cost and returns from thinnings. The indication is that where roading costs are high, or yields are low, the investment in roading, and thus the start of thinning operations, should be postponed, in some circumstances to the end of the rotation, so that in certain blocks thinning cannot be justified in financial terms.

Heavy expenditure, particularly on labour, has often been incurred in the brashing of plantations. In order to economise on the use of labour and supervision in first (and possibly second thinnings) a review of the usefulness of line thinning has been made jointly with the Chief Harvesting Officer, Work Study Branch and Mensuration Section. It appears that the adoption of patterns of line thinning which facilitate felling and extraction causes only slight reductions in discounted revenue, while the costs of brashing and harvesting may be reduced significantly.

Other investment subjects which were dealt with in the course of the year included intensive fertilisation from the time of establishment onwards, the fertilisation of pole-stage crops, protection against animal pests, the use of mixtures of species to ensure the formation of a crop on difficult sites where the preferred species may fail, and management of stands subject to risks of windblow.

Special Management Studies

A review of resource deployment in North Scotland was completed. This involved an appraisal of the quantities of different types of resources used and of the treatments and types of operation to which they were devoted, investment analysis to determine the expected return from these and any feasible alternative treatments, and studies of the organisation of operations to ascertain the effect of different arrangements of operations on the utilisation of resources. As a result of these studies, recommendations about the combinations of treatments and organisation of operations for the future were made, together with forecasts of the resources required.

Study of the management of plant supply was continued. This study started with a review of the information system needed for the management of plant supply and suggested additions to the information provided to particular managers responsible for planning and decision making. The simulation model taking account of the uncertainties in nursery production whose development was referred to last year (*Report* for 1967, page 110) is now being used to suggest nursery programmes and to assess the possible outcomes of programmes in train.

A study of control of harvesting and marketing in Thetford Forest is currently under way. This is being undertaken as a joint project with the Industrial Operations Unit of the Ministry of Technology.

In an earlier study on the supply of wood to Scottish Pulp and Paper Mills Ltd. at Fort William (*Report* for 1965, page 71), computer programmes were developed to handle growing stock records and calculate forecasts of production. The work of updating records and routine preparation of production forecasts by working plan areas has now been taken over by Working Plans Section.

Forecasts of yield under different management regimes and on the basis of different rates of planting have been made for the Highland region and estimates of the employment and income generated in forestry have been computed. At the other end of the scale of forestry interest, some assessments have been made of the costs and returns associated with different methods of providing standards and semi-mature trees for planting where a quick effect is desired.

Other Studies

A questionnaire was devised jointly with Statistics Section to collect data on the use of various recreational facilities in forests. This method of approach, which was adopted in four Commission forests during 1967, aims to relate the kind and volume of use of the facilities to characteristics of the site and of the users.

In connection with a review of the private woodlands grants, data compiled by the Forest Economics Sections of the Departments of Foresty at Aberdeen and Oxford Universities were combined to provide estimates for Great Britain of mean net income per acre, and the standard errors of these estimates, for the years 1961 to 1966. The results are shown in Table 44.

TABLE 44

ESTIMATES OF MEAN AND STANDARD ERROR FOR NET INCOME, INCLUDING FORESTRY COMMISSION GRANTS, PER ACRE IN SAMPLE DEDICATED AND APPROVED WOODLANDS OVER 100 ACRES

£ per acre

Year	1961	1962	1963	1964	1965	1966
Mean net income	−0·79	−1·38	−1·89	−1·78	−1·49	−2·37
Standard error	0·54	0·36	0·36	0·52	0·51	0·45

Analyses were made of the relationships between the components of net income, namely income and expenditure, with certain measures of physical activity such as area planted and volumes cut in relation to total woodland area. Though such work is still in an early stage it is hoped that it will help to improve sample design and to aid the interpretation of survey data on net income.

Economics Section is also collaborating in I.U.F.R.O. working groups dealing with national income measurement in forestry, and with forest economics in developing countries.

A. J. GRAYSON

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WORK STUDY

ORGANISATION

With the setting up of a team to investigate road construction, the expansion of the Work Study Branch has now been completed. The roads team is based on Inverness and it is hoped to conclude the Study over a period of about three years.

Machinery Research and Development responsibilities have now been firmly allocated to the Branch and the previous, close professional liaison with the Chief Engineer and his staff has been further strengthened.

The Machinery Investigation Committee has been dissolved and replaced by an Operational Efficiency Committee having wider terms of reference. The Committee includes functional heads of divisions as well as heads of the various branches, and should prove invaluable in across-the-board planning. In particular, it should greatly help in the formulation of work study programmes and in the translation of results into practice.

Further work on noise and vibration problems has been undertaken in co-operation with the National Institute of Agricultural Engineering and clinical aspects have been explored with the medical profession. In these studies we have been closely associated with the Commission's Industrial Training and Safety Officer.

MACHINERY INVESTIGATIONS

Roughly equal resources have been deployed on silvicultural and harvesting problems.

Shortwood Extraction Systems

These are logging systems which require the conversion of the tree length before extraction. The converted material needs to be piled in order to minimise terminal time for expensive extraction equipment. This can be heavy work and a series of studies has been concluded which will indicate the cost of bringing together piles of different sizes; the results await computer analyses.

Timber Carriers

These are tractor/trailer combinations with cranes which are usually hydraulic and mid-mounted. They may be all-wheel machines such as the Swedish Drivax or Brunett, or else threequarter-tracked like the M/F 165 Robur. The Robur and similar machines have tail-steering through hydraulic rams between tractor and trailer. The Robur was mentioned in the last *Report*; it has been well integrated with harvesting operations at Kielder Forest in Northumberland, where it has extracted pulpwood billets and associated saw-timber lengths. This machine needs a skilled operator and it is interesting to note that terminal times have decreased by about 40 per cent over the year as the operator gained experience with the outfit in general, and the manipulation of the hydraulic grapple in particular. It has been demonstrated that this machine works well on the relatively gentle slopes found there, provided there is enough brash to assist "flotation". Its performance over wet, "green" rides is more questionable and attention is being given to trailer re-design to see if improvements can be made. Meanwhile performance has been somewhat improved by fitting tyres with wider track-bars, set at a less acute angle, to the driving wheels of the tractor; this has prevented track-slip in reverse drive. Additionally, the front pair of trailer wheels has been fitted with tyres having track-bars, with the tread reversed: this has ensured that the wheels generally turn rather than skid in soft conditions. It is possible that successors to the Robur will be all-wheel machines, and British developments are in sight.

We have built up a relatively cheap timber carrier from a Fordson Major tractor equipped as follows:—

Bogie trailer of 6 ton capacity, the position of the bolsters and the wheels being adjustable for different load lengths.
Boughton hydraulic winch restricted to 2,000 lb (907 kg) pull.
Solenoid operated valve (Vickers).
Sepson live reel and switch for remote control (range 17 m or 18·6 yds) supplied with belt for switch so that the operator can use both hands.
Self-centreing, boom crane (907 kg, 2,000 lb load) fixed to the trailer.
A.A.B. Farming hydraulic stabilising cylinder.
Separate hydraulic pumps and circuits for winch and stabiliser.
Skarpsko chains for driving wheels.

The equipment is being tested in the New Forest and it has become apparent that unloading time must be reduced and the necessary modifications to equipment will be undertaken.

Cable Cranes

The Isachsen No. 3 double drum winch has been most successfully modified to fulfil the role of a 300 m (328 yd) skyline. It is now in use in a number of conservancies for both downhill and uphill extraction. Tag-line chokering is standard practice, each tag line carrying an extra key-hole choker and chain for millwood or a small, extra bundle of pulpwood. The Baco crane has proved unsatisfactory under our conditions, and Bamse and other proprietary winches are under test in the search for alternative, middle-range cable cranes.

Although cable cranes have been included under the Shortwood section of this Report, since this is their characteristic role in Great Britain, they can and do find an application in tree-length extraction of clear fellings. Earlier work showed that tree-length extraction of thinnings by cable crane was most difficult, but we plan to return to this problem.

Tree Length Extraction Systems

These are systems in which the tree length, topped at the appropriate point, is extracted as such, for conversion out of the wood. The techniques of multiple chokering are now quite generally applied.

Main studies have continued on two frame-steered tractors: the Holder A.20, a small machine particularly suited to early thinnings, and the Hough Paylogger which is best employed in clear fellings and the last one or two thinnings. Provisional standard times are now available for the Holder and currently we are fitting the machine with bigger tyres in an attempt to improve its performance over soft ground; a hydraulic winch is also being fitted. Numbers of Holder tractors are now operating in the conservancies and valuable experience is being gained. The Hough Paylogger has lived up to its early promise and it is plain that large, frame-steering tractors of this type will have an important role in the extraction of clear fellings.

At the present time we are developing a 65 brake-horse-power frame-steering, hydrostatic machine with many advanced features. Later we intend to apply the same principles to a light, frame steerer and possibly to a timber carrier.

The M/F 165 fitted with Svedlund half tracks has continued to operate at Kielder and demonstrated its superiority to wheeled tractors—even those fitted with chains—when travelling over soft ground. However, there has been continual trouble with the front axle and front wheels. These are being strengthened.

Chain Saws

Attention has been mainly directed towards light-weight chain saws. The market is highly competitive and we have concluded that vibration characteristics are the main criteria which will determine acceptability or rejection. Although medical opinion is not firm, it is thought likely that continual exposure to vibrations which exceed an amplitude of 100 microns in the frequency range of 40–150 Hertz, puts operators at risk. A most promising development has been the provision of anti-vibration handles to one make of saw: this has resulted in a reduction of vibration amplitudes in the "risk" frequencies by about 75 per cent. Inevitably, other manufacturers will have to follow suit and the risk of clinical effects, particularly "white hand" (Raynaud's Phenomenon) is likely to be greatly reduced in the future. This is particularly important since saw usage is increasing through the general employment of chain saws for snedding. During the year the National Institute of Agricultural Engineering has determined the noise and vibration levels of a range of saws on our behalf.

Lokomo Plough

After a prolonged and frustrating period of development, it now seems that, by replacing the mechanical winch by a hydraulic winch attached to the bulldozer A–frame, and by extending the track plates of the B.T.D. 20 tractor, a workable combination has been produced. Currently the equipment is working in North Wales and has produced up to 60 chains (1,206 m) of deep drain in one day at an estimated cost of 10 shillings per chain (20·1 m). Although further development work is needed, we now seem to have solved the major problems set by the needs for high drawbar pulls through tough ground, and also good terrain-crossing capacity on the part of the tractor. Studies on the "Humpy" deep draining plough have also been undertaken.

In order to link up feeders with main drains it may be necessary to use a back-acting digger in conjunction with the Lokomo plough. Now that the outfit is working our attention has turned to this aspect and to the logistics of the entire operation.

Weeding Equipment

Mechanical

An investigation into several types of brushcutters was concluded and recommendations made. The main value of brushcutters was shown to be in cutting woody weeds in narrowly-spaced plantations, especially prior to chemical treatment.

A Belos Graveley pedestrian-controlled weeding machine was modified and showed savings of 50 per cent over the cost of hand weeding.

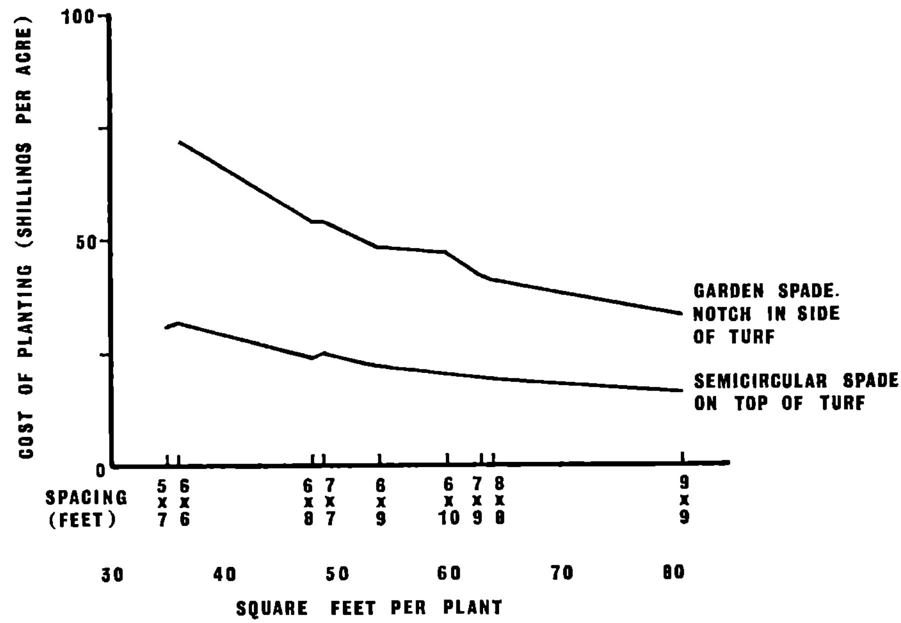

FIGURE 2: Effect of spacing on planting costs. Costs include labour and labour oncost, but exclude costs of plants and plant haulage from nursery to dumps on the afforestation area. Assumptions are: Shallow single mould-board tine ploughing; conditions moderately easy; "other work" = 10 per cent of actual planting time; price per standard minute 2·0d. including oncost.

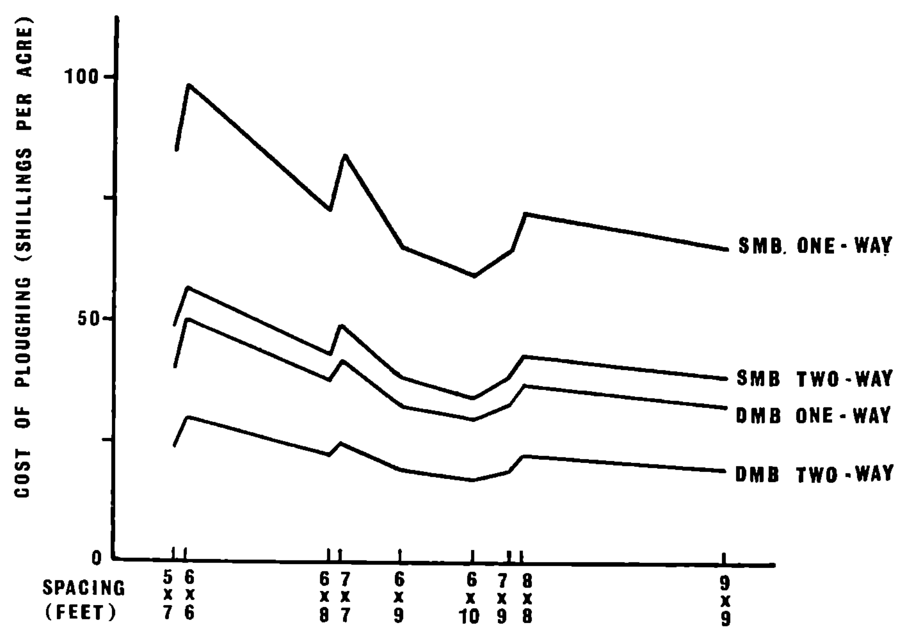

FIGURE 3: Effect of spacing on ploughing costs. Costs include labour, oncost, and a predetermined charge of 30s. per hour.

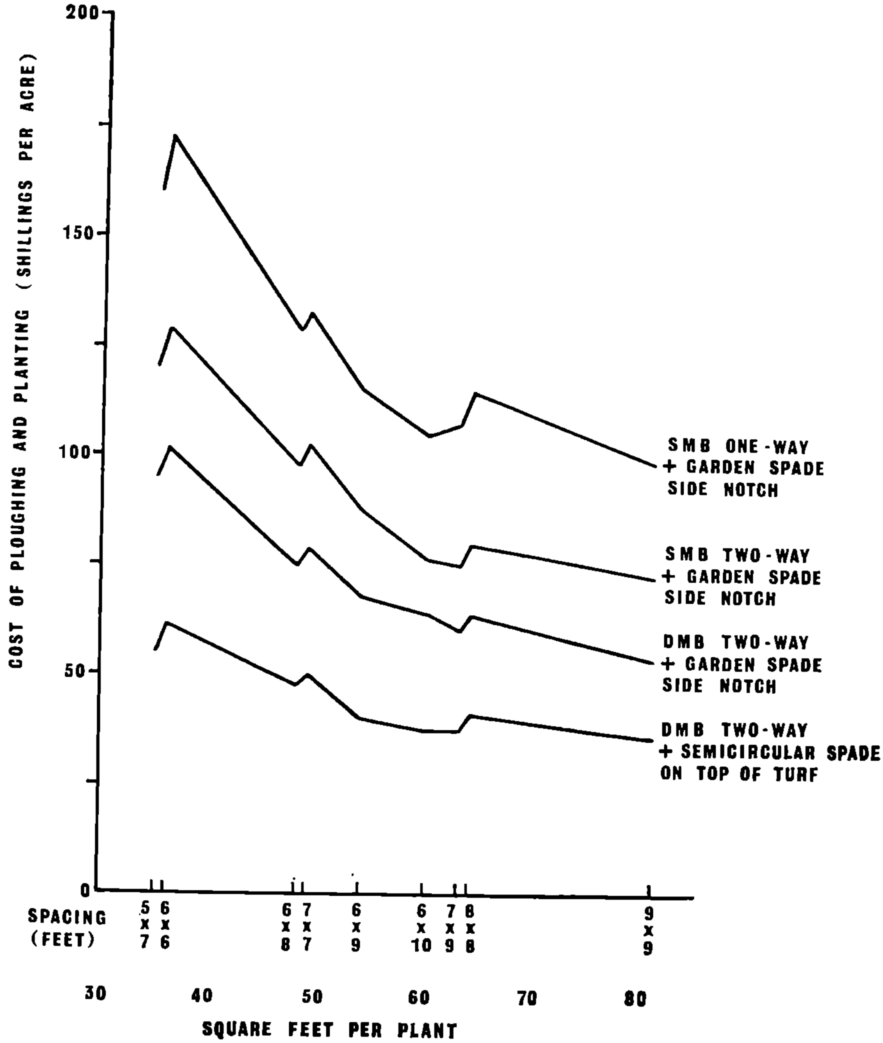

FIGURE 4: Effect of spacing on combinations of planting and ploughing methods, derived from Figs. 2 and 3.

Amongst tractor-powered machines the Bush Hog showed great promise. We have also developed a variable width (five to seven ft, 1·5 to 2·1 m, plant spacing) inter-row weeding machine, rear-mounted and currently powered by a M.F. 135 Vinyard Tractor. This has operated extremely well and savings of 50–60 per cent over the cost of hand weeding are in sight.

In general, there is no room for doubt that mechanical weeding is cheaper than other forms and should be used wherever conditions allow.

Chemical

The portable sprayer, designed and developed by the Branch and now christened "Pharos" (pump hose and reel on sledge) has been well received (see Plate 7, central inset). A Mk II version has been made and arrangements are going ahead for large-scale manufacture. The machine has been used successfully for cut stump, basal bark and foliage treatments. Indications are that it is competitive with knapsack sprayers except when spraying sites are both small and also adjacent to diluent containers. As slopes become steeper or obstacles make progress with knapsack containers more difficult, the spraying unit is increasingly advantageous.

Work is now being undertaken on wheeled spraying equipment.

DEVELOPMENT OF METHODS

Planting

Studies have shown that the semi-circular space, when used for planting on ploughed land and put in the hands of skilled workers, can double output. We are determining whether the method is as applicable in the Highlands as it has proved to be in Northern England. Using cine-camera techniques, the planting motions used by skilled workers have been studied and analysed and it is clear that the best techniques can be taught.

Ploughing

A series of studies has begun in order to determine those factors which affect ploughing output and the limitations of various types of tractors and ploughs under different conditions. These studies have also provided a good deal of information on the organisation of ploughing teams and on possible improvements to equipment. Figures 2, 3, and 4, indicate the effects on cost of planting method and ploughing method (single and double mould-board).

Weeding

Progress has been described under Weeding Equipment, p.125.

Brashing

As a result of detailed studies, in the spruces, reduced intensity brashing has been recommended.

Line Thinning

Work continues on this complex project. Felling methods have been compared and the cost of felling unmerchantable trees has been assessed. Comparisons between single and double row removal are also being undertaken. Current studies involve carefully controlled costings in replicated plots where comparisons will be made between: line thinning (single line), line thinning (double line), thinning in reduced-intensity random brashing, thinning in reduced-intensity lane brashing, and normal thinning.

SERVICE TO MANAGEMENT

Regional teams provided an advisory service and Work Study Courses were held in several Conservancies. Additionally, the Branch co-operated in running courses on chemical weeding. Various tables of standard times were issued and much attention given to the problem of "drift" from standards: as a result, it has been decided to restudy all major tables of standard times at intervals of about three years.

An officer from the Branch was seconded to Zambia for several months, to act as economic consultant and to further work study procedures.

We have co-operated with the Forest Service of Northern Ireland in setting up a work study section in that country.

INFORMATION

The F.A.O./E.C.E./I.L.O. Joint Committee for Forest Working Training and Forest Working Techniques has been provided with various Work Study Papers, and Summaries of these have been circulated to member countries.

A monthly "Information Sheet" has been introduced and distributed both within and without the Commission and overseas. The sheet contains summaries of papers, booklets etc., which appear to us to be important contributions to operational efficiency.

Relevant Work Study Papers have been provided to the Mechanical Development Committee.

L. C. TROUP

PUBLICATIONS BY STAFF MEMBERS

BARRACLOUGH, J. W. *Timber Extraction by Light Agricultural Tractor*. Bookl. For. Commn, **19**, 1967.

BRAMWELL, A. G. Planning for extraction of pulpwood and logs by cableways. *Forestry* **40** (1), 1967, 7–14.

DANNATT, N., and WITTERING, W. O. *Work Study in Silvicultural Operations with Particular Reference to Weeding*. (Paper for 9th Commonwealth Forestry Conference, India 1968.) Res. Dev. Pap. For. Commn, Lond. **58**, 1967.

RAWLINSON, A. S. *Norwegian Timber Extraction Methods; Report of a Study Tour*. Res. Dev. Pap. For. Commn, Lond. **52**, 1967.

ROWAN, A. A. *Work Study in the Improvement of Timber Harvesting Efficiency*. (Paper for 9th Commonwealth Forestry Conference, India 1968). Res. Dep. Pap. For. Commn, Lond. **59**, 1967.

TIMBER UTILISATION DEVELOPMENT

Properties of Home Grown Timber

The joint programme of research with the Forest Products Research Laboratory of the Ministry of Technology continued, entering its tenth year.

In the general programme, a comparison of the timber properties and graded sawn out-turn of Scots pine and Corsican pine, which was started in 1965, was completed. The results have shown that not only does Corsican pine usually give a significantly higher yield of sawn timber per hoppus foot than Scots pine of the same age, mainly on account of its superior log form, but also that there is little difference between the nominal specific gravities and the maximum crushing strengths of the two species.

While specific gravity and maximum crushing strength in both species improved with the age of the tree from which the log was cut, this trend was more pronounced in Corsican pine than in Scots pine.

In a project to assess the suitability of severely distorted softwood in the Laboratory's continuous laminating machine, it was found that distorted timber could be used with little difficulty for the production of laminated beams. Norway spruce and Douglas fir 2·286 m × 76 mm × 35 mm laminae (7 ft 6 in. × 3 in. × $1\frac{3}{8}$ in. laminae), in which up to 19 mm ($\frac{3}{4}$ in.) of bow, 3·75 mm ($\frac{3}{8}$ in.) of spring and 9 degrees of twist were tolerated, were accepted by the machine. The end jointing of severely twisted timber caused some difficulty if it were not preceded by a straight piece. The beams were found to remain stable during changing conditions of atmospheric humidity.

An investigation into the suitability of various species of home-grown softwoods for the manufacture of woodwool/cement building slabs demonstrated that the pines, the spruces, Grand fir and Western hemlock can be used without retarding unduly the setting time of Portland cement; of the species tested, only Douglas fir heartwood inhibited seriously the effect on the setting of the cement; the inclusion of decayed timber of any species also inhibits the setting; larch, which was not tested, was already known to be unsuitable.

A start was made on the assessment of the variability of moisture content and nominal specific gravity of Western hemlock. It is hoped to be able to assess the other main strength properties of this species by making use of the known correlations of these properties with specific gravity.

Fence Post Trials

Further assessments were made in the trials of round timber fence posts which were set up at nine sites in Scotland in 1957, and at 11 sites in England and Wales in 1958. In Scotland, where the species under test are Sitka spruce and birch, only 9 per cent of the untreated birch, and 32 per cent of the untreated Sitka spruce posts remain, while 70 per cent of the birch and 78 per cent of the Sitka spruce posts which were treated with a water-borne preservative have survived. Only one creosoted post out of a total of 288 has failed so far.

In England and Wales only 7 per cent of the untreated Scots pine posts remain, compared with a 97 per cent survival of Scots pine posts treated with waterborne preservative, and 100 per cent survival of Scots pine posts treated with creosote. Of the other softwoods under observation 75 per cent of the untreated European larch and 56 per cent of the untreated Japanese larch now remain.

Of the hardwoods, poor service has been given by untreated ash; only 2 per cent of the untreated ash posts remain, together with 37 per cent of the ash posts treated with water-borne preservative and 90 per cent of the ash posts treated with creosote. Practically all of the untreated birch posts have failed, but all of the birch posts treated with creosote remain intact.

Composting of Bark

The experiment at Thetford Chase in which replicated heaps of bark were treated with urea, or ammonia gas liquor, was continued. Thermistors were placed at the centre of each heap in one replicate, but the temperatures produced by the treatments have been disappointing as they never reached higher than 30°C (86°F). Furthermore, the volumes of the heaps turned out to be more variable than expected, and by chance the high nitrogen treatments coincided with the large volumes, thus reducing the effects. The conclusion, however, is that the large particle size of the bark coming off the peeler makes it unsuitable for composting without further shredding or grinding.

Measurements of the Rate of Drying and the Solid Content of Stacked Roundwood at Thetford

The barking and stacking of 2 m (6 ft 6 in.) billets, in a yard at Thetford where the wood is sorted by an electronic scanner into three diameter classes, has presented an opportunity to study the effect of species and diameter on the rate of drying of close-piled billets and on the solid content of the stacked measure.

The results so far have shown that substantial differences in the rate of drying exist between Scots and Corsican pine for all diameter classes.

J. R. AARON

PUBLICATIONS BY STAFF MEMBERS

AARON, J. R. *Wood-Consuming Industries in the Federal German Republic.* Res. Dev. Pap. For. Commn, Lond., **65,** 1967.

HOLTAM, B. W., CHAPMAN, E. S. B., ROSS, R. B., and HARKER, M. G. *Forest Management and the Harvesting and Marketing of Wood in Sweden.* Bull. For. Commn, Lond., **41,** 1967.

RICHARDS, E. G. *Appraisal of National Wood Production and Consumption Trends and their Interplay with Regional and World Trends.* (Paper for F.A.O. World Symposium on Man-made Forests, Australia 1967.) Res. Dev. Pap. For. Commn, Lond., **33,** 1967.

RICHARDS, E. G., and TINSON, E. J. F. *Some Problems of Long-term Marketing Arrangements.* (Paper for 9th Commonwealth Forestry Conference, India 1968.) Res. Dev. Pap. For. Commn, Lond., **62,** 1967.

STATISTICS

Staffing

The Statistics Section again experienced grave staffing difficulties. During the year Mr. J. N. R. Jeffers, who was Head of the Section and virtually founded and built it up, left to become Director of the Nature Conservancy's Woodland Research Station at Merlewood in Lancashire. Difficulties in staffing at a supporting level have also continued, and a major reassessment of the position is due in the light of increasing demands for service from all quarters of the Forestry Commission.

Equipment

In sharp contrast to the supply of staff, the supply of "hardware" was considerably increased. A second 7,000-word I.C.T. Sirius Computer has been purchased second-hand at about one-fifteenth of the cost of the first. An English Electric Lector document reader was commissioned just before the end of the year under review, and it is intended to develop its many possible applications to more automatic data processing. An eight-track paper-tape Teletype machine was obtained in December for the Edinburgh station, in order to make possible more efficient use of the resources of the Edinburgh Regional Computing Centre. Finally a card-to-tape converter was obtained at about the same time, to form a component of a developing system of data-capture based on I.B.M. Port-a-punch cards, though it now seems possible that the facilities of the Edinburgh Regional Centre may provide an alternative system. Statistical methods and equipment are rapidly evolving, and preliminary work has started to plan a new computer system so that the present research facilities can be replaced as they become obsolete.

Service

The main lines of the work of the section have continued to be the provision of advisory, analytical and computing services to Research Division, Management Services Division and others. Since the Forestry Commission is now engaged in a study in depth on the provision of computing facilities for routine management duties, it is to be expected that increasing demands will be made for development work towards a more integrated data processing system.

Brief mention should perhaps be made of a few of the major individual projects tackled during the year to indicate the directions in which the service is moving.

In the field of experimental design attention has been given to designs applicable in widely different fields, including early screening of plus-tree progenies and work-study investigations into line-thinning practice. The largest computing loads have concerned the analysis of the census of private woodlands and the preparation of the long-term forecasts of production for each working-plan area of the Commission's estate. Progress in the former has been disappointing. The system for updating the register of plus-trees has been applied to all the major species and is now working fairly smoothly. Development work has started on a system for updating a register for Research Division experiments based on the project register.

Statistics Section Papers

The following Statistics Section Papers have been prepared:—

No. 136. The Advisory Group of Forest Statisticians. A service to forest research and management.

No. 137. The management of research computing services.

No. 138. Ascending contingency tables in ordered nests.

No. 139. An analysis of measurements of alate *Adelgidae* (Hemiptera) as a possible technique for the separation of species groups.

No. 140. A questionnaire for the investigation of recreational uses of Forestry Commission forests.

No. 141. The contribution of statistical methods to forest research and management.

No. 142. Multivariate analysis of progeny and provenance trials.

No. 143. Problems associated with the layout of progeny tests in Britain, with special reference to a recent plot-size experiment.

No. 144. Applications of electronic digital computers to forest research and management.

No. 145. Data-capture in forestry research.

Enquiries regarding any of these papers should be sent to the Statistics Section at Alice Holt.

R. S. HOWELL

PUBLICATIONS BY STAFF MEMBERS

JEFFERS, J. N. R. *Advisory Group of Forest Statisticians: A Service to Forest Research and Management.* (Proc. Congr. Int. Un. Forest Res. Org. 14. Munich 1967, **3,** 426–34.) Res. Dev. Pap. For. Commn., Lond. **37,** 1967.

JEFFERS, J. N. R. The contribution of statistical methods to forest research and management. *Proc. Int. Statist. Inst.*, 36th session, Sydney 1967.

JEFFERS, J. N. R. A critical path through the woods. *Suppl. Timb. Trades J.* April 1967, 22–3.

JEFFERS, J. N. R. Two case studies in the application of principal component analysis. *Appl. Statist.* **16** (3) 1967, 225–6.

JEFFERS, J. N. R. The use of electronic computers in land-use surveys based on photo-interpretation. *Photogr. Rec.* **5** (30) 1967, 465–9.

STEWART, D. H. *ACTION (Ascending Contingency Tables in Ordered Nests).* Res. Dev. Pap. For. Commn., Lond. **47,** 1967.

EXPERIMENTAL WORKSHOP

Extensive use has been made of the facilities offered, and over 90 requests for the workshop's services were received during the period April 1967 to March 1968. The equipment made during this time ranged from transparent templates, for use with maps, to complete boring tools, and in addition, over 4,000 plastic labels and 90 girth bands were made.

Two sections of the Genetics Greenhouse have been connected to an automatic ventilation system, the proportional control unit being based on a simple timer.

Several Experimental pole ladders were made and are at present undergoing field trials.

Several experimental versions of calipers and Lector form boards have been made and negotiations are in progress with a possible manufacturer of these items.

It would appear that more use will be made of automatic data-recording units for both field and meteorological data, and work is continuing into the manufacture of special purpose transducers for water level gauging and tree sway.

R. E. STICKLAND

PUBLICATIONS BY STAFF MEMBERS

STICKLAND, R. E. Insect suction trap for collecting segregated samples in a liquid. *J. agric. Engng Res.* **12** (4), 1967, 319–21.

PHOTOGRAPHY

Photographic Collection

12,041 slides were loaned for various purposes. This is a reduction of some 3,000 compared to the previous year and reflects the cancellation of lectures due to the foot-and-mouth epidemic. 1,551 monochrome prints were used, mainly for exhibition and publication, and 332 loans of films were made.

In spite of screening of material going into the Collection, the total number of items now exceeds 38,000, nearly half of which are in colour, and problems of retrieval are becoming acute. The card index has become too large for rapid manual sorting, and efficiency and reliability has deteriorated. As an interim measure a simplified "key-word" system is being used to index all recent and new additions. Our ultimate requirement however is to obtain quickly, selective access to all relevant material in *visual* form. Several methods have been looked at and, with modifications, use of one of the microfilm systems having high speed scanning would appear to be the answer.

Audio-Visual Aids

Requests for audio-visual material are increasing apace. In order to assess the likely demand, present and future, the degree of sophistication required and, linked to this, to find just what facilities and equipment are available to staff who use audio-visual aids, a questionnaire was prepared and circulated. Response to this surpassed expectations and the results are now being studied.

What is already clear, is that though the desire to use aids exists in marked degree, the equipment, and indeed training in its use is lacking. Until this difficulty is resolved any great expansion in this field is naturally limited.

Nevertheless, a modest addition to the services available from the section was made during the year by the introduction of wild-life recordings on tape. At present there are twelve such tapes and this series will be added to as the sound library is built up.

General]

It is of passing interest that the first truly pictorial publication to be issued for the Forestry Commission, *Forestry in the British Scene* (Forestry Commission Booklet No. 24, by R. F. Wood and I. A. Anderson, H.M.S.O., 1968, 10s.) is based on, and the presentation follows the style of, the photographic exhibit used at the last national Forestry Exhibition held at Blackbushe, beside Bramshill Forest, Hampshire.

Work has already started on material for use in the various exhibitions etc. which will mark the Jubilee in 1969.

I. A. ANDERSON

PUBLICATIONS

The following nine 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-seventh Annual Report of the Forestry Commissioners, 1966. (HC.395. Session 1966–67.) (10s. 0d.)

Report on Forest Research for the year ended March 1967. (17s. 6d.)

Bulletins

No. 40. Rooting and Stability in Sitka Spruce, by A. I. Fraser and J. B. H. Gardiner. (8s. 6d.)

No. 41. Forest Management, and the Harvesting and Marketing of Wood in Sweden, by B. W. Holtam, E. S. B. Chapman, R. B. Ross and M. G. Harker. (13s. 6d.)

Forest Records

No. 60. Procedures used for Progeny Testing in Britain with special reference to Forest Nursery Practice, by R. Faulkner. (3s. 0d.)

No. 64. Pine Martens, by H. G. Hurrell. (2. 6d.)

Booklets

No. 17. Thinning Control in British Woodlands, by R. T. Bradley. (10s. 6d.)

No. 19. Timber Extraction by Light Agricultural Tractor, by J. W. Barraclough. (5s. 0d.)

Supplement to Booklet 16, Forest Management Tables. (1s. 0d.)

In addition ten priced publications sold by Her Majesty's Stationery Office were reprinted after varying degrees of revision.

Thirty-one unpriced *Research and Development* papers were produced mainly for internal circulation; copies are available free of charge from the Publications Officer, 25 Savile Row, London, W.1.

The titles are:

No. 33. Appraisal of National Wood Production and Consumption Trends and their Interplay with Regional and World Trends, by E. G. Richards.

No. 34. Practice and Research in Spacing, Thinning and Pruning, by P. A. Wardle.

No. 35. Afforestation Planning at the National and Project Levels, by A. J. Grayson.

No. 36. Standards of Sturdiness for Forest Tree Plants, by J. R. Aldhous.

No. 37. The Advisory Group of Forest Statisticians: A Service to Forest Research and Management, by J. N. R. Jeffers.

No. 38. Current Problems facing Fire Research, as seen by a Forest Officer, by C. A. Connell.

No. 39. Slash Disposal to Aid Regeneration, by S. A. Neustein.

No. 40. Review of Practice and Research in Weed Control in Forestry in Great Britain, by J. R. Aldhous.

No. 41. Problems Associated with the Layout of Progeny Tests in Britain, with special reference to a recent Plot-size Experiment, by A. M. Fletcher, R. S. Howell and R. Faulkner.

No. 42. Valuation in Forest Accounts: A Comparison of Methods, by P. A. Wardle.

No. 43. Oviposition Period of the Douglas Fir Seed Wasp, Megastigmus Spermotrophus, by J. T. Stoakley.

No. 44. Two Mathematical Models to aid in Nursery Planning, by J. G. Grevatt and P. A. Wardle.

No. 45. The Planning and Conduct of Provenance Experiments by R. Lines.

No. 46. Review of Research and Development in Forest Nursery Techniques in Great Britain, 1949–1966, by J. R. Aldhous.

No. 47. ACTION (Ascending Contingency Tables in Ordered Nests), by D. H. Stewart.

No. 48. Recreational Use of Forests in Holland, by M. H. Orrom.

No. 49. Progress Report on Chlorthiamid ("Prefix") in Forestry; 1962–1966, by J. R. Aldhous.

No. 50. Studies on Drainage and Soil Moisture for Tree Growth, by A. I. Fraser.

No. 51. Experiments on the Rehabilitation of Uneconomic Broadleaved Woodlands, by R. F. Wood, A. D. S. Miller and M. Nimmo.

No. 52. Norwegian Timber Extraction Methods, by A. S. Rawlinson.

No. 53. The Forester and the Landscape, by P. F. Garthwaite.

No. 54. Pre-Investment Survey Techniques for Forest Industries, by J. L. Davidson.

No. 55. Amenity and Landscaping: A Survey of their place in British Forestry, by M. H. Orrom.

No. 56. The Formulation of Production Goals in Forestry, by A. J. Grayson.

No. 57. Operational Research as an Aid to Forest Management Decision-Making, by P. A. Wardle.

No. 58. Work Study in Silvicultural Operations with particular reference to Weeding, by N. Dannatt and W. O. Wittering.

No. 59. Work Study in the Improvement of Timber Harvesting Efficiency, by A. A. Rowan.

No. 60. Inventories and Production Forecasts in British Forestry, by D. Y. M. Robertson.

No. 61. The Grey Squirrel and its Control in Great Britain, by Miss J. J. Rowe.

No. 62. Some Problems of Long-Term Marketing Arrangements, by E. G. Richards and E. J. F. Tinson.

No. 63. Thinning Experiments and the Application of Research Findings in Britain, by R. T. Bradley.

Eighteen unpriced publications for general public issue were revised and reprinted during the year.

H. L. EDLIN

RESEARCH INFORMATION

Library

The Library stock has continued to expand and 215 books have been acquired during the year. One thousand, three hundred and seventy-five publications were loaned out, and 432 publications were borrowed from other libraries.

A revision of the *Library Catalogue Supplement* of *Forestry Commission Translations* was issued, with items arranged in subject order. A further 35 translations were completed during the year.

During the year a survey was made of the arrangements at Alice Holt Lodge for receiving, classifying and storing information. Most of the Heads of Section and many other members of the staff were interviewed. The survey revealed that, unexpectedly, there was more general satisfaction and far less duplication of effort than had been supposed.

For some time the Reading Room has had to be used for other purposes, but a general re-allocation of accommodation at the Station has allowed the Library to make this room available at all times for Library users. The periodicals of more general coverage are now put on display for a period of three weeks instead of being "lost" on long circulation lists.

To ensure that Station staff are aware of the facilities available from the Library, a series of short courses has been started on the work and facilities provided by the library.

Visitors

During the year the Station received 703 visitors, and arrangements for most of the individuals and all of the parties were made by the Research Information Section staff. Two courses were held for Conservancy Forest Officers and a number of itineraries were planned for overseas visitors.

Information Services

Enquiries of all types and from all sources have been dealt with through the year, and there is a growing awareness of our availability, and ability to provide information promptly.

Records are being built up of the interests of all specialist staff in the Forestry Commission, and this is being extended to cover all field staff as well. This enables us to direct information positively to the people most likely to benefit from it, and also to know who to go to for specific enquiries.

A trial index of Forestry Commission literature has been made out, and is under test throughout the Forestry Commission. The definitive index when finally published should prove of considerable value.

Annual Report

The progressing of the *Report on Forest Research* is handled by Mr. S. H. Sharpley of this Section, and largely as a result of his labours the *Report* for 1967 emerged more than six months earlier than in previous years.

Annual Research Conference

All the arrangements for this Conference were handled by the Section. The subsequent circulation to staff outside Alice Holt of some of the papers delivered at the Conference attracted much favourable comment.

Liaison

Throughout the year more and more personal contact has been made by visits to Forestry Commission staff, Universities and other Research Stations and Libraries. The problems of communication in all aspects and all levels of our work are best overcome by personal contact, and there is good evidence to show that by emphasising this feature of our work we can make a major contribution to the efficiency of the department.

O. N. BLATCHFORD

PART II

Research Undertaken for the Forestry Commission at Universities and other Institutions

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NUTRITION EXPERIMENTS IN FOREST NURSERIES

By BLANCHE BENZIAN and S. C. R. FREEMAN

Rothamsted Experimental Station, Harpenden, Herts

Extract from *Rothamsted Annual Report* for 1967

Isobutylidene diurea (IBDU). The slow-acting N fertiliser IBDU made in Japan (*Rothamsted Report* for 1966, pages 43–44) was again tested on grass, and on conifer seedlings and transplants (of Sitka spruce, *Picea sitchensis*).

The experiments with one-year Sitka spruce seedlings, started in 1966 at Wareham Nursery in Dorset and Kennington Extension Nursery near Oxford, compared two granule sizes of IBDU (0·8–1·4 and 1·5–2·4 mm, both with 30% N) with formalised casein (11% N) and "Nitro-Chalk" (21% N). Four amounts of each were tested. IBDU and formalised casein were dug in early in February before sowing; "Nitro-Chalk" was split into four topdressings applied at the beginning of June, July, August and September. In 1967 similar experiments were started at the same nurseries on transplanted 1-year seedlings uniformly manured in the seed-bed.

TABLE 45

EFFECT OF FOUR NITROGEN FERTILISERS ON HEIGHT OF SITKA SPRUCE SEEDLINGS AND TRANSPLANTS AT TWO NURSERIES IN 1967

small N = mean of 6 and 12 g N/sq. yd
large N = mean of 18 and 24 g N/sq yd

Height (in)

Nursery and Treatment	Seedlings small N	Seedlings large N	Transplants small N	Transplants large N
Wareham				
without N	0·4		5·1	
IBDU (0·8–1·4 mm)	1·0	1·2	9·9	10·6
IBDU (1·5–2·4 mm)	1·3	1·8	8·9	9·8
Formalised casein	1·6	1·9	10·2	10·2
"Nitro-Chalk"	1·8	2·9	9·1	10·0
Standard error	±0·17	±0·17	±0·44	±0·44
Kennington Extension				
without N	1·4		10·4	
IBDU (0·8–1·4 mm)	2·4	2·3	13·4	13·7
IBDU (1·5–2·4 mm)	2·6	2·5	12·9	14·2
Formalised casein	2·5	2·5	13·7	15·4
"Nitro-Chalk"	3·0	3·1	13·2	15·2
Standard error	±0·13	±0·13	±0·48	±0·48

At Kennington Extension the summer rain was close to the 21-year average, but Wareham had 5 in. in May (the average is 2·2 in.). Table 45 shows, for *seedlings*, responses to N were large at both nurseries; the best treatments increased seedling height 7-fold at Wareham and more than doubled it at Kennington Extension. The finer IBDU (0·8–1·4 mm) was least effective, coarser IBDU (1·5–2·4 mm) behaved like formalised casein, but—in contrast to 1966—"Nitro-Chalk" was much better than the other three sources of N.

All large amounts of N doubled the height of *transplants* at Wareham; at Kennington Extension the best treatments increased height by nearly a half. Differences between sources of N were smaller and less consistent than with seedlings, and "Nitro-Chalk" was no better than the slow-release forms.

On the light sandy soil of Wareham all nitrogen treatments decreased soil pH. The sites had received a small basal dressing of lime, and on the plots without nitrogen the pH was 5·0 (in $CaCl_2$). In the seed-bed experiment (after two cropping seasons) the small amounts of N of the slow-release fertilisers decreased pH by at least half a unit and the larger amount of N by a whole unit or more. "Nitro-Chalk" also decreased pH, but to a lesser extent. The pH values in the transplant experiment (after one season) followed a similar trend but were less consistent. There is ample evidence that Sitka spruce seedlings grow best at pH 4·5 (Benzian, *Bull. For. Commn, Lond.* (1965), No. 37, Vol. 1), and the large decreases in soil reaction associated with nitrogen dressings make it difficult to interpret the results. On the sandy loamy soil of Kennington Extension (pH of the site is about 4·2) the decreases were very small—ranging from 0·1 to 0·3 pH unit.

TABLE 46

EFFECT OF FOUR DIFFERENT NITROGEN FERTILISERS ON DRY MATTER OF SITKA SPRUCE SEEDLINGS AND % N IN CROP AT DIFFERENT STAGES OF GROWTH IN TWO NURSERIES, 1967

Nursery and Treatment	Dry matter of tops (mg/plant)			% N in dry matter		
	July/ Aug.	Aug./ Sept.	Nov.	July/ Aug.	Aug./ Sept.	Nov.
Wareham						
Without nitrogen	8	16	24	(1·3)*	(0·9)	(1·2)
IBDU (0·8–1·4 mm)	25	92	154	2·0	1·1	0·9
IBDU (1·5–2·4 mm)	29	124	226	2·2	1·5	1·1
Formalised casein	30	139	234	2·4	1·4	1·1
"Nitro-Chalk"	26	146	257	2·6	1·8	1·3
Kennington Extension						
Without nitrogen	29	112	149	2·2	1·4	1·2
IBDU (0·8–1·4 mm)	41	172	314	2·7	2·0	1·6
IBDU (1·5–2·4 mm)	40	184	369	2·5	2·0	1·8
Formalised casein	40	179	324	2·6	1·9	1·7
"Nitro-Chalk"	40	208	416	2·6	2·3	1·9

* Brackets indicate there was not enough material for accurate analyses.

The speed at which nitrogen is released from the four fertilisers was followed during the growing season by sampling *seedling* tops (cut at ground level) at five times (July, early and late August, September and November). In Table 46 the results at first and second sampling dates are averaged, as are those at the third and fourth. At Wareham the finer IBDU (0·8–1·4 mm) produced plants with smallest weights and smallest N concentrations, presumably because N was lost during the very wet May. The coarser IBDU behaved like formalised casein. Except for dry weights at the first sampling, "Nitro-Chalk" was better throughout. At Kennington Extension differences between fertiliser forms were small, particularly effects on N concentrations. At Wareham the largest N concentrations (with "Nitro-Chalk") were less than the smallest (with IBDU 0·8–1·4 mm) at Kennington Extension.

In a small trial with *seedlings* at Wareham still coarser IBDU (2·5–4·0 mm) was better than the 1·5–2·4 mm fraction, but the plants were smaller than those given "Nitro-Chalk":

Height of seedlings (in.)

Without N: 0·8

	With IBDU:		*With "Nitro-Chalk"*
g N/sq yd	*1·5–2·4 mm*	*2·5–4·0 mm*	
12	2·6	3·3	4·3
24	3·7	4·0	4·8

RESEARCH ON FOREST SOILS AND TREE NUTRITION

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Work during the period has continued along the same broad lines described in the *Report* for 1967, no new experiments or lines of research having been initiated.

Tree Nutrition

The fertiliser experiments described in the *Reports* for the years 1963 to 1967 have continued and in general have shown little change in the patterns of response so far reported. The crop of mature Scots pine (Alltcailleach Forest, Aberdeenshire) that was fertilised with nitrogen in 1963 showed a progressive increase in growth rate over the two years following application to reach a maximum in 1965, the values for which were given in the *Report* for 1966. Subsequent to this, however, there has been a gradual decline in growth rate, but the shallow downward slope of the curve indicates that a positive effect of the treatments may be detectable for at least another three years, making a total response period in excess of eight years. The relatively extended period over which coniferous trees continue to show a response to a single application of nitrogen fertiliser suggests that some at least of the applied nitrogen must remain available for the formation of new tissue for a number of growing seasons after application. This nitrogen may be initially retained as adsorbed ammonium on the clay and humus of the mineral soil and organic layers, though further storage might occur within the actual tree crop.

Recent results from the investigations into the effect of nitrogen fertiliser on the movement and distribution of nutrients in a 36-year-old crop of Corsican pine at Culbin Forest, Moray (*Reports* for 1965 to 1967), have given an early illustration of the extent to which the trees themselves are capable of storing nitrogen during periods of plentiful supply. This crop was severely nitrogen-deficient, having a top-whorl foliage nitrogen concentration of 0·9 per cent, and it responded strongly to applications of ammonium sulphate. The heaviest rate, 504 kg of nitrogen per ha per annum for three years, raised nitrogen levels in the top-whorl foliage to 2·6 per cent and stimulated a basal area growth over the three year period of 5·8 m^2 per ha as against 2·8 m^2 in the control. As described in previous *Reports* the crop was intensively sampled both prior to establishing the experiment and again after the three years of fertiliser application, and in addition regular collection and analysis of rainwater and litter-fall are being carried out. Results of the nitrogen determinations, on samples taken from the fertilised trees at the second sampling, show the expected marked rises in concentrations in the foliage and foliage-bearing twigs of all ages and positions on the tree. Rather less expected, however, were the commensurate rises in the nitrogen concentrations of all the other components, with the sole exception of dead branches. The unweighted mean concentration values obtained for a number of these components are given in Table 47

TABLE 47

UNWEIGHTED MEAN NITROGEN CONCENTRATIONS FROM VARIOUS COMPONENTS OF DEFICIENT AND NITROGEN-FERTILISED CORSICAN PINE

per cent nitrogen, dry-weight basis

Tree Component	Untreated control	504 kg N per ha over 3 years	1,512 kg N per ha over 3 years
Current year's needles	0·9	1·7	2·3
Current year twigs	0·5	0·9	1·5
Live branches	0·20	0·26	0·34
Dead branches	0·20	0·20	0·20
Bark from upper stem	0·34	0·67	1·19
Bark from breast height	0·16	0·28	0·37
Wood from upper stem	0·07	0·16	0·21
Wood from breast height	0·04	0·06	0·08
Mid-position of stump	0·05	0·10	0·14
Lateral roots	0·25	0·39	0·70

Though increases in nitrogen concentration might reasonably be anticipated in components with a high proportion of meristematic tissue, such as bark from the upper stem or lateral roots, rises in the stem wood, stump and corky lower bark strongly suggest extensive storage of nitrogenous substances. As the weight of many of these components has also increased following fertilisation, the quantity of nitrogen contained by the tree crop will have been much enhanced.

The role of the litter and humus layers in retaining fertiliser nitrogen is at present being determined, and on the basis of preliminary results appears to be significant. To what extent this nitrogen will subsequently become available for uptake by the trees, however, remains unknown and is to be the subject of a new series of investigations. Certainly the large quantities of native organic nitrogen in these layers is largely unavailable for plant growth despite the presence of ample energy-rich material. It has already been reported (*Report* for 1966) that the organic layers prior to the application of fertiliser contained 322 kg of nitrogen per ha as against only 257 kg in the total existing tree crop (144 kg in the aerial portions alone). As it is known that these organic layers have been derived entirely from the present crop it has been possible to compare their weight and nutrient content with those of the fresh litter collected between 1964 and 1967 (Miller and Miller, 1967). This has shown that nitrogen is persisting in the decaying litter to a very much greater extent than is any other major nutrient. Indeed, the mean annual net rate of accumulation of nitrogen on the forest floor has been 8·9 kg per ha as against only 7·6 kg in the tree-crop (including thinnings removed). For no other element is accumulation on the forest floor greater than that by the trees, and unlike the other elements nitrogen is showing an increase in concentration with increasing decomposition of organic matter, from 0·59 per cent in the litter layer to 0·67 per cent in the humus. Furthermore the onset of deficiency in this crop can be related directly to the initiation, on a previously "bare" soil, of the humus layer in which nitrogen reserves are immobilised.

Work on these aspects of nitrogen nutrition and cycling within closed pine forests is continuing.

The experiment laid out in young Corsican pine at Culbin to investigate whether applications of boron, copper or zinc would eliminate the occurrence of bud death and necrotic shoots found to occur following prolonged heavy nitrogen fertilisation in certain areas of this sand dune forest (*Reports* for 1966 and 1967) has continued. No bud deaths have occurred over the past year, even in the experiments in which they were originally observed, indeed in the boron fertilised plots a dry browning of the tips of current year needles has been noticed similar to the boron toxicity symptoms in red and white pine described by Stone and Baird (1956). The absence of bud death may be related to the unusually high rainfall of the previous season or to the very mild conditions of the intervening winter. In a greenhouse trial, on the other hand, in which Corsican pine seedlings were grown in pots of Culbin sand regularly irrigated with complete nutrient solutions minus only copper, boron or zinc, those plants not supplied with boron exhibited very stunted growth in relation to the other treatments. Caution is required, however, in transposing this result to the field where the trees receive both rainfall and, possibly, slight sea spray.

Physical Chemistry

Investigations into the adsorption and release of nutrient ions in peat have continued, and new and improved techniques have been developed. A major problem in these studies is the rapid changes that can occur in samples of peat even over very short periods of storage. In order to minimise the irreversible effects of drying, all determinations in the laboratory are made on fresh moist samples, but the effects of chemical oxidation and bacterial decomposition have yet to be assessed.

The results of alkali-titrations on peat samples, using a potentiometric method, show that peat at pH 7·0 has a large cation-exchange capacity, with values ranging from 100 to 200 milliequivalents per 100 g of oven-dry peat. This reflects the high buffering capacity of peat caused by dissociation of weak organic acids. The degree of dissociation, however, is dependent on pH, and so the exchange capacity at field pH is likely to be considerably lower than that recorded at pH 7·0. To demonstrate this, a technique developed by Schofield (1949) for clay suspensions has been adapted to study the adsorption of exchangeable ammonium ions in peat as a function of pH. Preliminary results have illustrated the marked dependence of the exchange capacity on pH, a considerably smaller amount of exchangeable ammonium (30–40 meq per 100 g oven-dry peat) being adsorbed at pH 3·0 than at 7·0. Thus the pH of peat may be a factor in determining the balance between retention of nutrients and loss through leaching.

A further effect of the increased degree of dissociation at higher pH values is a swelling and enhanced moisture retention by the peat, which was initially observed as an impedence to the flow of water when filtering samples of raised pH. The same phenomenon of the dependence of water absorption on pH has been reported by Fraser (1933). Acidity may, therefore, exert an influence on the movement of water through peat on drainage, though it is not known whether this effect would be of significance at the range of pH values encountered in the field. Other features observed at higher pH values include a dissolving out of coloured material in the pH range 6–7, which suggests that pockets of higher pH values may suffer a loss of nutrients by the formation of soluble salts with the anions of organic acids.

This work is now being extended to cover peats of widely differing botanical origin and degree of decomposition. It may eventually be possible by this means to establish a scheme by which measurements of field pH, taken in conjunction with determinations of the pattern of adsorption of exchangeable cations with varying pH, can be used to assess the actual or potential capacity of an area of peat to support tree growth.

Peat Drainage

The drainage experiment on the Lon Mor at Inchnacardoch Forest, Inverness-shire (*Reports* for 1963 to 1967), has continued in collaboration with Dr. R. Boggie. This experiment comprises five plots each of which is isolated by a perimeter ditch in which the water level is maintained at depths of 0, 10, 20, 30 or 50 cm below the ground surface. One third of every plot has been fertilised and planted with Lodgepole pine. Five years after planting, these trees show a marked response to the treatment, those on the deepest drained plot having all survived and attained, on average, a height of 0·9 m, as against an average of only 0·3 m reached by the very few surviving plants on the undrained plot.

Samples of the peat and of the tree foliage are taken from this experiment, at regular intervals throughout the growing season, for moisture determinations and chemical analyses, respectively, In addition the heights of the water tables in the plots, and the temperature at various depths in the peat, have been recorded regularly and, more recently, the redox potentials in the peat have been measured. Despite the large differences in tree growth, the moisture content of the peat, excluding the immediate surface layer, has been found to show no striking difference between plots. The redox potentials, however, tend to show a wide scatter of values between sampling points in the undrained plots, as against a much narrower and more normal distribution in the others. There is no clear correlation between redox potential and depth in any one profile, but the mean values are higher in the more deeply drained plots.

Summary

Nutrition investigations continue to be concentrated on nitrogen. One aspect of nitrogen fertilisation is the prolonged response period (about eight years) brought about by a single application, which suggests that some of the applied nitrogen must be stored for later use. Determinations of the distribution of nutrients within the ecosystem following a period of heavy nitrogen fertilisation of pole-stage Corsican pine, has shown that a portion of the fertiliser nitrogen is retained in the organic layers, and also that there is appreciable storage within the tree crop, all tree tissues other than the dead branches showing marked rises in nitrogen concentrations. Investigations into a suspected trace element deficiency in a sand dune forest have produced somewhat contradictory results, and there has been little evidence of the deficiency over the past season, even in the control plots. Studies of the behaviour of peat as a nutrient-supplying medium have emphasised the pH dependence of many characteristics, in particular the cation-exchange capacity and moisture retention. It is hoped that these studies may eventually enable improved characterisation of peat as a medium for tree growth. A drainage experiment on peat has illustrated the marked response

of tree growth to drainage despite an apparent absence of any effect of the drainage on the moisture content of the peat, though it has had some influence on the redox potentials.

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EFFECT OF CULTIVATION TREATMENT ON WATER TENSION AND TREE GROWTH IN A NORMALLY WATER-LOGGED SOIL

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The investigation of water balance in a Forestry Commission experiment on the Estuarine Clays of North Yorkshire has continued. A very high water-holding capacity is a characteristic feature of these fine-textured soils. This has led to difficulty in establishment of coniferous crops in the area. Apart from the conventional single-furrow and complete ploughing treatments, the experiment incorporates a trial of the cambered bed or "rigg and furr" type of construction, which involves broad raised ridges (riggs) between lower furrows (furrs).

Problems of measurement of water tension under the treatments arise chiefly from the very low tensions experienced. In two years no tension in excess of one atmosphere has been recorded in the experiment. This is despite the fact that rainfall in the area is not normally above 40 in. a year.

To date a restricted number of instruments have been employed in the experiment on a trial basis. Measurements have therefore suffered from a lack of replication within plots. This is a serious weakness in view of the inherent variability of the site.

Initial results suggest that riggs may serve the purpose of producing a drier and deeper rooting zone for the crop. Drains on the other hand appear to have little if any effect on the water balance of the treatments.

VIRUS DISEASES OF FOREST TREES

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POPLAR MOSAIC VIRUS

Effects of Virus Infection on Growth

In the nursery, measurements have been made on a replicated block experiment with *Populus* x *euramericana* 'Poitou' and 'I 78'. The cuttings were planted at the beginning of 1966, and cut back in the autumn of 1966 and 1967. Severe growth reductions occurred in both these cultivars. The results for the two years are summarised in Table 48.

TABLE 48

EFFECT OF POPLAR MOSAIC VIRUS ON GROWTH OF 1+1 AND 2+1 *Populus* 'POITOU' AND *P.* 'I 78'.

Year	Height (cm) 1966	Height (cm) 1967	Diameter (cm) 1966	Diameter (cm) 1967	Weight (gm) 1966	Weight (gm) 1967
Populus 'Poitou'						
Healthy	201	183	1·61	1·60	325	338
Infected	185	171	1·39	1·44	242	259
Reduction	17	12	0·22	0·16	83	79
Critical difference ∓	5	5	0·07	0·05	32	29
% reduction	8	6	14	10	25	23
Significance level	***	***	***	***	***	**
Populus 'I 78'						
Healthy	171	172	1·41	1·66	216	324
Infected	155	156	1·24	1·43	164	221
Reduction	16	16	0·17	0·23	52	103
Critical difference ∓	8	8	0·10	0·12	25	66
% reduction	9	9	12	14	24	33
Significance level	***	**	**	**	***	**

Note: Critical differences expressed at P 0·05.

Measurements in plantations indicated no deleterious effect of virus infection on diameter increment of *P.* 'Robusta' during 1967. However, the significant diameter reductions which have occurred on most age groups suggests that this effect of virus on increment in 1967 was anomalous, and slight reductions should normally be expected.

The pattern of spread of virus during the season has supported the view that transmission of the virus between trees occurs subterraneously. An investigation in which radioactive bromine was injected into the roots, revealed only one root graft in the 1958 planting stock, and none at the younger ages. As the one graft was between a newly infected and a healthy tree, there is no evidence that root grafting might be associated with transmission of the virus.

Effect of Virus Infection on Wood Properties

Specific Gravity

The basal 20 cm of first year growth of 'Poitou' and 'I 78', were oven dried, and the dry weights and volumes determined. The area of pith was determined from microscopically enlarged sections, and an allowance made for the pith volume in computing the specific gravity. The specific gravity was shown to be closely correlated to the size of the cuttings. The larger ones usually had a lower specific gravity and were associated with healthy plants; the effect of this was eliminated by co-variance. The values for specific gravity, adjusted for sectional area, are given in Table 49, showing that virus infection had reduced the area of both clones, and also independently reduced the specific gravity. This was highly significant for 'Poitou', the adjusted means having a difference of specific gravity of 0·020, whereas the reduction of 0·012 in 'I 78' was only significant at the 10 per cent probability level.

TABLE 49

SPECIFIC GRAVITY OF HEALTHY AND INFECTED CUTTINGS OF *Populus* 'POITOU' AND *P.* 'I 78', ADJUSTED FOR SECTIONAL AREA

	'Poitou'		'I 78'	
	Specific gravity	Pith Area (cm^2)	Specific gravity	Pith Area (cm^2)
Healthy	0·387	1·85	0·413	1·47
Infected	0·367	1·52	0·401	1·21
Reduction	0·020	0·33	0·012	0·26
Critical difference ∓	0·008	0·31	0·014	0·23
% difference	5	18	3	18
Significance level	***	*	n.s.	*

Note: Critical differences expressed at P 0·05

Volume Proportions of Cells, and Lumen: Wall Ratio

The reduction in the specific gravity of virus-infected wood could be caused either by reduction of the specific gravity of the cell wall substance, or by alteration of the volume proportions of the cell walls and lumens. The latter possibility was investigated using sections of the two clones, mounted in aqueous safranin and gelatine, and photographed to give a magnification of × 250. A systematic dot grid was used to determine the volume proportions of cell wall substance, and the lumen areas of fibres, vessels, and rays. The results showed that there was no significant difference between the healthy and infected cuttings, suggesting that the difference in specific gravity is associated with variation in the chemical composition of the cell wall substance.

Compressive Strength of Timber

Most virus infections alter the metabolism of the host plant. One possible effect in trees is to alter the metabolism of the cambial cells, which could result in chemical variation of the cell wall structure. Any such alteration is likely to affect both the specific gravity as has been suggested previously, and all other attributes determined by cell wall composition, including the strength of timber.

Tests were made on two groups of material. The branchwood from prunings of *P.* 'Robusta' was compressed parallel to the grain, using the timber in the round with a length : diameter ratio of 3:1. The specific gravity and areas were also determined, but as neither were affected by the virus there is no need to correct for initial non-comparability of these factors. The results showed a small but significant increase in strength attributable to virus infection. The values were 220 kg/cm² and 214 kg/cm² for infected and healthy material respectively, a difference of 5·9 $\mp$ 5·7. However, tests on the first and second year cuttings of 'Poitou' failed to show any significant effect on the timber strength when allowance is made for the initial differences in specific gravity and area.

SPRUCE VIROSIS

Rod-shaped particles have been found in exudates from twigs of Sitka spruce. These particles are similar in morphology and size distribution, to those of the virus described by čech *et al.* (1961), which is unique in its characteristics. Infected trees have shortened chlorotic needles, and defoliation is frequently severe. The virus is probably identical with that described from Norway spruce in Czechoslovakia where it is transmitted by *Adelges abietis.*

Investigations into the distribution of this virus are being undertaken. It is expected that these will be extended to studies on the virus particle, and its effect on tree growth and wood structure.

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BIOLOGY OF THE FUNGUS CRUMENULA SORORIA CAUSING A STEM CANKER ON PINES

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The investigation into the biology of this fungus, which causes stem canker on Scots pine, has been contined. Further observations of the symptoms of the disease have shown that the vertical internodal slits give rise to the typical flattened cankers in the following season. Active resin bleeding usually accompanies the establishment of the internodal infections, but occasionally the onset of resin bleeding could be delayed until the winter following infection. These vertical internodal slits were found to be more common on the branches than on the trunks of the trees, and indeed, it was not uncommon to find two or more such cankers in the same internodal position. (Batko & Pawsey, 1964.)

In 1967, fresh resin bleeding from cankered trees, and from those trees infected in 1966, was observed in March and April. On certain trees, the resin bleeding was so severe that nearly the whole of the trunk below the cankers was rapidly covered with resin. In contrast to the prolific resin exudation, the fruiting of *Crumenula* tended to be sparse and irregular, and in consequence it was not easy to carry out the planned cultural and inoculation programme.

An extensive survey programme at Pitmedden showed that the cankers could occur on any part of the tree, and there was no evidence that the fungus was more common on the lower half of the trees, or that the infection occurred more frequently on the younger tissues higher up in the trees. This confirms the observations by Pawsey and Batko (1964) in this forest. This distribution contrasts with the findings of Batko & Pawsey (1964) who observed that the cankers were mainly confined to the bottom three feet of the stem of Corsican pine at Bramshill Forest, Hants. It is possible that the observed differences might be due to differences in the age and vigour of the two crops in question, or else that different strains of *Crumenula sororia* are involved in the two attacks.

Nevertheless, it is clear from the data collected on naturally occurring cankers, that infection could occur both at the whorl and at the internode. Multiple local infections could also occur. Anatomical investigations have shown that infection of the bark and wood cells apparently takes place through needle scars and wounds, but that the extent of travel of the fungus seems to be limited, so that annual (or at least periodic) re-infection of the young tissues is essential.

The examination of the relationship of the disease with aspect has been continued. Statistical tests on the data have shown that the aspect has a highly significant effect on the successful outbreak of the disease. Successful infection by *Crumenula* may be influenced by dew formation on the trees, or else by bark temperature, and to test this hypothesis dew records are being made, together with bark temperature recordings at eight different points round the trunks of a number of trees. Plate 8 (central inset) shows the different incidence of the disease with changing aspect, and this suggests, perhaps, that frost is unlikely to be an important factor, since the effect of frost is maximal only on the South and West aspects of the tree, and on other aspects is relatively unimportant. This section of the investigation is proceeding.

It seems likely that the fungus presently designated *Crumenula sororia* Karst. is composed of a number of different strains, since marked differences have been noted in the cultural characteristics, and temperature optima of a number of different isolates.

The main investigation is still in progress, and efforts will be concentrated in the current year to elucidate the role of climatic factors in aiding infection, and the extent of penetration of the fungus from one infection.

Summary

The investigation of the biology of *Crumenula sororia* has been continued. A provisional sequence of symptoms has been defined following infection. Aspect has a highly significant effect upon the level of infection, and investigations are proceeding to elucidate the role of certain climatic factors. The anatomical investigation is still in progress, together with various infection experiments. There is evidence that *Crumenula sororia* may comprise a number of different strains.

REFERENCE

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RESEARCH ON THE FUNGUS PERIDERMIUM PINI (PERS.) LEV. CAUSING BLISTER RUST ON PINES

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Peridermium pini, often referred to locally as "blister rust" of two-needled pines, is a troublesome disease of Scots pine in the north-east of Scotland. In most other regions of Britain it is relatively rare. Studies at Aberdeen have been concerned with its incidence and biology. This note is concerned only with incidence.

Incidence

Previous reports on incidence (unpublished) were concerned only with figures from badly-affected compartments. Such data give useful indications of possible severity but are otherwise limited. It was decided therefore to conduct a random survey of the pine stands in a limited area of north Scotland. The aims were:—

(*a*) To assess incidence
(*b*) To assess distribution within the area
(*c*) To record factors of crop and site and investigate their relationship to disease incidence.

Since the survey was randomly based it was hoped to produce means and associated confidence limits for the various categories. It was also hoped that analysis would reveal useful lines of research for later work.

Preliminary surveys were made to determine the pattern of diseased trees in stands, since the latter could conceivably affect survey methods. Three such surveys, made in crops aged respectively 20, 41, and 65 years, involving individual assessments of 16,097 trees over 25 acres, yielded no evidence of grouping of diseased individuals when the patterns were subjected to tests involving grids of different sizes. It was assumed from this that the distribution of infected trees in the crop was random and an appropriate sampling system was devised.

Full descriptions of the planning of the survey and detailed analyses will be published elsewhere. The survey planning entailed an area estimate of the pine stands in both state and private woodlands in the region surveyed, by age classes. This involved various difficulties but the estimate fitted closely the actual figures.

Another major problem was the intensity of sampling required. Preliminary work showed the likely range of disease intensity in the area to be 0–18 per cent. This was based on percentage of trees diseased with a probable mean of 1–2 per cent. While this gave a good basis for calculating sampling intensity for disease incidence, the correlations of site and crop factors with disease intensity demanded a higher sampling intensity. Finally, considerable work was involved in deciding the sampling pattern, i.e. by plots, or strips or single trees. When statistical discussions using data from the preliminary surveys described above showed that plots would be suitable, considerable effort was spent in deciding the optimum size of plot relative to time and effort. In the end, the decision was to sample randomly every fiftieth acre with a plot of 100 trees.

Species of pine chosen for investigation were Scots pine, the usual host, and Corsican pine in which disease had been found rarely in the area. Lodgepole pine, on which *Peridermium* had not been found in Scotland, was excluded.

As the work progressed, and the pattern of disease incidence relative to age emerged, the age class 0–5 years was dropped from the survey, and the sampling intensity of the 6–10 year age class was reduced to one plot in 200 acres. This decision was influenced also by the disproportionate representation of the age class 1–10 years comprising 34 per cent of the whole area. The final figures show a sampling intensity of one plot for about 80 acres for an area of 130,000 acres, or 16,428 plots altogether.

Full data are not given here but figures for infection are given in Table 50.

TABLE 50

PERIDERMIUM PINI INCIDENCE IN NORTH EAST SCOTLAND

Age Class years	Total area sampled acres	Total No. of plots	No. of plots with diseased trees	No. of diseased trees	% of plots diseased	% of trees diseased (based on 100 trees /plot)
1– 10	42,800	214	2	2	·9	·01
11– 20	35,900	359	12	25	3·3	·07
21– 30	10,800	216	34	57	15·7	·26
31– 40	15,650	313	108	266	34·5	·85
41– 50	6,700	134	77	281	57·5	2·10
51– 60	2,250	45	24	53	53·3	1·18
61– 70	4,150	83	50	111	62·5	1·34
71– 80	3,050	61	31	69	50·8	1·13
81– 90	3,550	73	25	50	34·2	·69
91–100	5,400	108	64	173	59·3	1·60
100+	1,100	22	14	35	63·6	1·60
	131,350	1,628	441			

The figures are of interest in showing how widespread the infection is in the area surveyed. More than 25 per cent of the plots showed infection. The low incidence in the younger age classes, with the generally steady level from the age of 30 onwards, is also striking. There is apparently no marked fall-off in infection in the later age classes, as was first suspected.

The survey was based on visible stem lesions, seen with the naked eye or with binoculars. Lesions of doubtful origin were omitted. Almost certainly lesions were missed and no account was taken of branch cankers. Thus, the figures given are conservative. Further work is required to apply corrections for these three factors.

The significance of a percentage figure of diseased stems at one point in time in the rotation also requires further work for its elucidation. Throughout a rotation, the number of diseased trees is reduced by death and preferential thinning. It is augmented by new infections of previously healthy trees. The relationship between a figure of one per cent for diseased individuals at a certain age and the total percentage of trees attacked over the rotation is unknown. Work is required involving both the life cycle of the rust and also fairly long term observation plots in pine of different ages, to establish such a relationship.

CONIFER SEEDLING PATHOLOGY

By G. A. SALT

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Extract from *Rothamsted Annual Report for* 1967

Experiments at Ringwood Nursery, Hants, which ended in 1966, showed that stunting of seedling trees there is mainly caused by ectoparasitic nematodes and was controlled only by soil fumigants, one application of which was beneficial for two or sometimes three seasons.

New experiments were started at Kennington (Oxford) and Wareham (Dorset) Nurseries to find how to improve seedling emergence and survival rather than growth. *Phytophthora cactorum* was isolated consistently from dying seedlings of Noble fir with severe root rot in one seed-bed at Old Kennington. Seedlings and transplants of Sitka spruce and Lodgepole pine with less-severe root rot in nearby seed-beds yielded mainly *Cylindrocarpon* and *Pythium*. However, a pure culture of *P. cactorum* was highly pathogenic to Sitka spurce seedlings in dishes of distilled water and caused brown root rot within 4 days at 20–25°C. *Rhizoctonia solani* was often isolated from diseased seed and seedlings of Sitka spruce and Norway spruce that failed to emerge at Wareham, and occasionally as a seed-borne contaminant.

At Old Kennington damping-off of Sitka spruce seedlings was mainly caused by *Pythium* spp., and was prevented by formalin applied to the soil during winter. A nabam drench applied to seed-beds before sowing and after emergence prevented damping-off but greatly damaged the seedlings. Thiram (80 per cent wettable powder) similarly applied was ineffective.

The "Psychrophilic seed fungus"

The spread and effect of this unnamed endophytic fungus of Sitka spruce (*Report* for 1967, pages 142–145) was studied in seed-beds. Inoculum was prepared by incubating small pieces of agar cultures with autoclaved Sitka spruce seed at 15°C for 6–8 weeks. One-yard-square plots were inoculated, just before the live seed was broadcast, by placing a single row of inoculated seeds one in. apart across the middle of each plot. Emerged seedlings were counted in a 2-in. wide strip along the row of inoculum, and in two or four similar strips across un-inoculated parts of the plots. At Wareham inoculation decreased emergence by 57 per cent where seed was sown early (8th March), by 16 per cent where sown at the usual date (22nd March) and had no effect where sown late (5th or 19th April). In other experiments 21 per cent of seed sown on 22nd March failed to emerge in inoculated strips, irrespective of pH ranging from 4·5 to 6·5; Norway spruce suffered more than Sitka spruce. The experiments at Old Kennington were sown on 20th March, and inoculation decreased emergence by from 24 to 30 per cent. Fumigation with formalin before sowing had no effect, but treating the seed with 50 per cent thiram controlled the attack completely.

STUDIES ON VIRUSES OF FOREST INSECTS

By J. F. LONGWORTH

Insect Pathology Unit, Commonwealth Forestry Institute, University of Oxford

Miss Palmer left the Unit in September 1967; Mrs. J. Underwood replaced her in assisting in the following investigations.

Cytoplasmic Polyhedrosis Viruses

Work was done to characterise these viruses by morphological and serological methods with the eventual aim of introducing a rational classification to a large group of isolates which at present are only described by the specific name of the host from which they were identified.

A group of seven isolates, affecting species from a wide range of orders within the Lepidoptera, were found to be indistinguishable, and this may have important applications in biological control. An account of this work has been accepted for publication in the *Journal of Invertebrate Pathology.*

A new cytoplasmic polyhedrosis virus was isolated from *Anoplonyx destructor*; this is the first of these viruses recorded from the Hymenoptera. Studies on this virus will continue to assess its potential as a means of controlling *A. destructor.*

Non-occluded Viruses

Investigations on the non-occluded viruses of the Saturnidae are continuing; particular problems in the purification of these small (33m μ) viruses, which occur in low yield, are being studied.

Further investigations on purification of insect viruses have been made with the non-occluded virus of *Galleria mellonella*; this has shown that extreme care must be exercised in the preparation of antigens for comparative serological work. Methods for the removal of host antigens from virus preparations are described in a paper accepted for publication in the *Journal of General Virology.*

New non-occluded viruses have been isolated from:—

Philudoria potatoria
Lasiocampa quercus
and *Icthyura* sp., a pest of poplar in Pakistan.

FISH POPULATIONS IN FOREST STREAMS

By D. H. MILLS

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University of Edinburgh

The study of the salmon and trout populations in the Glentress Burn, Peeble-shire, has continued during the last year. The overall mortality of 6,100 salmon ova planted in three sections of this stream in perspex boxes amounted to 38 per cent. The mortality was caused by heavy silt deposition. The fry survival to the end of the first summer was only 0·16 per cent. These three sections of stream, from which the trout population had been removed in October, 1966, had been recolonised by trout. In October, 1967, the values for the standing crops of trout in the three sections were similar to those recorded in October 1966, prior to trout removal. The trout were removed from these sections in October 1967, and 5,300 unfed salmon fry from the River Tweed Commissioners' hatchery were introduced in February 1968.

Felled trees and cuttings caused temporary stream jams during thinning operations last summer. Further stream blockages were caused by trees blown down during the severe gale early this year. Silting behind these jams was heavy.

Some of the results of this study were presented at a Symposium on "Salmon and Trout in Streams" sponsored by the H. R. MacMillan Lectures in Fisheries at the University of British Columbia, Vancouver, in February.

Summary

Heavy silting caused a high mortality (38 per cent) of salmon ova planted out in perspex boxes. The salmon fry survival to the end of the first summer was only 0·16 per cent. Considerable recolonisation of stream sections previously cleared of these fish was recorded.

This February 5,300 unfed salmon fry were introduced into stream sections cleared of trout.

REFERENCE

MILLS, D. H. (in the press) The survival of juvenile Atlantic salmon and brown trout in some Scottish streams. *Symposium on Salmon and Trout in Streams, H. R. MacMillan Lectures in Fisheries, 1968*. University of British Columbia, Vancouver, Canada.

STUDIES ON TIT AND PINE LOOPER MOTH POPULATIONS AT CULBIN FOREST

By MYLES CROOKE

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In the spring of 1967, for the first time in the course of this long-term investigation, a census of the number of breeding pairs of coal tits based on the definition of territories by plotting the positions of singing males was made in both of the c. 200-acre study plots. Prior to 1967 it had been possible to make an accurate census of the number of breeding pairs of coal tits in only one of the study plots, that in which nest boxes had been erected. The figures recorded for this plot (Plot 1) were 17–18 pairs in 1964 and 22–23 pairs in 1966. The 1967 census of Plot 1 yielded a figure of 19 pairs so that the population has remained quite stable for some time. In plot 2, 22 pairs of coal tits were recorded. Comparison of the cenus figures for the two plots confirms three facts which had previously been suspected but which had remained unproven (Crooke, 1966). These are that Plot 2 with its more varied crop conditions is a slightly richer habitat for bird life than is Plot 1 and supports a fractionally higher population of coal tits; that the numbers of breeding pairs of coal tits in the two plots are broadly similar; and that the provision of artificial nest boxes in Plot 1 has not increased the breeding density of coal tits there above the level found in similar but "unboxed" areas. In view of the last finding winter feeding has been commenced in Plot 1 in an effort to reduce winter mortality (Gibb, 1960) and so possibly to induce a denser breeding population. Twelve feeding tables were erected in Plot 1 in the summer of 1967 and artificial feeding on a diet of mixed nuts was commenced in September 1967. Preliminary observations indicate that this has resulted in unusually high numbers of tits wintering in the plot.

In addition to the census work, nesting records are kept for those pairs of coal, blue, and crested tits which occupy boxes in Plot 1. Details of these records are sent to the British Trust for Ornithology. The information about crested tits is particularly valuable since records relating to this species are very scanty.

REFERENCES

CROOKE, M. 1966. Studies on tit and Pine looper populations at Culbin Forest, Morayshire. *Rep. Forest Res., Lond.* 1965, 190–200.

GIBB, J. A. 1960. Populations of tits and goldcrests and their food supply in pine plantations. *Ibis* **102** 165–208.

RESEARCH ON THE GREEN SPRUCE APHID, ELATOBIUM ABIETINUM

By W. H. PARRY

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Studies on the population dynamics of *Elatobium abietinum* Walker were begun at Forest of Deer, Aberdeenshire, and Fetteresso Forest, Kincardineshire, early in 1967. Four tenth-acre circular plots of Sitka spruce were chosen at Deer, in Compartment 71, and two similar plots in Fetteresso, in Compartment 81, from a series of experimental plots already set out by the Forestry Commission Research Division. Two of the plots at Deer and one at Fetteresso were sprayed with malathion concentrate in water by a motor mist-blower at the beginning of April 1967 and again in the middle of June 1967. At fortnightly intervals from April to October inclusive four shoots were taken from each of eighteen randomly selected trees in each plot. Two shoots were taken from the lower crown and two from the middle crown. Counts were made of the number and type of aphids, the number of needles and length of shoot, and the number of predators and parasitised aphids on the main axis of each shoot.

In April 1967 a fairly large overwintering aphid population was found at Deer whilst that at Fetteresso was considerably smaller. Spraying with malathion early in April resulted in an almost complete kill of the aphids, thus enabling the loss of needles from infected and uninfected trees to be compared throughout the succeeding summer.

From April to the end of June a steady increase in the number of aphids occurred in all six plots. A peak, varying in size according to plot treatment and forest, was reached at the end of June, after which a rapid decline in the number of aphids occurred. In the sprayed plots this decrease was precipitated by spraying malathion in mid-June, resulting in a high mortality of these aphids. The peaks in the unsprayed plots were markedly different at Deer and Fetteresso. At Deer peaks of 50–70 aphids per 100 needles were observed, while at Fetteresso the population never reached a level higher than about ten aphids per 100 needles. The rate of population increase was basically similar in both forests, so that the main reason for the differences exhibited by the summer population peaks appears to be the differences in the numbers of overwintering aphids.

By spraying in early April the population is artificially lowered so that, given a similar rate of increase, a smaller summer population peak is reached in comparison with unsprayed plots.

Counts of predators showed that Coccinellid beetles, in particular *Aphidecta obliterata L.*, with a few *Adalia decempunctata L.*, were the main predators. Adults were scarce in spring, the larval peak being reached in June (at the same period as the aphid peak was reached), pupation taking place mainly in July. The predator level, a maximum of about 40 larvae for about 6,000 aphids at Deer, was considered to be too low to be more than a minor contributory factor in the collapse of the aphid populations which took place in July. Very small numbers of syrphid larvae and parasites of *E. abietinum* were observed and these had little effect on the population levels. Winged adults were found mainly in June in both the sparsely and densely populated plots. The peak number of these aphids occurred before the dramatic drop in aphid numbers in late June and early July, so that it was considered that alate emigration was not the main factor involved in this decrease. Some evidence of an immigration of alate adults into the sprayed plot at Forest of Deer during early June was obtained. The occurrence of winged aphids in all plots irrespective of population density suggests that wing formation is not correlated with population density.

From April to July a steady fall in the rate of increase of the aphid populations occurred, in all three unsprayed plots, before any appreciable needle fall was seen at Deer or Fetteresso. Kloft and Ehrhardt (1959) noted that the nitrogen content of Sitka spruce sap decreases from April onwards, reaching a minimum value in July. It is suggested that the main reason for the population decrease in late June and early July in sparsely populated plots such as that at Fetteresso is a density-independent lowering of the food quality. In plantations densely populated with aphids, such as Forest of Deer, where up to 75 per cent needle loss was recorded, this factor plus a density-dependent loss of needles is responsible for the dramatic population collapse.

Count of the needles showed that the main loss of needles from the unsprayed plots at Forest of Deer occurred during the period April to July, more especially in June and July during and just after the peak aphid population. No detectable needle shedding occurred at Fetteresso Forest in either plot. In the middle crown of the sprayed trees at Deer there was evidence of a significant loss of needles, the cause of which remains unknown.

This work on the population dynamics of the insect will be continued. It is planned to follow the aphid population peaks from year to year and to correlate these with the physical and biological variables. It is also intended to investigate the migration of alatiform aphids within a Sitka stand by means of aphid traps.

Work on the feeding behaviour of the aphid on Sitka spruce needles in the laboratory is now entering its preliminary stages. It is planned in the first instance to study probing activity and sap uptake by the aphid at various temperatures.

REFERENCE

KLOFT, W., and EHRHARDT, P. 1959. Zur Sitkalauskalamität in Nordwestdeutschland. *Waldhygiene* **3** 47–9.

STUDY OF LIGHT RELATIONS OF TREES IN NURSERY AND FOREST

By W. A. FAIRBAIRN

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University of Edinburgh

The experiment (described in the *Report* for 1967) at Bush Nursery on light intensity investigation begun in April, 1966, was concluded on 30th September, 1967, at the end of two growing seasons.

Additional information in regard to soil temperatures, moisture content and soil reaction (pH) were obtained during 1967. All data obtained are now undergoing statistical analysis; once completed it is intended to publish an account of the findings in one of the professional forestry journals.

Photographic records were again made, showing the six species in the five different light intensities both, in the nursery and in the laboratory, once all the measurements had been obtained.

ENVIRONMENTAL FACTORS AND THE GROWTH OF SITKA SPRUCE

By D. C. MALCOLM

Department of Forestry and Natural Resources, University of Edinburgh

This project has been in the data collection phase during the period under report. Sampling was completed in both Inverliever (Argyll) and Glen Garry (Inverness-shire) forests. In both these areas it was found possible to locate about 30 sample plots in stands that met the constraints placed on age and uniformity. Considerable difficulty was experienced in trying to obtain an adequate number of sites to represent the lower yield classes. Many of the stands in this category which were examined proved to be irregular or to have had a history of early checked growth.

The 70 sample plots in the field have provided about 350 separate horizon samples for laboratory analyses. As a result a considerable amount of data has been accumulated and is in the process of analysis.

An initial comparison of measures of productivity was made. Those compared were the five-year intercept, yield class from the published curves and mean annual height growth. It appears that the last may prove to be the most useful in this study. The measurement of the five-year intercept does provide however, an indication of any abnormality in the growth pattern of the sampled trees.

A study of the floristic data collected so far shows that the development of any simple vegetation classification of sites into productivity groupings will be difficult to achieve. An ordination of the data, using selected species, displayed some groupings; but these appear to have more of a regional than productivity basis.

A strong relationship between Sitka spruce productivity, as measured by height growth, and altitude has appeared in the data. It is interesting that this should be true for all the sites taken together, even when these are some considerable distance apart. Elevation, as read from a contour map, is of course, an integrative factor comprising a number of variables, mainly climatic but also edaphic to some extent. This relationship however, may allow the removal of some of the local climatic variations from the data resulting in improved appreciation of the role of other factors. In particular, it may account for most of the exposure factor for which no adequate single measure is available.

These relationships are being investigated further.

Summary

The data collection for this study continues. An interesting correlation between elevation and Sitka spruce productivity has emerged and may permit an improved assessment of the contribution of non-climatic parameters.

FIRES IN FOREST AND HEATHLAND FUELS

By A. J. M. HESELDEN and M. W. WOOLLISCROFT

Ministry of Technology and Fire Offices' Committee
Joint Fire Research Organization, Boreham Wood, Herts

Fieldwork

A team from the Fire Research Station again visited the New Forest in March, 1968, and took rate of spread and thermal measurements at controlled burnings carried out by the Forestry Commission. Together with last year's field measurements, data on a total of 11 fires have now been analysed.

The rate of spread of the head fires was in most cases controlled by radiation from the flames since heating from the flames was generally two to three times greater than that through the fuel bed.

The rate of spread of two head fires in gorse was much greater than could be accounted for by the thermal measurements and this may well be due to the tendency of this fuel to produce spot fires ahead of the main fire front.

Attempts are being made to correlate the field measurements of flame deflection. Flames appear to be deflected by the wind somewhat less than laboratory experiments have indicated but the reason for this is not yet known.

Statistical Analysis

Forty-six fire cards, giving measurements by the Forestry Commission at controlled burnings, have now been received. The rates of spread plotted on arithmetic probability paper give three distinct straight lines suggesting that there are three populations, one of slow and two of fast fires. There was no discernible difference between the distribution of slow heather and slow grass fires but the rates of spread of fast fires in these fuels were different.

Such data, and data for wild fires, as they are accumulated, will permit more detailed analysis and more profitable comparison with both experimental fires and theory.

APPENDIX I

Main Experimental Projects and Localities

(See Maps, page 187, for situations)

NURSERY EXPERIMENTS

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, near Alloa (Clackmannanshire)

AFFORESTATION EXPERIMENTS ON PEAT

Achnashellach Forest (Wester Ross)
Beddgelert Forest (Caernarvonshire)
Clocaenog Forest (Denbighshire and Merioneth)
Eddleston Forest (Peeblesshire)
Inchnacardoch Forest (Inverness-shire)

Kielder Forest (Northumberland)
Naver Forest (Sutherland)
Shin Forest (Sutherland)
Strathy Forest (Sutherland)
Watten (Caithness)

Wauchope Forest (Roxburghshire)

AFFORESTATION EXPERIMENTS ON HEATHLAND

Allerston Forest, Harwood Dale (Yorkshire)
Black Isle Forest, Millbuie (Easter Ross)
Clashindarroch Forest (Aberdeenshire)
Inshriach Forest (Inverness-shire)
Land's End Forest, Croft Pascoe (Cornwall)

Taliesin Forest (Cardiganshire and Montgomeryshire)
Teindland Forest (Mcray)
Wareham Forest (Dorset)

FOREST NUTRITION

Allerston Forest, Broxa (Yorkshire)
Arecleoch Forest (Ayrshire)
Clocaenog Forest (Denbighshire and Merioneth)
Culbin Forest (Moray)
Exeter Forest (Devon)

Inchnacardoch Forest (Inverness-shire)
Mabie Forest, (Dumfriesshire)
Selm Muir (Mid and West Lothian)
Shin Forest (Sutherland)
Tarenig Forest (Cardiganshire and Montgomeryshire)

Teindland Forest (Moray)
Wareham Forest (Dorset)
Wilsey Down Forest (Cornwall)

SOIL MOISTURE STUDIES

Aldewood Forest (Suffolk)
Bernwood Forest (Oxfordshire and Buckinghamshire)
Bramshill Forest (Berkshire and Hampshire)
Inchnacardoch Forest (Inverness-shire)
New Forest (Hampshire)

Queen Elizabeth Forest (Hampshire and Sussex)
Thetford Chase, Feltwell (Norfolk and Suffolk)

DRAINAGE EXPERIMENTS

Forest of Ae (Dumfriesshire)
Bernwood Forest (Oxfordshire and Buckinghamshire)
Clocaenog Forest (Denbighshire and Merioneth)
Hafren Forest (Montgomeryshire)
Halwill Forest (Devon and Cornwall)

Kershope Forest (Cumberland)
Kielder Forest (Northumberland)
Lennox Forest (Stirlingshire and Dunbartonshire)
Loch Ard Forest, Flanders Moss (Perthshire and Stirlingshire)
Orlestone Forest (Kent)

Rumster Forest (Caithness)
Towy Forest (Cardiganshire, Breconshire and Carmarthenshire)

PROVENANCE EXPERIMENTS

Scots pine:

Black Isle Forest, Findon (Easter Ross)
Thetford Chase (Norfolk and Suffolk)

Corsican pine:

Brighstone Forest (Isle of Wight)
Cotswold Forest (Gloucestershire)
South Yorkshire Forest
Thetford Chase (Norfolk and Suffolk)
Wareham Forest (Dorset)

Lodgepole pine:

Achnashellach Forest (Wester Ross)
Allerston Forest, Wykeham (Yorkshire)
Black Isle Forest, Millbuie (Easter Ross)
Brendon Forest (Somerset)
Ceiriog Forest (Denbighshire)

Clocaenog Forest (Denbighshire and Merioneth)
Forest of Deer (Aberdeenshire)
Glen Trool Forest (Kirkcudbrightshire and Ayrshire)
New Forest (Hampshire)
Taliesin Forest (Cardiganshire and Montgomeryshire)

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 Ddu Forest (Breconshire and Herefordshire)
Radnor Forest (Radnorshire and Herefordshire)
Ratagan Forest (Wester Ross and Inverness-shire)
Taliesin Forest (Cardiganshire and Montgomeryshire)

Wark Forest (Northumberland)
Wilsey Down Forest (Cornwall)

PROVENANCE EXPERIMENTS—contd.

Sitka and Norway spruces:	The Bin Forest (Aberdeenshire) Brendon Forest (Somerset) Cannock Chase (Staffordshire) Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire) Halwill Forest (Devon and Cornwall) Newcastleton Forest (Roxburghshire and Dumfriesshire) Salisbury Forest (Wiltshire)
European larch:	Coed y Brenin (Merioneth) Mortimer Forest (Herefordshire and Shropshire) Plym Forest (Devon) Savernake Forest (Wiltshire and Berkshire) Walcot Forest (Shropshire)
European and Japanese larches:	Clashindarroch Forest (Aberdeenshire) Drummond Hill Forest (Perthshire) Fetteresso Forest (Kincardineshire)
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 (Breconshire) Brendon Forest (Somerset) Clocaenog Forest (Denbighshire and Merioneth) 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 (Wester Ross) Radnor Forest (Radnorshire and Herefordshire) Thetford Chase (Norfolk and Suffolk)
Silver fir, Abies lowiana/concolor:	Brendon Forest (Somerset) Honiton Forest (Devon) Mortimer Forest (Herefordshire and Shropshire)
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)

CONVERSION OF COPPICE

Alice Holt Forest, Marelands (Hampshire and Surrey)
Cranborne Chase (Dorset and Wiltshire)
Forest of Dean, Penyard and Flaxley (Gloucestershire, Herefordshire, and Monmouthshire)
Hursley Forest (Hampshire)

PLANTING EXPERIMENTS ON CHALK DOWNLANDS

Friston Forest (Sussex)
Queen Elizabeth Forest (Hampshire and Sussex)

CULTURE OF OAK

Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Dymock Forest (Gloucestershire and Herefordshire)
Micheldever Forest (Hampshire)
Tintern Forest, Crumbland Wood (Monmouthshire)

POPLAR TRIALS AND SILVICULTURAL EXPERIMENTS

Alice Holt Forest (Hampshire and Surrey)
Bedgebury Forest (Kent and Sussex)
Blandford Forest (Dorset)
Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Lynn Forest, Gaywood (Norfolk)

Quantock Forest (Somerset)
South Yorkshire Forest
Stenton Forest (East Lothian and Berwickshire)
Wentwood Forest (Monmouthshire)
Wynyard Forest (Co. Durham)

ELMS

Westonbirt, Silkwood (Gloucestershire and Wiltshire)

ARBORETA

National Pinetum, Bedgebury (Kent)
Westonbirt Arboretum (Gloucestershire)
Whittingehame (East Lothian)

MAJOR COLLECTIONS OF SPECIES PLOTS

Bedgebury Forest (Kent and Sussex)
Benmore Forest, Kilmun (Argyll)
Brechfa Forest (Carmarthenshire)
Minard Forest, Crarae (Argyll)
Thetford Chase (Norfolk and Suffolk)

SPECIES COMPARISONS IN RELATION TO SPECIAL SITES

Achnashellach Forest (Wester Ross)
Forest of Ae (Dumfriesshire)
Aldewood Forest (Suffolk)
Allerston Forest, Rosedale (Yorkshire)
Allerston Forest, Wykeham (Yorkshire)

Beddgelert Forest (Caernarvonshire)
Bodmin Forest (Cornwall)
Brendon Forest (Somerset)
Brownmoor Forest (Dumfriesshire)
Caeo Forest (Carmarthenshire)

Cairn Edward Forest (Kirkcudbrightshire)
Clashindarroch Forest (Aberdeenshire)

SPECIES COMPARISONS—contd.

Coed Morgannwg (Glamorgan)
Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Dovey Forest (Merioneth and Montgomeryshire)
Garadhban Forest (Stirlingshire and Dunbarton)
Glentress Forest (Peeblesshire)

Glen Trool Forest (Kirkcudbrightshire and Ayrshire)
Glen Urquhart Forest (Inverness-shire)
Gwydyr Forest (Caernarvonshire and Denbighshire)
Inchnacardoch Forest (Inverness-shire)
Kielder Forest (Northumberland)

Kirroughtree Forest (Kirkcudbrightshire)
Land's End Forest (Cornwall)
Micheldever Forest (Hampshire)
Mynydd Ddu Forest (Breconshire and Monmouthshire)
Naver Forest (Sutherland)

New Forest (Hampshire)
Pembrey Forest (Carmarthenshire)
Queen Elizabeth Forest (Hampshire and Sussex)
Rockingham Forest (Northamptonshire)
South Yorkshire Forest

Teindland Forest (Moray)
Thetford Chase (Norfolk and Suffolk)
Wareham Forest (Dorset)

RE-AFFORESTATION EXPERIMENTS

Forest of Ae (Dumfriesshire)
Allerston Forest (Yorkshire)
Coed Morgannwg, Michaelston (Glamorgan)
Culloden Forest (Inverness-shire and Nairnshire)
Culbin Forest (Moray and Nairnshire)

Drumtochty Forest (Kincardineshire)
Kielder Forest (Northumberland)
Kirkhill Forest (Aberdeenshire)
Lennox Forest (Stirlingshire)
Newcastleton Forest (Roxburghshire)

Radnor Forest (Radnorshire and Herefordshire)
Redesdale Forest (Northumberland)
Thetford Chase (Norfolk and Suffolk)

WEED CONTROL

Alice Holt Forest (Hampshire and Surrey)
Bramshill Forest (Berkshire and Hampshire)
Brendon Forest (Somerset)
Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Eddleston Water Forest (Midlothian)

Farigaig Forest (Inverness-shire)
Faskally Forest (Perthshire)
Glentress Forest (Peeblesshire)
New Forest (Hampshire)
Rogate Forest (Sussex)

St. Leonards Forest (Sussex)
Vinehall Forest (Kent)
Wareham Forest (Dorset)

WIND STUDIES

Kielder Forest (Northumberland)
Redesdale Forest (Northumberland)
Wauchope Forest, Whitrope (Roxburghshire)

HIGH ELEVATION STUDIES

Beddgelert Forest (Caernarvonshire)
Clocaenog Forest (Denbighshire and Merioneth)
Hafren Forest (Montgomeryshire)
Myherin Forest (Cardiganshire)
Mynydd Ddu Forest (Breconshire and Monmouthshire)

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:	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 (Breconshire) Clocaenog Forest (Denbighshire and Merioneth) Coed Morgannwg, Rheola (Glamorgan) Gwydyr Forest (Caernarvonshire and Denbighshire)
Norway spruce:	Clocaenog Forest (Denbighshire and Merioneth) Coed Morgannwg, Rheola (Glamorgan) Kerry Forest (Montgomeryshire, Shropshire, 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:	Bodmin Forest (Cornwall) Brechfa Forest (Carmarthenshire) Caeo Forest (Carmarthenshire) Coed Morgannwg, Rheola (Glamorgan) Crychan Forest (Breconshire 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 (Easter Ross)* Cannock Chase (Staffordshire) Crown Estates, Fochabers, near Speymouth Forest (Moray and Banffshire) Edensmuir Forest (Fife)* New Forest (Hampshire) Swaffham Forest (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)* Swaffham Forest (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)* Loch Eck Forest (Argyll)*
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) Coed Morgannwg, Rheola (Glamorgan) Drumtochty Forest (Kincardineshire) Glentress Forest (Peeblesshire) Stourhead Estate (Wiltshire)
Douglas fir:	Alice Holt Forest (Hampshire and Surrey)* Glentress Forest (Peeblesshire) Gwydyr Forest (Caernarvonshire and Denbighshire) Mynydd Ddu Forest (Breconshire 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)

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)
Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Drumtochty Forest (Kincardineshire)
Keillour Forest (Perthshire)

Ledmore Forest (Perthshire)
Lynn Forest (Norfolk)
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 (Easter Ross)
Aultmore Forest (Banffshire)
Benmore Forest (Argyll)

Bramshill Forest (Berkshire and Hampshire)
Chillingham Forest (Northumberland)
Clocaenog Forest (Denbighshire and Merioneth)
Coed Sarnau Forest (Radnorshire)
Coed y Brenin Forest (Merioneth)

Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Devilla Forest (Fife and Clackmannanshire)

GENETICS—contd.

PROGENY TRIALS—contd.

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)
Saltoun Forest (East and Mid-Lothian)

Speymouth Forest (Moray and Banffshire)
Stenton Forest (East Lothian and Berwickshire)
Teindland Forest (Moray)
Thetford Chase (Norfolk and Suffolk)
Thornthwaite Forest (Cumberland)

Torrie Forest (Perthshire)
Wauchope Forest, Whitrope (Roxburghshire)
Westonbirt (Gloucestershire)

PATHOLOGICAL RESEARCH AREAS

ELM DISEASE TRIALS

Alice Holt Forest (Hampshire and Surrey)

TOP DYING OF NORWAY SPRUCE

Allerston Forest, Wykeham (Yorkshire)
Coed Morgannwg (Glamorgan)
Knapdale Forest (Argyll)

FOMES ANNOSUS

The Bin Forest (Aberdeenshire and Banffshire)
Bramshill Forest (Berkshire and Hampshire)
Kerry Forest (Montgomeryshire, Shropshire and Radnorshire)
Lael Forest (Wester Ross)
Thetford Chase (Norfolk and Suffolk)

ARMILLARIA MELLEA

Alice Holt Forest (Hampshire and Surrey)
Bramshill Forest (Berkshire and Hampshire)
Chiddingfold Forest (Surrey and Sussex)

POLYPORUS SCHWEINITZII

Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)

BACTERIAL CANKER OF POPLAR

Blandford Forest (Dorset)
Fen Row Nursery, Aldewood Forest (Suffolk)

DIDYMASCELLA (KEITHIA) THUJINA ON WESTERN RED CEDAR

Alice Holt Forest (Hampshire and Surrey)
Slebech Nursery (Pembrokeshire)

CRUMENULA SORORIA ON PINE

Ringwood Forest (Dorset and Hampshire)

BLUE STAIN IN PINE

Thetford Chase (Norfolk and Suffolk)

ENTOMOLOGY

PINE LOOPER MOTH: BUPALUS PINIARIUS

Cannock Chase (Staffordshire)

LARCH SAWFLY: ANOPLONYX DESTRUCTOR

Drumtochty Forest (Kincardineshire)

SPRUCE 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)

PINE SHOOT BEETLE: TOMICUS PINIPERDA

Bramshill Forest (Berkshire and Hampshire)

BLACK PINE BEETLE: HYLASTES SPP.

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)

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APPENDIX III

Staff Engaged in Research and Development

As at 31st March, 1968

Staff engaged in Research and Development, apart from outstationed Foresters, are based at the following main centres:

FORESTRY COMMISSION RESEARCH STATION
Alice Holt Lodge,
Wrecclesham,
Farnham, Surrey. Tel. Bentley (Hants) 2255

FORESTRY COMMISSION
Government Buildings,
Bankhead Avenue,
Sighthill,
Edinburgh 11. Tel. Craiglockhart 4010

FORESTRY COMMISSION
25 Savile Row,
London, W.1. Tel. Regent 0221 (01 734 0221)

FORESTRY COMMISSION
Priestley Road,
Basingstoke,
Hampshire. Tel. Basingstoke 3181.

Director*	J. R. Thom, B.Sc. (*Alice Holt*)
Chief Research Officer (South)	D. H. Phillips, M.Sc., Ph.D., M.I.Biol. (*Alice Holt*)
Administration and Finance Officer†	C. Ridley (*Alice Holt*)
Director's Secretary	Miss O. A. Harman (*Alice Holt*)

SEED (*Alice Holt*)

G. M. Buszewicz, Mgr. Ing., Head of Section

Laboratory:	D. C. Wakeman, Mrs. L. S. Elgy, Miss R. E. Crumplin
Seed Store:	T. A. Waddell, J. C. Ray
Office:	D. T. Baker, E. R. Parratt

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.)
M. Nimmo

Office:

R. G. Harris: Miss E. Burnaby, Miss A. Davidge, F. H. Khawaja

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* Mr. Thom was succeeded in April, 1968 by Mr. G. D. Holmes, B.Sc.
† Mr. Ridley was succeeded in April 1968 by Mr. G. H. Bowers.

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, A. J. A. Graver, P. D. Howard, D. W. H. Durrant	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 J. E. J. White	Exeter
Dean and South Wales Area	F. Thompson 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 C. W. Webber, D. Downs	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
East England Area	R. M. Ure K. Mills, D. J. Williams R. E. A. Lewis	Santon Downham, Nr. Thetford

SILVICULTURE (NORTH) (*Edinburgh*)

D. T. Seal, B.Sc., Head of Section
J. Atterson, B.Sc.
R. Lines, B.Sc.
A. J. Low, B.Sc., Ph.D.
S. A. Neustein, B.Sc.
G. G. M. Taylor, B.Sc.

Office:

P. Hunter: T. T. Johnston, Miss M. E. Grant, G. F. Campbell, Miss E. P. Beattie, Mrs. M. J. Pedder

Research Foresters		*Centre*
	G. R. Dunbar, J. Howarth, R. D. Wishart	Edinburgh
North Scotland Region	A. Macdonald	Fort Augustus
North Scotland Area	J. B. McNeill, A. A. Green, D. C. Coutts	Fort Augustus
North East Scotland Area	G. Bartlett N. P. Danby, A. McInnes	Mid-Ardross, Ross and Cromarty

Research Foresters		*Centre*
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	Drumtochty, Laurencekirk, Kincardine
West Scotland Area	A. R. Mair J. E. Kirby, A. B. Lewis	Kilmun, by Dunoon, Argyll
South West Scotland Area	E. Baldwin K. A. S. Gabriel, J. D. McNeill W. Brown	Mabie, Dumfriesshire
North England Region	J. Weatherell	Wykeham, Scarborough
North East England Area	T. C. Booth M. K. Hollingsworth P. Priestley	Wykeham, Scarborough
Borders Area	G. S. Forbes A. H. Reid, D. L. Willmott, J. D. Lindsay	Kielder by Hexham, Northumberland
North West England Area	D. S. Coutts	Grizedale, nr. Hawkshead, Westmorland

ECOLOGIST (*Alice Holt*)

J. M. B. Brown, B.Sc., Dip.For.

Research Foresters: B. G. Howland, P. Marsh

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, B.Sc.

Research Foresters: D. F. Fourt, A. E. Coates, T. E. Radford

Laboratory: Mrs. M. J. Cardrick, Miss S. Dabek, E. Darlington, Miss C. Y. Davis

Instrumentation: R. E. Stickland

FOREST GENETICS (*Edinburgh*)

R. Faulkner, B.Sc., Head of Section
A. M. Fletcher, B.Sc., Ph.D.
R. B. Herbert, B.Sc. (*Alice Holt*)

Research Foresters:

Alice Holt	I. J. M. Dawson, A. S. Gardiner, R. B. Collins, G. Simkins
Edinburgh	J. Howarth
Bush Nursery, Roslin, Midlothian	C. McLean
Grizedale, Lancs.	D. S. Coutts
Newton, Elgin	M. T. T. Phillips
Westonbirt, Glos.	G. C. Webb

Laboratory: D. R. Hill

Office: Miss L. S. Devereux

FOREST PATHOLOGY (*Alice Holt*)

D. A. Burdekin, B.A., Dip.Ag.Sci.(Cantab.), Head of Section (acting),
S. Batko, D. Ing.

Research Foresters:

Alice Holt	C. W. T. Young, B.W.J. Greig, J. E. Pratt, R. G. Strouts, P. J. Webb
Edinburgh	J. D. Low, M. Cruickshanks
Laboratory:	Mrs. J. M. Lord, Miss J. D. Machin, Miss A. Trusler
Office:	J. G. Jackman, Mrs. D. Dewé (Typist)

FOREST 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)
J. T. Stoakley, M. A.

Research Foresters:

Alice Holt	R. M. Brown, A. R. Barlow, C. H. Hudson, C. J. King, C. Walker, L. A. Tee (Mammals), D. Elgy (Mammals), H. M. Pepper (Mammals), I. G. Carolan (Mammals, Dundeugh)
Edinburgh	R. C. Kirkland
Laboratory:	C. I. Carter, B.Sc., M. I. Biol., G. Barson, N. R. Maslen, T. G. Winter
Office:	Miss B. Parfitt

PLANNING AND ECONOMICS (*Alice Holt*)

J. A. Spencer, M.A., Head of Section
R. T. Bradley, M.A.
A. J. Grayson, M.A., B.Litt.
G. J. Hamilton, B.Sc.
G. M. L. Locke, B.Sc. (*Edinburgh*)
A. M. Mackenzie (*Edinburgh*)
J. F. Morgan, B.Sc.
D. G. Pyatt, B.Sc. (*Edinburgh*)
D. Y. M. Robertson, B.Sc.
P. A. Wardle, B.Sc.

Foresters: Based on Alice Holt: J. Mc.N. Christie, G. Haggett, G. D. Spiller, P. Bond, E. J. Fletcher, I. C. Embry, R. Oakes, M. A. Mitchell, M. Wigzell, M. H. Webb, M. D. Witts, M. D. Whitlock

Based on Edinburgh: J. Armstrong, A. F. Brown, I. M. Parrott, A. Little, D. A. T. Douglas, W. Thomson, J. Meechan

Working Plans and Mensuration:

Field Parties—England and Wales

R. F. E. Bartlett, A. Beardsley, A. C. Miller, D. A. Bell, C. R. Alpe
D. D. G. Davies, A. J. Maisey, K. Shuker, J. B. Kingsmill, R. J. Rogers, D. Ellis, J. B. Richards, M. R. Wigzell
E. R. Hall
R. N. Smith, G. Harrison, G. J. Jones
E. B. Jury, M. B. Scutt, J. L. Williams
A. C. Dover, S. Cooper, M. W. Davies, J. Dickinson

Field Parties—Scotland

J. Straiton, J. L. Davidson, I. D. MacDonald
J. C. Anderson, P. J. Lodge
J. R. Boyd, J. C. Phillipson, J. B. Smith
W. Elger, K. Fryer, P. G. Risby
A. A. J. Rees, A. N. Gordon, L. C. MacCallum
B. Thompson, F. G. O. Thom, L. D. Macrae
J. J. Waddell
C. R. Liversidge, G. A. Watson
A. E. Surman, P. J. Humphries

PLANNING AND ECONOMICS (*Alice Holt*)—contd.

Soil Survey:

D. Harrison, A. S. Ford
G. N. Kearns, F. Webster
J. S. Innes, G. F. Moysey

Office:

Mrs. E. Simpson, Mrs. M. D. Redknap, Miss P. A. M. McCunnin

WORK STUDY (*Alice Holt*)

L. C. Troup, B.Sc., Head of ~~Section~~ Branch,
J. V. St. L. Crosland, B.Sc. (*Edinburgh*)
E. S. B. Chapman, B.Sc. (*Edinburgh*)
T. W. G. Coulson, B.Sc. (*Langholm*)
A. A. Cuthbert, B.Sc. (*Annan*)
N. Dannatt, B.Sc.
J. A. Drummond (*Kilmun*) B.Sc.
D. M. Hughes (*Bangor*) B.Sc.
J. Laurie-Muir, B.Sc.
A. A. Rowan, B.Sc. (*Fort Augustus*)
A. H. A. Scott, B.Sc. (*Lyndhurst*)
A. R. Sutton, B.Sc. (*Brecon*)
D. H. Wallace (*Dolgellau*) B.Sc.
A. Whayman (*Hawick*)
W. O. Wittering (*Olney, Beds.*) A.S.F.

Machinery Research and Development

R. B. Ross, A.M.I.Mech.E.
W. S. Mackenzie (*Kielder*)

Roads Research and Development

K. T. Davidson, B.Sc., A.M.I.H.E. (*Fort Augustus*)

Foresters:

C. E. Allison (*New Forest*), St. J. G. D. Bland-Flagg (*Yardley*), A. C. F. Bowdler (*Langholm*), R. H. Brown (*Byrness*), C. F. Dampney (*Lyndhurst*), P. P. Davis (*Dolgellau*), M. J. Day (*Santon Downham*), P. Featherstone (*Olney*) M. J. C. Graham (*Langholm*), G. H. Ivison (*Byrness*), P. W. Lansdown (*Lyndhurst*), R. S. MacInnes (*Ae*), D. J. Morris (*Brecon*), D. M. Percy (*Lyndhurst*), F. B. W. Platt (*Mildenhall*), I. Pollock (*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*), B. D. Symes (*Langholm*), W. Trotter (*Kilmun*), G. D. Watt (*Fort Augustus*), P. Wood (*Santon Downham*)

Office:

R. D. Duncan, Mrs. E. Butler

ENGINEERING (*Basingstoke*)

A. J. Cole, T.D., A.M.I.Mech.E., A.M.B.I.M.
K. A. Kernahan (*Alice Holt*)

HARVESTING AND MARKETING (*London*)

B. W. Holtam, B.A. (*Marketing*)
J. R. Aaron, M.A. (*Marketing*)

STATISTICS (*Alice Holt*)

R. S. Howell, A.I.S., Head of Section
D. H. Stewart, B.Sc., M.I.Biol.
D. K. Lindley
Miss J. M. Cowie (*Edinburgh*)

STATISTICS (*Alice Holt*)—contd.

Assistants:

C. A. Thorne (Research Forester), I. D. Mobbs (Research Forester), Mrs. R. J. F. Glynn, Miss E. C. Bridger, Mrs. S. M. Read, Miss J. E. Hudson, Miss S. Nairne (*Edinburgh*) (Machine Operators).

Office:

Miss A. M. Welch, Mrs. U. Schofield (Typist)

PHOTOGRAPHY (*Alice Holt*)

I. A. Anderson, F.I.B.P., Head of Section
Mrs. T. K. Evans, A.R.P.S.
B. J. Lambsdown
R. W. Genever
A. W. Coram (Illustrator)
Miss M. Trusler

Office:

Mrs. S. C. Cockrem

PUBLICATIONS (*London*)

H. L. Edlin, B.Sc., Dip.For., Head of Section
P. A. Mayne
M. Abrahams

RESEARCH INFORMATION SECTION (*Alice Holt*)

O. N. Blatchford, B.Sc., Head of Section
S. H. Sharpley
F. C. Fraass
Miss L. Watson
Mrs. L. D. Birchall (Typist)

ADMINISTRATIVE STAFF (*Alice Holt*)

Deputy Adminstration and Finance Officer:	W. D. Wardrop
Establishment:	P. H. Hamilton: Mrs. D. M. Pearson, Mrs. C. Gore
Finance:	J. J. Richardson: A. R. Taggart, J. Empson, Miss G. B. Hayden
Stores:	L. W. Thomas: B. D. Higgins, D. I. Carlyle
Typists:	Miss M. Hopkin: Mrs. J. G. Anderson, Mrs. E. L. Allen, Mrs. B. 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, T. G. Watts

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 (1)
1 bushel	=36·37 litres (1)

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 (1/ha)

Weight/Volume

1 pound per gallon (lb/gal)	=0·09978 kilogrammes per litre (kg/1)
1 ounce per bushel (oz/bushel)	=0·7795 grammes per litre (g/1)

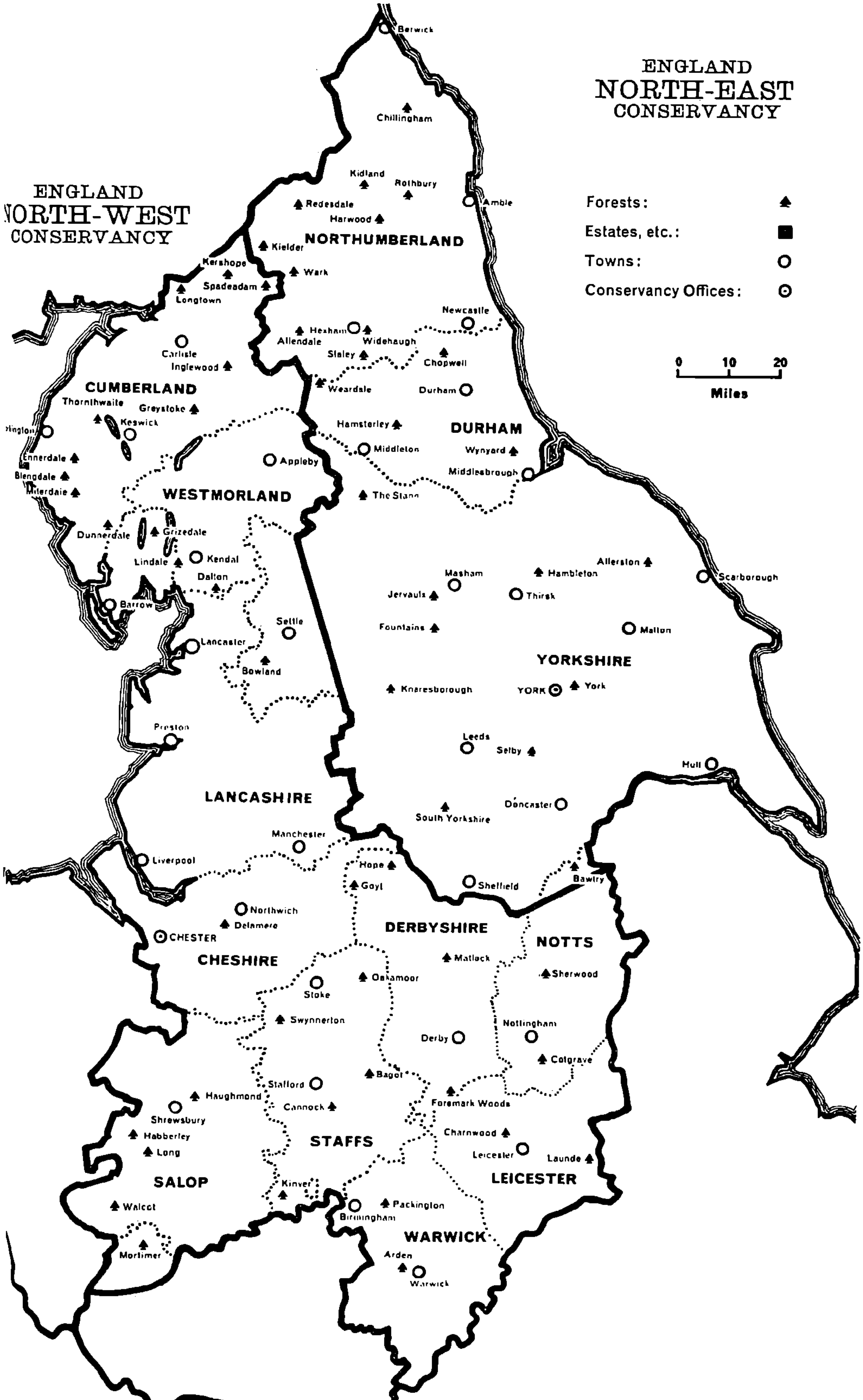
Linear Velocity

1 foot per minute (ft/min)	=0·00508 metres per second (m/sec.)*

Note. Forestry Commission Booklet 6. *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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Newcastle
Hexham
Allendale
Widehaugh
Slaley
Chopwell
Carlisle
Inglewood
Weardale
Durham
CUMBERLAND
Thornthwaite
Greystoke
Keswick
Hamsterley
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Middleton
Wynyard
Appleby
Middlesbrough
Ennerdale
Blengdale
WESTMORLAND
The Stang
Dunnerdale
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Barrow
Allerston
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Hambleton
Scarborough
Jervaulx
Thirsk
Settle
Fountains
Malton
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Bowland
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Hope
Goyt
Sheffield
Bawtry
Northwich
Delamere
CHESTER
DERBYSHIRE
NOTTS
CHESHIRE
Matlock
Sherwood
Oakamoor
Stoke
Swynnerton
Nottingham
Derby
Colgrave
Bagot
Stafford
Haughmond
Foremark Woods
Shrewsbury
Cannock
Charnwood
Habberley
STAFFS
Long
Leicester
Launde
SALOP
LEICESTER
Kinver
Walcot
Packington
Birmingham
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Mortimer
Arden
Warwick


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Cromer
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Northampton
Yardley Chase
Salcey
Hazelborough
Buckingham
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CAMBRIDGE
Bury St. Edmunds
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Lavenham
Ipswich
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Ampthill
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Bramfield
Hertford
Walden
Colchester
Honeywood
ESSEX
Chelmsford
Bernwood
Oxford
Hampden
Kennington
Chilterns
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Bucklebury
Reading
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Bramshill
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Andover
Basingstoke
Micheldever
Alton
Alice Holt
Winchester
Guildford
Dorking
Redhill
Mildmay
Shipbourne
Rochester
KENT
Canterbury
Challock
SURREY
Abinger
Chiddingfold
Tunbridge Wells
Ashford
Orlestone
Dover
Hursley
Petersfield
Rogate
Horsham
St. Leonards
Bedgebury
Southampton
Queen Elizabeth Forest
Maresfield
Brightling
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Havant
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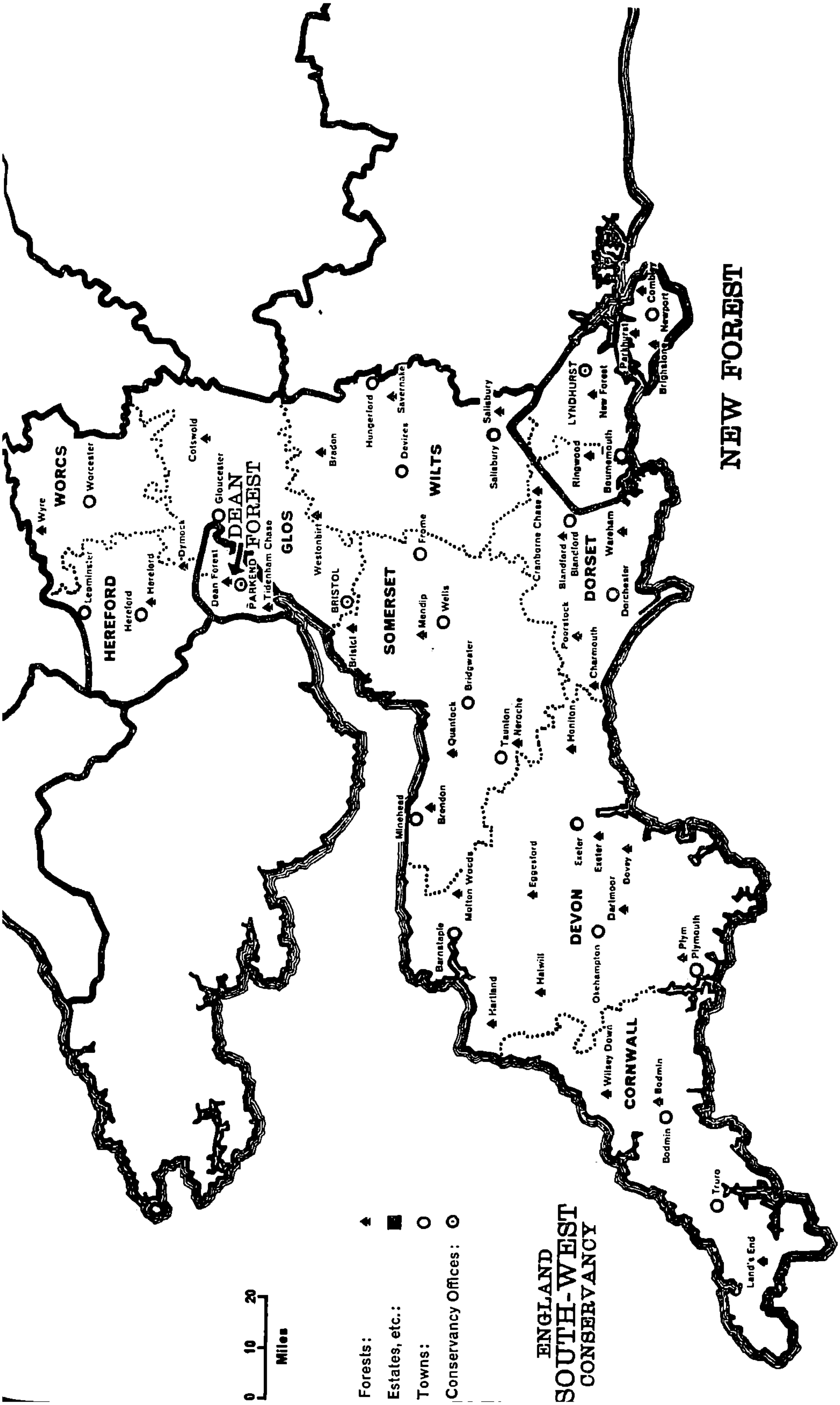
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Dymock
Cotswold
Gloucester
Dean Forest
Tidenham Chase
Westonbirt
Bristol
Mendip
Wells
Bridgwater
Quantock
Taunton
Neroche
Minehead
Brendon
Frome
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Hungerford
Savernake
Devizes
Salisbury
Cranborne Chase
Blandford
Ringwood
Bournemouth
New Forest
Wareham
Dorchester
Poorstock
Charmouth
Honiton
Exeter
Eggesford
Haldon
Dartmoor
Molton Woods
Barnstaple
Halwill
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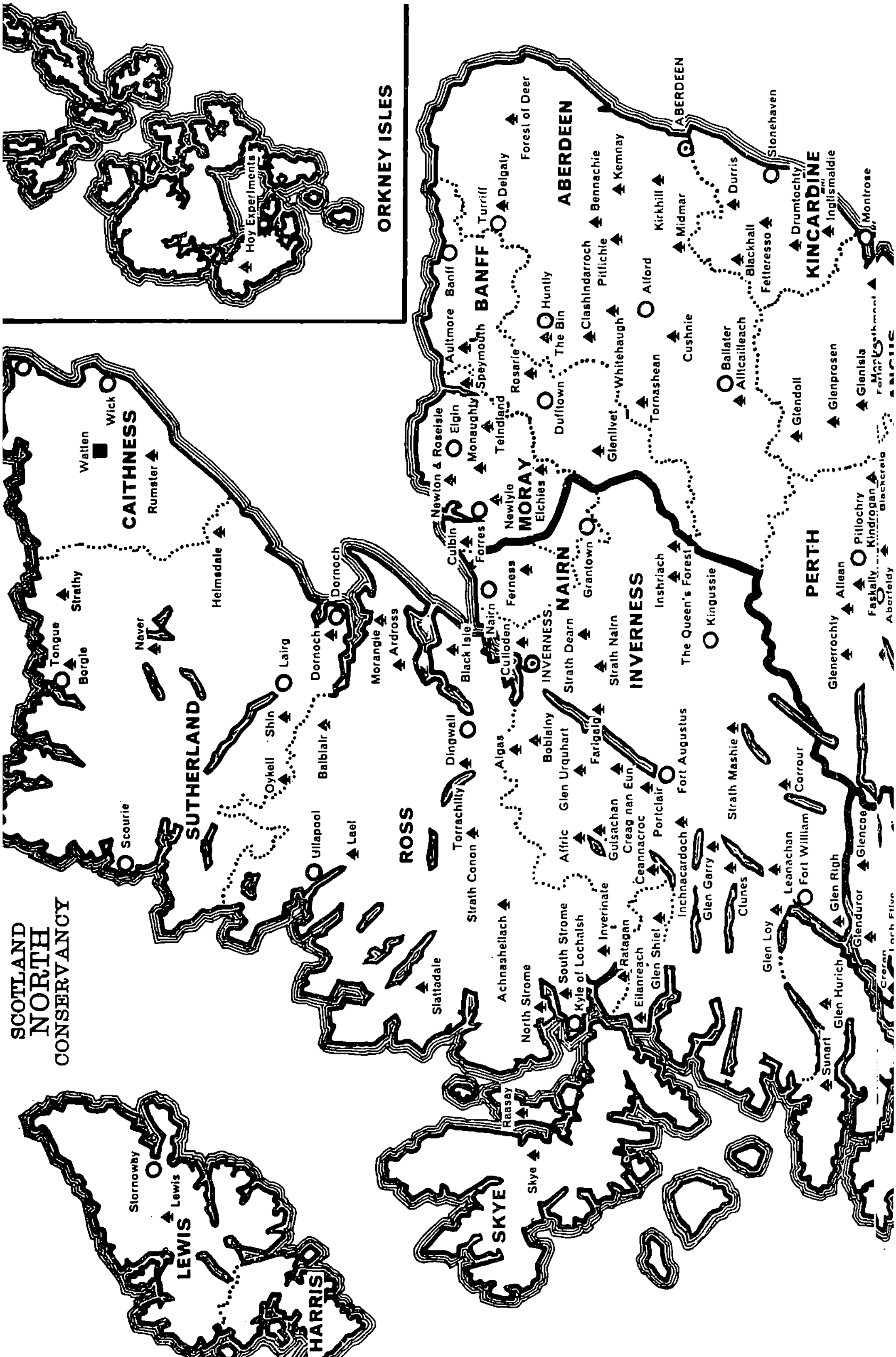
Hartland
Plym
Plymouth
Wilsey Down
Bodmin
Truro
Land's End
Parkhurst
Brighstone
Newport
Combley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Slattadale
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North Strome
South Strome
Kyle of Lochalsh
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Stornoway
Lewis
HARRIS
SKYE
Skye
Raasay
Culbin
Forres
Newton & Roseisle
Elgin
Monaughty
Teindland
Newtyle
MORAY
Elchies
Nairn
NAIRN
Ferness
Culloden
INVERNESS
Strath Dearn
Grantown
Strath Nairn
INVERNESS
Inshriach
The Queen's Forest
Kingussie
Algas
Boblainy
Glen Urquhart
Farigaig
Fort Augustus
Affric
Guisachan
Creag nan Eun
Ceannacroc
Portclair
Inverinate
Ratagan
Eilanreach
Glen Shiel
Inchnacardoch
Glen Garry
Strath Mashie
Clunes
Corrour
Leanachan
Fort William
Glen Loy
Glen Righ
Glencoe
Glenduror
Glen Hurich
Sunart
Banff
Aultmore
Speymouth
BANFF
Turriff
Delgaty
Huntly
The Bin
Rosarie
Dufftown
Glenlivet
Forest of Deer
ABERDEEN
Bennachie
Kemnay
Clashindarroch
Pitfichie
Whitehaugh
Alford
Kirkhill
Midmar
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Durris
Tornashean
Cushnie
Ballater
Allcailleach
Blackhall
Fetteresso
Stonehaven
Drumtochty
Inglismaldie
KINCARDINE
Montrose
Glendoll
Glenprosen
Glenisla
PERTH
Pitlochry
Kindrogan
Allean
Faskally
Glenerrochty


SCOTLAND
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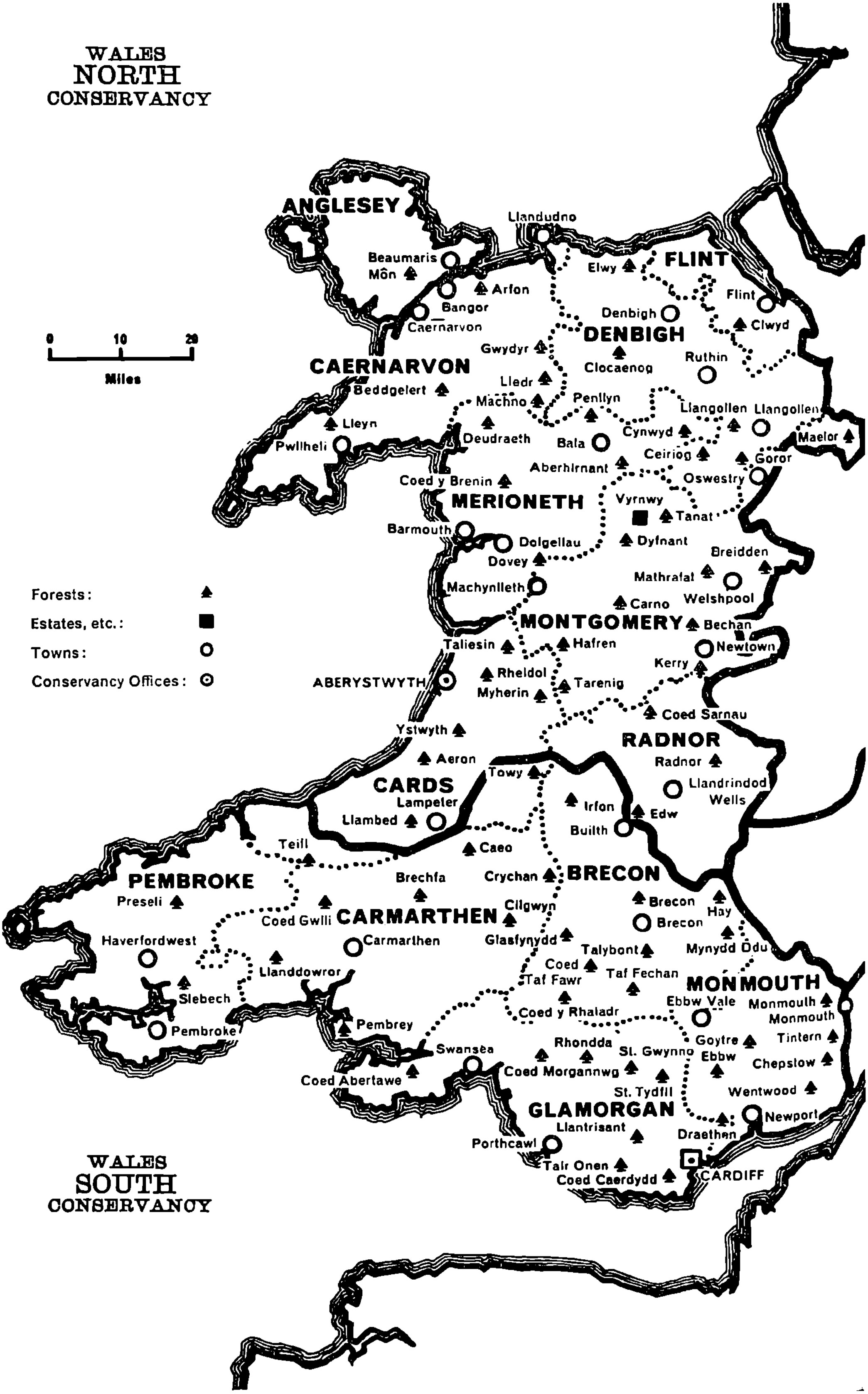
ANGUS
FIFE
KINROSS
PERTH
CLM.
STIRLING
DUNB.
RENFREW
ARGYLL
MULL
JURA
ISLAY
ARRAN
BUTE
AYR
LANARK
W. LOTH.
M. LOTHIAN
E. LOTHIAN
BERWICK
PEEBLES
SELKIRK
ROXBURGH
DUMFRIES
KIRKCUDBRIGHT
WIGTOWN
EDINBURGH
GLASGOW
DUMFRIES
0 10 20
Miles
Forests:
Estates, etc.:
Towns:
Conservancy Offices:


WALES
NORTH
CONSERVANCY
0 10 20
Miles
Forests:
Estates, etc.:
Towns:
Conservancy Offices:
ANGLESEY
Llandudno
Beaumaris
Môn
Arfon
Bangor
Caernarvon
FLINT
Elwy
Flint
Denbigh
DENBIGH
Clwyd
Gwydyr
Clocaenog
Ruthin
CAERNARVON
Lledr
Beddgelert
Machno
Penllyn
Llangollen
Llangollen
Lleyn
Deudraeth
Bala
Cynwyd
Maelor
Pwllheli
Ceiriog
Goror
Aberhirnant
Oswestry
Coed y Brenin
MERIONETH
Vyrnwy
Tanat
Barmouth
Dolgellau
Dyfnant
Breidden
Dovey
Mathrafal
Welshpool
Machynlleth
Carno
MONTGOMERY
Bechan
Taliesin
Hafren
Newtown
Kerry
ABERYSTWYTH
Rheidol
Tarenig
Myherin
Coed Sarnau
Ystwyth
RADNOR
Aeron
Radnor
Towy
CARDS
Lampeter
Llandrindod Wells
Irfon
Edw
Llambed
Builth
Teifi
Caeo
PEMBROKE
Brechfa
Crychan
BRECON
Preseli
Coed Gwili
CARMARTHEN
Cilgwyn
Brecon
Hay
Brecon
Haverfordwest
Carmarthen
Glasfynydd
Talybont
Mynydd Ddu
Llanddowror
Coed Taf Fawr
Taf Fechan
MONMOUTH
Slebech
Coed y Rhaladr
Ebbw Vale
Monmouth
Monmouth
Pembroke
Pembrey
Rhondda
Goytre
Tintern
Swansea
St. Gwynno
Ebbw
Chepstow
Coed Abertawe
Coed Morgannwg
St. Tydfil
Wentwood
GLAMORGAN
Newport
Llantrisant
Draethen
Porthcawl
Tair Onen
Coed Caerdydd
CARDIFF
WALES
SOUTH
CONSERVANCY

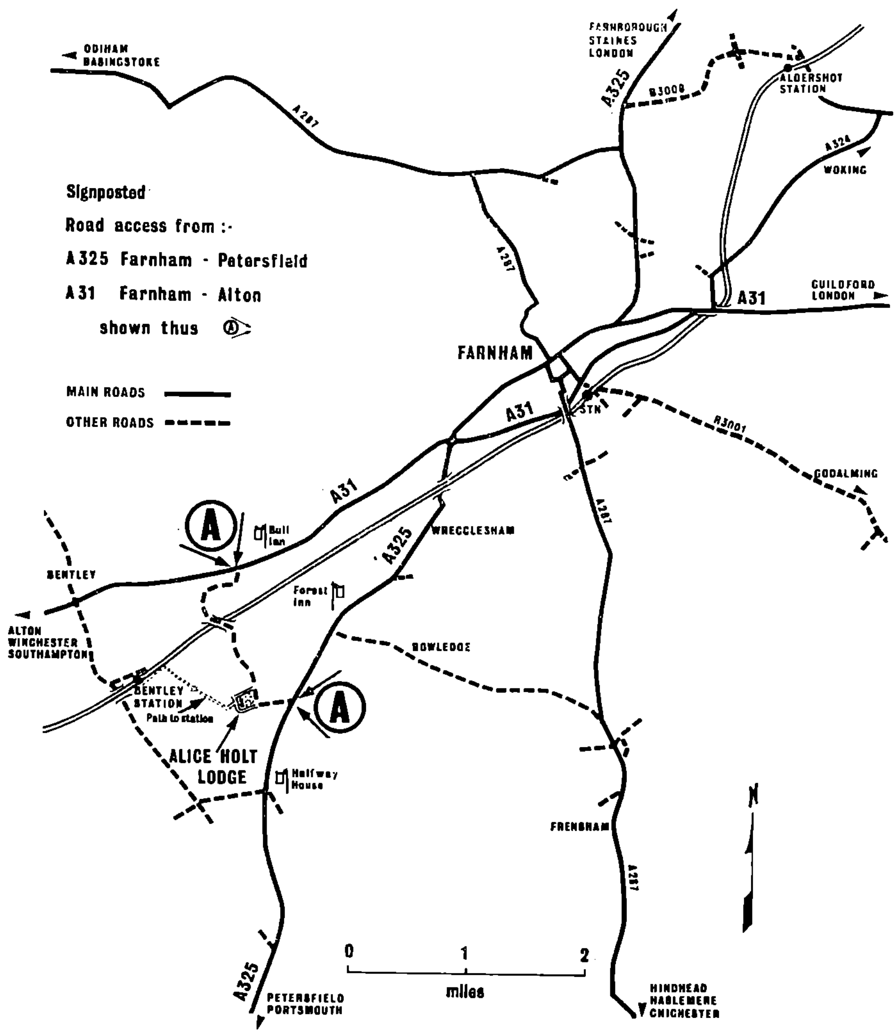


FIGURE 5: Approaches to Alice Holt Research Station, which lies 3½ miles south west of Farnham, Surrey, between the Farnham–Winchester road, A31, and the Farnham–Petersfield road, A325—A and A mark signposted approach roads.

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