REPORT ON

FOREST RESEARCH

1970

FORESTRY COMMISSION

LONDON
HER MAJESTY'S STATIONERY OFFICE: PRICE £1 10s 0d [£1·50] NET

FORESTRY COMMISSION

REPORT ON FOREST RESEARCH

for the year ended

March 1970

LONDON
HER MAJESTY'S STATIONERY OFFICE
1970

ADVISORY COMMITTEE ON FOREST RESEARCH

Membership as at 31st March 1970

Chairman

SIR FREDERICK BAWDEN, F.R.S.
Director, Rothamsted Experimental Station, Harpenden, Herts.

Members

DR. W. P. K. FINDLAY,
St. George's Hill, New House Lane, Salfords, Redhill, Surrey (formerly Assistant Director of the Brewing Industry Research Foundation).

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. R. L. MITCHELL,
Director, Macaulay Institute for Soil Research, Craigiebuckler, 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, F.R.S.
Professor of Botany, University College of Wales, Aberystwyth.

Secretary

MR. G. H. BOWERS,
Forestry Commission, Forest Research Station, Alice Holt Lodge, Wrecclesham, Farnham, Surrey. Tel. 0420–4 2255.

The abbreviated title of this Report is
Rep. Forest Res., Lond. 1970

CONTENTS

880191 A 3

The cover picture (described on inside front cover) and all other photographs are from the Forestry Commission's Official Photographic Collection. The diagrams in the Joint Fire Research Organisation's contribution were supplied by the author Dr. P. H. Thomas. All other diagrams were prepared by the Commission's Photographic Section, from data supplied by the respective authors.

INTRODUCTION

By G. D. HOLMES

Director of Research

This *Report* reviews the progress of research within the Research, Management Services, and Harvesting and Marketing Divisions of the Forestry Commission, with short reports on outside work done in conjunction with, or with some assistance from, the Commission. The style of the *Report* remains unchanged but we have tried with small amendments to the lay-out and index to make it easier to read selectively, and the summary at the beginning should give a general view as well as a lead to specific results and events reported.

Research Aims

The Open Days held at Alice Holt on 26th–28th June 1969 to celebrate the Forestry Commission's Jubilee were a very successful feature of the year, and over 2,000 invited guests and 3,000 members of the general public visited the displays. Eighty-six separate exhibits were presented to demonstrate our research aims and achievements. Although sections of our work have become progressively more specialised, particularly within the last ten years, the work remains closely orientated to practical ends, including advisory and extension work. Our main aims can be summarised as the enhancement of crop and man-power productivity in public and private forestry within the context of sound land management. This is a weighty sentence but places the emphasis firmly on research and development into means of increasing the production of industrial wood of the right quality and at the lowest cost—and much of the work on site, tree, and method improvement falls into this category. In addition, increasing attention is being required on problems of growing trees outside the strictly wood-producing context, i.e. trees for amenity and reclamation purposes, and trees for ornamental and landscaping use. Much of our production work is relevant to these aspects, and fresh research is mounted on these problems where it seems justified. Similarly, new emphasis has been given to assessment and improvement of the social and particularly the recreational value of forests, and Management Services staff are engaged in studies on this subject.

Research Facilities

Our new Northern Research Station at the Edinburgh Centre of Rural Economy is almost completed and the staff occupied the building in February 1970. This new Station (see Plate 1) will house existing staff of the Silviculture, Genetics and Statistics Sections who have been inadequately accommodated for years in Edinburgh ; there will also be additional staff representing the Soils, Pathology and Entomology Sections who for the first time will have laboratory facilities in Scotland. A major development is the fitting out of our new Physiology Section with its modern growth rooms and glasshouse facilities. For the first time, we shall have some of the equipment and physiological skills to begin study of variation in tree growth and the influence of environmental factors on growth under controlled conditions—facilities which are long overdue if we are to improve our understanding of the growth processes, the effects of experimental treatments, and means of improving

growth. The work of the Northern Research Station, and the centre at Alice Holt, will be planned as parts of a single research programme for the country as a whole.

Research Achievements

The most obvious gains from research come when new knowledge derived from a research programme leads to practical innovations benefiting costs and/or production. This may happen dramatically as, for example, with spring steel fencing, a new weed control technique, improved seed or provenance selection, or development of a new harvesting system. More commonly, however, the gains are achieved by a gradual improvement of forestry practice through better understanding, and the existence of expert specialist staff who are aware of research progress here and abroad, and are able to influence practical events through their contacts with forest management. In this context, a substantial proportion of research staff time is devoted to advice and consultancy, including training courses, etc., and we consider this work vital to application of up-to-date knowledge as well as contact with field problems. Dr. D. H. Phillips has summarised research progress on pages 7–25, and I would merely highlight some special features.

In the crop productivity field, the time factor looms large because of the long periods that may be required to produce answers from empirical field experimentation, notably from drainage/cultivation experiments, and from species/provenance/progeny trials; hence the increasing interest and activity in more intensive research methods often requiring complicated instrumentation as in some soil physics studies, or controlled environment work. Properly handled, such approaches could permit more rapid forecasting of crop performance and practical developments than hitherto.

Work on physical up-grading of sites to improve their rootability has led to advances in plough design and treatment specifications based on soil types. Good progress has also been made in intensive production of container plants to reduce costs and extend planting seasons. Control of weed competition, notably by herbaceous weeds and heather, still presents major problems and there are developments both in chemical and machine weeding methods. Special attention is being given to study of possible side effects associated with herbicide treatments.

A country-wide study of the silviculture and wood properties of Western hemlock, Grand fir and Noble fir has been completed and will be reported shortly. Sitka spruce is now the major species in our tree improvement work, and plus-tree selection is nearing completion. Useful advances were made in techniques for vegetative propagation of selected spruce as cuttings.

In the protection field, a survey of the pest and disease status of forests throughout Scotland and Northern England was initiated, and progress was also made in evaluating the increment loss associated with attack by the Green spruce aphid.

Labour productivity studies, including mechanical development, are featured more prominently in this *Report* than hitherto on account of their immediate importance to management in holding wood production costs. Progress is reported on several topics, notably in the development of timber harvesting equipment and systems.

Forest products research is also reported more fully, notably the work done under the joint Forestry Commission/Forest Products Research Laboratory (Timberlab) programme. The work on the influence of vigour of growth on wood properties of spruce is of special importance in terms of controlling the type of wood that we grow.

One of the outstanding benefits of research in recent years has derived from the co-operative programme of research between Rothamsted and the Forestry Commission on nursery nutrition. This extensive programme, which began in 1945 under the leadership of Rothamsted, terminated in March 1970 having achieved advances in methods and plant quality standards which have transformed nursery practice. This research under the Rothamsted lead, the principal results of which are published in Bulletin 37, *Experiments on Nutrition Problems in Forest Nurseries* (H.M.S.O. £3 10s.) can aptly be described as classic, and it is a privilege to record my tribute to the work of this joint team.

Planning

Our Research Advisory Committee met at Alice Holt in October 1969 under the Chairmanship of Sir Frederick Bawden. The Committee considered and endorsed the joint programme of research between the Forestry Commission and the Timberlab of the Ministry of Technology. An important part of the function of the Committee is through its Visiting Groups, the next one being in September 1970 to examine the work and organisation of our Silviculture, Soils and Ecology Sections—Sections which collectively account for over fifty per cent of Research Division resources.

During the year, B. W. Holtam led a Study Group on Project Evaluation in Research, and on the basis of the Group's report a simplified system of benefit/cost evaluation has been adopted for use on selected applied Research and Development projects as an aid to planning. The method requires great care and judgement in application, but it can be helpful and has recently proved to be so in evaluating the probable returns from several lines of research on *Fomes* butt rot, and on investments in seed orchards. In addition, a simple system of project costing and control by working time sampling has been developed, with the aim of providing broad cost data with the minimum inroads into research time.

Research Liaison and Communications

Very close links were maintained with Timberlab and with the Universities, particularly those with active programmes of research relevant to forestry. We continued to work closely with the Nature Conservancy and with their Woodland Research Station at Merlewood in Lancashire in particular. The Forestry Commission is represented on the Forestry and Woodlands Research Committee of the National Environment Research Council (NERC) of the Ministry of Education and Science. It is of course vital to foster a close association with NERC and its staff as plans are developed for NERC's new Institute of Forestry Research which it is proposed should be built near our own Northern Research Station on the Bush Estate, Edinburgh. The new Station should go a long way to meeting the agreed need for more fundamental research on the growth of trees and

tree crops, and we shall do everything possible to ensure close liaison with its new Director and staff.

The Division provides an advisory service to management, and most research officers function as extension officers directly or through the Research Liaison Officer. An important link with private growers is through the Scottish Woodland Owners Association and the Timber Growers Organisation which operates in England and Wales.

Conferences

The Annual Research Conference was held in January 1970, guests including T. A. Oxley, Director of Timberlab, and representatives of the Nature Conservancy and Macaulay Institute. Commissioners Dr. F. C. Hummel and G. G. Stewart attended, and for the first time three territorial Conservators, J. S. R. Chard, J. H. James, and E. J. M. Davies, attended the full Conference.

Our staff attended eighteen scientific and technical meetings or conferences in Britain, and a number of overseas meetings, including: Dr. D. H. Phillips (European and Mediterranean Plant Protection Organisation Working Party on Phytosanitary Regulations in Forestry, Florence); D. R. Johnston (FAO/ECE* Working Party on Forest and Forest Products Statistics, Geneva); R. Faulkner (OECD* Meeting on Control of Forest Reproductive Material Moving in International Trade, Paris); D. Bevan (The Nordic Forest Entomologist Group, Oslo); D. A. Burdekin and J. D. Low (Forest Pathology Group Meeting, Eire); D. A. Burdekin (FAO International Poplar Commission Working Party on Diseases, Vienna); A. A. Rowan and J. V. Crosland (FAO/ECE/ILO* Group on Mechanisation of Forest Work, Geneva); A. Whayman and R. T. Bradley (IUFRO* Joint Meeting on Thinning and Mechanisation, Stockholm).

Visitors

This year many visitors were channelled to the Open Days (see above). Nevertheless, a total of 533 visitors came from 26 countries at other times. They included parties from the University of British Columbia, the Czechoslovak Forestry Association and the German Forestry Association, and a Parliamentary Delegation from Nepal accompanied by three British Members of Parliament. Exchange visits of scientific staff took place between the Research Division and Long Ashton Research Station.

Courses were held for territorial Assistant Conservators and District Officers and two-day visits were made by forestry students from Aberdeen, Bangor and Oxford Universities.

Visits Abroad

At the invitation of Export-Kontor, Gartenbau, Hamburg, G. D. Holmes, Dr. D. H. Phillips and R. M. Brown visited Schleswig-Holstein to see nursery and planting techniques and discuss plant health legislation.

---

* ECE: Economic Commission for Europe. FAO: Food and Agriculture Organisation of the United Nations ILO: International Labour Office. IUFRO: International Union of Forest Research Organisations.

OECD: Organisation for Economic Co-Operation and Development.

D. R. Johnston visited Yugoslavia as a consultant on forest management.

Dr. A. M. Fletcher toured tree breeding stations in Norway, Sweden and Denmark.

R. M. Sidaway made a study tour of forest recreation areas in the U.S.A., following an academic year at Yale University.

Staff Changes

A. Watt, who was Director of Research from 1963 to 1965, retired from his post as Commissioner for Forest and Estate Management in November 1969. He was succeeded by G. G. Stewart, formerly Conservator West Scotland, who was a silviculturist in Research Division from 1955 to 1961.

J. R. Aldhous, on promotion to Assistant Conservator, became Principal Silviculturist (South) in succession to R. M. G. Semple, who took over from D. T. Seal as Principal Silviculturist (North). D. T. Seal left Research Division to join North Scotland Conservancy*.

D. A. Burdekin and G. M. Buszewicz were promoted to Principal Scientific Officer. Dr. K. A. Longman, of the Genetics Section, on promotion to Principal Scientific Officer, was appointed head of the Physiology Section at the Northern Research Station, to succeed Dr. I. D. J. Phillips who had resigned to take up a new appointment at Exeter University.

Other transfers and promotions were:

Dr. D. B. Redfern (Senior Scientific Officer, Pathology), from Alice Holt to Northern Research Station.

A. I. Fraser (District Officer, Silviculture (South)) returned after two years leave at Edinburgh University.

D. G. Pyatt (District Officer), Planning and Economics, to Soils (North) on return from a year's leave at Aberdeen University.

R. M. Sidaway (District Officer), Dean/South-west England Conservancy, to Planning and Economics.

R. C. B. Johnstone (District Officer), East England Conservancy, on promotion, to Genetics (South).

C. I. Carter (Entomology) was promoted to Scientific Officer, and T. G. Winter (Entomology) to Assistant Experimental Officer.

D. F. Fourt (Soils) was promoted to Chief Forester.

Miss M. Hopkin was promoted to Superintendent of Typists.

Mrs. V. O. C. Lampard was promoted to be Personal Secretary to the Director.

Departures from the Commission included Dr. S. A. Batko (Experimental Officer, Pathology), who retired after twenty years' service to research. His wide knowledge of the identification of the fungi was invaluable in building up the Pathology Section, and he became the first Mycologist to be appointed by the Commission.

R. B. Herbert (District Officer, Genetics (South)) resigned to take up work in private forestry.

---

* These moves took place during April and May 1970.

D. K. Lindley (Scientific Officer) and J. F. Varley (Assistant Experimental Officer), both of Statistics Section, resigned.

Miss O. A. Harman (Secretary to the Director) retired after almost forty years' service in the Commission, during over twenty of which she had acted as a loyal personal assistant to a succession of Chief Research Officers and Directors.

A. W. Coram (Illustrator) retired after three years as a Forest Worker followed by twelve years as Illustrator.

This year saw the retirement of two Chief Foresters, both from Silviculture (North). J. Farquhar played a large part in the successful experiments in afforestation on the unpromising soils of northern heathlands, notably at Teindland Forest in Moray. Later he was concerned in establishing the first experiments on the Shetland Islands, of which he was in charge at the time of his retirement.

J. Weatherell's major work was also in heathland afforestation, at Allerston Forest in Yorkshire. In addition, he was involved in experimental work on peats, especially at Kielder Forest in Northumberland, and was in charge of experiments in the Pennines.

Staff newly appointed during the year were:

Dr. C. M. Brasier and Dr. J. N. Gibb (Senior Scientific Officers, Pathology);

Dr. D. R. Causton (Senior Scientific Officer, Statistics (North));

R. C. Boswell (Experimental Officer, Statistics);

C. J. Ashton and Miss C. M. Ironside (Assistant Experimental Officers, Statistics);

Mrs. J. M. Boyd (Assistant Experimental Officer, Statistics (North));

E. J. Parker (Assistant Experimental Officer, Pathology);

I. S. D. Hay (Illustrator, Photography).

Appointments

Miss J. J. Rowe was elected a member of the Council of the British Mammal Society.

REVIEW OF THE YEAR'S WORK

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

PART I

RESEARCH DIVISION

Forest Tree Seed

Advantage was taken of the large crop of cones of Sitka spruce, particularly in West and North Scotland, to collect at minimum cost over 900 kg (2,000 lb) of seed, mainly by felling selected trees of good form. When extracting this seed it was found that the usual dry de-winging process was causing damage, and work was therefore done to perfect a less damaging wet method.

In laboratory tests aimed at discovering whether graded seed would produce more even-sized tube-raised seedlings, it was found that larger, heavier seed germinated more rapidly than smaller seed. Supporting nursery trials indicated that the larger seed also produced larger seedlings. Work on seed grading will therefore be continued.

Reports will soon be available on researches on the storage of seed of *Abies procera* and on the storage of seed dressed with lithofar red. Work on these topics will be concluded.

Collaboration with the International Seed Testing Association on testing rules and referee testing was continued. Assistance was given to the Commonwealth Forestry Institute, University of Oxford, for whom the processing, storage, testing and distribution of tropical tree seeds was carried out. The training of Seed Officers for overseas governments was again undertaken.

Production of Planting Stock

The main lines of research continued on slow-release fertilisers and on the development of methods for the large-scale production of tubed seedlings and of transplants raised in " Nisula " rolls.

Trials were repeated in seedbeds and transplant lines to compare fertiliser regimes based on " Enmag ", potassium metaphosphate and potassic superphosphate. Effects of the various regimes on seedling growth differed little, but in transplant lines the relatively insoluble " Enmag " and potassium metaphosphate gave better results than the readily soluble potassic superphosphate, which, probably as a result of the very dry summer, produced some scorch on Norway spruce and Grand fir.

Long-term experiments were continued to test the effect of repeated annual use of " Enmag " at up to four times the recommended rate. The fertiliser generally had little effect on seedling or transplant numbers, though it caused a marked reduction in seedling numbers of Western hemlock. It gave improved height growth of seedlings and transplants of most species, despite a considerable increase in soil concentrations of P and Mg.

In the south of England, transplants that had received various late top-dressings as seedlings again showed little resulting improvement in size or appearance at the end of the season.

A long-term fertility trial in Teindland heathland nursery, Moray, has demonstrated that continuous use of purely artificial fertilisers on such soils has not led to deterioration in seedling quality. The trial is now being closed.

In precision-sowing trials with paper-mounted, plastic-mounted and pelleted seed, all three, particularly the first two, showed slower germination than unmounted seed, and height growth of pelleted and paper-mounted seed was also somewhat reduced. Precision spacing has such potential advantages, however, that further work on these methods seems justified.

Simazine at or above the recommended application rate (2.24 kg/ha) gave excellent weed control in long-term experiments in southern England, but rates above normal damaged transplants of various conifer species. Bioassays after eight years of annual application indicated that if simazine is used at the recommended rate there is little danger of the accumulation of phytotoxic residues.

An extensive programme of greenhouse experiments continued at three centres in Scotland to develop satisfactory production methods for tubed seedlings of Lodgepole pine and Sitka spruce. The results indicated that no major changes were needed in the " standard " technique used for the past two seasons. However, there was some suggestion that modification of the fertiliser regime and the use of graded seed might increase the out-turn of usable seedlings.

At Alice Holt, trials of the " Nisula " roll transplant method continued, with the testing of various fertiliser regimes. Survival and growth of Sitka spruce and Grand fir in the rolls was excellent, but survival of Corsican pine was poor.

In small trials of intensive production methods at Alice Holt and Inchnacardoch, Inverness-shire, two successive crops of transplantable Lodgepole pine and Sitka spruce were successfully raised in greenhouses during the growing season. Seedlings from both crops were transplanted into rolls (and at Inchnacardoch also into ordinary nursery soil) ; so far survival and growth have been good.

Planting

Most work on planting was done on the establishment of tubed seedlings and " Nisula " transplants. Trials with tubed seedlings began in 1967, and assessments this year of these early experiments suggest that such plants are probably suitable for use on ploughed deep peat sites. Survival of the plants has generally been encouraging. Though some animal browsing occurred, it was less serious than was expected, and most of the affected plants recovered. Tubed seedlings have benefited very clearly from " step " planting, and to produce a ridge in which a satisfactory step can be cut single mould-board or *deep* double mouldboard ploughing would appear to be necessary. May, June and July planting have so far given the best results (both in survival and in height growth), with a gradual falling off in August and September and a

more substantial fall in October. There appeared to be little to choose between 8- and 12-week-old seedlings or between a range of tube soil mixes tested. Subject to some further tests, the choice would seem to lie with the planting stock that costs least to produce.

A further ten experiments planted in 1969 in Scotland and Wales have given promising results, and plantings on a larger scale in blocks of up to 4 hectares in selected peatland forests are planned for 1970.

On mineral soils tubed seedlings have met with less success. Frost lift has been excessive in almost all treatments and all experiments. As a result, both survival and height growth have been poor. Performance has improved on sites with increasing depths of peat over the mineral soil, but results indicate that tubed seedlings, at least of the size and type so far tested, are not suitable for afforestation on mineral soils unless sufficient peat covers the soil to form not less than half the thickness of the plough ridge. Hence future experimental work on mineral soils will be very limited, at least until techniques for establishment on peat have been fully worked out.

"Nisula" transplants were also planted out in both peat and mineral soils, but so far survival and growth have at best been no more satisfactory than those of plants produced by present standard methods.

Choice of Species

Trees in a single plot of Oregon alder (*Alnus rubra*) on a deep infertile peat at Shin Forest in Sutherland have reached a height of about two metres in two seasons after planting and fertilising with phosphate and potash. A subsequent review of available information on this and other alder species indicated, however, that although several species make initial rapid growth on acid peats, a characteristic deterioration takes place after 10 to 15 years. The alders can themselves secure adequate nitrogen, and falling off in growth may perhaps be due to a lack of potassium and phosphorus. The choice of species on northern deep acid peats is at present restricted to Lodgepole pine and Sitka spruce, and over extensive areas to Lodgepole pine alone. The ability to grow a broadleaved species, if only for its amenity value, would therefore be useful, and limited further work on the nutrition of Oregon alder has been planned.

Research on the performance of species on gley soils was concerned mainly with continued experiments to study the effect on growth of pole-stage Sitka spruce of defoliation by the Green spruce aphid, *Elatobium abietinum*. Unsprayed crops on three sites were again compared with controls sprayed with malathion. In the Forest of Dean infestation this year was high. The foliage retention was increased by spraying, but increment of both treated and untreated trees fell sharply in 1969, and there was no gain from the 1969 treatment. Over the three years of the experiment, however, the net gain in radial increment of the sprayed trees was 1·30 m^2/ha. At the other two sites, at Rosarie and Fetteresso in East Scotland, infestation was low in 1969, and differences in increment attributable to the treatment were negligible.

This season, fifteen years after planting, an assessment was made of a mixture experiment at Clashindarroch Forest in Aberdeenshire. The soil was freely draining and the dominant vegetation was heather, *Calluna vulgaris*.

Eight species of spruce and seven of Silver fir were planted with, and without, Japanese larch nurses. The spruces are now above the heavy growth of *Calluna*, which has been partially controlled by weeding. All those planted with larch nurses have shown an increase in height growth, some species benefiting more than others.

As an aluminium smelter and an oil refinery are to be built near Invergordon, Ross-shire, arrangements have been made to measure the levels of air pollutants in tree foliage and to study the lichen flora of the area before and after the start of the industrial operations. The first foliage sampling and the survey of the lichen flora have now been completed. Monitoring of sulphur dioxide (SO_2) levels round the Westfield gas works, Fife, has now been terminated after nine years. From the results it appears that the gas works has not significantly increased the sulphur dioxide content of the atmosphere in the surrounding area, and no damage to tree growth specifically attributable to its presence has been identified.

Work on the propagation of English elm (*Ulmus procera*) from softwood cuttings, using bottom heat and automatic mist irrigation, has given encouraging results. Studies on the propagation of Leyland cypress and London plane were also carried out.

Minor Species Survey

The evaluation of the possible place in British forestry of the minor species Western hemlock, Western red cedar, and Grand and Noble fir has been completed. Results suggest that Noble fir and Western red cedar will not be major components in future British forests. Grand fir and Western hemlock have greater prospects in suitable circumstances as alternatives to present major species.

Provenance

Eighty-six provenances of Lodgepole pine, collected in North America in 1965/66, were sown in 1968 in four nurseries, two in Scotland and two in England. The seedlings and transplants of the various provenances have shown differences in germination time, number of seedlings at the end of the season, height growth (which was associated with seed weight), root/shoot ratio, and autumn colour. The plants have now been put out in forest experiments. Gaps in the collection are being filled by provenances collected in 1966/68, now sown as part of an international provenance experiment.

For six years, analyses have been carried out of the needles of the plants in a Lodgepole pine provenance experiment containing six provenances and planted in 1938. Analysis of the results has shown significant variations between provenances in needle weight, and in N, P, and K content of the needles. These findings could be of value in provenance identification.

A large collection of Douglas fir provenances was made in 1966/68 by the International Union of Forest Research Organizations. Twenty-nine of these provenances were selected to represent in some detail the part of the range covered by this tree that older experiments have indicated as most promising. They were sown in two nurseries in Scotland and two nurseries in southern England. In Scotland, the provenances have shown differences in

date of germination, number of seedlings per plot, seedling height, needle colour, and in susceptibility to frost and to damping-off fungi. Losses in the nurseries in the south have hampered the work there, and the southern experiments are being resown in 1970.

Arboriculture

The Forestry Commission's Golden Jubilee was marked at Bedgebury Pinetum, Kent, where Mr. Winston Churchill planted a commemorative tree and unveiled a plaque at Churchill Wood, renamed and dedicated to the memory of his grandfather, Sir Winston Churchill, K.G. A ten-year plan for the development of Westonbirt Arboretum, Gloucestershire, is being implemented, and areas have been cleared for the extension of the collections of *Sorbus, Quercus* and *Betula.*

Further additions were made to the *Eucalyptus* collection at Kilmun Arboretum, Argyll, and at Crarae Arboretum, also in Argyll, where public access was improved by the completion of a new forest road.

A new *Short Guide to Bedgebury Pinetum and Forest Plots* was published during the year. (H.M.S.O. 9d).

Nutrition of Forest Crops

In experiments on phosphate treatment at planting on deep peats, growth on a very poor but sheltered lowland peat bog was better than that on richer but more exposed peat sites, which indicates the possibilities of apparently unpromising but sheltered areas.

Trials on the early application of nitrogen, in the year after the planting of Sitka spruce on poor unflushed peat, indicated that such early nitrogen treatments are unnecessary, and may indeed by detrimental by depressing uptake of P and K.

Among the experiments on gley soils was one at Kielder Forest, Northumberland, in which the trees were given either no fertiliser or else only a small quantity of P at planting. Early growth was good, but after fifteen years has become very slow. Top-dressing is therefore being tried in such experiments.

Work on Sitka spruce on a *Molinia*-dominated peaty gley has shown that K deficiences may be encountered on such sites, and may be accentuated by manuring with P.

Evidence from experiments on the application of fertilisers to pole-stage crops of Scots pine of low yield class on freely-drained soils shows that the maximum response is given in the third year, and no further effects are to be expected after the sixth year after application. Work is now needed to examine the results of further applications, both at the end point of the present known effect and at the point of maximum response. So far, however, it has been found, at least in some experiments, that additional growth has not paid for the materials used, or has been only marginally profitable.

Experiments on pole-stage manuring of crops of higher yield classes on freely-draining soils gave conflicting results, with good responses in some cases and poor ones in others. Varied results, from rapid to negligible, were also given in experiments in which pole-stage Sitka spruce crops already treated with N or P were given a second P treatment.

Following earlier research results, large areas of checked or unsatisfactory crops have now been treated with fertilisers. An attempt was therefore made to assess the responses to these treatments. It was often difficult to reach well-based conclusions, but the evidence suggested that most treated crops of Sitka and Norway spruce and of Scots pine had improved, sometimes dramatically.

Forest Weed Control

Three trials to test the risk of damage to crop trees from applications of chlorthiamid to control herbaceous weeds and grasses will be continued with annual applications for three years. Results this season confirmed those of preliminary tests, as survival of Western hemlock, already known to be susceptible, was reduced at one site (though height of the surviving trees was unaffected), and Corsican pine and Norway spruce (respectively resistant and intermediate) were undamaged.

Atrazine was tested at five sites, primarily for control of grass in coniferous species. Although the trees were not protected from the spray, crop damage was slight, and occurred only at the heaviest rate used. Application was more effective in March and April/May, rather than in June. Many, though not all, grasses were effectively controlled, with beneficial effects on height growth of the tree crop.

Generally good control of bracken was given by dicamba. Residue from winter applications of this chemical has previously caused some damage to the succeeding crop, so this season autumn pre-planting treatments were tested. Some damage to spring-planted crops still resulted. Grand fir at the Forest of Dean suffered heavy losses, but European larch, Douglas fir and Corsican pine recovered well after superficial damage. Scots pine and Sitka spruce were not affected.

Tree injection of 2,4,5–T to kill broadleaved trees, when used at a rate of 0·9 ml of undiluted unformulated chemical, gave results comparable with those by basal bark spraying or frill girdling. When 2,4–D was used similarly it gave less satisfactory results. At least a further season's work is needed to test both these materials used in this way.

Extensive work, mainly in Scotland, was done on the control of heather in young crops of Sitka spruce and Lodgepole pine. Applications of 2,4–D in May, just before flushing of the trees, gave less satisfactory control than did the recommended August treatments, mainly because regrowth of the heather took place in the autumn. Nevertheless, the colour of the trees improved, and in experiments on *Calluna*-dominated plots in which fertiliser comparisons were also included, following May applications of 2,4–D, both species showed marked increases in the uptake of the three major nutrients. If damage to the crop is to be avoided, the timing of these spring applications is important, and must be related not to calendar date but to time

of flushing. In other experiments on the control of heather, picloram, 2,4–D, and 2,4,5–T, separately and in mixtures, have been compared. Early indications are that picloram takes effect more slowly than the other chemicals, and is translocated more effectively. It was also noted that Lodgepole pine, which is damaged by 2,4–D, was not affected by picloram.

Soil Studies

Now that investigations already done have given us some understanding of soil moisture and drainage problems in the lowland areas, work is beginning on the more complex problems in the northern and western uplands.

Studies on a heavy silty clay soil at Halwill Forest, Devon, show that considerable benefits from mole drainage have persisted for eight years. In an experiment on heavy soil at Bernwood, Oxfordshire, so far pure crops of Scots pine and Norway spruce have not shown growth differences related to drainage, but in mixed plantings of beech and pine and of oak and spruce, all species, particularly the broadleaved ones, have responded to drainage improvements.

Work has now begun on the physical properties of some soils with indurated layers. The sites studied are on ironpan soils at Teindland Forest and Black Isle Forest, and on surface-water gleys at Culloden Forest and Black Isle Forest, all in northern Scotland. Results so far suggest that bulk density of the fine-earth fraction of the soil gives a good indication of the physical conditions associated with induration. The bulk density figures from the indurated layers examined were higher than those from normal soils, and well above those usually taken to indicate limiting conditions for root penetration.

Drainage

Following recent studies on deep peat sites, a new double mouldboard ploughing technique has been developed that promises to give intensive local drainage on such sites, together with a wide enough platform between drains to give crop stability. A plough has been designed for this work, and has performed well in an experiment and in an extensive field trial, in which it was tested on peaty gley soils as well as on deep peat.

Promising results after six years in a trial of drainage by rigg and furr at Allerston Forest in Yorkshire suggest that this method may be of value in dealing with heavy-textured gley soils.

In the south, the sixth and last of a series of drainage experiments on gleys has now been established at Crychan, Brecon. Borehole readings for the first year after drainage show a fall in water levels only in those plots with the deepest drains (0·9 m) at the closest spacing (10 m).

Cultivation

A new plough—called the "Sickle" plough because of its shape—has been developed to deal with severely compacted soils and felled woodlands. It will subsoil to 0·9 m (3 ft) and mix and overturn topsoil some 0·6 × 0·6 m (2 × 2 ft) in cross-section. It has been used for cultivation for research purposes on ironpan and gley soils with indurated subsoils, and has been successfully

tested in the field under felled woodland conditions at Black Isle, Speymouth and Allerston Forests. Pine stumps up to 45 cm in diameter have been ploughed out with no great difficulty. (See Plate 2.)

Crop Stability

Analysis of anemograph records and of wind damage to crops in forests in Dumfriesshire and Cumberland suggests that serious damage begins when gust speeds exceed 60 knots.

Records of windthrow in Forestry Commission forests collected over the past nine years have been summarised for publication. A cheap method of aerial photography may provide a means for the precise recording of wind damage over large areas, and trials to test it have therefore been arranged in north-east England.

Sample trees of Scots and Lodgepole pine and of Sitka spruce were pulled out at Allerston Forest and Kielder Forest to further investigations into the relationships between soil profile, root development and tree stability. In a peaty gley soil at Kielder, roots of Lodgepole pine had penetrated almost twice as deeply as those of Sitka spruce.

Regeneration

On gley soils at Kielder Forest in Northumberland, large-scale replanting after clear felling has been accompanied by high losses in the first year. Major site changes appear to result from extensive felling on such soils, and investigations of the resulting establishment problems have therefore begun.

Assessments were made in two experiments in which six years previously various species had been underplanted under larch. At Drumtochty, Kincardineshire, a significant decrease in height growth with increasing overwood density occured only in Lodgepole pine and Sitka spruce, though foliar analyses of chlorophyll content and sugar concentration of the underplanted trees indicated generally marked differences between overwood densities. At Radnor Forest in Mid-Wales, of seven underplanted species, Western hemlock was the most vigorous and *Abies alba* the least. Sitka spruce and Douglas fir were next in vigour to Western hemlock, but the spruces and Douglas fir grew less well under an overstorey of 500 stems per hectare than they did in the open. The larch overstorey showed no check in growth even after the most severe thinning on the exposed sites at Drumtochty.

In Thetford Chase, Norfolk, at one site where eighteen species have been planted under an overwood of Scots pine, two-year-old Grand fir suffered considerable frost damage where the overstorey contained less than about 250 stems per hectare. On two other sites, *Fomes annosus* has killed underplanted trees in several plots of the fastest growing species, mainly those of Western hemlock, Leyland cypress, Douglas fir and *Nothofagus obliqua.*

Some of the areas in Scotland cleared after the gale of January 1968 may be restocked with Sitka spruce by natural regeneration. Distance of dissemination from seed sources is therefore being investigated. A study of survival of natural seedlings is also being made, and so far has indicated that half the seedlings die in the first two years after germination, with the heaviest losses occurring in the first summer.

Ecology

Work on growth problems in forests of the South Wales Coalfield area was hindered by staffing problems, but a good deal of site survey work was done. There were indications from one area that growth of the Sitka spruce crop there, which had previously been good, had been adversely affected by the hard winter of 1962/63, though more work is needed to investigate the matter further.

Forest Genetics

Older Scots pine seed orchards in east and south-west England and central and north-east Scotland, and stands of Sitka spruce and Japanese larch in west and north-west Scotland produced heavy cone crops. Lodgepole pine of Alaskan origin coned well in the far north of Scotland, and good beech crops occurred in south-west Scotland and north-west England.

Some years ago, owing to difficulties at Newton Nursery, Moray, both in obtaining good growth and in establishing grafts, it was decided to move the National Douglas fir tree bank from Newton to Westonbirt, Gloucestershire. Good progress has now been made with the transfer, and on-site grafting using well-established rootstocks has been particularly successful.

Work on the rooting of cuttings has given promising results with Sitka spruce under "mist", using short cuttings obtained from young plants and from an older, deer-browsed tree. It appears that cutting material of this type may not present the problems of later plagiotropic growth often associated with cuttings of middle-aged and older spruces, Douglas fir and larch. When birch seedlings, cuttings of which are usually difficult to root, were girdled just above the root collar and kept in a moist atmosphere, they produced numerous roots above the ring. This may provide a means for the clonal multiplication of difficult species.

In studies on the control of flowering, Western red cedar produced many female flowers in response to branch girdling, and male and female flowers were successfully induced in one-year-old cuttings of *Metasequoia glyptostroboides*.

To provide data for quantitative work on the inheritance of measurable characters in Sitka spruce, the most important commercial conifer grown in Britain, a population study has been initiated of Sitka spruce of Queen Charlotte Island origin, using a middle-aged stand at South Strome Forest, Ross-shire, for the purpose. One-hundred-and-fifty heavily seeding trees representing all the size-classes have been selected and will be progeny-tested.

Work on controlled pollination has centred on the crossing of Sitka spruce with five other spruce species, and on an extension of the programme of inter-provenance crosses of Lodgepole pine to make additional "coastal" × "inland" provenance hydrids. Of the spruce crosses only one with *Picea likiangensis* produced viable seed.

A programme of research on early-testing continued at Alice Holt, where Sitka spruce progenies resulting from a 7 × 7 diallel crossing pattern were raised in the partially controlled environment of a glasshouse. Detailed results

are not yet available, but during the first growing season it was noted that one parent responded strongly to long-days.

Trials with a mechanical tree shaker used for harvesting cones from mature trees were not successful on Sitka spruce, Scots pine, Noble fir or Western hemlock. There were indications that the machine might be useful for Douglas fir (see Plate 10).

Forest Pathology

Work on techniques for removal of stumps to eradicate sources of *Fomes annosus* on alkaline pine sites suggested that on balance a method using a Challenger 33 with a grubber blade was the best of those tested. Economic calculations showed that the cost of removal is only just balanced by the direct benefit resulting from disease control, but other benefits, including cheaper and better establishment of the succeeding crop, may make the process worth while.

A method of site survey was devised to enable field staff to assess likely losses from *F. annosus* attack on replanting.

In continued studies on susceptibility of Grand fir and Western hemlock to *F. annosus* butt rot, the susceptibility of hemlock was confirmed. Grand fir was found to be resistant on most sites, but significant decay was present in three stands, which will be further studied.

Biological control of *F. annosus* in pine stands by inoculation of stumps with the fungus *Peniophora gigantea* has continued on a forest scale, and a new liquid formulation in small glass phials has replaced the former tablets, so that overnight soaking to form a suspension is no longer necessary.

In Scotland and northern England, a disease survey of pests is being carried out, mainly to identify disorders that require research, and so to give a sound basis for the research programme of the Pathology staff of the Northern Research Station. The species being surveyed are Scots and Lodgepole pine, Japanese and Hybrid larch, Norway and Sitka spruce, Douglas fir, and Western hemlock, and any variation from normal health and vigour in the crops sampled is being noted. About a third of the stands examined so far have shown some kind of disorder, though often to only a minor degree. The commonest problem was growth check in the spruces, though death of pine caused by *Fomes annosus* was commoner than had been expected, and Norway spruce often showed damage by timber extraction and by deer.

For some years past, a serious dieback has been affecting London plane, *Platanus acerifolia,* in central London. An investigation of the problem was therefore made. At present it appears that the damage is probably caused by over-rapid thawing of twigs and small branches on sunny mornings after cold nights. Some clones of the tree among the London population seem to be resistant to the disorder, so it may be possible to select from these for future planting.

Advisory work continued to increase. About 80 per cent of the queries came to Alice Holt from Wales and the southern part of England, and the rest, from Scotland and northern England, were dealt with by the Northern Research Station.

Forest Entomology

In most parts this year the pupal survey figures for the Pine looper moth, *Bupalus piniarius,* showed little change from 1968/69, but in the Hambleton and Pickering districts of Yorkshire infestation proportions were reached in some blocks.

Some preliminary information has been obtained on the penetration and persistence of BHC in bark sprayed against attack by *Tomicus piniperda.* After one month, about 15 per cent of the original deposit had penetrated to the inner bark. Biological studies continued on various *Hylastes* spp. Future work on the control of these bark beetles, and of the Large pine weevil, *Hylobius arbietis,* is designed to test materials for use as alternatives to the organochlorine insecticides.

Investigations have continued on host plant susceptibility to the Green spruce aphid, *Elatobium abietinum,* and on the forecasting of attack by this insect. Further information has been collected on the distribution and hosts of the common but little-studied conifer aphids grouped in the *Cinarinae.* Special attention has been paid to the possible association of Adelgids with dieback of larch. Experiments using winter washes to control Adelgids have given promising results.

Entomological factors affecting growth and survival of young crops are being investigated in a number of sample sites spread over the whole country. So far, on most of the sites, the young trees have been damaged more by blackgame, hares, deer, frost, drying winds, and weed competition than by insects.

Work at Alice Holt on the identification of the more difficult micro-lepidoptera adds continually to the list of recorded insects.

Mammals and Birds

Promising trials using Warfarin to kill grey squirrels were carried out to confirm the effectiveness of the chemical and to devise methods of baiting that do not endanger other animals.

In work on deer, red, roe and fallow deer were marked by freeze-marking with dry ice and liquid nitrogen. The dry ice method proved the more satisfactory.

It was found that the bird-scaring cartridges used in starling roost dispersal could be fired satisfactorily from a 1½-inch Verey pistol with a 12-bore sleeve adaptor.

The use of spring steel fencing can save very large sums, and new methods of joining wires and of fixing wires to netting were developed. The effects of atmospheric corrosion on the life of various fencing materials are being studied in an unpolluted area, in one subject to industrial pollution and in one subject to salt spray and blown sea sand.

Statistics and Computing

Early in the year, the Statistics Section was rehoused in an up-to-date building and the staffing of the Section was improved. Training in statistics of junior statistics staff has continued, and the first of a series of courses for Research Foresters was given.

Service work has continued for Research and Management Services Divisions, that for the latter including the completion of the main work on the census of private woodlands.

Work on a method of audio data-capture for use in the field has pressed ahead, and a suitable system now seems to have been evolved.

Some time was found for studies in statistical methods, particularly in relation to a model of tree growth and to nursery sampling.

Research Workshop

Among the items made for the Commission's Jubilee exhibitions and open days was a quiz unit in which colour slides of forest birds and animals could be matched by press-buttons with tape recordings of their sounds. This was prepared in collaboration with the Photographic Section.

Samples of a movable 2-man high seat for use in wild-life control have been made and offered for testing in field Conservancies, and a 1-man seat is also undergoing preliminary trials.

The usual engineering service was provided for the Research Sections, and much time was spent in devising and supplying metric conversion equipment in preparation for the impending change to the metric system.

Photography

Much of the time of the Section was spent in the preparation of photographs for the Commission's Jubilee exhibitions and open days. In addition, however, a much needed reclassification of the photographic collection to speed access has been almost completed, and to prevent loss or damage to originals, duplicates for loan have been made of a large proportion of the colour transparencies.

Publications

Ten new priced publications were isued through Her Majesty's Stationery Office, and twelve others were revised and reprinted. In addition, three new unpriced publications were issued, and twelve others were revised and reprinted.

Research Information

Loans made by the library continued to increase, and the preparation of a new library catalogue was almost completed. A further enlarged and revised "Keyword Index to Selected British Forestry Literature" was produced with the aid of the computer.

Almost all the Commission's territorial Assistant Conservators and District Officers have now attended one of a series of Research Appreciation Courses. At these courses it has been possible for research findings to be discussed and for the field officers to make their needs and problems known to research workers. One course was held this year, to complete the present series, and future arrangements are now being considered.

MANAGEMENT SERVICES DIVISION

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

Planning and Economics

In studies on policy and corporate planning, work on research evaluation was done to examine the costs and benefits associated with seed orchard research and investment. All the assumptions that have to be made in such investigations may not be valid, but it appeared that, because the financial benefits from seed orchard investment are long in coming, they are not outstandingly impressive if compared with some short-term projects. The best candidate for further research and investment in this field is clearly Sitka spruce.

A good deal of work intended ultimately to assist the forest manager was done on fire incidence and loss. It is hoped that some of the results may be used to assist speculation on the likely outcome of reducing expenditure on fire protection, and also to help in the detection of changes in the fire situation resulting from changes in the protection policy.

A report was made on a recreational survey carried out in the summer of 1968. In this, an attempt was made to estimate the numbers of recreational visits paid to Forestry Commission land in the period from the beginning of June to the end of September, and the survey covered most of Great Britain. The results suggested that between 10 and 18 million visits were made to Commission land during the period, and the survey gave useful indications for the improvement of censuses on the recreational use of forest areas.

Over eighty per cent of the work on metric revision and updating of area and yield class data was completed. Much of the time of the Mensuration Section was also concerned with the impending change to the metric system, and most of the necessary tables are now ready for publication.

Some topographical and site survey studies were also carried out, and several regional soil guides are in preparation.

Work Study

This year, Work Study has been more fully reported than previously. Most of the work done has been in the main fields of forest management and harvesting, and a few miscellaneous studies have also been carried out.

After work with the semi-circular spade it was concluded that this tool can be recommended particularly for use on ploughed peat sites that are not too exposed. In suitable areas it can raise the planting rate from about 1,200 to 1,500 or 1,600 trees per day.

Designs were produced for tools for use in planting tubed seedlings. Encouraging results were gained in trials in Thetford Chase with a Finn Forester tree planter.

Development work with the Lokomo plough and its associated tractor was completed, and preliminary studies were done on the Oja-Viska ditch digger and other equipment to seek ways to mechanise drain maintenance, which in most areas remains an expensive manual task.

Fertiliser distributors often give a very uneven spread. After a study of several machines it was concluded that distribution patterns could be much improved when granulated phosphate became available. Of the machines studied, the Vicon tractor-mounted model has the advantage that it makes it possible to plough and distribute fertiliser at the same time.

Trials using a tractor-mounted mistblower to apply weedkillers gave good results, and the costs of the treatment were considerably lower than those incurred when using a knapsack mistblower. Tests were also begun with two small hand-held ultra-low-volume sprayers.

Work on tree injectors to kill unwanted weed trees has been continued, and provisional recommendations made for the use of these tools.

For the mechanical control of weeds, a front-mounted heavy-duty brush cutter has been built to cut woody growth, and a roller of an advanced type has been produced to control grass.

In comparative trials on plots set up in 1966/67, it was established that, in general, machine weeding costs less than chemical treatment, which in turn costs less than hand weeding.

Some work was done on brashing by means of chainsaws modified or fitted with special attachments. One machine, when fitted with a prototype attachment, did brashing of good quality, but was heavy and slow, and subject to excessive vibration. Further work seems warranted.

Harvesting studies were done on the design and production of new equipment, the testing of commercially available machinery, and method study and work measurement of operations.

In co-operation with outside industry, a ruggedly constructed hydrostatic frame-steering 75 brake-horse-power skidding tractor was developed. (Plate 7.) Designs have also been drawn up for a similar but smaller machine.

A series of hydraulically-operated timber tongs for use in timber extraction has been developed. Indications are that in Thetford Chase, where in the past manually-operated tongs have long proved useful, the hydraulic version will reduce extraction costs very considerably. (Plate 9.)

Other work has been done to develop a trailer to aid in the efficient working of cable cranes by keeping clear the site around the tractor and winch, and to produce an improved nose-cone for ground-skidding winches.

In machinery trials, the Massey Ferguson Treever 2200, a timber forwarder, was tested, and its trailer modified so that the machine can carry timber as well as pulpwood.

The Hough Paylogger, a frame-steering skidding tractor, has also been tested over several years, and would appear to have a place on flat and moderately sloping sticky clays and shallow peats if the latter are covered with brash. Its use will only be justifiable, however, in areas with a large annual programme of extraction.

The Volvo LM 840 loader was used at Thetford Chase in the experimental removal of stumps for the control of *Fomes annosus*. This and the smaller LM 640 were therefore used in harvesting operations to compare them with machines used in current harvesting systems. In these trials the costs of various harvesting systems using the LM 640 were lower than those using the other equipment tested.

Other work was done on the Agria Drabant skidder, a light tracked machine developed in Norway, and on skyline systems for use with cable cranes.

From a study of various shortwood and tree-length harvesting systems it seemed likely that in time tree-length systems will be increasingly favoured because they save labour and also allow labour to be redisposed in depots, where the working environment is more favourable and where time lost on account of bad weather should be reduced.

Work on the felling phase of line thinning in the spruces was concluded, and a report is being prepared.

In connection with work by Harvesting and Marketing Division on the use of pulverised conifer bark in horticulture, a machine was developed to process bark at Brandon Depot in Thetford Chase.

Also at Brandon Depot, a hydraulic lifting device was developed to lift poles to the sawbench for cross-cutting. The prototype needs further work to make it fully automatic.

Other work has been carried out on the economics of roads (particularly those constructed before plantation establishment begins), on the problem of chainsaw vibration, and on the role of radio equipment in harvesting operations.

HARVESTING AND MARKETING DIVISION

Timber Utilisation

Work on the use of bark in horticulture continued to show promise, and a wide range of horticultural crops was raised in potting composts containing bark.

An experiment was undertaken to investigate possible treatments to prevent needle fall in Christmas trees. The two most promising methods were to retain the freshly-cut butt under water, or to dip the foliage in a solution of alginate ; both these methods gave an 80 per cent reduction in the dry weight of needles shed. Sealing the butts with bitumen also gave good results, needle fall being reduced by nearly half.

Assessments of the service given by fence posts, of different species, treated with creosote or with waterborne preservatives. were made for the twelfth successive year in Scotland and for the seventh successive year in England and Wales. No new trends were observed.

The Joint Programme of Work on home grown timber being carried out with the Ministry of Technology's Forest Products Research Laboratory (Timberlab) was continued, and is summarised below.

In view of the great importance of Sitka spruce, special attention was given to the effect of vigour of growth on the timber properties of young trees of this species, and of spacing on its wood density and yield. The information gained will be useful in management, and in the selection of material for ultimate use in the breeding of trees with high yield combined with good timber quality. In the studies on vigour of young plantation-grown trees, it was found that as vigour of growth increased, wood density declined. In a paper in which the full findings are being presented, the possibility is discussed of forecasting the adult wood characteristics from an examination of the juvenile wood. From the studies on the effects of spacing, it was concluded that in young plantations, planting distance had little effect on yield, and if yields of wood material, e.g. for pulp, are the main concern, wide initial spacing is justified. If timber quality, e.g. for saw timber production, is important, however, the proportion of trees with a low wood density on sites planted at wide spacings becomes important. Further, as within a crop the larger trees tend to have the lowest wood density, it may be argued that to get the best financial return these large trees should be removed in the early thinnings.

Work on machine stress-grading of timber has shown that the Australian "Computermatic" machine is suitable for use in Britain. This machine is now being used in trials with home-grown Scots pine, Sitka spruce and Douglas fir saw logs to assess the quantities and proportions of sawn timber suitable for structural use in building, obtainable from these species.

Laboratory trials of chemicals for use against blue stain in pine have been carried out, and supplementary forest trials initiated.

Further work on preservation of home grown timbers by diffusion indicated that "Timbor" (a sodium polyborate) applied as a preservative to Scots pine, Sitka spruce, and Western hemlock, was not readily leached out even after the equivalent of six months weathering.

A comparison was made between the cant and taper sawing methods of conversion, the former involving sawing parallel to the pith, the latter parallel to the bark. The results gained from two consignments of home grown Douglas fir suggested that, for the particular log saw used, the cant method was economically superior to the taper sawing technique, and it would be economic to use the taper sawing method only when straightness of grain is especially important.

PART II

This section consists of reports on work assisted by the Forestry Commission or done for it by other organisations.

Miss B. Benzian and Mr. S. C. R. Freeman, of *Rothamsted Experimental Station*, Hertfordshire, note that Needle tip-burn of Sitka spruce, associated with copper deficiency, reappeared at Wareham in 1968, though it was absent from plots given copper sprays as long ago as 1965. They also discuss the effects on trees newly planted in the forest of nitrogen top-

dressings given the previous September while the trees were in the nursery. The trees were planted out in April 1969 at two sites in Wales, one high and exposed, the other more sheltered but frosty, and at Bedgebury Pinetum, Kent, where frost damage is also common. In most cases, the nitrogen treatment speeded up bud development and increased growth in height and diameter, and the results did not support the widely accepted view that a high N content is disadvantageous on frosty or exposed sites.

Dr. H. G. Miller and Dr. B. L. Williams, of the *Macaulay Institute for Soils Research,* Aberdeen, summarise the results of work on tree nutrition and on peat soils. A nitrogen-deficient, 40-year-old Scots pine stand was treated with nitrogen as ammonium sulphate, sodium nitrate, ammonium nitrate, and urea. At the end of the first season, needle weight and needle nitrogen concentration were highest in the plots treated with ammonium nitrate and lowest in those treated with sodium nitrate or urea. By the end of the second season, the differences were much reduced. Needle nitrogen concentrations remained highest in the ammonium nitrate plots, now followed by those given urea, ammonium nitrate, and sodium nitrate, in that order.

Preliminary small-scale studies on the amount and distribution of dry matter and nutrients within a stand of 21-year-old Sitka spruce suggested that this species carries more foliage than does pine. Some indication of distribution of nitrogen, phosphorus, potassium, sodium and calcium was obtained, and further full-scale work is now being done.

Foliage samples of young Lodgepole pine, Sitka spruce, Douglas fir, Grand fir and Western hemlock, planted under five densities of shade under larch, were examined to find the effect of shading on foliar nutrient and chlorophyll contents. Chlorophyll content tended to increase with increasing shade. The effect of increasing shade on needle size varied with the species, but no species produced morphologically specialised " shade needles " under the range of conditions studied.

Important new studies have begun to elucidate some of the factors affecting the release of mineral nitrogen from coniferous mor, humus and deep acid peats. These materials contain large stores of organic nitrogen, but trees on them often grow poorly through lack of available N. Incubations on samples of Scots pine humus suggested that applications of nitrogenous fertiliser caused the release of some further organic N.

In similar incubation work on peats, mineral nitrogen accumulated very slowly, but again there was some evidence that fertiliser treatments could in some circumstances increase the availability of the nitrogen in the peat.

Dr. G. A. Salt, of *Rothamsted Experimental Station,* has carried out experiments which showed that inoculum of the " psychrophilic seed fungus " did not survive the winter in dead seed in the soil. Precision sowing of seed is now a possibility, and losses through damping-off in carefully spaced sowings would be particularly damaging. Experiments were therefore done with seed precision-sown between sheets of absorbent tissue. Seeds infected with the " psychrophilic fungus " were spaced along the tissue strips, and the fungus spread from these foci of infection and caused substantial loss. If precision sowing methods are adopted, therefore, seed treatments with thiram may well be desirable.

Dr. C. S. Millar of the *Forestry Department, University of Aberdeen,* reports work on premature browning and death of needles of Corsican and Scots pine in two Scottish forests. The primary cause of the damage has proved to be the fungus *Lophodermella* (*Hypodermella*) *sulcigena,* which enters at the bases of the current year's needles. *L. conjuncta* may sometimes affect Corsican pine in the same way. Various secondary fungi may later invade and accelerate needle-cast.

Dr. P. G. Biddle, of the *Commonwealth Forestry Institute, University of Oxford,* discusses work on virus diseases of forest trees. He has so far found three disorders of conifers that may be due to virus infection. The first is a vivid yellow or yellowish-white chlorosis of the needles of Sitka and Norway spruce. The second, on the same two species, may show as a chlorotic banding of the needles and a shortening and deformation of the terminal internodes. The third is a bushy stunt of Scots pine. All these conditions appear to have associated virus-like rod-shaped particles, and work is being done to decide whether they are indeed virus diseases.

Dr. J. F. Longworth, of the *Insect Pathology Unit, Commonwealth Forestry Institute, Oxford University,* gives an account of work with inclusion bodies of the granulosis virus of the butterfly *Pieris brassicae.* The studies showed that two separate, serologically unrelated proteins were present in solutions of inclusion body protein. This may affect serological comparisons between granulosis viruses.

Mr. W. H. Parry, of the *Department of Forestry, University of Aberdeen,* summarises studies on the Green spruce aphid, *Elatobium abietinum.* These were aimed in part to find a means for the prediction of severe attacks by this pest. A formula using aphid numbers alone gave predictions good enough to warrant further testing (Table 35 p. 183). Aphid numbers were only moderate, and decline in numbers over the season was slow, with little emigration by alatae, and small activity by predators and parasites. Eventual fall in numbers was probably related mainly to quality of the available food supply.

Dr. Myles Crooke, of the same *Department,* gives an account of his further work on Coal tit and Pine looper moth populations in Culbin Forest, Moray. Two additional study plots have been established, and once again it has been found possible to increase the breeding and wintering numbers of birds by provision of additional feed. Dispersion of the birds has been followed successfully by ringing techniques, but preliminary sampling of Pine looper has posed sampling problems because of low insect numbers.

Dr. D. H. Mills, of the *Department of Forestry and Natural Resources, University of Edinburgh,* further studied the brown trout population of the Glentress Burn, Peeblesshire. Movement of the fish was affected by stream blockages caused by tree felling.

Dr. L. Leyton, Dr. E. R. C. Reynolds and Mr. F. B. Thompson, of the *Department of Forestry, University of Oxford,* report studies on forest hydrology, new work on which includes some on the effects of the deciduous

habit on rainfall interception. Plots containing living oak trees were compared with others in which the trees were killed, and so were leafless throughout the year. The interception losses in the plots of live trees were almost always greater than in those of dead ones, but the differences were statistically significant only from June to August, when the trees were in full leaf, and in November when about half the foliage still remained. Significant differences during the other leafy months could not be established, no doubt because the standard errors of the throughfall estimates for these months were very high.

Dr. P. H. Thomas, of the *Joint Fire Research Organization* at Boreham Wood in Hertfordshire, has made a further study of data from controlled head fires in the New Forest, to correlate the data broadly with previous laboratory experiments, and to interpret some of its features in terms of a heat balance for the unburnt fuel.

PART I

Work carried out by Forestry Commission Research and Development Staff

RESEARCH DIVISION

FOREST TREE SEED

SERVICE

The Seed Section is the central unit for seed procurement, extraction, storage, testing and distribution for both the Forestry Commission and private forestry. Work is largely of a service character and this occupies about 80 per cent of the available resources of the Section. Research is carried out with the remaining capacity, mainly on topics connected with the improvement of the seed services. The report on seed services is included here for practical reasons because it is not published elsewhere.

Register of Seed Sources

The Register was begun in 1956, when a new seed identification system was also introduced. The Register slowly grew as survey work by the Geneticist progressed and the first comprehensive source list was produced in 1961. During 1965/66 a thorough revision took place and the Register assumed its present form. At this time its maintenance was transferred from the Geneticist to the Seed Section, and since then yearly amendments have been published in this *Report.*

During the year the main changes were:—

	Number of Stands	*Hectares*	(*Acres*)
Areas gained	1	4·1	(10)
Areas lost—Total	12	34·8	(86)
Clear-felled	5	27·5	(68)
Reduced in area	6	6·8	(16·8)
Windblow	1	0·5	(1·2)
Stands Thinned	14	95·2	(235·2)

Recently a quite drastic decision was taken to reduce by 60 per cent the area of Scots pine seed orchards. This reduction will be carried out during the next three years. About 40 acres will remain, and should be sufficient for the decreased planting programme for this species.

Slowly the registered seed stands are maturing and being felled. During the last four years about 50 stands have been lost, and this number will rapidly increase during this decade. As this happens the replacement of the losses will become imperative. Therefore plans are already being formed for how this should be accomplished. The main aspect of this work will be a critical review of the whole system in order to revise the Register in such a way that it will be properly adjusted to current development in seed requirements.

This problem also interacts with the international certification scheme being organised by OECD (Organisation for Economic Co-operation and Development), as if this country takes part in the scheme our Register must fulfil its requirements.

Seed Procurement (Table 1)

Unfortunately the end of the reporting period comes in the middle of our seed procurement programme and, therefore, Table 1 contains only those amounts the collection and processing of which were completed before 31st March, and these make up about half the total season's collection. The remaining amounts not included will be recorded in next year's *Report*. However, in the review below the whole season's crop is taken into account.

There was an extremely good crop of Sitka spruce, especially in West and North Scotland where altogether over 900 kg (2,000 lb) of seed were collected. This success was achieved mainly through the excellent co-operation of the Conservancy staffs and the fact that the selected, well-shaped trees were felled instead of climbed. As a result, the collection costs were reduced to a minimum.

This collection was well worth making, because the value of the seed from an average tree was about £20, i.e. much more than the value of the timber. This success leads us to the conclusion that the method should be explored for other species as well, and therefore appropriate plans are being made.

Another species with a good crop was Scots pine. It provided over 225 kg (500 lb) of seed which almost all originated from registered sources, 70 per cent of these being from seed orchards. It should be emphasized that the production of Scots pine seed from seed orchards is increasing very satisfactorily and is already very nearly sufficient to cover the requirement for the whole country.

Hybrid larch also produced more seed this season than during previous years, and altogether over 45 kg (100 lb) should be available for the next year's sowing.

Among other conifer species only Corsican pine and Noble fir produced small collectable amounts, i.e. 36 and 32 kg (80 and 70 lb) respectively. As regards hardwoods there were some small crops of acorns but no beechnuts. Sycamore, ash, maple, birch and some others yielded enough seed for the requirements of the relevant Conservancies.

This year's import was very small, probably the smallest ever recorded. Altogether 538 kg (1,185 lb) were imported, of which the main items were 304 kg (670 lb) of acorns (mainly Red oak) and 136 kg (300 lb) of Sitka spruce.

TABLE 1

Total Seed Procurement during the Period 1.4.69 to 31.3.70

Species	Imported		Home collections						Grand Total	
	General*		General		Registered		Total			
	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb
Scots pine			21·6	48·0	259·6	571·5	281·2	619·5	281·2	619·5
Corsican pine			20·0	44·1	6·0	13·4	26·0	57·5	26·0	57·5
Lodgepole pine	20·7	45·8							20·7	45·8
Sitka spruce	138·9	305·6	459·0	1,011·0			459·0	1,011·0	597·9	1,316·6
Hybrid larch			16·2	35·8	3·6	8·1	19·8	43·9	19·8	43·9
Douglas fir	0·3	0·8							0·3	0·8
Western hemlock	18·3	40·3							18·3	40·3
Noble fir					30·3	66·9	30·3	66·9	30·3	66·9
Other conifers	51·9	114·3							51·9	114·3
Total conifers	230·1	506·8	516·8	1,138·9	299·5	659·9	816·3	1,798·8	1,046·4	2,305·6
Oak	304·5	670·0	90·9	200·0			90·9	200·0	395·4	870·0
Sycamore			19·7	43·5			19·7	43·5	19·7	43·5
Ash			2·2	5·0			2·2	5·0	2·2	5·0
Other broadleaves	3·8	8·4	140·8	309·8			140·8	309·8	144·6	318·2
Total broadleaves	308·3	678·4	253·6	558·3			253·6	558·3	561·9	1,236·7
Grand Total	538·4	1,185·2	770·4	1,697·2	299·5	659·9	1,069·9	2,357·1	1,608·3	3,542·3

* No seed from registered sources.

Broadleaves: Collected for Central Store 119 kg (262·1 lb)
Collected for Conservancies' own use 134·3 kg (296·2 lb)
253·3 kg (558·3 lb)

Seed Extraction

Because of the reasonably good crops, especially of Sitka spruce, and of the centralization of seed extraction work at Alice Holt, this year's turnover for this plant was the heaviest since its establishment in 1964. Altogether nearly 145·47 m^3 (4,000 bushels) were processed, and a final yield of about 1,360 kg (3,000 lb) of valuable and reasonably cheap seed is expected.

Sitka spruce with over 90·91 m^3 (2,500 bushels) formed the main bulk, followed by Scots pine, with 36·36 m^3 (1,000 bushels), Corsican pine with 3·63 m^3 (100 bushels), Hybrid larch with 6·18 m^3 (170 bushels), and Noble fir with 2·54 m^3 (70 bushels).

This was the first time that the Alice Holt extraction plant had had to deal with Sitka spruce cones, which created some problems, especially with the de-winging process, as it was found that the standard safe method for de-winging other species caused damage to Sitka spruce seed. (See *Research* on page 30.)

Seed Storage

The total seed stock in hand at 31st March was 6,752 kg (14,857 lb). This is the lowest ever recorded since the establishment of the Central Seed Store in 1958. With a yearly requirement of about 3,400 kg (7,500 lb) this means that we hold only two years' supply as opposed to the three to four years' supply stocked previously.

The small size of last year's crops on the west coast of America prevented us from procuring as much seed from there as was required. However, the situation is not critical as we have sufficient supplies of the main species for next year, but no effort will be spared to fill gaps in the existing stock. Special attention will be concentrated in procuring at least 2,270 kg (5,000 lb) of Sitka spruce, 450 kg (1,000 lb) each of Noble and Grand fir, 230 kg (500 lb) of Western hemlock and any available amounts of Hybrid and Sudeten larch.

Seed Testing (Table 2)

The total number of tests during the year under review was similar to that of the previous one. However, testing for research purposes has

TABLE 2

TESTS PERFORMED ON SEED

Kind of test	Service	Research	Total	Total of previous year
Purity	377	31	408	417
Seed size determination	439	95	534	603
Germination	663	303	966	1,124
Tetrazolium	12	7	19	30
X-ray	—	4	4	6
Cutting	155	—	155	34
Moisture content	327	104	431	401
Cone test	—	57	57	24
Total	1,973	601	2,574	2,639

increased, with some decline of the service work. The decrease of routine testing was due to the decrease of seed stocks in hand and the increase of research was caused mainly by seed de-winging investigations.

All these tests were performed on 478 service samples and 237 research samples. Within the service samples there were 70 for outside parties, i.e. about the same as last year.

Seed Supply (Tables 3 and 4)

As in previous years the private sector required slightly more seed (about 180 kg ; 400 lb) than the Commission (Table 3). However, the overall usage increased quite significantly by over 625 kg (1,500 lb), which reflects the increased planting programme for the near future. This increase is shared more or less evenly between both sectors.

The popularity of the individual species is not static either, and changes that have taken place in recent years are illustrated in Table 4. The general pattern of Commission and private forestry is somewhat similar, but it is noticeable that with some species (e.g. Scots pine, Norway spruce, Douglas fir and Noble fir) private forestry is not decreasing its usage as rapidly as is the Commission. However, the most striking feature is the rapid increase in sowing of Sitka spruce and Grand fir. The relatively high popularity of Japanese larch in the Commission is also interesting, but here one can assume that the shortage of Hybrid larch seed is a contributory cause.

A similar analysis, with species subdivided according to seed provenance, should also be valuable, and this work is being contemplated for the near future.

RESEARCH

Sitka Spruce Cone and Seed Processing

As already mentioned, the collection of over 90·91 m^3 (2,500 bushels) of Sitka spruce cones created some problems which had to be dealt with as quickly as possible. The main object was to obtain the maximum amount of high quality seed.

The first batches of processed seed did not show a satisfactory standard and a special investigation was therefore organised in order to find the causes. This investigation strongly indicated that damage was occurring during the de-winging process which, after additional trials, was modified to the so called " wet de-winging method ", where the seed is moistened before being fed into the de-winging machine. The accumulated evidence indicates that our dry method, which is safe for other species, may impair the germination capacity of Sitka spruce very significantly. The work on the wet de-winging method continues, with a special emphasis on the development of suitable machinery.

However, it was also found that some consignments were more prone to damage than others, and it is believed that this characteristic is closely related to the state of seed ripeness. It is thought therefore that this observation warrants a thorough investigation into the ripening process of Sitka spruce cones in order to increase our knowledge about the optimum collection time for this species.

TABLE 3—SEED SUPPLIED FROM CENTRAL SEED STORE FROM 1.4.69 TO 31.3.70

Species	Weight in Kilograms and Pounds from General and Registered Sources												Exports Research and Gifts		Grand Total	
	Forestry Commission						Private Forestry									
	General		Registered		Total		General		Registered		Total					
	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb	kg	lb.	kg	lb	kg	lb
Scots pine	18·8	42·0	28·3	62·7	47·1	104·7	50·1	111·2	43·8	97·0	93·9	208·2	14·4	31·7	155·4	344·6
Corsican pine	6·4	14·1	166·6	366·7	173·0	38·80	45·4	100·2	60·3	133·2	105·7	233·4	0·9	2·1	279·6	616·3
Lodgepole pine (AL)	10·4	23·2			10·4	23·2									10·4	23·2
(SC)	71·6	157·8			71·6	157·8	39·7	87·6			39·7	87·6			111·3	245·4
(SK)	19·3	42·5			19·3	42·5	16·7	37·0			16·7	37·0			36·0	79·5
(CI)							2·0	4·5			2·0	4·5			2·0	4·5
(SI)	24·9	55·0			24·9	55·0	25·8	57·5			25·8	57·5	40·0	88·2	90·7	200·7
Sitka spruce	811·9	1,789·5			811·9	1,789·5	519·8	1,170·4			519·8	1,170·4	1·8	4·0	1,333·5	2,963·9
Norway spruce	44·0	97·4			44·0	97·4	106·3	234·6	32·2	71·0	138·5	305·6	0·1	0·4	182·6	403·4
European larch			11·0	24·5	11·0	24·5	5·4	12·0	57·8	127·5	63·2	139·5	0·9	2·2	75·1	166·2
Japanese larch	74·7	164·7	7·8	17·4	82·5	182·1	201·5	443·7	0·4	1·0	201·9	444·7	0·2	0·6	284·6	627·4
Hybrid larch	0·3	0·8	2·5	5·5	2·8	6·3							0·4	0·8	3·2	7·1
Douglas fir	19·8	44·0	31·7	69·9	51·5	113·9	73·9	163·0	85·0	187·2	158·9	350·2	0·3	0·7	210·7	464·8
Western hemlock	24·5	54·1			24·5	54·1	62·5	138·0			62·5	138·0	0·1	0·3	87·1	192·4
Western red cedar	14·9	32·8			14·9	32·8	46·5	102·4			46·5	102·4	0·6	1·5	62·0	136·7
Grand fir	127·9	282·4			127·9	282·4	225·4	496·5			225·4	496·5	0·1	0·4	353·4	779·3
Noble fir	80·3	176·9	2·1	4·8	82·4	181·7	56·5	125·0			56·5	125·0	0·3	0·8	139·2	307·5
Other conifers	1·5	3·5	3·0	6·6	4·5	10·1	28·6	63·2	3·9	8·7	32·5	71·9	6·8	15·2	43·8	97·2
Total conifers	1,351·2	2,980·7	253·0	558·1	1,604·2	3,538·8	1,506·1	3,346·8	283·4	625·6	1,789·5	3,972·4	66·9	148·9	3,460·6	7,660·1
Oak	196·2	432·0			196·2	432·0	124·5	274·0			124·5	274·0	0·4	1·0	321·1	707·0
Sycamore	0·4	1·0			0·4	1·0							0·4	1·0	0·8	2·0
Ash	3·0	7·0			3·0	7·0	0·2	0·5			0·2	0·5	0·5	1·2	3·7	8·7
Other broadleaves	5·1	11·6			5·1	11·6	18·7	41·2			18·7	41·2	1·8	4·0	25·6	56·8
Total broadleaves	204·7	451·6			204·7	451·6	143·4	315·7			143·4	315·7	3·1	7·2	351·2	774·5
Grand Total	1,555·9	3,432·3	253·0	558·1	1,808·9	3,990·4	1,649·5	3,662·5	283·4	625·6	1,932·9	4,288·1	70·0	156·1	3,811·8	8,434·6

TABLE 4

TRENDS IN SEED USAGE DURING THE LAST FIVE YEARS

(Expressed as the Percentage of 1966 Requirements)

Species	1966	Forestry Commission				Private Forestry			
		1967	1968	1969	1970	1967	1968	1969	1970
Scots pine	100	34	35	29	38	103	43	58	51
Corsican pine	100	46	64	53	73	87	51	54	50
Lodgepole pine	100	41	25	48	60	41	19	38	57
Sitka spruce	100	75	122	130	213	138	165	241	317
Norway spruce	100	40	54	13	30	91	61	50	49
Douglas fir	100	38	31	27	27	85	78	58	77
Japanese larch	100	105	43	137	108	97	26	46	67
European larch	100	105	53	58	56	105	55	61	50
Grand fir	100	76	180	197	174	97	202	86	419
Noble fir	100	32	39	29	27	60	69	69	90

This large collection also gave us an opportunity to study the morphological differences between cones and seed from different plantations. A large amount of material was gathered which should be examined in the near future. This research is also to be carried out on seedlings in the nursery with the co-operation and help of the Silviculture Sections, both North and South.

Seed Grading

Most of the work on seed grading was done on behalf of Silviculturist North. The investigation aims to find whether graded seed used in tubed seedlings experiments can produce more even-sized seedlings by more rapid and better germination. The work was concentrated on Sitka spruce and Lodgepole pine, for which a standard procedure was worked out in order to produce a good sequence of seed densities. The laboratory tests indicate that larger (=heavier) seed germinates more quickly, and the nursery evidence shows that these seeds also produce larger seedlings.

It is thought that the introduction of grading into routine seed distribution should be beneficial to nursery practice and this work will therefore be continued.

Seed Storage

There are several experiments in progress on which routine yearly checks of quality have been performed. Two of them are being concluded and full reports will be ready in the near future. They are:

(a) Ten years storage of *Abies procera* seed at a range of temperatures from 20°C–30°C, seed moisture content from 4 per cent to 16 per

cent including hermetic seal, vacuum and CO_2 atmosphere. An interim report after 5 years was included in the *Report* for 1965.

(b) Three years storage of seed dressed with lithofar red dye carried out on ten main species. The observed behaviour varies between species but the results are generally promising, and the dressing may be introduced as a routine treatment for seed for some species before they are placed in storage.

Seed Testing

Here, again in conjunction with Silviculturist North's experiments on tubed seedlings, a study was carried out to discover whether a constant temperature of 20°C, 25°C or 30°C produced more rapid germination than the standard method alternating the temperature from 20°C to 30°C, with and without pre-chilling at 3°C to 5°C. For practical reasons the application of constant temperature is preferable for tubed seedling production. Four species were employed using two different samples of each of the species Sitka spruce, Lodgepole pine, Grand fir and Western hemlock.

The results indicate clearly that our standard method with alternating temperatures from 20°C to 30°C is not necessarily the best one, and 25°C constant offers equal and sometimes better conditions both for the rate of germination and total germination. Further investigations are in progress and will be reported in due course.

Co-operation with the International Seed Testing Association (ISTA) was continued, and during the period activities concentrated on gathering material for the next revision of the testing rules, and preparatory work for the referee testing for 1970. The main object of referee tests will be the critical examination of the excised embryo method as a supplement to the biochemical one (Tetrazolium method).

Tropical Seed

The Seed Section co-operates closely with the Commonwealth Forestry Institute of Oxford University on its Research Scheme for "Fast Grown Tropical Timber Trees". This co-operation is restricted to processing, storing, testing and distributing seed consignments which are being procured by the CFI. Although the work is basically of a service character, it requires an increased amount of research due to limited knowledge of tropical seed physiology and increased activities of the CFI.

Simultaneously and probably as a result of the above the Commonwealth countries are requesting more and more advice on seed technology, which again contributes to the increased demand for research.

In connection with the above the Seed Section undertakes the training of seed officers, and during the year under review one officer from the Philippines spent 2½ months with us and another from Nigeria spent 4½ months.

G. M. BUSZEWICZ.

PRODUCTION OF PLANTING STOCK

Research during the year, mainly during the 1969 growing season, included work in conventional nurseries and on the production of special types of planting stock, mainly tubed seedlings and " Nisula " roll plants. In conventional nurseries work was concentrated on slow release fertilisers and on methods of precision sowing. Research on tubed seedlings was conducted mainly in the north and that on " Nisula " plants mainly in the south.

The nurseries in which experiments were laid down were:

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

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

In addition to the experiments described here, work was undertaken by Miss B. Benzian of the Chemistry Department, and Dr. G. A. Salt of the Pathology Department, of Rothamsted Experimental Station (see accounts in Part II, pp. 168 and 174).

FERTILISERS

Slow-Release Fertilisers

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

Experiments comparing fertiliser regimes based on " Enmag ", potassium metaphosphate or potassic superphosphate (see *Report* for 1968, p. 30 ; and for 1969, p. 29–30) were continued for their third year at Alice Holt, Kennington and Wareham.

On seedbeds, differences between regimes at the end of the season were very small, and even the late top-dressings of nitrogen and potassium had little effect on colour. It thus appears that all regimes supplied adequate N and K throughout this season. There was unusually low rainfall from April to September, which would reduce the leaching of N and K.

On transplants, the dry summer seemed to favour the use of " Enmag " and potassium metaphosphate. This result was reflected particularly in those species known to be susceptible to damage from soluble inorganic fertilisers (see Table 5).

TABLE 5

HEIGHT OF NORWAY SPRUCE AND GRAND FIR TRANSPLANTS IN AUTUMN 1969 AFTER ONE YEAR IN TRANSPLANT LINES UNDER DIFFERENT FERTILISER REGIMES

cm

Nursery	Species	"Enmag"	Potassium metaphosphate	Potassic superphosphate
Alice Holt	Norway spruce	20·6	18·8	13·7
	Grand fir	12·7	11·4	9·7
Kennington	Norway spruce	17·8	15·5	16·0
	Grand fir	18·0	18·0	18·0
Wareham	Norway spruce	16·0	15·5	13·0
	Grand fir	23·6	21·6	20·8

The reduced height in the potassic superphosphate plots of Norway spruce and Grand fir at Alice Holt, and Norway spruce at Wareham, was accompanied by clearly visible symptoms of fertiliser scorch in the early part of the season. At Alice Holt this scorch from potassic superphosphate was also sufficiently serious significantly to reduce survival of both the Norway spruce and Grand fir.

Fertiliser Damage

Experiments testing the risk of damage to transplants from regimes based on "Enmag" containing KCl or K_2SO_4, potassium metaphosphate and potassic superphosphate, were continued for a fourth year at Alice Holt, Kennington and Wareham.

In spite of the dry summer, scorch symptoms were rare, and only clearly affected the health of Norway spruce at Alice Holt. However, the danger of scorch to sensitive species from soluble fertilisers in this type of season can be assessed from similar experiments in the same nurseries, which are reported above.

Effects of Repeated Applications of "Enmag"

In the north, two long-term experiments on the repeated use of "Enmag" and "Kay-nitro" on seedbeds were continued in 1969, one at Fleet which began in 1964 and one at Newton which began in 1967.

The experiment at Fleet was sown with Lodgepole pine, Sitka spruce and Japanese larch and the results did not differ markedly from those obtained in previous seasons (see the 1969 *Report*). In general, application of any fertiliser treatment slightly reduced end-of-season seedling numbers relative to the unfertilised control.

Height growth was best where "Kay-nitro" was applied in 1969 following "Enmag" in 1968, and where "Enmag" was applied in 1969. Also, height, particularly of Japanese larch, increased with increasing rate of application, except in plots given only "Kay-nitro" annually. Repeated annual use of

" Kay-nitro " top-dressing without any other fertiliser resulted in poor growth, similar to that in the unfertilised control plots.

At Newton Nursery the " Enmag " treatment, particularly at high rates, caused a marked reduction in Western hemlock seedling numbers in comparison with control plots and with treatments receiving top-dressing only. Other species were not significantly affected although Lodgepole pine numbers also appeared to have been slightly reduced by high " Enmag " rates.

In contrast to the 1968 results, " Enmag " gave the best height growth of Lodgepole pine and Sitka spruce as well as of Japanese larch, although there was some evidence that height of Lodgepole pine and Japanese larch was reduced at the highest rate. However, in the case of Western hemlock, potassic superphosphate with " Kay-nitro " top-dressing continued to give the best results. For all four species, plots treated only with annual " Kay-nitro " gave results as poor as, or poorer than, the unfertilised control plots.

There is still no clear evidence from these experiments of seedling damage due to repeated, heavy applications of " Enmag " (up to three or four times the recommended rate of 1380 kg/ha (11 cwt/acre)) despite concentrations of P and Mg in the soil having risen very markedly with this treatment.

Experiments on transplant lines continued for their third season at Newton and Benmore. Lodgepole pine, Sitka spruce and Douglas fir were included at both nurseries, together with Japanese larch at Newton and Norway spruce at Benmore.

At Newton, survival differences between treatments were relatively small for Lodgepole pine, Sitka spruce and Japanese larch, although there was some indication of a reduction in numbers with high rates of application. In the case of Douglas fir, survival was reduced on plots receiving either " Enmag " or potassic superphosphate and decreased significantly with increasing rate of application.

Height growth did not differ markedly between fertiliser treatments at the lower application rates, and growth was good in the unfertilised control plots and in plots treated annually with " Kay-nitro " only. However, the highest rates of " Enmag " and potassic superphosphate ($2\frac{1}{2}$–4 times the recommended rate) gave distinctly poorer growth than the lower rates. The experiment at Benmore was affected by simazine damage and in consequence results must be treated with caution.

A similar experiment at Fleet continued for its second season, using the same species as at Newton. As far as survival was concerned there were no apparent differences between treatments. However, as in 1968, height growth was distinctly better with " Enmag " than with any of the other fertilisers and increased with increasing rate of application, particularly in the case of Sitka spruce and Japanese larch.

Residual Effect of Late Top-Dressings on Seedlings

At Alice Holt, Kennington and Wareham, seedlings of ten species which had received late top-dressings of N, K, or both, in the previous year (1968) were put out into transplant lines to see if these treatments affected growth or resistance to extremes of weather. Treatments had produced marked differences in the foliar contents of N and sometimes of K (see 1968 *Report*).

Although plants which had received N and some plants that had received K flushed slightly earlier than those that had received no late top-dressings, and were sometimes greener early in the growing season, by the end of the year their height and colour were similar. Root collar diameter measurements at the beginning and end of the season suggest that these late top-dressings may increase the root collar diameter of some species, thereby producing a sturdier seedling.

This is the third and final year of these experiments. It is proposed to publish the results of the whole series elsewhere.

Residual Effect of Late Top-Dressings on Transplants

The effects of late top-dressings to transplants in 1968 on their performance in the forest during 1969 are reported by Miss B. Benzian in Part II of this *Report*, pp. 168-170.

Long-term Maintenance of Fertility

The long-term fertility trial at Teindland heathland nursery, last mentioned in the 1967 *Report*, was re-sown for its 20th season in 1969.

Since 1950, crops of one-year Lodgepole pine and Sitka spruce seedlings have been raised on permanent plots treated annually with artificial fertilisers only, with organic manures (hop-waste) only and with a combination of the two types.

In 1969, as in previous seasons, all three regimes produced satisfactory crops of seedlings, but on this occasion numbers were significantly higher in plots receiving hop-waste (with or without additional artificial fertilisers) than in plots given only artificial fertilisers, or in the unfertilised control plots. Height growth of Lodgepole pine was considerably better with artificial fertiliser only (" Enmag " has been used since 1968) than with purely organic, or organic plus artificial, regimes. However, in the case of Sitka spruce, the organic plus artificial regime gave the best height growth.

This trial was designed to determine whether or not continuous use of a purely artificial fertiliser regime in a heathland nursery would lead to a deterioration in the quality of seedlings. Over the years there has been no real evidence of such deterioration and it has now been decided to end the trial.

PRECISION SOWING

Methods of Precision Sowing

Trials in the South

A series of experiments was begun at Alice Holt, Kennington and Wareham nurseries to test three techniques of precision sowing: paper-mounted seed, plastic-mounted seed, and pelleted seed. Sitka spruce, Ident. No. 66(7111)1, was the test species.

The paper-mounted seed is described in *Report* for 1969, p. 33. The plastic-mounted seed consisted of a ribbon of polyethylene oxide plastic tape about 1·2 cm wide, folded to enclose and hold seed at regular intervals. This tape

is strong enough for the seed to be sown by feeding the tape off a spool onto the ground and covering it with grit. The plastic is readily soluble and dissolves in a few minutes in damp soil conditions.

Pelleted seed is seed coated with an inert clay substance to increase its size and produce a round shape easily handled by direct precision-sowing machinery.

A number of problems were experienced at sowing, none appearing insurmountable except for those occurring with plastic-mounted seed. The plastic strips shrank rapidly and forcibly upon taking up moisture immediately after sowing. This caused the strip to move through the grit and often to work its way to the surface. Precision was thus lost, and the number of seedlings germinating and establishing themselves was reduced.

Paper-mounted seed plots especially, and to a lesser degree pelleted seed plots, were slow in germinating. At all three nurseries the paper persisted on the plots for most of the growing season and may have presented an obstacle to the germinating seed, thus accounting for the slower germination.

Table 6 shows the end-of-season results for height and numbers at Kennington and Wareham nurseries.

TABLE 6

HEIGHTS, NUMBERS AND PERCENTAGE YIELD OF SITKA SPRUCE SEEDLINGS IN AUTUMN 1969 FROM DIFFERENT PRECISION SOWING METHODS

Nursery	Factor	Treatment*				
		CB	CP	PE	PA	PL
Kennington	Height (cm)	6·1	5·9	4·5	5·4	6·3
	Numbers per m²	819	1,010	924	582	717
	Per cent yield	65	80	69	62	59
Wareham	Height (cm)	5·3	5·5	5·1	5·6	5·3
	Numbers per m²	1,166	1,113	1,143	806	655
	Per cent yield	93	88	92	78	56

* *Treatment Notes:* CB = control, bare seed, broadcast sown.
CP = control, bare seed, precision sown by hand.
PE = pelleted seed.
PA = paper-mounted seed.
PL = plastic-mounted seed.

All seed commenced at a germination percentage of 81, and was re-tested after pelleting or mounting. Germination percentage of the plastic-mounted and pelleted seed was insignificantly altered, but that of the paper-mounted seed had been reduced to as low as 65 in some cases. It is probable that this reduction could be avoided when mounting seed in the future. To make comparisons of numbers it was necessary, therefore, to calculate the percentage yield from viable seed using the post-pelleting or mounting test figures for germination percentage. Even so, the paper seemed to have reduced the number of seedlings. End-of-season height was also reduced at Kennington.

Pelleting had little effect on numbers at Wareham, but reduced numbers compared with precision-sown bare seed at Kennington. The most consistent effect of pelleting however, was an overall reduction in end-of-season height. The effect of plastic mounting on the numbers of seedlings was predictable, but it was interesting to note that there appeared to have been no effect on height.

Trials are continuing with pelleted and paper-mounted seed.

Trials in the North

A small experiment at Newton nursery compared results from paper-mounted, pelleted and normal seed of Sitka spruce sown at similar densities with and without watering immediately after sowing. The paper-mounted seed was spaced at 2·5 cm × 2·5 cm (1 in × 1 in), giving 1,550 seed per m^2 (1296/yd^2).

Paper-mounted and pelleted seed gave lower seedling numbers than did normal seed, and pelleted seed also gave poorer height growth. Watering immediately after sowing improved germination of the pelleted seed and gave slightly better height growth in all three treatments. However, none of the differences was statistically significant.

Conservancy Trials

About 10 m linear run (roughly 10 m^2) of seedbed was sown with paper-mounted seed of Sitka spruce, Ident. No. 61(7972), by each of six major Conservancy nurseries. This has provided useful additional data and tends to confirm the reduction in numbers. Height growth was, on the whole, satisfactory.

Effect of Density of Sowing

Tests of the effect of broadcast sowing density on Sitka spruce and Lodgepole pine (see *Report* for 1967, p. 29) and the preliminary experiment with paper-mounted seed in 1968 (see *Report* for 1969, p. 34) gave some evidence on the effect of sowing density. Both indicated increased yield at lower sowing densities, and the latter an increase in root collar diameter in Corsican pine.

In experiments in 1969 at Alice Holt, Kennington and Wareham, paper-mounted seed was used to examine the effect of sowing density in precision-sown seed, and the interaction of sowing density with the level of fertilisers applied.

In these experiments seed of Sitka spruce, Ident. Nos. 61(7972) and 66(7111)1, was sown at 2·5 cm (1 in) between rows by 1·9 cm ($\frac{3}{4}$ in), 2·5 cm (1 in) or 3·1 cm ($1\frac{1}{4}$ in) within rows, and combined factorially with 4/5th normal fertiliser level, normal fertiliser level or $1\frac{1}{3}$rd normal fertiliser level.

Data have not been analysed sufficiently to confirm whether lower densities are giving higher yields. Table 7 summarises data on root collar diameters.

TABLE 7

EFFECT OF SOWING DENSITY AND FERTILISER RATE ON ROOT COLLAR DIAMETER (MM) OF SITKA SPRUCE AT KENNINGTON AND WAREHAM NURSERIES

mm

Nursery	Ident. No.	Spacing of seed			
		2·5×1·9 cm		2·5×3·1 cm	
		4/5th fertiliser	1⅓rd fertiliser	4/5th fertiliser	1⅓rd fertiliser
Kennington	61(7972)	1·7	1·7	1·7	1·9
Wareham	61(7972)	1·6	1·6	1·7	1·9
Kennington	66(7111)1	1·7	1·8	1·9	2·1
Wareham	66(7111)1	1·7	1·8	1·7	2·0

At the greatest density of sowing there was little or no response to higher fertiliser rates, whereas at the lowest density there were quite large responses to higher fertiliser rates. At the densities used, Queen Charlotte Isles was the more responsive provenance.

Height at the end of the season followed a similar pattern, except that there was a greater response to higher fertiliser rates at the highest density of sowing.

These results show a definite interaction between density and fertiliser rate, and suggest that seedlings will not respond to higher fertiliser rates unless each seedling has adequate room. The results may suggest that the optimum spacing for diameter development is wider than for height development.

Long-term Effects on Site

In the south, soil samples were taken from experiments designed to test for damage from fertilisers on transplants (see section on Fertiliser Damage, p. 35), to see how the different types of fertiliser are affecting certain soil factors which may be important to growth. The results for three of these factors are given in Table 8 opposite.

The continuous use of " Enmag " is having little effect on soil pH, although it is building up soil magnesium. Soil samples will be analysed in 1970 to discover if exchangeable calcium is being displaced from the soil by magnesium. This could explain the unaltered pH.

The increase in soil phosphorous levels on plots receiving " Enmag " should also be noted.

At Kennington, large differences occurred in soil pH between the replicates of the experiment, and it was noted that at the lowest pH (4·7) the leading shoots of Douglas fir became very pale—almost white—and that many of these shoots died back in the autumn. In replicates having the highest pH (6·7 and 6·8) this occurrence was rare.

TABLE 8

SOIL pH, AVAILABLE PHOSPHORUS AND MAGNESIUM (p.p.m.) AFTER CONTINUOUS USE EITHER OF THE SLOW RELEASE FERTILISERS, "ENMAG" AND POTASSIUM METAPHOSPHATE OR OF POTASSIC SUPERPHOSPHATE

cm

Nursery	No. of years experiment has been on same plots	Soil(1) factor	Regime			
			"Enmag" (Cl)	"Enmag"	Potassium meta-phosphate	Potassic super-phosphate
Alice Holt	2	pH	3·9	4·1	4·0	4·0
		P	10	11	7	6
		Mg	48	75	12	10
Kennington	4	pH	6·3	5·9	5·7	6·0
		P	82	87	58	56
		Mg	129	173	61	52
Wareham	2	pH	4·2	4·3	4·0	4·1
		P	24	22	19	17
		Mg	50	51	5	7

Note: (1) pH measured in water.

P, Mg } expressed as available quantities in parts per million.

WEED CONTROL

Simazine on Transplants

Experiments at Kennington and Wareham, in which simazine is being applied annually at 1·12, 2·24, 4·48 or 8·95 kg active ingredient per hectare (1, 2, 4 or 8lb per acre) to newly lined-out transplants, continued for the eighth year.

Weed control at both centres was excellent at 2·24 kg active ingredient and above, but many species were clearly damaged at the 4·48 and 8·95 kg per hectare rates. At Kennington damage to Sitka spruce, Norway spruce and Grand fir was clearly visible, whilst analysis showed that Douglas fir and Western hemlock had been significantly reduced in height at Wareham, although visible symptoms were not noted.

Bio-assays for residues carried out by the Weed Research Organisation on samples collected in March 1969 (after seven years of applications) have given the following results. Residues at Kennington nursery in the top 15 cm were 0·9 kg/ha at the 2·24 kg/ha rate, and 3·70 kg/ha at the 8·95 kg/ha rate. Residues at depths in excess of 5 cm were very small (less than 0·34 kg/ha at 8·95 kg/ha rate), and this suggested that most of the residues were from the current year's application because plots are cultivated to about 15 cm depth each year before lining-out.

At Wareham, simazine residues could not be detected in any plot at any depth. However, the test crop (turnips) cannot detect simazine residues which are less than about 0·3 kg/ha.

The bio-assays suggest that there should be no danger of toxic residues accumulating at Wareham at any of the rates tested, and although the position is a little less satisfactory at Kennington, there seems little danger of accumulation from the normally recommended rate of 2·24 kg per ha.

R. M. BROWN

A. J. LOW

SPECIAL TYPES OF PLANTING STOCK

Tubed Seedlings

Work continued at Inchnacardoch, Tulliallan and Newton Nurseries on techniques for the production of tubed seedling stock. (See Report for 1969, page 36 and Plates 13 to 15.) The "standard" technique described last year was again used as a basis for experimental comparisons. Germination at the beginning of the growing season was poorer than in 1968 but there was an improvement later in the season without requiring a change in technique.

Similar series of experiments were carried out at all three nurseries, and most experiments were repeated during the second half of the growing season. Results of the various groups of experiments are summarised below and refer to Lodgepole pine and Sitka spruce except where otherwise indicated.

Fertiliser Regime

The fertiliser regime best suited to Lodgepole pine and Sitka spruce was investigated in two related series of experiments. A third series tested the effect of adding ground limestone to the peat/sand mixture used for filling the tubes.

The first series compared three rates of "Enmag" addition—0·5, 1·5 and 2·5 kg/m^3 (0·5, 1·5 and 2·5 oz/ft^3) of soil mix. The two lower rates were tested with and without regular top-dressing with solutions of ammonium nitrate (3 g/litre) or Fison's FL3P (a complete liquid fertiliser—3 ml/litre). Top-dressings were applied 4, 6, 8 and 10 weeks after sowing. A regime without basal fertiliser was also included, using FL3P (3 ml/litre) applied at weekly intervals from 4 weeks to 10 weeks after sowing. All fertiliser solutions were applied at 2·5 litre/m^2 (0·5 gal/yd^2).

At all three nurseries the lowest rate of "Enmag" and FL3P without basal fertiliser generally gave the best germination, but differences between these treatments and the middle rate of "Enmag" (the "standard" rate) were often small. The highest rate of "Enmag" consistently depressed germination. Height growth differences between the various treatments were inconsistent and often small, but on average the lowest rate of "Enmag" with top-dressing, and the middle rate with or without top-dressing, gave the best results. There was little to choose between FL3P and ammonium nitrate top-dressing. Numbers of usable seedlings tended to reflect germination differences but were usually less consistent.

In the second series, fertiliser regimes based on FL3P alone and on potassic superphosphate with top-dressing were compared with the "standard" rate of "Enmag" (1·5 kg/m³ of soil mix). Three concentrations of FL3P were included—3, 6 and 9 ml/litre (0·5, 1·0 and 1·5 fluid oz/gal). Potassic superphosphate used at 0·75 kg/m³ (0·75 oz/ft³) was tested with top-dressings of FL3P treatment, which had no fertiliser added to the soil mix prior to sowing. All fertiliser solutions were applied at weekly intervals from 4 to 10 weeks after sowing, using an application rate of 2·5 litre/m² as in the first series.

Germination was usually slightly, but rarely significantly, better in the FL3P treatment, which had no fertiliser added to the soil mix prior to sowing. In almost every case the standard rate of "Enmag" gave height growth equal to or better than any other treatment. There was frequently little to choose between "Enmag" and the three FL3P regimes, but the potassic superphosphate regimes tended to give poorer results, particularly where the top-dressing used was ammonium nitrate rather than FL3P. Numbers of usable seedlings tended to parallel germination numbers with FL3P giving slightly better results than the other two regimes.

The two series of experiments suggest that a slight improvement in usable seedling out-turn might be obtained by a regime based purely on FL3P or on a reduced rate of "Enmag" (0·5—1 kg/m³ of soil mix) with FL3P top-dressing, instead of the present "standard" regime using "Enmag" (at 1·5 kg/m³ of soil mix) without top-dressing.

The third series of experiments was intended to determine whether or not the addition of 0·5 kg/m³ (0·5 oz/ft³) of ground limestone to the soil mix (adopted as part of the "standard" technique) had a beneficial effect on seedling growth. "Enmag" (1·5 kg/m³) and FL3P (3 ml/litre applied at weekly intervals from 3 to 10 weeks after sowing) provided two contrasting fertiliser regimes which were compared with and without limestone addition.

Although results at the three centres were not consistent, it appeared that ground limestone improved germination and growth to some extent. This improvement was more noticeable with Lodgepole pine than with Sitka spruce, and with "Enmag" rather than with FL3P fertiliser.

Use of Fungicides

Thiram seed-dressing and post-germination drenching with captan were adopted as part of the "standard" technique in 1968. During 1969 experiments were sown at the beginning and towards the end of the growing season to test the actual effect of these treatments on growth of tubed seedlings. Seed was sown with and without a dusting of thiram, and trays were drenched with captan suspension (at the manufacturer's recommended rate) either at 2 and 4 weeks or at 1, 2, 3 and 4 weeks after sowing. There was rarely any evidence of a positive benefit from either the thiram seed-dressing or the captan drenching, and in a number of cases the thiram in particular caused a significant reduction in seedling numbers. Further trials will be made in 1970.

Use of Graded and Pelleted Seed

In the production of tubed seedlings it is important to obtain rapid and maximum germination. Use of weight-graded seed is a possible means of

improving germination and a comparison was therefore made between normal ungraded seed and three seed grades (heavy, medium and light) separated by a vibrating gravity table. Pelleted seed (as described earlier on page 37) was also included because of its suitability for mechanical precision sowing.

In all cases either the heavy or the medium grade gave the best germination, although the difference between these and the normal ungraded seed was often small and not statistically significant. The light grade usually gave distinctly poorer germination, particularly in the case of Lodgepole pine, while the pelleted seed gave by far the poorest results and germinated more slowly than unpelleted seed. A similar pattern was shown in numbers of usable seedlings eight weeks after sowing. Height growth differences were usually less pronounced, but on average the heavy and medium seed again gave the best performance, with normal ungraded seed only slightly poorer.

On these results it has been decided that the seed used for tubed seedling work in 1970 should have the lightest seed (approximately one-fifth by volume) removed beforehand in an attempt to improve germination. Experiments will also be carried out to test a larger number of seed grades than was possible in 1969. Pelleted seed gave much poorer results than when sown in conventional seedbeds (see p. 38), and appears to be unsuitable for sowing in tubes, although the reasons for this poor performance are not clear.

Root Control by Copper Paint

It is common to find vigorous roots emerging from the tube bases before seedlings are ready for planting, and these roots are usually broken in planting. Work in Canada (Saul, 1968) has indicated that this root emergence and subsequent loss can be prevented by applying copper paint to the bases of the trays used to hold the tubes, and a trial was carried out at Tulliallan to confirm this for Lodgepole pine and Sitka spruce. It was found that two different brands of copper paint effectively prevented root emergence of both species for the duration of the experiment (12 weeks from sowing). Apart from a slight height reduction in Lodgepole pine when 12 weeks old, there was apparently little effect on shoot growth or on the root/shoot ratio of the seedlings.

Despite the success of the treatment in controlling root emergence it will not be adopted as standard practice until more is known about its long-term effects on seedling growth after planting.

Trials of Other Conifer Species in Tubes

The germination and growth in tubes of Corsican pine, Norway spruce, Douglas fir and Western hemlock were investigated in a general trial, using two fertiliser regimes (based on "Enmag" at 1.5 kg/m^3 of soil mix and on FL3P at 3 ml/litre) and two depths of seed cover (3 and 6 mm). For all four species there were no outstanding differences between the fertiliser treatments but in each case the deeper seed cover reduced both germination and growth. The results indicate that there should be no major problem in raising Corsican pine and Norway spruce in tubes using the "standard" technique ; both species germinated rapidly and evenly, grew vigorously and gave a high

out-turn of usable seedlings. Douglas fir is likely to be a more difficult species because of its slow germination and lower seedling out-turn. Germination of Western hemlock was very poor, and major difficulties have already been encountered in attempting to produce seedlings of this species.

A further trial of Grand fir confirmed the difficulty of raising this species in tubes, although results were better than those reported in the 1969 *Report.* Seed given cold-wet stratification for three weeks prior to sowing gave considerably faster and higher germination than unstratified seed. Germination was considerably better with 6 mm of seed cover than with 12 mm, and liquid fertilising with FL3P gave somewhat better results than "Enmag" added before sowing. However, the most striking feature was the high seedling mortality which occurred soon after germination, frequently associated with stem breakage of the emerging seedlings. It may be that the standard 1.3 cm (0.5 in) diameter tube is too narrow to allow the germinating Grand fir seedlings sufficient space for satisfactory emergence; stem breakage was rare in the case of some seedlings raised in 1.8 cm diameter tubes.

Roll Transplanting and Intensive Seedling Production

Roll ("Nisula") Transplants from Conventional Seedlings

At Alice Holt, conventional 1+0 seedlings of Sitka spruce, Corsican pine and grand fir were incorporated in rolls in March 1969, to test the effect of fertiliser regimes based on "Enmag", on potassic superphosphate and on Fison's FL3P (a completely liquid fertiliser regime).

Sitka spruce and Grand fir performed well under all three regimes. Survival for both species was generally over 90 per cent, with heights of 25-30 cm (10-12 in) for both Sitka spruce and 20-25 cm (8-10 in) for Grand fir. Corsican pine survival was poor, suggesting that the typical lining-out losses with Corsican pine will not easily be avoided with this technique. The surviving Corsican pine were generally between 6 and 8 cm tall.

Roll Transplants using Seedlings Raised by Intensive Methods

At Alice Holt and Inchnacardoch seedlings were raised in greenhouses for about three months, lifted and incorporated in "Nisula" rolls (see *Report* for 1969, page 39 and plate 16), and then allowed to grow on to produce transplant stock. The object was to see if conventional sized roll transplants could be raised in one year as $\frac{1}{2}+\frac{1}{2}$ plants.

At Alice Holt the greenhouse phase tested John Innes No. 1 potting compost, Levington potting compost and a compost made of 1:1, sand:peat by volume, plus "Enmag". Space heating gave approximately a 22°C day and 10°C night, and day length was maintained throughout the growing period at a minimum of 16 hours with supplementary lighting. The "Nisula" phase tested two rates of "Enmag" and the effect of keeping rolls either inside the greenhouse or outside in normal nursery conditions.

Results were promising. Plants of the first crop (transplanted into rolls in June 1969) were generally 12-18 cm (5-7 in) high at the end of the season. but rather less sturdy than 1+1 transplants of equivalent height. The second

crop of seedlings (sown late June) was of good height by the end of November in the greenhouse. One unexpected problem was the occurrence of copper deficiency in transplants in the roll phase, especially under regimes involving only peat and sand. This may mean that micro-element nutrition will be important in the intensive raising of planting stock, particularly when growing media are based on peat and sand.

At Inchnacardoch two successive 12-week-old crops of usable Lodgepole pine and Sitka spruce seedlings were successfully raised during the growing season using a 15 cm (6 in) deep peat bed in a polythene greenhouse. There was little to choose between fertiliser regimes based on "Enmag" applied before sowing and on FL3P applied in solution after sowing.

In early July, half of the seedlings from the first crop were transplanted into peat/polythene rolls and half were lined-out conventionally in normal nursery soil. A similar procedure was followed for the second crop at the beginning of October. At the end of the growing season, survival of the July-transplanted stock was over 90 per cent both in rolls and in the nursery. In rolls both species had grown vigorously and had reached plantable size, while even in the nursery plants had grown appreciably and looked healthy. Some winter damage seemed likely in view of the soft nature of the October-transplanted seedlings, and the July-transplanted roll plants. During 1970 it is hoped to plant out stock from both crops under forest conditions.

A. J. LOW

R. M. BROWN

REFERENCE

SAUL, G. H. (1968). Copper safely controls roots of tubed seedlings. *Tree Plrs' Notes, Wash.* **19** (1), 7.

PLANTING

Forest Use of Tubed Planting Stock

Afforestation Trials on Peat

Results from experiments on ploughed deep peat in various parts of Scotland and in South Wales continued to indicate the probable suitability of tubed seedlings for use on such sites.

The oldest trials, planted at Naver Forest (Sutherland) in August and September 1967, reached the end of their second full growing season. Survival in most treatments remained at over 85 per cent, and there was little sign of browsing damage. In one experiment, Lodgepole pine had reached an average height of 27 cm (10·5 in) where planted on stepped single mouldboard (SMB) ploughing, with individual tree heights ranging up to 49 cm (19·5 in). On un-stepped double mouldboard (DMB) ploughing, the average height was only half as great, and taken in conjunction with the much lower survival (see 1968 *Report*) demonstrated clearly the beneficial effect of planting tubed seedlings in the relatively sheltered step position.

Two other experiments have been planted entirely on DMB ploughing and in them the average heights were 13 cm (5 in) for Lodgepole pine and 9 cm (3·5 in) for Sitka spruce. The pine plants appeared more healthy than the spruces, which had suffered from frost damage at the beginning of the growing season and which also showed possible potassium deficiency symptoms. In view of the results obtained in the earlier experiment mentioned above, it is highly probable that growth in these two trials would have been considerably better if step planting had been used.

Survival and height were also assessed in the eight experiments established during 1968—two at Naver Forest, three at Tighnabruaich Forest (Argyll) and one each at Shin Forest (Sutherland), Rumster Forest (Caithness) and Selm Muir Forest (Midlothian). All except the two experiments at Naver were planted on stepped SMB ploughing. The most important factors under test in these trials are seedling age at planting, month of planting and type of soil mix used for filling the tubes.

Results at the end of the first full growing season indicated that survival was highest (usually over 90 per cent) for May, June and July planting, fell off gradually for planting in August and September and dropped distinctly for October planting. Height growth followed a similar pattern. At Tighnabruaich, for example, the average height of Sitka spruce for May–June planting was 17·5 cm (7 in), which was more than twice that of 7 cm (3 in) for September–October planting. Differences in performance between 8-week-old and 12-week-old seedlings were mostly small and inconsistent, and there appeared to be little advantage in using the older, larger stock. As regards the soil mix for filling the tubes, there was some evidence that a John Innes seeding compost mix (loam, peat and sand in the ratio 2:1:1) gave better results than the "standard" 1 : 1 peat-sand mixture, undiluted peat, or "Levington" potting compost. However, it is doubtful if the slight

advantage to be gained from using the John Innes mix will out-weigh the greater cost and practical disadvantages involved.

Considering these 1968 experiments as a whole, early survival has been very satisfactory and growth of both Lodgepole pine and Sitka spruce often good in view of the very small size of the seedlings when planted. Animal browsing has continued to prove a less serious problem than expected, although considerable damage by deer and hares has occurred in the experiments at Tighnabruaich, by blackgame and sheep at Selm Muir, and by hares at Rumster. However, recovery from browsing has in most cases been good and only at Selm Muir has it been necessary to abandon an experiment because of damage. Most of the sites have required little or no weeding, but at two of the Tighnabruaich experiments vigorous grass growth provided a clear demonstration of the difficulty of finding small seedlings in dense vegetation.

A further ten experiments were planted during 1969 at Shin, Tighnabruaich, Selm Muir and Towy (South Wales). Early indications are that seedling performance in these will be at least as good as in the 1968 experiments, because seedlings planted between April and July frequently reached heights of 10 cm (4 in) or more by the end of the growing season.

Experimental work will continue in 1970 on a considerably increased scale. In addition to a new series of conventional experiments, relatively large blocks, each 3–4 hectares (8–10 acres) in area, will be planted with tubed seedlings at selected peatland forests in order to provide experience of using seedlings on a much larger scale than has hitherto been possible.

Afforestation Trials on Mineral Soil

The oldest trials with tubed planting stock on mineral soil were planted in 1967 on an imperfectly drained peaty podsol at Glen Garry Forest (Inverness-shire). At the end of the 1969 growing season, survival of Lodgepole pine and Sitka spruce in these trials remained relatively high at over 80 per cent. Height growth of both species has generally been poor, but in places showed a distinct improvement associated with increased thickness of peat layer. The best mean heights recorded were 10 cm (4 in) for Lodgepole pine and 15 cm (6 in) for Sitka spruce. During the 1968/69 winter, frost-lifting of tubes was frequent, although less severe than during the first winter after planting. It was again noted that an increase in the peat depth was associated with reduced frost lift. As indicated in the 1968 *Report*, detailed treatment comparisons are not possible in these early trials.

A series of more comprehensive experiments was planted at Glen Garry during 1968, and results have so far been similar to those for the 1967 trials. In each experiment a high proportion of the seedlings was affected to a greater or lesser extent by frost lift during the 1968/69 winter, and there were no obvious differences between various treatments under test, including dates of planting from May to October and a range of tube lengths. May-July planting gave somewhat better survival than planting later in the growing season, but overall survival was slightly poorer than in the earlier experiments. Height growth was generally poor, but again showed a distinct improvement with increasing thickness of the peat layer. Treatment

differences were largely obscured by the poor growth, but there was some evidence that growth was better with a John Innes seeding compost mix than with either undiluted peat or a peat-sand mixture in the tubes.

Further experiments were planted during 1969 at Farigaig Forest (Inverness-shire) on a peaty podsol, at Selm Muir on a gley soil, at Tighnabruaich on a podsolic brown earth, at Towy on an ironpan soil and at Thetford on a brown earth. At the end of the season, survival in most of these experiments was good in spite of the very dry late summer, but the appearance of the seedlings suggested that height growth was likely to be as poor as in the earlier experiments.

In view of the degree of frost lift and the poor height growth in all experiments to date, it appears that tubed seedlings (of the size and type tested) are not suitable for afforestation on mineral soils with little or no peat present, while on southern sites heavy weeding costs and damage by game birds and finches are additional adverse factors. Because of this, future experimental work on mineral soils will be very limited, and will be restricted to peaty gley soils with a peat layer sufficiently thick to form at least half the thickness of plough ridges.

Regeneration Trials

Survival remained reasonably high in a small experiment planted with tubed seedlings in May 1968 on a clear-felled, gently sloping, peaty gley site at Kielder Forest (Northumberland) although some frost lifting occurred during the 1968/69 winter. Growth during 1969 was variable, Sitka spruce performing somewhat better than Norway spruce and Grand fir. Available evidence suggested that water-logging of the peat layer was affecting growth adversely.

Further experiments on peaty gley sites were planted during 1969 at Kielder and Glenbranter Forest (Argyll). Initial growth has been considerably better at Glenbranter (on a fairly steep slope) than at Kielder (on an almost level area) and tends to confirm that water-logging is the major adverse factor at Kielder.

A. J. LOW

R. M. BROWN

Forest Use of Roll (" Nisula ") Transplants

One-year-old seedlings of Sitka spruce, of Queen Charlotte Island origin, and Corsican pine were incorporated in rolls in March 1969 for subsequent forest planting in July and September 1969, and spring 1970. The Sitka spruce was planted on a deep peat and on an ironpan soil both at Towy Forest (South Wales), and the Corsican pine on two brown earth sites at Thetford, one with and one without overhead shade.

At Towy, survival of July-planted roll transplants was excellent at over 95 per cent, and was satisfactory for September planting. Early growth was satisfactory, but it was noticed that the plants were slow in setting terminal buds and hardening off, especially on the peat site where only 4 per cent of the " Nisula " plants had terminal buds in November 1969. By spring 1970,

roll plants looked healthier and greener on peat than on mineral soil, but on neither site were they as green and sturdy looking as the surrounding trees planted as normal transplants in the spring of 1969.

On the Thetford site with overhead shade, survival at November 1969 of both July- and September-planted stock was exceptionally good, the lowest survival being that of the July stock at 94 per cent. Early growth, however, had not been exceptional and the roll plants were very much the same size as freshly planted bare-rooted stock (6–7 cm). Survival at November 1969 was also adequate on the site without overhead shade, with that of the July-planted stock at 84 per cent, but inspection in March 1970 suggested that ultimate survival might be somewhat lower than this and many plants were so sickly that their subsequent death seemed likely. There was some difficulty at Thetford in planting the trees firmly. Roll transplants are slender and the presence of peat round the roots seemed to prevent the soil gripping the plant. The trees were consequently inclined to " socket " in the planting spot.

R. M. BROWN.

Planting Mechanisation

Modifications of the Finn Forester Tree Planter have been carried out with the continued co-operation of the British agent for the machine. The object has been to adapt it to cope with spaced furrow ploughing, and the prototype model is to be tested on a practical scale in the 1970 planting season.

S. A. NEUSTEIN

Spacing

A study of the effects of spacing upon wood density in Sitka spruce at the Forest of Ae (Dumfriesshire) was carried out in co-operation with the Forest Products Research Laboratory. The experiment sampled was 34 years old and covered four initial spacings ranging from 0·9 m by 0·9 m (3 ft by 3 ft) to 2·4 m by 2·4 m (8 ft by 8 ft), and also included two markedly different subsequent thinning treatments. The experiment provided a wide range of sample material and a number of important conclusions can be drawn from the data. The results are being published by Brazier (1970), but points of particular interest to the forest manager are:

(1) that only the largest trees from the wider end of the range of spacings show density values which might be considered too low for normal saw-milling purposes, and

(2) that irrespective of the initial spacing or subsequent thinning treatment all plots contained a very wide range of tree sizes. It would be possible therefore to manipulate even widely spaced stands by suitable thinning, to produce a more uniform crop of a type suitable for the intended end use of the material.

G. G. M. TAYLOR

REFERENCE

BRAZIER, J. (1970). The effect of spacing on the wood density and wood yields of Sitka spruce. Paper delivered to Symposium, "The Timber we Grow", Society of Foresters of Great Britain, Edinburgh 1970. (To be published in Supplement to *Forestry*, 1970).

CHOICE OF SPECIES

TRIALS OF SPECIES ON PEATS

Alder

Various alders have been used in afforestation experiments over the last forty years, with mixed results. The main species have been *Alnus glutinosa, Alnus incana* and *Alnus rubra* (Common, Grey and Oregon alder). Oregon alder has grown extremely rapidly on a poor deep peat site at Shin Forest (Sutherland) after initial fertilising with phosphate and potash, and some trees were nearly two metres (6 feet) tall after their second growing season. If this rate of growth could be maintained over a short rotation, then the yield per hectare might equal that of the most productive conifers, with the added advantage that the next crop could be established from the coppice shoots. Accordingly a review of past experience with alder species in the North was made.

This review showed that considerable caution must be exercised in attempting to predict later trends from the growth during the first five years. In the great majority of the experiments which included alder species, the characteristic rapid early burst of growth was short-lived. After ten to fifteen years, growth had slowed down, and die-back was often starting. In general, growth declined most rapidly on heath or peatland sites of lower fertility, whereas on a heavy clay site at the Lennox portion of Carron Valley Forest, (Stirlingshire) with serious rooting difficulties for conifers, Oregon alder remains healthy. At Drummond Hill Forest (Perthshire) a plot of *Alnus incana* on a brown earth was 18·9 m (62 ft) tall when 33 years old, with a total production of 372 m^3/ha (4174 h ft/acre)—equal to Sitka spruce of Yield Class 160—and continuing to grow well. Oregon alder reaches quite large dimensions in North-west America, where it typically invades rich moist sites which carried high quality Sitka spruce before cutting.

These examples indicate that alders are ecologically misplaced when planted on impoverished heathland or peatland sites, but the question of whether they can be preserved on such areas in a healthy state if the site is improved by fertilisers and cultivation has not been fully explored. At Inchnacardoch Forest (Invernesshire) an experiment with *Alnus glutinosa, Alnus incana* and *Alnus spuria* planted in 1957 throws some light on this. Early growth was characteristically fast and the tallest Grey alder had reached 2·13 m (7 ft.) after two seasons. By the spring of 1961 dead twigs were noted on this species and a small trial of the effects of phosphate, potash and trace elements (molybdenum+cobalt) was superimposed There was a clear response to phospate, and a minor response to potash, while the trace elements had little effect. Subsequent overall top-dressing with phosphate and potash was done in 1963 and 1967/68. Despite these applications the rate of growth has slowed down, and is currently less than Lodgepole pine in the same experiment.

Minor work will continue on nutrition and pathology of alder, particularly Oregon alder, in view of its possible amenity role as one of the few

broad-leaved species which will grow on the extensive areas of poor peatland now being planted in the north of Scotland. Its special mode of nitrogen nutrition with bacterial nodules suggests that in addition to the macro-nutrients, some micro-nutrients may also be required for continued healthy growth on these infertile sites.

TRIALS OF SPECIES ON GLEY SOILS

Growth Problems in Pole-Stage Sitka Spruce

Three experiments at Forest of Deer, (Aberdeenshire), Rosarie Forest (Banffshire) and Fetteresso Forest (Kincardineshire), set up in 1967 to study the effect of defoliation by the Green spruce aphid *Elatobium abietinum* on the increment of pole-stage Sitka spruce crops, were continued in 1969.

At the Forest of Deer, the population of *Elatobium abietinum* was high in 1969, in contrast with the low population in the 1968 season, and there was a severe loss of foliage in unsprayed plots. The plots sprayed with malathion insecticide had 64 per cent better foliage retention than the unsprayed controls and could be readily distinguished in the forest. Increment in both sprayed and unsprayed plots dropped sharply compared with 1968, the greater reduction occurring in the sprayed plots which showed no benefit from the 1969 spraying.

The differences in length of live crown were so large between the treatments that it seemed possible that measurement at breast height might be giving a misleading indication of radial increment, which is normally at maximum in the lower part of the live crown. Diameter measurements at 4·57 m (15 ft) and at 1·3 m (4 ft 3 in) on the same tree were carried out on a stratified sample of nine trees per plot. They showed no difference between treatments in the upper diameter expressed as a percentage of the diameter at breast height, and the latter can therefore be regarded as adequate for measurement of radial increment. Even after taking account of the 1969 figures, there has been a net benefit of 1·30 m^2/ha (4·4 ft^2 qg/acre) in basal area increment for the sprayed plots over the whole three years of treatment.

At Rosarie and Fetteresso the incidence of *Elatobium* was low in 1969, and the difference in increment negligible. At Rosarie spraying had resulted in a 36 per cent increase in basal area increment the year before. Increment improved markedly there during 1969 in treated and untreated plots. The net benefit in basal area increment for the sprayed plots at Rosarie over the three years of treatment was 0·98 m^2/ha (3·4 ft^2 qg/acre). At Fetteresso, no differences are to be expected until an attack by *Elatobium* occurs.

See also paragraph: *Green Spruce Aphid, Elatobium abietinum* on page 121 of this *Report*.

TRIALS OF SPECIES ON FREELY DRAINED SOILS

Mixtures at Clashindarroch

In 1954 an experiment (numbered 44) was planted at Clashindarroch Forest (Aberdeenshire), in which eight species or varieties of spruce and seven species of silver fir were planted in plots either pure or in mixture with three rows of Japanese larch. The site is a podzolised brown earth on

a steep, north-facing slope at an elevation of 228 m (750 ft). The vegetation is dominated by heather, *Calluna vulgaris,* with some *Vaccinium myrtillus* and *Erica tetralix.* The area was tine ploughed and the trees planted without fertiliser, as an adjacent experiment showed no benefit from basic slag. However, *Calluna* rapidly colonised the area bared by ploughing.

In 1957 the spruce section was given phosphate at 42·5 g (1½ oz) per tree and by 1960, six years after planting, heights varied between 0·18 m (0·7 ft) for *Abies veitchii* and 0·76 m (2·5 ft) for *Picea abies* with the Japanese larch nurses up to 1·22 m (4 ft). Growth of the latter accelerated while that of the spruces and firs continued to be very slow, so that the tallest spruce (Sitka) was only 1·09 m (3·7 ft) at ten years while the best larch was 3·05 m (10 ft) high. As little suppression of the *Calluna* had taken place and as the larch were liable to suppress rather than nurse the other species, the *Calluna* in the pure plots was sprayed with 2,4-D in August 1965 and some hand weeding of the worst-checked trees carried out in the mixture plots. Larch which were suppressing spruce or firs were cut out at the same time and a deer fence erected around the pure plots of silver firs.

The experiment was assessed at fifteen years (Table 9), by which time the spruces had improved considerably and were mostly above the *Calluna,* which had largely regrown or recovered from the spraying. The beneficial effects from the Japanese larch nurse were greater in some spruce species than in others. They were completely masked in the Silver fir section where the pure plots were fenced while the mixed plots continued to be cropped by deer. It is increasingly evident that without fencing it is a waste of time to plant silver firs.

TABLE 9

ASSESSMENT OF CLASHINDARROCH MIXTURE EXPERIMENT 44

MEAN HEIGHTS AT FIFTEEN YEARS IN METRES (FEET)

Species	Pure	Mixed	% Gain from nursing	Japanese larch nurse
Picea abies	1·72 (5·8)	2·46 (8·1)	40	5·18 (17·0)
Picea sitchensis	1·67 (5·6)	2·84 (9·4)	66	5·08 (16·4)
Picea omorika	2·31 (7·7)	2·62 (8·7)	13	5·36 (17·7)
Picea glauca var. *albertiana**	1·42 (4·8)	1·52 (5·0)	6	5·40 (17·9)
Picea engelmannii	1·83 (6·0)	2·15 (7·2)	22	5·08 (16·8)
Picea glauca	1·67 (5·6)	2·28 (7·6)	35	5·28 (17·4)
Picea pungens	0·79 (2·7)	0·84 (2·9)	6	5·31 (17·5)
Picea rubens	1·62 (5·4)	1·96 (6·5)	20	5·03 (16·6)
Abies grandis	1·83 (6·0)	1·42 (4·8)	No conclusion possible because of deer damage	4·65 (15·3)
Abies lasiocarpa	0·81 (2·8)	0·63 (2·1)		5·03 (16·6)
Abies procera	1·27 (4·2)	0·84 (2·9)		4·16 (13·8)
Abies veitchii	0·63 (2·1)	0·61 (2·0)		4·11 (13·6)
Abies concolor	1·42 (4·8)	1·01 (3·4)		—
Abies magnifica	1·55 (5·1)	1·55 (5·1)		—
Abies nordmanniana	1·01 (3·4)	0·79 (2·7)		—

* Believed to be a product of introgression with *P. engelmannii.*

R. LINES

High and Exposed Sites

Scotland and Northern England

On North Uist (Outer Hebrides), two new trial plantations, incorporating a range of nutritional inputs, have been planted on land acquired in 1968. Two other similar new experiments in the Weardale Beat of Hamsterley Forest (County Durham) and at Queen's Forest (Inverness-shire) have been ploughed and are ready for planting in spring 1970.

Following evidence that applications of fertiliser (especially nitrogen) to fairly exposed crops can markedly improve needle retention, a preliminary trial of top-dressing of severely exposed trees, with and without artificial shelter, was established. As there was little response to added fertiliser in the unsheltered plot, it is postulated that there may be a level of exposure beyond which plants do not respond to added nutrients—a possibility of significance in deciding whether to top-dress severely blasted upland plantations. A new experiment at Penninghame (Wigtownshire) aims to test the experimental methods which might be used to quantify the interaction between exposure and fertilisation. Exposure will be controlled by means of a permeable screen and assessed by means of tatter flags at various distances from the screen.

A disquieting occurrence of the past year has been the onset of windthrow in Lodgepole pine crops of about 9 m (29 ft) in height in the trial plantations set up in Planting Year 1950 at Strathy Forest (Sutherland). The damage has not yet been inspected in detail but it is assumed to have been caused by the severe gales of September 1969, when gust speeds exceeded (45m/s, 100 mph).

Wales

The experiment at Radnor Forest which includes the use of potted plants, and was referred to on page 52 of last year's *Report*, continues. In the second growing season the benefit of individual plant shelters has been much greater than that from the potting treatment. This is a reversal of the situation after one growing season.

At the end of two growing seasons the mean heights were:

	Planted from cold-store (Bare-rooted)	*Potted*
	cm. (in.)	cm. (in.)
Not sheltered	37·25 (15·55)	48·50 (19·10)
Sheltered	51·00 (20·08)	66·70 (26·26)

Standard error—1·22 cm. (0·48 inches).

Despite the elevation of 610 m (2,000 ft), no plant losses occurred even in the *unsheltered/planted from cold-store* treatment.

Reference was made in the 1969 *Report* to the shorter growing season at high elevation sites, and a small trial was started in 1969 to examine the possible effect of this. Shoot elongation of Sitka spruce seedlings of Queen

Charlotte Island origin has been recorded at weekly intervals, at the high elevation site at 610 m (2,000 ft) elevation and at a lower site at 200 m (650 ft) elevation.

During 1969 the following points were noted:

(1) The length of the growing season (160 days) and total shoot growth (155 mm, 6·1 in) was the same at both sites.

(2) The onset of secondary or lammas growth and the ratio *primary/secondary growth* was the same at both sites.

(3) Growth at the lower site started and finished two weeks before that at the higher one.

These results may be a reflection of the particularly favourable weather in the late summer of 1969, but this should be resolved as the experiment will be repeated in 1970, when air and soil temperature will be recorded.

S. A. NEUSTEIN

J. EVERARD

Basal Bowing of South Coastal Lodgepole Pine

Two new experiments, at Kirroughtree Forest (Kirkcudbrightshire) and Shin Forest (Sutherland), have been planted to test variations in planting position, because previous experiments have indicated that windsway, and hence basal bowing, can be influenced in this way.

Basal Bowing and Timber Properties

The two studies of conversion loss and compression wood referred to in last year's *Report* have been completed. The amount of compression wood was not found to differ significantly between South Coastal and an Inland provenance; the growth of the latter is slower than that of the former, but as the inland provenance has the greater saw-log potential, its planting may be justified on sites where pulpwood production is not the main objective.

Atmospheric Pollution

An aluminium smelter and an oil refinery with associated petro-chemical industry currently under construction near Invergordon (Ross-shire) are potential producers of atmospheric pollution which could affect tree growth in the hinterland. Following an appraisal of hazard and economic risk it was decided to assess pollutant levels in tree foliage before and after the start of industrial operations. The assessment is based on a stratified sample within a radius of 16,000 metres (10 miles) of the factories, using Scots pine, the predominant forest tree, as the main test species and including the following variables: distance from and direction relative to pollution source, exposure, crop age, crop vigour and canopy position of individual trees. The first "clean air" sampling has been completed as well as a concurrent pilot study of technique near the established smelter at Fort William, in crops suspected to be subject to pollution. Chemical analysis

will be carried out by Kings College, University of London. In addition, a contract survey of lichens in the Invergordon region has been completed by a lichenologist with experience in this field. Some lichens are known to be particularly sensitive to pollution and the response of different species may assist in discriminating between flourine and sulphur dioxide, and indicate when a re-sampling of tree foliage is justified.

The monitoring of sulphur dioxide levels around Westfield gas works (Fife) by means of lead dioxide candles, has been terminated after nine years. The levels of SO_2 were well below those recorded in the Pennines, and showed a general drift eastward from the gas-works. There were marked annual peaks between November and March often associated with periods of calm weather, but these were not correlated with gas production or non-operation of the sulphur recovery plant. It appeared that the gasworks itself did not raise the SO_2 level significantly above that attributable to local urban and other sources, and no damage to tree foliage or growth has been identified as resulting from its presence.

S. A. NEUSTEIN

TRIALS OF SPECIES WITH SPECIAL CULTURAL AND SITE REQUIREMENTS

Poplars

Varietal Studies

Interest has been confined to selected clones of *Populus trichocarpa* and to a small number of hybrids having *P. trichocarpa* as one of the parents which, because of their sustained vigour in trials, have continued to merit attention. Sample trees were felled at three sites, at Stenton Forest (East Lothian), Wynyard Forest (Co. Durham), and Flaxley, Forest of Dean, to provide Bryant and May Limited with timber for tests of splint strength. Though match splints are traditionally made from aspen, and on a limited scale in recent years have also been made from hybrid black cultivars of *P.* x *euramericana,* none of the potentially valuable species and hybrids in the balsam groups of poplars has been utilised commercially by the match industry. As the prospects for growing *P. trichocarpa* and its related crosses for timber are reasonably favourable, scientific tests are being arranged at match factories as timber of selected clones becomes available in trials.

Plans are well advanced for the official release of *P. trichocarpa* 'MB' to growers and the nursery trade. This clone, which was introduced from Washington State, United States of America, in 1950, has shown good resistance to bacterial canker in rigorous field tests. Like several other selections of this species recently obtained for trial it grows rather faster and appears to tolerate marginal site conditions better than the commonly planted black hybrid poplars. As the clone is likely to be made available for commercial propagation in a number of other countries there has been international discussion during the year on its general release. A cultivar name has been proposed and accepted, and a botanical description has been prepared and awaits publication in the Netherlands. The question of its registration with the International Poplar Commission has also been reviewed.

There were no changes during the year to the Populetum or to the varietal collection located at Alice Holt. There are nearly 500 clones in the collection, and of these 320 have been established in the Populetum.

Elms

Varietal Studies

During the year the number of clones housed in the central collection at Alice Holt was increased to 82. The additions were clones of English elm, *Ulmus procera,* obtained for propagation studies. The collection now includes 56 selections made in this country of the main timber-producing and ornamental elms.

In the disease trial located at Alice Holt, Commelin elm, *U.* x *hollandica* ' Commelin ', again showed good resistance to elm disease after innoculation with the casual organism, *Ceratocystis ulmi.* Additionally a clone of Huntingdon elm, *U.* x *hollandica* var. *vegeta,* also displayed sufficient resistance to suggest that it may remain comparatively free of disease in the field. It will be rigorously tested in the next year or two to see if its behaviour in 1969 was exceptional.

Silvicultural Studies

In the nursery, work was confined largely to developing techniques for raising English elm from softwood cuttings, employing bottom heat and automatic mist irrigation. The results were sufficiently encouraging to suggest that if they could be repeated during the coming summer, firm recommendations on methods could be made to the nursery trade. The main criteria for success appear to be insertion of cuttings as early in the growing season as possible, minimal handling during collection and preparation, and copious watering after insertion to prevent wilting.

Studies continued at Lynn Forest (Norfolk) and at Alice Holt, to improve the survival, rate of growth and stability of newly planted rooting cuttings. As in earlier planted experiments, cutting-back the plants to within an inch or two of the root collar immediately after planting improved rate of growth, but neither this treatment nor deeper-than-normal planting influenced survival and stability. The occurrence of hare damage in the experiment at Lynn Forest disclosed, however, that while cutting back newly planted stock might be culturally advantageous, survival and stem shape could be adversely affected unless suitable protective measures were taken.

Leyland Cypress

Techniques likely to lead to improvements in the rate of rooting of cuttings inserted in heated frames were again examined at Alice Holt and Kennington Nurseries. At Alice Holt none of the treatments significantly increased rooting percentage, but it was noted that by raising soil temperature from 21°–24°C. to 27°–30°C. the number of cuttings that rooted was slightly increased, while at a temperature of 15° –17°C. the number was reduced. The relationship between soil temperature and rooting percentage appears sufficiently interesting

to justify further study. Dipping cuttings in hot water prior to insertion, a technique said to improve the " take " of some horticultural conifer clones, did not improve rooting, nor did reduction in size of cutting. At Kennington Nursery hand watering led to better rooting than automatic misting.

London Plane

A short-term investigation has recently been started on methods of reproduction of London plane, particularly to devise techniques for quickly raising small numbers of plants. The survey recently conducted by Pathology Section on London plane (discussed on page 117 of this *Report*) has led to the selection of several clones for propagation to produce stock needed for research. The traditional methods of propagation, by layering and from hardwood cuttings inserted in the open nursery, are, for various reasons, unsatisfactory, and at least in the initial stages special attention will be paid to reproduction from softwood cuttings in mist and from hardwood cuttings inserted in heated beds. There are already indications that a successful technique will be found, as hardwood cuttings collected and inserted in early March had developed a basic root system within three weeks. This followed treatment with indol-3-ylbutyric acid (in solution), the cuttings then being inserted in a medium maintained at a temperature of 21°–24°C.

J. JOBLING

MINOR SPECIES SURVEY

The evaluation of minor species has now been completed and the following section is the summary from a report made on it during the year.

In order to evaluate the current performance and future potential of Western hemlock (*Tsuga heterophylla*), Western red cedar (*Thuja plicata*), Grand fir (*Abies grandis*) and Noble fir (*Abies procera*) for forestry in Britain, visits were made to a total of over 200 stands of these species and a similar number of stands of major species for comparison. Crop growth and site characteristics were assessed and the soil described.

In addition, information was obtained from over 150 silvicultural experiments and from Conservancy records on survival and rates of growth shortly after planting, susceptibility to frost and response to overwood shelter, and on likely growth rates using improved seed from seed orchards or seed of more productive provenance.

Observations on damaging influences made during the visits for growth measurement were supplemented in the case of drought crack and of incidence of *Adelges piceae* by data from survey studies prior to the present study; for estimates of timber losses due to *Fomes*, and of susceptibility to windthrow, small special studies were made purposely for this investigation.

Information on timber properties was obtained from published and unpublished data prepared by Forest Products Research Laboratory during studies commenced prior to this investigation.

The results of all investigations were converted into terms of discounted revenue or discounted cost.

The factors which have the greatest influence on relative value are: timber density, differences in discounted revenue for a given yield class consequent on differences in the time of first thinning; differences of future potential compared with existing crops, consequent on seed orchard, tree selection or provenance research and development programmes. Factors having a moderate effect on the relative value of species are: establishment costs, susceptibility to *Fomes* heart rot, susceptibility to drought crack, and poor stem form. Factors which could not be shown to have any differential effect were: stability of crops, and susceptibility to insect and to animal damage.

On the more productive sites, the minor species grew faster than the comparable major species. However, for various combinations of reasons, the value of the four minor species was lower, yield class for yield class, than the major species. The extent to which the more vigorous growth of minor species compensated for their lower value determined the extent to which the minor species should be favoured, given the various assumptions made at different times.

Only Grand fir on the most productive sheltered sites appears to be more profitable than any other. Noble fir is nowhere the most profitable species. Hemlock is nowhere more profitable than Sitka spruce but on many sites

is more profitable than Norway spruce and larch. It is more valuable than Douglas fir on the best sites in England and Wales but not in Scotland. Red cedar is more profitable than other species only in the southern half of Britain and then only on lowland sites on the heavier soils.

It has been assumed that planting policy should be designed to foster a long-term market for home-grown sawn timber of species by name. The least area able to sustain a regional market in a named home-grown sawn softwood is considered to be 2,000 ha (5,000 acres) producing yield class 200 or better, or 3,250 ha (8,000 acres), average yield class 140 and so on pro rata. Double these areas would be better. Such areas would have to be maintained by planting programmes of between 40 and 120 ha (100 and 300 acres) per annum on a 50-60-year rotation to feed any one potential regional market. These criteria apply as much to existing major species as minor species, Douglas fir in particular being present in some regions on a smaller scale than is desirable by these standards. Increases in area of minor species may be at the expense of other species with an already established market.

None of the minor species has been planted on a scale which, without further planting, could support any such regional market. The nearest is Western hemlock which has been planted extensively in the last twenty years in Wales and southern England. The area could be readily extended by using hemlock to replace the larch, Norway spruce and old hardwood areas shortly to be felled. This would not be the most profitable course if it was decided to plant Grand fir extensively, since the better part of such mature crops could carry satisfactory crops of Grand fir. While Red cedar appears more profitable than other species (except Grand fir) on a limited number of sites, the smaller sizes of roundwood, because of their colour, can be expected to be difficult to market in intermediate quantities. There is no prospect of sufficiently large quantities anywhere to support a kraft mill utilising Red cedar. Because of this uncertainty and relatively small existing scale of planting, it is considered that Red cedar should not be planted extensively.

The existing plantations of Grand fir and Noble fir are so small in extent that, in respect of the possibility of marketing home-grown Grand fir in substantial quantities, they can be ignored. Any future market has to be planned as from the present, reckoning that it would take 25 to 30 years for sawlogs to come to the market in quantity from the time any extensive programme started in a region. The ultimate product would be of appreciably lower density (and by inference, strength) than timbers commonly used in Britain. It is likely that, in particular localities with very high risk of losses of timber due to *Fomes* rot, Grand fir may be somewhat more profitable than in the general case. In areas subject to risk of late spring frosts such as eastern England, protection in the form of overhead shelter, or an equivalent, must be given in the early years if Grand fir is to be established easily.

There is no case for extensive planting of Noble fir, though it could have an important role as an amenity tree.

J. R. ALDHOUS

A. J. LOW

PROVENANCE

Lodgepole Pine

A collection of eighty-six Lodgepole pine provenances obtained in 1965/66 was sown in 1968 at four nurseries: Inchnacardoch (Inverness-shire), Fleet (Kirkcudbrightshire), Kennington (Oxfordshire) and Wareham (Dorset). The provenances were mostly divided between the two Scottish sites to reduce each experiment to a more easily managed size, though twelve lots were sown at both sites to facilitate comparisons. In England 72 provenances were sown at each nursery.

The "South Interior of British Columbia" group of provenances was the first to germinate; some of the Alaskan and Vancouver Island lots were much delayed. Although the same number of viable seed was sown per plot, the number of seedlings at the end of the season differed significantly and height differences were highly significant. Regression of seedling height on seed weight showed that this accounted for a fairly large proportion of the height differences. The tallest seedlings were from the South Interior of B.C. region and from the South Coastal region of Washington, Oregon and California, while the poorest were from Edmonton, Alaska and the Central Interior of British Columbia.

The seedlings developed characteristic autumn colouration due to anthocyanins. Northern provenances were dark purple and South Coastal ones were a grass green. High elevation Californian provenances and one from Klamath, Oregon, stood out as being pale green. During the first winter a few plants from Mendocino, California, were killed by frost. Dry weights of seedlings from five provenances showed significant differences in root/shoot ratios, the highest proportion of roots being on the Alaskan origin from Glacier Bay, which had double the root/shoot ratio of lots from Mount Ida, South Interior of British Columbia, and Tillamook, Oregon coast. The South Coastal region provenances, particularly one from Mendocino, developed strong lammas growth during the second year, whereas most of the northern provenances had little late season growth.

Height variation as 1+1 transplants followed the pattern of seedling height closely, and after adjustment by co-variance to remove the effect of height as one-year seedling, no significant variation remained in the transplant heights. There were some appreciable changes in rank, and in many cases it was noted that the provenances which fell in rank order were those with large seed in relation to others in the provenance group. It is of interest that in spite of the smaller proportion of lammas growth on the plants originating from the South Interior of British Columbia, compared with those from the South Coastal region, they still held four out of the top five positions for height at Inchnacardoch. The position was different at Fleet where the southern coastal origins were outstanding. Samples have been taken for further studies on root/shoot ratios of twenty provenances, which may throw light on the problem of basal bowing.

These provenances were planted in 1970 at eight sites in the North and at six sites in the South. In South-West England and Wales Lodgepole pine is a possible alternative species to Sitka spruce, so at Beddgelert Forest (Caernarvonshire) and Towy Forest (Cardiganshire) seventy-two provenances were used, with three provenances of Sitka spruce included in the design. At Thetford Forest (Norfolk) and Brendon Forest (Somerset), Lodgepole pine may be regarded as an alternative to Corsican pine, and at these forests the same provenances of Lodgepole pine are being compared with three provenances of *Pinus nigra*. Unreplicated demonstrations were planted at Honiton (Devon) and Bedgebury (Kent).

In Scotland the full range of eighty-six provenances is included at Mabie Forest (Dumfriesshire), while at the other sites provenances have been selected so as to test most thoroughly the ones which seem most appropriate for that locality. On the deep peat sites of Shin (Sutherland), Glengarry (Inverness-shire) and Glen Trool (Kirkcudbrightshire), a large number of coastal provenances have been included, while only a selected number of inland provenances are present. At the heathland sites of Rosarie (Banffshire) and Allerston, Broxa (Yorkshire) this procedure has been reversed. Scots pine would oiginally have been the choice of species at both these sites, so a genetically improved strain of this species has been included, together with Sitka spruce and (at Broxa only) Corsican pine. These provenances have been added to the collections of demonstration plots at Shin and Inchnacardoch Forests.

The 1965 collection left certain gaps in the coverage of this very variable species. It was nearly all organized through commercial collectors so that details of exact location, elevation and appearance of the parent stands are usually unknown. In 1966-68 collecting teams organized by the International Union of Forest Research Organizations gathered seed from 123 sources with full details of origin. As many of these duplicated provenances in the earlier collection, 24 provenances have been selected which (a) fill gaps in the existing set, (b) provide detailed locations for sources for which we needed supplementary information, or (c) duplicate intentionally some known provenances so as to enable us to correlate the performance of the unknown ones with that of known ones in older experiments. The forest experiments using these IUFRO provenances will be on a smaller scale than those of the 1965 collections. Seed was sown in 1970 at Newton Nursery (Moray), Wareham Nursery (Dorset) and by twenty-seven international co-operators throughout the world. R. Lines has been appointed co-ordinator by Section 22 of IUFRO for these international trials.

At Black Isle Forest (Millbuie Ross-shire), in an experiment planted in 1938, foliar analysis has been carried out in each of five replications on six provenances every year for six years. The results have now been analysed and are summarised in Table 10. They show that there were very highly significant differences between provenances in needle dry weight and in the percentages of nitrogen, phosphorus and potassium in the needles.

Differences in magnesium were not significant. For needle weight the coastal provenances were markedly lower than inland ones, with one from Terrace British Columbia, occupying an intermediate position. Needle nitrogen was highest in the slow-growing provenance from Klamath, Oregon,

TABLE 10

FOLIAR CONCENTRATION OF NUTRIENTS IN SIX PROVENANCES OF LODGEPOLE PINE AT BLACK ISLE FOREST, NORTH SCOTLAND

Provenance	Height at 20 years m(ft.)	Needle weight g	Nitrogen %	Phosphorus %	Potassium %	Magnesium %
Coastal						
Washington coast	8·87 (29·1)	20·17	1·149	0·146	0·597	0·100
Queen Charlotte Islands British Columbia	7·44 (24·4)	20·00	1·317	0·141	0·618	0·096
Inland						
Terrace, Skeena River, British Columbia	8·29 (27·2)	22·80	1·359	0·154	0·610	0·107
Prince George, Central Interior of British Columbia	8·56 (28·1)	28·92	1·447	0·175	0·566	0·102
Shuswap Lake, South Interior of British Columbia	8·29 (27·2)	25·07	1·230	0·161	0·488	0·110
Klamath, Cascade Mountains, Oregon	7·19 (23·6)	31·08	1·527	0·197	0·524	0·120
Standard error ±	0·24 (0·8)	0·69	0·022	0·004	0·018	0·011

and lowest in the vigorous Washington coastal provenances. The northern coastal provenance from the Queen Charlotte Islands British Columbia, had significantly higher nitrogen than the latter. This Queen Charlotte Islands origin had the lowest percentage of phosphorus while the Klamath plants were very high in this element. There was no difference between the two coastal provenances, and the Terrace origin was intermediate between coastal and inland groups. The variations in potassium were less marked than with the other elements on this ironpan soil. The coastal provenances had the highest potassium content while the vigorous inland provenance from Shuswap Lake British Columbia, was lowest. The Terrace lot was nearer to the coastal provenance in potassium than to those from inland areas. These differences may have important practical applications in forest fertilisation.

Douglas Fir

In 1966 a team organized by Section 22 of IUFRO made a very comprehensive collection of Douglas fir seed. Previous British experiments have sampled only part of the range covered by this tree, using seed from commercial sources, which leaves the possibility of doubtful authenticity of origin.

Twenty-nine provenances were selected as covering the range in which earlier experiments had indicated that the most promising provenances were to be found. They were sown in 1968 at Newton Nursery (Moray), Tulliallan Nursery (Fife), Alice Holt, Headley Nursery (Hampshire/Surrey borders) and Wareham Nursery (Dorset).

There was a fortnight's difference in date of germination at Newton, with northern provenances mostly germinating before southern ones. At Tulliallan the pattern was similar and an assessment showed that there were highly significant differences between provenances. At both these sites there were significant differences in number of seedlings per plot, even though each plot was sown with the same number of viable seeds. Seedling height showed highly significant differences between provenances at both sites and

a regression of height on seed weight was calculated to see whether this helped to explain the differences, but it proved to be non-significant in each case. Needle colour was assessed in January 1969 at Newton, and this showed that the provenances from British Columbia were a more healthy dark green colour than those from Washington, which in turn were marginally better than those from Oregon. This collection included only provenances of variety *viridis,* so that the Rocky Mountain forms with blue-green foliage are not present.

At three nurseries frost damaged many seedlings, damage being least at the most northerly site and worst in the south of England. When assessed in January 1969 at Newton there were very highly significant differences in frost damage between provenances, with virtually no injury to provenances originating north of 50°30′ latitude and severe damage to those from below 47° north. The provenances from Cathlamet, Washington, and from Coquille and Brookings, Oregon, were severely damaged at Newton and the last two were almost eliminated at Tulliallan.

The previous August the Newton experiment had been affected by " damping off " fungi which attacked individual provenances to a significantly different degree. Alder Lake and Arlington, both in Washington, and Grand Ronde Agency, Oregon, suffered up to 30 per cent deaths, while Tatla, British Columbia, was virtually unaffected. Fewest deaths occurred in the replication with poorest height growth, but there was no obvious correlation between height growth and stocking of individual provenances and deaths due to " damping off ".

The height of the transplants at Newton followed a similar pattern to the seedling heights, with a tendency for the northern provenances to be smaller than those from Washington. The effect of winter frosting, as might be expected, markedly reduced the height of the southernmost provenances. There was no cline for vigour related to latitude or elevation. At Tulliallan the results were appreciably different from those at Newton, with four of the five tallest provenances coming from British Columbia. The outstanding provenance was from Stuie, British Columbia, one of the most northerly of the origins represented.

These plants have been used in three forest experiments in Scotland. Two, at Culloden (Nairn) and Craigvinean (Perthshire), are well replicated with small plots in a partially-balanced incomplete block design and the other, also at Craigvinean, is an experiment with a triple lattice design using three replications of 17 provenances. These localities are well-known for good growth of Douglas fir, though the site at Culloden will test the plants for frost hardiness as it is somewhat exposed to cold easterly winds. Because of heavy losses in the nursery at Alice Holt, in the south, these provenances were planted only at Alton Forest (Hampshire), and they are being re-sown at Wareham for later planting. At Fleet Nursery nine additional provenances were sown in 1970 to supplement the earlier collection.

Bishop Pine

At Newborough in Môn Forest, Anglesey, a trial of three provenances of Bishop Pine, *Pinus muricata,* was planted on a site very exposed to sea-winds, and a vigorous, southerly, coastal provenance of Lodgepole pine, *P. contorta,* was planted for comparison.

Silver Firs

Abies amabilis and *Abies magnifica* both grow stems of good size with remarkable rapidity in certain areas. Provenance is probably of great importance in *A. amabilis,* in which growth is very variable, but probably of less importance in *A. magnifica,* which has a more restricted geographical range. Five provenances of *A. amabilis* and two of *A. magnifica* have been planted in small trials on one site in Hampshire and one in Devon.

R. LINES

A. F. MITCHELL

ARBORICULTURE

Arboreta and Forest Plots

At Kilmun Arboretum in Benmore Forest (Argyll), further clearance of windblown plots provided an opportunity to expand the *Eucalyptus* collection. New planting included plots of *E. camphora, E. gigantea, E. gunnii, E. johnstoni, E. nitens* and *E. viminalis,* together with small groups of a range of other *Eucalyptus* species. In addition a large plot of *Alnus rubra* was planted, together with groups of various other broadleaved and conifer species.

An access road was completed into Crarae Arboretum near Minard (Argyll). Unfortunately, clearance of windblown timber was further delayed because suitable extraction equipment was not available, as all machinery was fully committed to windblow clearance elsewhere. It is hoped that the necessary work will be completed by mid-summer of 1970.

At Westonbirt (Gloucestershire), as part of a ten-year plan, areas have been cleared for the planting of extensions to the collections of *Sorbus, Quercus* and *Betula* species. Of the new ride system in Silk Wood, 200 yards of one new broad ride has now been cleared. Stumps are being removed using the " Stump Master ", and the ride will be ready for mowing in the 1970 season. Planting of the large features is now starting in this section. The rather extensive collection of notices that has grown up in the car-park area is being re-organised as a preliminary trial forming part of a scheme to rationalise and improve the standard of Forestry Commission notices in public places.

At Bedgebury (Kent), a large area of rhododendron around Marshall's Lake has been cleared. Fourteen Generic Demonstration groups were planted and 50 plants added to the landscaping of the Thornhill slope. Fourteen new cultivars of Lawson cypress were added to the extension of the already large collection of these decorative trees. Mr. Winston Churchill planted a commemorative tree in the Pinetum and unveiled a plaque at Churchill Wood, renamed and dedicated to the memory of his grandfather, Sir Winston Churchill K.G., in the Golden Jubilee year of the Forestry Commission.

A. F. MITCHELL

A. J. LOW

NUTRITION OF FOREST CROPS

NUTRITION OF TREE CROPS ON DEEP PEAT (PROJECT 346)

Phosphate Fertilisers: Forms, Rates and Methods of Application

After three growing seasons, the long-term phosphate trials comparing rates and types of rock phosphate are showing different response patterns according to site. Table 11 shows the comparable foliage phosphorus levels for South Coastal Lodgepole pine according to the rate of phosphate applied, together with the phosphorus content of unflushed oligotrophic peat at Mabie Forest (Dumfriesshire), Shin Forest (Sutherland) and Glen Trool Forest (Kirkcudbrightshire).

TABLE 11

FOLIAGE P CONTENT OF 3-YEAR-OLD LODGEPOLE PINE, AND P CONTENT OF THE TOP 15 CM OF PEAT AT MABIE, SHIN AND GLEN TROOL FORESTS

Forest	Per cent oven-dry weight				mg P/100 g of oven-dry peat
	Rate of application, kg P/ha				
	17	34	67	134	
Mabie	·093	·118	·149	·159	37
Shin	·155	·158	·163	·183	48
Glen Trool	·172	·171	·186	·180	108

The figures indicate that the better the peat type the better the uptake of phosphorus, but the smaller the difference in uptake between rates. In contrast Table 12 shows there is little difference in height growth as yet between rates and methods of application of phosphate at any one site. At Mabie the trees with the lowest broadcast rate are already falling behind, as one might expect, on this very poor peat, but despite this the tree growth on this lowland raised bog is more than twice that of the richer but more exposed hill peats. This indicates the potential of these very poor, but sheltered sites.

So far in these experiments the different types of phosphate are not having significantly different effects on growth, but it is encouraging to find that both at Mabie and Shin crude phosphate rock produces the highest foliar P concentration. This is the type that is being applied successfully from the air on a large scale.

The increasing mechanisation of forestry has included attempts to spread fertilisers by ground machines, and top-dressing of plantations from the air has also been practised on a small scale for many years. The latter, however,

TABLE 12

MEAN HEIGHT OF THREE-YEAR-OLD LODGEPOLE PINE AT MABIE, SHIN AND GLEN TROOL FORESTS

cm

Forest	Method of application	Rate of application kg P/ha			
		17	34	67	134
Mabie	Spot	126	124	126	126
	Broadcast	110	122	122	128
Shin	Spot	49	43	49	46
	Broadcast	49	49	43	49
Glen Trool	Spot	48	44	43	47
	Broadcast	47	49	44	48

has only recently come into its own with the use of unground phosphate rock (i.e. phosphate rock crushed and then passed through a ¼-in mesh screen). This has a consistency rather like fine sand and can be passed through the spinners used on aircraft, whereas ground phosphate rock clogs the spinners and triple superphosphate is too expensive. Mechanical application of fertilisers from ground machines still presents problems, as unground phosphate rock has been shown to have a very poor distribution pattern compared with granular materials (see Work Study, p. 145).

A trial of unground phosphate rock triple superphosphate, and granulated phosphate rock (imported "Hyperphos") has been started this year in Towy Forest in South Wales on newly-planted Sitka spruce on deep peat. Granulated phosphate rock was included in this trial because there was a possibility that it might be manufactured in Britain, and could be a useful material. The three materials were applied in three different ways: broadcast before ploughing, broadcast after planting, and laid in a strip under the plough ridge, simulating, respectively, mechanical distribution by tractor spinner before ploughing, aerial application after planting, and application by the tractor doing the ploughing. Broadcasting of phosphates before ploughing on highly phosphate-deficient soils is now common practice in Northern Ireland, and it seems sensible to try to raise the nutrient status of such poor sites rather than feed the immediate area round the plants.

The trial also compared plots with and without potassium at 90 kg K/ha, and because this was a relatively unimportant comparison a split-plot design was used, the K treatments forming the main plots. The sub-plots compare methods of application and these are split again for types and for two rates of phosphate, 40 and 80 kg P per ha (roughly equivalent to 2½ and 5 cwt Gafsa phosphate per acre).

Nitrogen Fertilisers

From experiments involving early application of nitrogen (in the year after planting) to Sitka spruce on very poor unflushed peat, it appears that such

treatment is detrimental to growth and can depress phosphorus and potash uptake which upsets the balance of nutrient within the plant. The excess nitrogen leads to a tendency towards strong lateral growth, rather than terminal growth, and this is especially noticeable on the plots with annual applications of nitrogen. Table 13 illustrates the nutrient uptake pattern at Mabie Forest in Dumfriesshire.

TABLE 13

FOLIAGE ANALYSIS FOR SITKA SPRUCE THREE YEARS OLD, AFTER NITROGEN APPLICATION (EXPERIMENT MABIE 7 P.67)

per cent oven-dry weight

Treatment	N	P	K	N:P:K ratio
160 kg/ha N in 1968 and 1969	2·58	·169	·67	15:1:4
160 kg/ha N in 1968	2·20	·168	·70	13:1:4
No nitrogen	1·81	·206	·89	9:1:4

The observation that even on the poorest peats early nitrogen application is not necessary, given adequate ground preparation and sufficient P and K fertiliser, is further demonstrated in the "deficiency garden" at Eddleston Water Forest (Peebleshire). Here the treatments without nitrogen, but with the other major nutrients supplied, are growing as well as the treatment with all major nutrients supplied. This raises the question of what constitutes adequate P and K fertiliser input, and new experiments will be laid down to observe tree growth under different PK regimes, and also to compare their respective economics.

Fertilisers and Herbicides

As far as Sitka spruce is concerned, successful growth without added nitrogen requires early herbicide application to remove *Calluna* competition. An experiment at Shin Forest (Sutherland) has shown that Sitka spruce can be successfully established on *Calluna*-dominated peat with minimal P (42 g (1·5 oz) phosphate rock, 5·3 g (0·2 oz) P/plant) and heather removal with herbicide at planting. However, PK top-dressing is now required (5 years after planting) to maintain a good nutrient balance within the plants. Where *Calluna* only becomes dominant after ploughing and draining, herbicide application first appears to be necessary between 3 and 5 years after planting.

Fertiliser/herbicide trials on checked crops indicate that, on deep peats, the combination of both treatments is more effective than either on their own. Table 14 shows the foliage analysis from an experiment at Drumtochty Forest (Kincardineshire) two seasons after treatment.

Whether nitrogen is required in the fertiliser is not certain. Early indications (after one season) from an experiment at Durris Forest (Kincardineshire) show that, while uptake of added nitrogen has been good, uptake of P and K was much greater in the absence of N than in its

TABLE 14

FOLIAGE ANALYSIS OF SITKA SPRUCE IN A FERTILISER/HERBICIDE TRIAL AT DRUMTOCHTY FOREST

per cent oven-dry weight

Treatment	N	P	K
Control, no treatment	0·86	·128	·56
NPK fertiliser only (160N:50P:95K kg/ha)	1·51	·188	·71
Herbicide only	1·57	·155	·76
Fertiliser and herbicide	1·89	·210	·71

presence. Table 15 illustrates this point. Time will tell which treatments are necessary to provide sufficient reserves to carry the crop through to the thicket phase with suppression of any heather regrowth.

TABLE 15

FOLIAGE ANALYSIS OF SITKA SPRUCE IN A FERTILISER/HERBICIDE TRIAL AT DURRIS FOREST

per cent oven-dry weight

Treatment	N	P	K
Control, no treatment	1·05	·184	·55
Herbicide+N (160 kg N/ha)	1·89	·196	·63
Herbicide+PK (50P, 95K kg/ha)	1·54	·274	1·20
Herbicide+NPK	2·30	·209	·80

NUTRITION OF TREE CROPS ON GLEYS WITH CLAY OR ROCK SUBSOILS (PROJECT 347)

The long-term phosphate experiments laid down in the early 1950's and early 1960's on peaty gleys in the Border areas are being used to determine what is the most effective top-dressing treatment. At Kielder Forest (Northumberland), trees with no fertiliser and trees given 42 g P per tree at planting were both growing very slowly after 15 years, although early growth was good ; there has been little difference between treatments since planting. The lack of response to phosphate may have been because the rate was too low, but foliage analysis suggests that although the P level is now slightly below optimum, N deficiency appears to be the cause of the poor growth, so nitrogen and phosphate top-dressings are being tried to stimulate growth. Younger experiments in this series at Wark Forest

(Northumberland) and Ae Forest (Dumfriesshire) are being top-dressed now while growth is still good, to counter an anticipated fall-off in growth after about 10 years.

The response to phosphate manuring has been disappointing in the Sitka spruce drainage experiment established in 1966 at Towy Forest (Cardiganshire), which is sited on a *Molinia*-dominated peaty gley. In 1968 a small trial was established on adjacent and similar ground to investigate the relative benefit of phosphate and potash. The treatments and results to date are given in Table 16.

TABLE 16

HEIGHT INCREMENT OF SITKA SPRUCE IN A PK FERTILISER TRIAL AT TOWY FOREST

cm (in)

Treatment nutrient element kg/ha (lb/acre)		Height of plants in 1968	Height increment in first year after treatment	Height increment in second year after treatment
P	K			
0	0	34 (13·0)	11 (4·0)	16 (6·5)
50 (45)	0	32 (12·5)	7 (2·5)	19 (7·5)
0	94 (84)	34 (13·0)	11 (4·0)	27 (10·5)
50 (45)	94 (84)	34 (13·5)	10 (4·0)	25 (10·0)

Foliar analysis at the end of the second year after fertiliser application confirms that the untreated crop was deficient in potash and that the application of K has resulted in satisfactory levels in the needles. Analysis shows that the levels of phosphate were satisfactory before treatment and the addition of P has resulted in an induced K deficiency. This deficiency, typified by the yellowing of the shoot tips, had been noted throughout the previous summer. The marked response to potash at this site can, no doubt, be related to the depth of peat, which is greater than the average for peaty gleys.

This suggestion of potash deficiency on *Molinia*-dominated peaty gleys and peat was confirmed by the results of foliar analysis on samples collected in a slightly older crop, also at Towy Forest. These samples were collected when establishing an experiment on rates of phosphate. Of thirty-two samples collected only one indicated satisfactory potash levels, and seven satisfactory phosphate levels. The phosphate treatments in this experiment will, therefore, be repeated with and without 90 kg/ha (80 lb/acre) of K.

NUTRITION OF TREE CROPS ON IRONPAN SOILS (PROJECT 349)

In a fertiliser/herbicide trial at Clashindarroch Forest (Aberdeenshire), similar to that mentioned under Project 346 at Drumtochty Forest, on soils with a weakly developed ironpan, a mixed crop of Sitka spruce

and Lodgepole pine of Sooke provenance, planted in 1961, was treated with NPK fertiliser supplying 160 kg N, 50 kg P and 95 kg K per hectare in May 1968, and with a 50 per cent 2,4 -D ester herbicide applied in August, 1968. Table 17 shows that for Sitka spruce the herbicide treatment alone is as effective initially as either the fertiliser treatment, or the combination of both. In contrast, the best nutrient uptake for Lodgepole pine came from the combination treatment, but quite severe damage was caused by the herbicide. This illustrates the difficulty in prescribing remedial treatment for young mixed crops in check.

TABLE 17

FOLIAGE ANALYSIS OF SITKA SPRUCE AND LODGEPOLE PINE FROM A FERTILISER/HERBICIDE TRIAL AT CLASHINDARROCH FOREST

per cent oven-dry weight

Treatment	N		P		K	
	SS	LP	SS	LP	SS	LP
Control, no treatment	1·21	1·63	·159	·177	·67	·66
NPK fertiliser	1·77	1·87	·232	·200	·97	·63
2,4-D herbicide	2·13	1·96	·215	·184	·93	·65
Fertiliser+herbicide	2·12	2·25	·222	·205	·88	·64

As the benefits of deep complete cultivation are becoming increasingly obvious in North-East Scotland, the next phase is to test the response to fertilisers on ground which has had the maximum improvement of its physical condition. This is to be done at Rosarie Forest (Banffshire) where different nutritional regimes will be applied to different species including Scots pine, Lodgepole pine and Sitka spruce, to investigate their potential growth under different nutrient inputs.

NUTRITION OF TREE CROPS ON FREELY DRAINED SOILS (PROJECT 350)

Young Crops

Unexpectedly slow growth of Sitka spruce on brown earth soils derived from basalt led to an experiment being laid down at Fiunary Forest (Argyll). Different rates of phosphate are being tested in case such soils have phosphate-fixing properties. Foliage phosphorus levels are not in the deficiency range, but they are lower than might be expected from trees growing in these grass/bracken sites.

The response to various nutrient inputs on the southern heaths of the Hampshire Basin, has been the subject of experiment for many years. The results obtained in these experiments have been variable, but the importance of heather (*Calluna*) control is a common theme. Started at Ringwood Forest (Hampshire) in spring 1970 is an experiment which examines the response of both Corsican pine and heather, *Calluna vulgaris*, to four levels of phosphate and three levels of nitrogen, the pine with and without heather killing.

Established Crops—Low Yield Classes

In a pole-stage fertilising experiment on Scots pine at Speymouth Forest (Moray), the basal area response to NPK fertiliser has now finished. It thus confirms the Scandinavian response pattern of maximum in the third year after fertilising and finishing in the sixth year. However, in this particular experiment the additional volume produced by fertilising did not pay for the materials used. This is mainly because the control plots had responded dramatically to the thinning carried out at the time of fertiliser application, and the location of these control plots on the outside edge of the experiment block may well have influenced the response pattern. The profitability has also been reduced by using an expensive NPK material rather than trying a factorial approach and selecting the most appropriate combination of elements. A similar, more recent experiment of different layout shows the controls, which again were thinned at the time of fertiliser application, to be maintaining a more even growth rate.

Certainly more experiments are required before pole-stage fertilising can be generally recommended as a practical measure. The next phase is to investigate the response pattern to re-application, both at the end of the known curve (i.e. at 6 years) and at the point of maximum response (i.e. at 3 years), using a factorial approach.

A final crop fertilising experiment on Scots pine at Curr Wood, Seafield Estate (Inverness-shire), again using an NPK fertiliser has produced an extra 3.6 m^3 (100 h ft) of volume in three seasons since fertiliser application. The profitability of fertilising this crop at this stage appears to be marginal, so far.

An experiment on Scots pine on a private estate near Reading (Berkshire), was begun in 1968. This compared 113 kg N per ha (101 lb N per acre), 46 and 92 kg P per ha (41 and 82 lb P per acre) in factorial combination. The Scots pine crop was 25 years old when the experiment began. Yield Class* is about 140, but the Production Class* is probably low. The soil is a gravelly sandy one for the most part, although there are some areas with a little more clay and silt. The treatments were prescribed on the result of foliage analysis which showed 1.68 per cent N, 0.18 per cent P, and 0.56 per cent K ; it was judged on these that a phosphate response was more likely than a nitrogen response. After the first two years the basal area increment has been highly significantly increased by the nitrogen treatment, while there has been no effect of phosphorus so far. There is a small suggestion that the nitrogen increase is greater in the presence of phosphorus, but this is not significant. It is possible that a phosphorus response will appear later, since nitrogen responses are rapid but phosphorus responses are often delayed: it is clear though that the experiment would have been better had a higher rate of nitrogen been included.

Established Crops—Higher Yield Classes

Little is known of responses to fertilisers in higher-yielding stands, though as the yield class rises the greater is the likelihood that physical soil factors or climatic factors will limit the response to fertilisers.

* These terms are discussed by Bradley, Christie and Johnston (1966).

The pole-stage experiment on Yield Class 180 Sitka spruce at Ae Forest (Dumfriesshire), *Report* for 1969, p. 70, has shown no significant increase on basal area increment after two growing seasons, in spite of increased nitrogen uptake.

The existence at Dartmoor Forest (Devon) of an older stand of Sitka spruce of Yield Class 180, planted in 1921, and large enough in extent to accommodate an experiment, allowed us to put down a factorial experiment testing nitrogen at 75 and 150 kg N per ha (67 and 134 lb N per acre) and phosphorus at 50 kg P per ha (45 lb P per acre). Basal area assessments after two years, when adjustments have been made for differences in basal area existing at the start of the trial, show a significant increase of $9\frac{1}{2}$ per cent in basal area increment due to phosphorus. The soil is transitional between a brown earth of low base status and podzol (it might be described as a podzolised brown earth) on a solifluxion deposit derived from granite.

It has not been possible so far to sample foliage from these trees (which are now over 25 m tall), but an attempt will be made in the autumn of 1970. The treatments had to be applied without any knowledge of the nutrient status of the trees and it was guessed that nitrogen rather than phosphorus would be the limiting element ; it now appears that this was a faulty guess and that phophorus may well be the element which will produce the greater response, since one would expect any nitrogen response to show within the first two years.

The contrast between the responses in the experiments at Ae, Dartmoor and Brecon (see the section below on Repeated Fertilisation), all on Sitka spruce of Yield Class 180, suggests once again that much more needs to be known about the limiting factors at any particular site before useful recommendations for fertilisation can be made.

EFFECT OF REPEATED FERTILISATION ON POLE-STAGE STANDS

In the 1969 *Report* we showed variations in the course of response of pole-stage stands of four species to single applications of N or P. The three stands of Sitka spruce were all re-treated with phosphorus in late 1968 and Figure 1 shows the varying reactions. It is noteworthy that the response in each case resembles the original one: rapid at Glasfynydd (or perhaps one should say the existing response is well maintained), rapid but not as large at Gwydyr, and negligible at Brecon. It looks as though to maintain an even response the stands at Gwydyr and Brecon should have been re-treated in 1966, two years earlier.

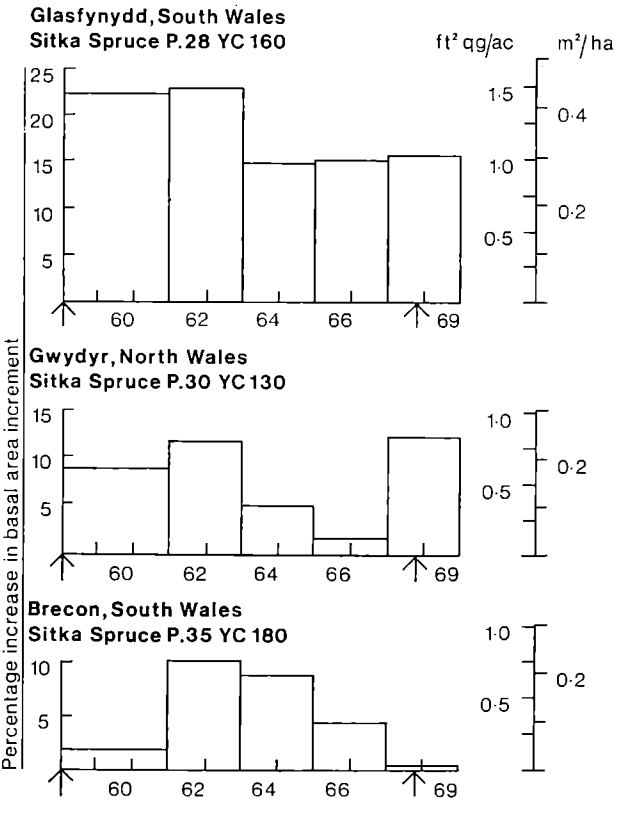


Figure 1: Effect of two dressings of 94 kg P/ha (88 lb P/acre), as triple superphosphate on the growth of pole-stage Sitka spruce in Wales. Applications were made early in 1959 and again in September 1968 as shown by arrows. The basal area scales are approximate.

EFFECT OF FERTILISERS ON HEIGHT AND FORM IN POLE-STAGE STANDS

Most of our information on fertiliser responses is gained from measurement of basal area alone. Measurements of height are less frequently done because the low precision of measurement means that differences of, say, 10 per cent in height increment are easily missed. Furthermore, measurements of girth are seldom made other than at breast height, so we do not know whether the increased girth increment is proportionally the same all the way up the stem. One experiment on old Scots pine (Binns and Grayson, 1967) suggested that response to nitrogen was greater at 7½ m (25 ft) than at breast height for the first three years after treatment; this effect has now persisted for a further three years.

A heavy thinning in one of the 3^5 fertiliser experiments, on 1923 Scots pine of Yield Class 100 at Exeter Forest (Devon), where there has been an increase of 18 per cent in basal increment over eleven years following application of 44 kg P per ha, gave an opportunity to study the height and form responses. A stem near the mean girth of the crop was selected in 64 out of the 81 possible plots, and a stem analysis of height and girth, according to sample plot procedure, was done. This showed that the phosphate had increased the height growth of these thinnings by about 25 cm in 4 m (about 1 foot in 13 ft) over the eleven years, about $6\frac{1}{2}$ per cent, but there is no obvious effect on the form of the trees, though the data have not yet been fully processed. These results suggest that in this stand at any rate the main effect of the treatments has been on basal area increment, that there has been a smaller, but useful effect on height, but little effect on form.

TREATMENT OF CHECKED CROPS BY CONSERVANCY MANAGEMENTS (PROJECT 391)

Large areas of "checked" or unsatisfactory Forestry Commission plantations have been treated with fertilisers, the earliest about 1961. For two main reasons we need to know the responses to these fertilisers. If the responses have been clearly profitable, there is a strong justification for further investment in fertilising. On the other hand, if we find areas where the responses have not been profitable we need to discover why this is so (for example there may have been a wrong identification of the limiting factor, or an inadequate rate or inefficient application of the fertiliser).

Furthermore, as in all fertiliser work, we hope eventually to discover those features which go with response to particular nutrients so that remedial programmes can be more soundly based. Most of the crops in South-East and South-West England, top-dressed (between 1961 and 1967) by hand, by machine, or from the air have been examined and the growth rates assessed. The major difficulty in looking at these crops is that there are no proper controls, because they are Conservancy operations, not experiments. It is very often impossible to find an untreated area with which to compare the treated area and we can only assess the response to the fertiliser treatment on internal evidence, that is from changes in the rate of height or diameter increment. We have, therefore, to try to distinguish between changes in growth rate due to the fertiliser treatment and changes in growth rate due to other factors, for example closure of canopy or growth out of the frost level.

Where dramatic changes in growth rate follow application of fertilisers, sometimes immediately, sometimes after a year or two, there is little doubt that the change is due to the treatment. We have, however, found some cases where the rate of height growth was already slowly increasing and it is difficult to establish with certainty how much of the subsequent change is due to the fertiliser treatment and how much would have occurred anyway.

The results so far suggest that most of the Sitka and Norway spruce and Scots pine which have been treated have responded to the fertilisers. At Wareham and Ringwood Forests, however, treatment of slow-growing

Corsican pine with phosphate, phosphate and nitrogen, or phosphate and 2,4-D has not been particularly effective, whereas Corsican pine at Exeter Forest, treated only with P, has increased its growth rate dramatically. Two examples from these sites are shown in Figure 2.

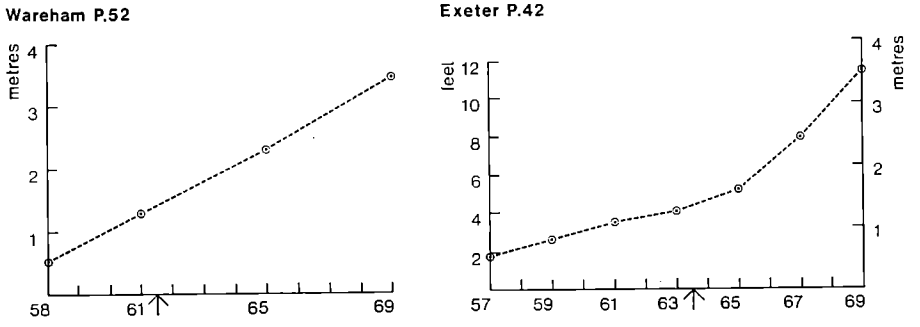


Figure 2: Contrasting effects of 79 kg P/ha (70 lb P/acre) on slow-growing Corsican pine crops at Wareham (Dorset) and Exeter (Devon). The Wareham crop is about Yield Class 80. Arrows indicate the year of treatment. When the phosphate was applied to this Wareham crop, its ground cover was treated with the herbicide 2,4-D.

Most of the crops which have been looked at were treated when they were less than 3 m tall, but some crops of Sitka and Norway spruce 3 to 4 m tall have shown some of the most dramatic responses when treated with phosphate only.

Examination of areas in North Wales, where nearly 2,200 ha (5,500 acres) had been top-dressed by 1966, has now begun.

MAXIMUM SITE AMELIORATION (PROJECT 381)

The intention of this project is to try to raise to the optimum all factors of the environment which can be controlled by the experimenter, leaving only those factors which cannot be modified by him (for example, rainfall, temperature, wind) to reduce yield below the maximum: this should enable us to determine the limiting effect of these major unalterable factors. Until we have this information it is difficult to make any objective assessment of how far a particular combination of site variables can be improved for tree growth by man and, for example, how far drainage, fertilising, cultivation and use of herbicides can improve the yield: in other words, it is difficult to assess objectively the practicable potential of any site.

Until recently only small experimental plots have been established, usually as an adjunct to other larger experiments. However, a new experiment has been laid down at Wareham Forest (Dorset) based on the results of the "Deficiency Garden" (*Report* for 1969, pp. 80 and 81). This new experiment is on the abandoned Conservancy nursery at Sugar Hill, which has a

reasonably well-drained soil of good depth over most of its area, and 0·175 ha plots of Sitka and Norway spruce, Monterey pine, Douglas, Grand and Noble fir, Lawson and Leyland cypress, Western red cedar and Western hemlock have been planted, with half plots of Bishop pine (*Pinus muricata*) and the Southern beech, *Nothofagus procera*. These are all species which might be expected to yield as much or more than Corsican pine, the most commonly planted species at Wareham, of which there is also a plot. They will be given as much fertiliser as appears necessary to maintain maximum growth rate ; in this way we hope to demonstrate the climatic limitations of the site. Small control plots have also been planted without any fertiliser and these are all together in a chequer-board.

PERMANENT FOLIAGE SAMPLING PLOTS

The 1969 foliage analysis data from the permanent sampling plots in Scotland and North England are given in Table 18. Compared with 1968, the major differences are a rise in needle weight, nitrogen and phosphorus. The potash values were slightly lower for spruce, and calcium values were slightly higher. Magnesium values showed little change.

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

ANALYSIS OF SOILS AND FOLIAGE

Mineral Soils

Almost the only soil analyses done during the year have been routine determinations for the Site Survey Officer, together with a small amount of other work.

Foliage

A quiet summer allowed a thorough review of analytical methods and though no major changes were made a number of small modifications have been introduced, particularly to the digestion routine for nitrogen determination. These changes have produced a useful increase in speed.

During the autumn and winter nearly 3,500 samples of tree foliage (and a few samples of other vegetation) were received. Due to equipment failure, work got off to a slow start, and this together with the larger programme meant that there were still some samples awaiting analysis at the end of March.

Because of the steadily increasing number of samples for analysis, shown in Figure 3, we need to reconsider our methods of drying and storage and think of ways of speeding up methods of analysis so as to meet deadlines, such as those imposed by an urgent need for results for use when advising on fertiliser treatment in the forest. In this connection a little forethought, both by

TABLE 18

FOLIAGE ANALYSIS FROM PERMANENT SAMPLING SITES

Species	Needle wt. (mg oven-dry)	Percentage oven-dry weight					N : P : K ratio
		N	P	K	Ca	Mg	
Sitka spruce (growing well)	*7·8* 6·1—9·6	*1·59* 1·19—1·93	*0·22* 0·19—0·34	*1·27* 0·81—1·67	*0·35* 0·25—0·55	*0·14* 0·07—0·20	7 : 1 : 5¾
Sitka spruce (partial check)	*5·8* 3·4—7·8	*1·09* 0·86—1·34	*0·16* 0·09—0·27	*0·88* 0·52—1·15	*0·43* 0·36—0·59	*0·14* 0·08—0·25	6¾ : 1 : 5½
Lodgepole pine (Washington Coastal Provenance)	*1·71* 10·1—23·2	*1·48* 1·17—1·79	*0·16* 0·12—0·22	*0·53* 0·44—0·60	*0·13* 0·04—0·21	*0·08* 0·06—0·11	9¼ : 1 : 3¼

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

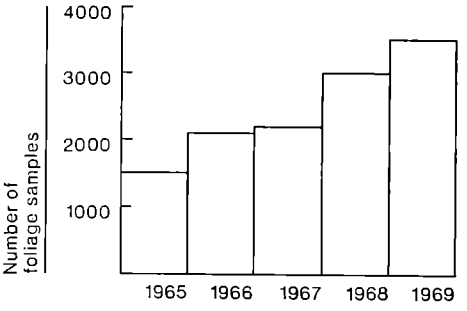


Figure 3: Numbers of tree foliage and vegetation samples for analysis received at Alice Holt. 1965 to 1968.

Research and Conservancy staff, could help enormously in reducing the pressure on the analysts, for example by taking samples eighteen months before treatment is contemplated, rather than six months before.

W.O. BINNS
J.M. MACKENZIE
J.E. EVERARD

REFERENCES

BINNS, W.O., and GRAYSON, A.J. (1967). Fertilisation of established crops: prospects in Britain. *Scott.For.* **21**(2), 81–98.

BRADLEY, R.T., CHRISTIE, J.M., and JOHNSTON, D.R. (1966). *Forest management tables.* Bookl. For. Commn **16,** 218 pp.

FOREST WEED CONTROL

CHEMICAL CONTROL OF SPECIFIC WEED POPULATIONS:

I. HERBACEOUS WEED CONTROL

Chlorthiamid (" Prefix ")

Further experiments were laid down at five forests in the south to test for damage to trees from chlorthiamid applications. Unfortunately, severe damage from other causes made it necessary to abandon two experiments.

In each experiment, 0, 4·5 or 6·7 kg active ingredient per ha (0, 4 or 6 lb/acre) were applied in January, March or April 1969. Representative tree species from those classed as resistant, intermediate, and definitely sensitive to chlorthiamid were tested at different sites. The experiments involve annual applications and will run for three years.

At the end of the first year no significant reduction in growth or survival was noted in Corsican pine (resistant class) at Thetford, or Norway spruce (intermediate class) at Breidden (Mathrafal Forest), North Wales, but the survival of Western hemlock (susceptible class) at Friston, Sussex, was significantly reduced by chlorthiamid applications, although height was unaffected.

Atrazine

Work on the effectiveness of atrazine for herbaceous weed control continued in a new series of experiments at five forests. 2·2, 3·4 and 4·5 kg active ingredient per ha (2, 3 and 4 lb/acre) were applied in March, April/May or June, in newly planted crops of a range of coniferous species. In this series the trees were not protected from the spray and no attempt was made to avoid them.

March and April/May application provided much better weed control than June application on four sites out of five, and in general on these four sites 3·4 kg/ha gave adequate results.

Control was so good at Neroche Forest (Somerset) and Hursley Forest (Hampshire) that in some plots at the higher rate, bare earth conditions persisted for most of the growing season. Many grass species, including *Holcus lanatus,* several *Agrostis* species, *Anthoxanthum odoratum* and *Deschampsia flexuosa* were well controlled. *Holcus mollis,* however, seemed to be completely unaffected in the Forest of Dean, while *Deschampsia caespitosa* at Hursley and *Dactylis glomerata* at Neroche were only moderately checked.

Sites were chosen on which grasses were the predominant weeds, but the indications were that atrazine had little effect on broadleaved weeds.

Because of the overall application, the effect of atrazine in the crops was of particular interest. Only at Neroche and Hursley were there any visible signs of damage, and at Hursley damage was very slight. At Neroche the 4·5 kg/ha rate, and to a much smaller degree, the 3·4 kg/ha rate, " scorched " and reduced the length of needles. Even so, the end of season heights suggest that the crop benefited slightly from the removal of the grass (Table 19).

TABLE 19

MEAN HEIGHT AND NUMBER OF TREES WITH LAMMAS GROWTH—
SITKA SPRUCE TREATED WITH ATRAZINE AT NEROCHE, SEPTEMBER 1969

Factor	Hand-weeded	Paraquat 1·1 kg/ha	Atrazine (mean of 3 application dates) 2·2 kg/ha	3·4 kg/ha	4·5 kg/ha
Height (cm)	48	48	50	52	49
Percentage of trees with lammas growth	5%	7%	33%	35%	38%

The greater height of the plants in plots treated with atrazine may have been largely due to the fact that more trees developed lammas growth in these plots than in those hand-weeded or treated with paraquat (Table 19).

Analysis of the data for other species at other sites revealed no consistent trend, except that the height of some species was reduced in plots where the lowest rate of atrazine was applied in June. It seems very unlikely that this was due to direct atrazine damage, and it is more likely to be a reflection of the poor weed control from June applications.

II. BRACKEN CONTROL WITH DICAMBA

Experiments in the winter of 1967/68 showed that pre-planting winter applications of dicamba, applied from December to February, provided good control of bracken during the following summer, but residues damaged the subsequently planted crops (see 1969 *Report*).

Since the object of winter applications is to enable advantage to be taken of the first season's bracken control, it seemed worth while to test September, October and November applications to see if bracken control was still good, but dicamba residues sufficiently small to allow spring planting.

Experiments were laid down at four forests, testing rates of 3·4 and 4·5 kg/ha (3 and 4 lb/acre) applied in September, October or November 1968, and followed by planting of various conifers in March/April 1969.

Bracken control during the first season has generally been excellent, except at Radnor Forest in North Wales where control was moderate and patchy.

Mid-season examination of all sites showed that dicamba residues had still been present at the time of planting in sufficient quantities to affect most species. The symptoms were recurving of needles (e.g. in European larch and Douglas fir), or failure of terminal shoot to develop normally (typical of Corsican pine). Scots pine and Sitka spruce were apparently unaffected. By the end of the growing season species other than Grand fir appeared to have recovered so well that little reduction in height or survival was reflected in the assessments. However, Grand fir at the Forest of Dean suffered heavy mortality due to dicamba residues.

III. WOODY WEED CONTROL

Tree-Injection on Broadleaved Species

The first results are now becoming available from tree-injection trials laid down in the autumn of 1968 and spring and summer 1969. These indicate the effects after only one growing season, and in some cases after only four to five months (following treatment in June 1969), whereas at least two seasons are needed for reliable assessment of the end result.

In the main trial, 0·45 m litres and 0·90 m litres undiluted, unformulated 2,4,5-T (1 kg active ingredient per litre/10 lb per gal) per injection point was injected at 10 cm centres round the base of various broadleaved species in the autumn of 1968. Trees with a butt diameter of 5–10 cm and 10–20 cm were treated and a normal basal bark or frill girdling treatment (as appropriate) was included for comparison.

Results show that the smaller trees were killed more easily than the bigger ones, and that 0·90 m litres per injection was considerably more effective than 0·45 m litres. Generally, the killing by injections was not quite as good as by basal bark treatments when 0·45 m litres was injected, but injections of 0·90 m litres proved sometimes better and sometimes poorer than basal bark treatments.

2,4-D amine (0·5 kg per litre/5 lb per gal) was also compared both injected into pole-size stems and on cut stumps, with injections of 2,4,5-T (5 kg active ingredient per litre/5 lb per gal) and normal basal bark or stump sprays (as appropriate) of 2,4,5-T in diesel oil.

On pole stage trees, injection of 1·0 m litre of 2,4-D amine in January or June 1969, at either 5 cm or 10 cm centres, gave poorer results than basal bark applications of 2,4,5-T, although even the latter killed less than 50 per cent of the trees in these experiments.

On stumps, injections of 1·0 litres were made at 7·5 cm or 15 cm centres in January, April, July or October 1969. 2,4-D appeared to kill fewer trees than did injected 2,4,5-T, which at the closer spacing of injection points gave results very similar to those with the conventional overall spray of 2,4,5-T in diesel oil.

Tree-Injection on Coniferous Species

Herbicides have a possible use for thinning conifer crops endangered by windthrow, which may be postponed by killing instead of removing thinnings, and so avoiding sudden change in the canopy. Experiments have been established in Sitka and Norway spruce crops, now almost due for first thinning, at Ae Forest (Dumfriesshire) and Kielder Forest (Northumberland). Trees will be injected with 2,4-D amine, picloram, picloram plus 2,4-D amine, and cacodylic acid, during growing and dormant season, to determine the most effective chemical.

Control of Heather (*Calluna vulgaris*)

A Conservancy trial at Kielder Forest (Northumberland) suggested that heather could be successfully killed by a 2,4-D application in May. To confirm this, a trial was laid down at Durris Forest (Kincardineshire) in 1969, to check whether the recommended post-planting period in August could be extended

to include a later winter/early spring application. Weekly sprayings of 8·4 litres of 50 per cent 2,4-D ester in 225 litre/ha (6 pints 2,4-D in 20 g/acre) were applied by mistblower from the beginning of April to the end of May, just before tree flushing, and from the end of June to the middle of August. Climatic data and general weather conditions were recorded at, and after, the time of spraying. Preliminary observations show that 55 to 65 per cent of the heather can be killed by sprays applied between the middle and the end of May. Initially, a higher percentage of the heather appeared to have been killed by these applications, but 30 to 45 per cent regrowth occurred during the growing season. This regrowth did not prevent an improvement in the colour of the tree foliage, so a year may be saved in recovery from *Calluna* check. Applications in August, however, gave a better kill (75 to 95 per cent) and may result in a more permanent benefit to tree growth.

2,4-D was successfully applied in May on other fertiliser experiments on *Calluna*-dominated deep peat at Durris Forest and Arecleoch Forest (Ayrshire). Table 20 shows the improvement in nutrient uptake of Sitka spruce and Lodgepole pine (Sooke provenance) following application of this herbicide. The improvement in appearance of the Sooke Lodgepole pine following heather removal was notable, although some browning of the lower branches occurred. Responses in growth on both species are expected in 1970.

TABLE 20

FOLIAGE ANALYSIS OF SITKA SPRUCE (SS) AND LODGEPOLE PINE (LP) FOR NITROGEN (N), PHOSPHORUS (P) AND POTASSIUM (K) AFTER MAY APPLICATION OF 2,4-D HERBICIDE AT ARECLEOCH FOREST

per cent oven-dry weight

Treatment	N		P		K	
	SS	LP	SS	LP	SS	LP
Unsprayed	1·02	1·30	·140	·124	·51	·46
Sprayed	1·34	1·56	·204	·141	·86	·57

The timing of spring application has to depend on tree flushing time. The 1969 spring was late, and hence mid to late May appeared suitable. In other years following milder winters, application should be earlier. The experiment is being repeated in 1970, again at Durris Forest and also at Eddleston Water Forest (Peebleshire), to increase the range of weather conditions in which spraying has been tried.

Further work on winter applications in planted areas is being carried out at Duns Forest (Berwickshire). In this experiment high- and low-volume sprays are being compared at different times from September to May, and the use of a small quantity of diesel oil to increase herbicide penetration is also being tested.

Other chemicals, including picloram, picloram/2,4-D and 2,4,5-T/2,4-D are being tested at Durris Forest on heather of different ages, especially with the object of controlling the older leggy heather. Early observations indicate

that both picloram and picloram/2,4-D affect the heather more slowly than either 2,4-D or 2,4,5-T/2,4-D and have a greater translocation effect, regardless of heather age. It is worth noting that Lodgepole pine foliage was undamaged by the picloram spray, but affected by the herbicides containing 2,4-D.

In the 1969 *Report,* it was recorded that 2,4-D produced a better kill of heather under an overwood of Scots pine, but underplanted species (Douglas fir and Grand fir) suffered considerable damage. An experiment to test whether lower rates of 2,4-D would still kill the heather satisfactorily showed that the rate could be reduced to 4·2 litres/ha (3 pints/acre), but it is not known whether this rate may still cause damage to the underplanted species.

Two experiments are being laid out to compare the effects on heather regrowth of various ground preparation techniques, including burning, " swiping " or rotary cutting, and herbicide application before ploughing. One is on a predominantly peaty gley site at Durris Forest, and the other is on unflushed deep peat at Clydesdale Forest (Lanarkshire).

R. M. BROWN

J. M. MACKENZIE

SOIL STUDIES

This year has seen the end of one experimental era in soil research and the beginning of another. For about nine years, work of the Soils Section on soil moisture problems has been concentrated on lowland sites in England mainly in the drier East and South-east Conservancies, together with some studies on drainage problems in the South-west Conservancy. Problems of soil moisture and drainage encountered in the northern and western uplands are many and great, and before they could be studied it was considered desirable to concentrate our efforts on the relatively simpler problems of the eastern and south-eastern lowland areas. Now that our understanding of soil-tree-atmosphere relationships is somewhat improved (though it still remains regrettably sketchy in parts) it becomes possible to begin work on the poorly drained soils of the uplands where poor rooting poses serious problems in stability, and where a great deal of money is spent on drainage.

Because of the urgent need to decide where drainage is worth while and what is the most economical intensity in any situation, we need to anticipate the evidence which will ultimately be provided by crop growth and stability. One way to do this is to determine what changes take place in soil properties following drainage, and we are concentrating on this task in the new phase of research. We hope to establish the first forest trials during 1970 on peaty gley soils in Wales ; progress on instrumentation is reported below.

A further difficulty in working in upland regions, especially in Scotland, has been the distance of many of the areas concerned from the Soil Section's base at Alice Holt. For the first time we now have Soil Section staff based near Edinburgh, at the new Northern Research Station, and it is now possible to do detailed soil research in the north. Indeed, a prior report on the properties of indurated soils in North East Scotland is given below.

STUDIES IN THE FOREST

Soil Moisture Studies

Bramshill Forest, Hampshire

The experiments at Bramshill Forest have been concluded and a paper accepted for publication (Fourt and Hinson, 1970). The final year's readings from the neutron soil moisture gauge (Figure 4) show the same differences between Corsican pine and Douglas fir that we have seen in previous years. This year the normal interval between readings was three weeks, but this was increased as necessary to satisfy the condition that no more than 7·5 mm (0·3 in) rain should have fallen during the preceding 24 hours ; the interval was also increased during long spells of fine weather. We think it is more useful to time readings according to the weather, with an upper limit of say five weeks, rather than to set a fixed interval which is adhered to regardless of circumstances.

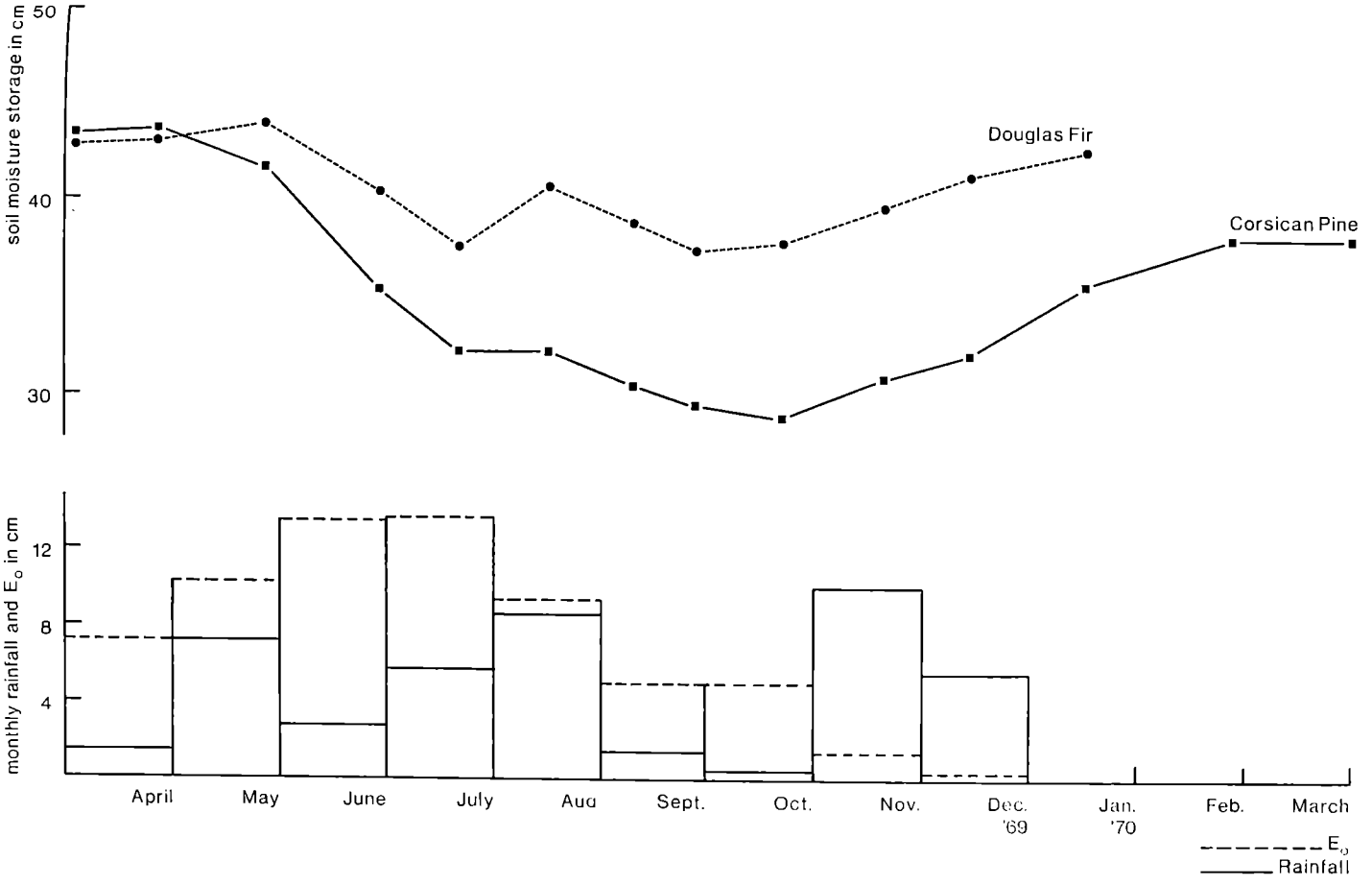


Figure 4: Soil moisture storage at Bramshill Forest (Hampshire) under Corsican pine and Douglas fir, as determined by neutron soil moisture gauge, together with monthly rainfall and E_o (30 to 200 cm storage depth).

It will be noticed from Figure 4 that the soil in the Douglas fir stand did not depart from field capacity until after 29th May, and had regained it by 19th January: in contrast, the soil in the Corsican pine stand left field capacity sometime between 28th April and 29th May, and was still some way from regaining it by the end of March, 1970. Indeed, Figure 4 suggests that this year the soil under the Corsican pine will not return to field capacity at all and that the deficit will carry over into the next hydrologic year, as happened in 1965 (*Report* for 1966, p. 60).

Drainage Studies

Halwill Forest, Devon

Study of the results of the series of daily borehole water level measurements taken from 14th January to 31st March 1969, mentioned in last year's *Report*, has lead to the following conclusions.

The annual rainfall in this area is 1100-1300 mm (45-50 in) and slightly more than half of it falls during the winter six months from October to March. Dry spells suitable for study were few, with one of 8 days, one of 6, and four of 3 days. Only the 8-day period was immediately preceded by more than 25 mm (1·0 in) of rain, which is needed to raise levels near to the winter maximum and thus to create conditions suitable for study.

Figure 5 shows the average water level in ten boreholes for each day, over four extreme experimental treatments.

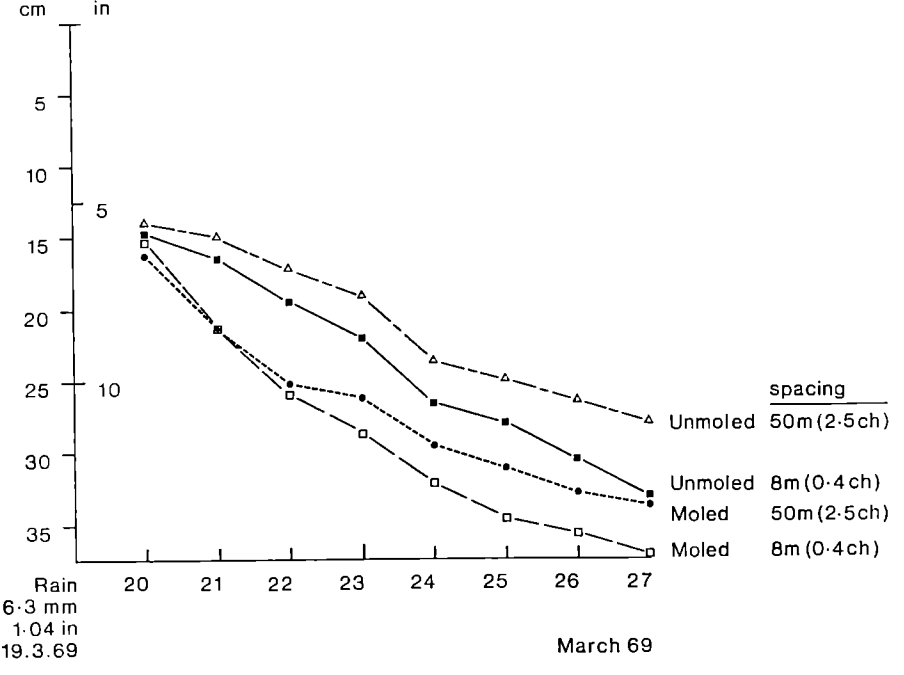


Figure 5: Halwill Forest (Devon). Borehole water level run-down during dry spell after storm. Mean slope of ground 3·6°.

Although it was in 1962 that mole drainage was carried out on this silty-clay soil, it appears that benefits to site drainage not only persist for eight years, but are considerable. The 50 m (2·5 chain) drain spacing with moles at 1·5 m (5 ft) compares favourably with an unmoled treatment drained at 8 m (0·4 chain).

On impeded soils in regions of high rainfall, a system which allows the coarse pores to drain rapidly after a storm ceases has the advantage of being less prone to flash flow of surface run-off and long periods of waterlogging.

The results from Halwill suggest that, on heavy soils which are stone-free and have not carried a tree crop in recent times, the most economical system to achieve this state may be one with mole drains crossed by widely spaced open drains.

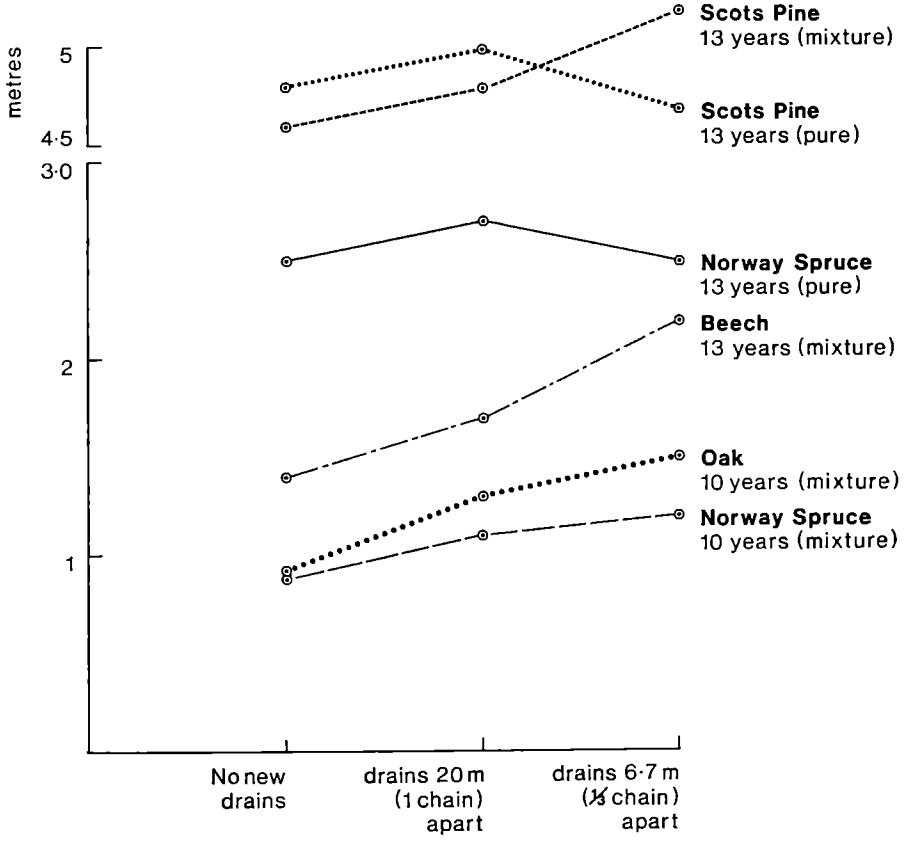


Figure 6: Bernwood Forest (Oxfordshire). Response in height growth of tree species to increasing drainage intensity, after ten or thirteen growing seasons.

Bernwood, Oxfordshire

The revised working plan mentioned in the last *Report* has been implemented and the plots of Douglas fir, Corsican pine and Grand fir have been

planted. The area has also been fenced for deer protection, but some damage by vermin is still occurring.

The new plan did not specify intensive drain maintenance since little maintenance is needed on this site except for the removal of woody growth from the drain sides. The response of some of the species planted in 1955 is shown in Figure 6. Pure crops of Scots pine and Norway spruce have not yet shown differences related to treatment, but in mixtures of both beech and pine, and oak and spruce, all species, especially the hardwoods, have shown some response to increased drainage intensity.

Physical and Mechanical Properties of Soil Types

Studies of the physical and mechanical properties of soils with so-called indurated layers have begun at sites within the area of Old Red Sandstone rocks around the Moray Firth.

Indurated layers vary considerably in thickness and hardness, and probably also in permeability to water since they may underlie a variety of soil types, including brown earths, podsols, ironpan soils and surface-water gleys (Pyatt, 1970). Mechanical properties being assessed in these studies include shear strength and resistance to mechanical penetration, and the variation in these will be examined in relation to the physical properties of the material, which include the particle size distribution, bulk density, stoniness and moisture content. Measurements of shear strength and penetration resistance have proved difficult in the stony, brittle material of most indurated layers, and it is proposed to extend the studies to artificially compacted specimens, prepared with a variety of bulk densities and moisture contents, using techniques devised by soil engineers. The use of these specimens will also facilitate the measurement of permeability. Although it is unlikely that artificially compacted specimens will precisely reproduce the natural soil condition, it is hoped that tests on such samples will give useful information on the inter-relationships between mechanical and physical soil properties. The technique of impregnation of undisturbed blocks of soil (10 × 5 × 3·5 cm ; 4 × 2 × 1·3 in) with epoxy or polyester resins, from which thin sections can be prepared for examination under a polarizing microscope, promises to reveal useful information on the micro-morphology of indurated layers.

Four sites have been sampled: ironpan soils at Teindland Forest (Moray) and at Black Isle Forest (Ross) ; and surface-water gleys at Culloden Forest (Inverness-shire) and Black Isle Forest. Early results indicate that the bulk density of the fine-earth fraction (less than 2 mm diameter) of the soil is a useful measure of the physical conditions associated with induration. The bulk density of the fine earth is deduced from the bulk density of the whole soil by taking account of the proportions of the total weight and volume which are occupied by stones.

Bulk density figures both for whole soil and fine earth from the indurated layers studied are extremely high when compared with those of normal soils, being in the ranges of 1·90 to 2·10 and 1·70 to 2·00 g/cm^3 respectively. These are well above the level usually considered to indicate limiting conditions for penetration by roots, which is about 1·40 to 1·60 g/cm^3. The need for intensive

cultivation is thus apparent, though it is not thought likely that the need for intensive drainage of at least the surface-water gleys will be obviated by cultivation.

W. H. HINSON
D. G. PYATT
D. F. FOURT

INSTRUMENTATION

Reading Water Levels in Boreholes

Measurement of the depth to standing water in a borehole remains one of our simplest techniques for studying the seepage patterns in soils. Within its limitations, though it does not determine the moisture status of the soil, it can provide a basis of comparison for different drainage regimes such as those reported from Halwill or those proposed for the Welsh peaty gley soils.

Manual Methods

Reading water levels in small diameter holes in the ground by means of eye and ruler is difficult and imprecise, particularly in dull weather and when levels are low, and we have long felt the need for a device to sense the water level and help the reader.

We have now developed a dipstick which lights up when the tip touches the water surface. The prototype is powered by two small 1·5 v torch batteries, is suitable for boreholes up to 1 m deep and weighs less than 400 g. A full description will be published when the device has been fully tested in the forest and the final design decided.

Automatic Methods

Manual readings are expensive, particularly if they are required each day for several weeks, and it may sometimes be impossible to arrange for them to be made in remote forests. Last year we mentioned that several possible systems for transducers were being investigated, and two have been developed during the year.

The first system, which has been selected for forest trials, is based on the variation in capacity of a polythene-covered rod. When compatible data logging equipment has been found and the whole system tested, a description will be published.

The alternative system, based on strain gauges mounted on a cantilever and employing Archimedes' principle, will not be tried out in the forest at present, but the system will be completed and a description published in due course.

W. H. HINSON
G. P. MOFFATT

REFERENCES

FOURT, D. F., and HINSON, W. H. (1970). Water relations of tree crops. A comparison between Corsican pine and Douglas fir in South-East England. *J. appl. Ecol.* **7** (2). 295–309.

PYATT, D. G. (in the press). *Soil groups of upland forests.* Forest Rec. Lond. **71.**

DRAINAGE

Drainage of Deep Peat

Following the results published last year on the drainage effects achieved in deep peat at Achray Forest (Stirlingshire), it was decided that a suitable technique for large areas of peatland might be found in the use of a deep, double mouldboard drainage plough. The object of the technique is to provide intensive local drainage, together with large turf ridges for initial establishment at low cost, but with a reasonably wide platform between drains for enhanced stability. The system envisaged would provide drains approximately 80 cm (31 in) deep at intervals of about 4·8 m (16 ft), requiring the minimum of additional cross-drainage.

A plough to meet these requirements has now been developed and has been used in a new experiment at Clydesdale Forest (Lanarkshire), and on a field scale in Wark Forest (Northumberland). Despite the need for two crawler tractors as the motive force, the cost of the operation appears likely to be less than the cost of conventional ploughing followed by cross-drainage. The technique would appear to be appropriate for large areas of peatland of gentle relief, but inappropriate in broken terrain, due to the need for more frequent main drains.

Drainage of Gleys with Clay Subsoils

The cultivation and drainage experiment (Rosedale 11 P64) at Allerston Forest (Yorkshire) is now six years old. This experiment, previously mentioned in the *Reports* for 1964, 1965, 1967 and 1968, compares conventional spaced furrow ploughing, deep complete ploughing and "riggs and furrs" (i.e. raised strips with hollows in between), all with and without cross-drainage. Despite a slow start, the trees on complete ploughing and on the "riggs" are now clearly superior in height and vigour to those planted on conventional ploughing. The growth on the "riggs" appears to be only marginally better than on complete ploughing at this stage, but the growth of trees planted adjacent to the "furr" is now remarkably good, despite a very slow start. The potential advantages of a rigg and furr system for heavy textured soils may be summarised as follows:

(1) Permanent improvement of site drainage with the minimum of obstacles to future traffic on the site.

(2) The requirement for cross-drainage is minimal and drain maintenance costs should also be low.

(3) The rooting platform provided is good and should lead to improved stability.

(4) Vegetation suppression is excellent and should facilitate the use of heather-sensitive species such as Sitka spruce on the poorer soils.

(5) Machine planting would be facilitated.

These early results are very encouraging and further trials of the system on a wider range of sites are now proposed. The problem of forming riggs and furrs at a reasonable cost remains to be solved, but should not prove to be unduly difficult with the aid of modern, powerful tractors.

The southern series of experiments, which examines the effect of three drain depths and three spacings, in Sitka spruce crops of varying age, has been completed by the establishment of the sixth replicate at Crychan Forest (Brecon). Here the pre-drainage borehole readings indicate that the replication has been sufficient to even out site differences. Boreholes were installed in the autumn of 1968 and drains dug in the 9 m (30 ft) crop in autumn 1969. The soil profiles exposed show an unusually uniform soil, but there are some patches of poor growth. No windthrow attributable to rack-cutting and drain-digging has occurred in the first winter after draining, despite the continuance of windthrow in other parts of the forest.

As yet no assessments have been made of post-drainage tree growth in this series. Borehole readings, which have been summarised, suggest that only at the closest spacings, 10 m (33 ft), do the 90 cm (36 in) drains as yet produce a marked reduction in water table levels. Similarly, the benefit of the closest spacing is best achieved by the 90 cm (36 in) drains.

Canopy removal and drainage is the subject of an experiment at Kesteven Forest (Lincolnshire), which started in 1969. The treatments include no drainage and very close spacing, together with retention and removal of the scrub hardwood canopy.

Drainage of Gleys with Indurated Subsoils

A number of new experiments have been established involving various combinations of cultivation and drainage (see Cultivation, p. 94). It has now been demonstrated that drains can be prepared in such soils relatively cheaply by the use of suitable ploughing equipment. The optimum combination of cultivation and drainage has still to be determined.

G. G. M. TAYLOR

J. E. EVERARD

CULTIVATION

Cultivation of Ironpan Soils

Deep cultivation equipment capable of dealing with severely compacted soils has been developed, and was used in a new cultivation experiment at Teindland Forest (Moray). The new plough, designated the "Sickle" plough because of its shape, is illustrated in Plate 2. It is capable of subsoiling to a depth of 90 cm (36 in), while the mouldboard mixes and overturns topsoil some 60 cm by 60 cm (24 in by 24 in) in cross-section. This plough was also employed to prepare sites for fertiliser and provenance experiments at Rosarie Forest (Banffshire); it was also used in the establishment of new experiments on gley soils with indurated subsoils (see below). In addition to cultivation for research purposes on bare sites the plough has been successfully tried out under felled woodland conditions at the Black Isle Forest (Ross-shire), at Speymouth Forest (Moray) and at Allerston Forest (Yorkshire). Freshly-felled pine sites with stumps up to 45 cm (18 in) in diameter have been ploughed without undue trouble, although previous clearance of lop and top appears to be essential with the present plough model. Further development work is in progress, but it is already clear that re-cultivation of sites on which soil treatment for the pioneer crop was inadequate is now a practicable possibility. Development work on multiple cultivation ploughs to reduce the cost of complete cultivation on bare sites is now in hand.

The experiment at Towy Forest (Brecon), referred to in last year's *Report*, has now been established (see Plate 3). The four cultivation treatments have produced a good range of intensities of soil working, as follows:

Ploughing treatment	*Depth of cultivation (centimetres)*	*Volume of soil disturbance (cubic metres per hectare)*
Double mouldboard turf ploughing	25	440
Spaced Parkgate tine	50	1,000
Complete Parkgate tine	50	4,140
Complete Parkgate tine plus ripping to 75 cm. depth.	50	5,010

The detailed soil report, prepared by the Site Survey Section of the Management Services Division, indicates that peaty gley, intergrade and ironpan soils occur intermixed and to about the same extent. This will lead to some difficulties in interpreting growth responses, but the site is representative of the soil conditions in the area. The cultivation method most readily applicable to all three soil types and producing most uniformly good results is likely to be preferred in general practice.

Cultivation of Gleys with Indurated Subsoils

New experiments to determine the cultivation requirements for indurated gley soils were established at Montreathmont Forest (Angus), Culloden Forest (Inverness-shire), Black Isle Forest (Ross-shire) and Dornoch Forest (Sutherland). The experiments at Culloden and Dornoch were established on bare land, the experiment on the Black Isle in a moribund thicket stage crop and the Montreathmont experiment on a felled woodland site. All sites are on soils derived from Old Red Sandstone deposits, a material which is of major importance in the forest areas of north-east Scotland and which in many places gives rise to induration problems. The intensive treatment effects achieved by means of the "Sickle" plough appear to have relieved any physical impediment to healthy root growth; it is hoped that much enhanced rates of tree growth will henceforth be achieved.

G. G. M. TAYLOR

J. E. EVERARD

CROP STABILITY

Airflow Studies

An analysis of wind recorded by the anemographs at Eskdalemuir (Dumfriesshire) and Spadeadam (Cumberland) was completed and correlated with windthrow. There were strong indications that the frequency and duration of gusts exceeding 60 knots were the main characteristics of a damaging wind.

This work has also shown up a marked difference in wind climate between these two stations and confirmed a need to establish an anemograph at Kielder Forest (Northumberland), where a large area of susceptible crops is situated.

Studies of Site Factors

A number of small pilot surveys of windthrow in the Borders were carried out, partly to familiarise new staff with the problem, and partly to study aberrant crops in forests which have been zoned for windthrow susceptibility, to attempt to explain divergence from forecasts.

Windthrow Recording

The system of windthrow notification has now been running for nine years, and a total of 2,400 Notification Cards have been received. Some 4,860 ha (12,000 acres) of windthrow have been recorded, and this represents 2 per cent of all Forestry Commission crops planted before 1950. The data have been summarised by species, planting year and top height.

A very cheap technique of aerial photography has been developed by Mr. R. Moreno, a post-graduate student at Edinburgh University, and the value of this both as an aid to management and as a means of obtaining periodic accurate maps of distribution and extension of damage will be tested.

Thinning

Three new experiments comparing the stability of crops thinned normally, line-thinned, and unthinned have been established at Kielder Forest and Castle O'er (Selkirkshire). In the south similar experiments have been established at Clocaenog Forest (North Wales), Coed Morgannwg (Glamorgan) and Hartland Forest (Devon). All these are on soils classified as windthrow-susceptible, and all thinning is standardised at an intensity indicated by Forestry Commission Booklet 16, *Forest Management Tables.*

Rooting and Stability

Studies employing the tree-pulling technique described by Fraser and Gardiner (1967) have been continued on a number of sites. At Allerston Forest (Yorkshire) the rooting and stability of Scots pine on a variety of soil

types were investigated in co-operation with Mr. M. Faulkner, a post-graduate student from Edinburgh University, who carried out a detailed examination of the soils and root systems. This study confirmed previous findings in indicating a close correlation between root exploitation of the site and a variety of readily assessed soil profile features. The degree of root exploitation was in turn correlated with the rate of growth and potential stability of the forest crops. Similar studies are proposed in rather more difficult soils to identify those soil features which can be used to indicate production and stability potentials.

A comparison of the rooting and stability of Lodgepole pine and Sitka spruce on a peaty gley soil was carried out in Kielder Forest. The site had been planted as part of a mixture experiment and conditions were comparable for both species. Analysis of the study data is not yet completed, but it is clear that the penetration by the pine roots is almost double that of the spruce. This evidence tends to confirm the suggestion from earlier work that Lodgepole pine may be a better root pioneer on wet sites than most of the other major conifer species.

J. E. EVERARD

S. A. NEUSTEIN

G. G. M. TAYLOR

REFERENCE

FRASER, A. I., and GARDINER, J. B. H. (1967) *Rooting and stability of Sitka spruce*. Bull. For. Commn, Lond. **40** (HMSO 8s 6d).

REGENERATION

ARTIFICIAL REGENERATION

On Deep Peat

Early survival of the two experiments noted in last year's *Report* has been inconsistent. In one, both notch and turf plantings were successful (i.e. above 95 per cent) whereas in the other the turfed treatment was superior. This result is akin to the variable results being obtained on peaty gleys (see below), and the causes will be investigated.

It was noteworthy that natural regeneration of Lodgepole pine from the surrounding crop fully restocked one experimental site. The density of natural regeneration fell by more than 50 per cent over the first 15 m (50 ft) from the seeding edge.

On Gley Soils

Extensive experimentation between 1958 and 1969 indicated that prompt direct notching through lop-and-top was an adequate method of restocking felled spruce areas. However, in large-scale replanting following "anticipatory" felling at Kielder Forest (Northumberland), using the above treatment, losses in the first year have been high ; in addition there has been the normal post-planting check in growth. Hence a new experiment is being laid down this year to compare a range of planting treatments to identify the cause of failure in conservancy practice and to determine an optimal technique.

On Freely Drained Soils

Underplanting of Larch

A full assessment of underplanted species was carried out in an experiment now six years of age at Drumtochty (Kincardineshire). In terms of tree height, a statistically significant response to the density of the larch overwood occurred only in Lodgepole pine and Sitka spruce (heights decreasing with increasing overwood density), and this was reflected also in the lengths of the current leading shoots. The diameter of the leading shoots showed a consistent reduction with increasing shade only in Lodgepole pine, but if sturdiness was expressed as the ratio of leader length to leader diameter no species showed an obvious pattern.

Crown width of the underplanted species showed a reduction with increasing shade only in Lodgepole pine, and the number of branches was quite independent of overwood density. These latter parameters were used in an attempt to assess potential quality.

Foliage analyses, including chlorophyll and sugar concentrations of underplanted trees, have been undertaken by Dr H. G. Miller of the Macaulay Institute, Aberdeen, and preliminary results indicate marked differences between overwood treatments.

Measurements of basal area increment of the larch overwood indicate that there has been no growth check following even the most severe thinning treatment on what is a fairly exposed site.

In the younger experiment at Allerston (Yorkshire), frost damage on susceptible species was markedly reduced by an overwood density of more than 150 stems/ha (60 stems/acre).

In Wales, at Radnor Forest, where the behaviour of seven replacement species is being compared beneath an overwood of 75, 150, 300 and 500 stems/ha of larch, plus a comparison of replanting in clear-felled plots, assessments of height after six seasons disclosed that, overall, Western hemlock was easily the most, and *Abies alba* much the least, vigorous species. The second tallest species overall was Sitka spruce, which was marginally taller than Douglas fir. Only Douglas fir, Sitka and Norway spruce had grown markedly less well at a density of under 500 stems per hectare (200 stems per acre) than in the open: Light-meter measurements were again made in this experiment during the summer, and in the comparable experiment at Coed Morgannwg, Michaelston (Glamorgan).

Underplanting of Pine

At Thetford, where the survival and early growth of eighteen species are being compared on three contrasting soil types, the main observations were again on the occurrence and severity of frost injury. On the comparatively fertile High Lodge site, satisfactory establishment and early vigour permitted the removal of the pine overwood during the 1968/69 winter in five-year-old plots of ten of the eighteen species, and none of the newly-exposed trees suffered injury even though unseasonal frosts were recorded on the site. However, local damage occurred in plots of the five slower-growing and more sensitive fir species, though they retained their overwood ; this was because the felling of pine in adjacent plots lessened the protection afforded to the underplanted crop. Damage was confined, however, to the relatively exposed perimeter trees.

On the same site, where the survival and early growth of Grand fir and Corsican pine are being studied under different densities of pine overwood, further evidence was obtained of the increased risk of frost injury to Grand fir, notably in the early part of the growing season, associated with reduction in overwood cover. Where the cover was less than about 250 stems per hectare (100 stems per acre) the two-year-old fir tended to be seriously damaged.

At the two other sites, which are markedly less fertile, growth of the under-planted species has been slower and no overwood felling has been undertaken. Here, there have been deaths in several plots due to attack by *Fomes annosus*, mainly among the fastest growing species (Western hemlock, Leyland cypress, Douglas fir and *Nothofagus obliqua*).

Preliminary investigations into the economics of shelterwood regeneration are encouraging. Early calculations suggest that, where crops are increasing in value at a rate higher than the ruling discount rate, the retention of an overwood of 125 to 250 stems per hectare (50 to 100 stems per acre) for 5 to 10 years after underplanting may be more profitable than clear felling. Further data are being collected.

S. A. NEUSTEIN

J. JOBLING

NATURAL REGENERATION

Estimates of Seedfall

Following the Scottish gale of January 1968 large areas have been cleared and may, at least in part, be restocked by natural regeneration of Sitka spruce. The current cone crop is very heavy, and following the good summer of 1969 an equally good one might be anticipated in 1970. Sitka spruce is the desired crop, and existing provenances are acceptable. An investigation has begun at Inverinan Forest (Argyll) to determine the distance of seed dissemination relative to the height and orientation of the seed source, in order to advise local management on the extent and distribution of replanting required.

Natural Regeneration of Sitka Spruce

Monitoring of growth and survival of natural regeneration of Sitka spruce at the Forest of Ae (Dumfriesshire) continues. The pattern of losses is now becoming clearer. Forty-seven per cent of the 1968 germinants had died by December 1969 and more than half of these losses occurred in the two summer periods (i.e. June–August inclusive), with the first summer occasioning the greater proportion of losses.

A similar monitoring scheme will be begun at Inverinan Forest in conjunction with the seed-trapping investigation.

S. A. NEUSTEIN

ECOLOGY

Tree Growth in the Forests of the South Wales Coalfield

Progress in the South Wales Coalfield (Pennant Project 164) has been seriously held up by illness and staff changes. Two significant things, one affecting methods, the other results, have come to light. Estimates of age of trees based on actual stump ring counts are often in sharp disagreement with planting-year dates on the stock maps provided by the local management. Accurate assessment of Yield Class is vital in this work and so any avoidable errors of this kind must be corrected at all costs. Long-drawn-out "beating up", or replacement of failures, on difficult ground; sporadic small fires; and changes in compartment boundaries (due to road building, or the trend towards larger compartments) have all conspired to cause differences between some of the data collected during the first rapid Working Plan Survey made ten years ago, and the facts as revealed by current investigations.

In one area of 30 to 38-year-old Sitka spruce (*Picea sitchensis* (Bong.) Carr.) at 280 m (900 ft), comprising three compartments affected in varying degrees by wind, air pollution and bad drainage, measurements of annual height increments over the past 18 years have shown a remarkable feature. Up to 1962, when the average increment reached its maximum of 59 cm, there was rather consistent, and not unsatisfactory, average growth of about half a metre (20 in) each year. In 1963, the value dropped to 38 cm and, for the next six years, it ranged from 33 to 42·5 cm. This tentative result, based on a small sample of felled trees, must be checked by more data, then looked for elsewhere, before any attempt is made at correlation with local factors. It is desirable too that the distribution of diameter increment on the trunks of the sample trees be examined. If the unusually low winter temperatures (especially in January) of 1963 impaired the health of the spruce, it is unlikely that recovery would not have occurred within seven years. Other possible causes of fall-off in height growth are greater exposure to wind as the trees grew taller (winds have in general been rather stronger in recent years); a sequence of relatively wet springs; and a possible increase in atmospheric pollution.

Corsican Pine

In a month-of-planting experiment on Corsican pine (*Pinus nigra* Arn. var. *maritima* (Ait.) Melville), duplicated in Thetford Chase (Norfolk) and Wareham Forest (Dorset), survival was poor, especially at Wareham, where many deaths followed the hot dry midsummer period. The trial will continue through 1970 and 1971 and there is no indication so far of a most favourable time for planting this sensitive tree in the forest. Ancillary studies on root regeneration after transplanting are continuing.

TABLE 21

MONTHLY WEATHER RECORDS, ALICE HOLT LODGE, HAMPSHIRE (115 m), FOR THE YEAR 1969

Month	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	April to Sept.
Air temperature screen (°C)—														
Mean daily maximum	7·9	4·1	7·5	12·7	15·9	19·2	22·5	20·6	18·2	16·9	8·9	5·4	13·3	18·2
Mean daily minimum	3·3	−1·6	0·8	2·7	6·8	8·5	11·8	12·0	10·6	8·5	2·7	0·8	5·6	8·7
Monthly extreme grass minimum temperature (°C)	−7·2	−11·1	−11·1	−8·9	−1	−1	4	4·5	−3·3	−5	−11·1	−9·4		
Soil temperature (°C) at 9 hours—														
Mean at:														
10 cm. (4 in.) under bare soil	4·1	1·0	3·4	7·1	11·9	16·0	19·6	17·1	14·8	11·8	5·6	3·0	9·6	14·4
20 cm. (8 in.) under bare soil	4·4	1·8	4·0	7·2	11·6	15·4	19·3	17·5	15·4	12·6	6·8	3·8	10·0	14·4
60 cm. (2 ft.) under short grass	5·1	3·8	4·9	7·9	11·5	14·6	17·7	17·8	16·2	14·1	9·9	6·0	10·8	14·3
Precipitation (mm.)	120	50	67	15	86	28	53	90·5	18	2·5	120	74	724	290·5
Number of days with rain (·2 mm. or more)	25	15	14	9	21	9	6	15	10	6	20	21	171	70
Number of days with rain (1 mm. or more)	16	11	11	3	17	7	4	9	6	1	14	12	111	46
Lysimeter (Garnier Gauge) Evaporation losses (mm.) A	0·5	−6·1	25·9	45	63	81·7	102·3	70·1	37·6	20·8	8·6	7·6	457	399·7
B	1·0	−11·4	19·8	63·5	61·7	95	107·2	67·8	44·9	17·5	13·5	14·7	495·2	440·1
Total hours bright sunshine	34·3	73·2	69·7	207·5	164·8	256·2	237·5	165	109·8	117·3	81·2	22·6	1,539	1,140·8
Mean daily run of wind (km.)	117·6	73·7	95·5	116·4	89·4	84·2	58	55·8	54·6	50·8	85·8	55·5	78	

The Weather of the Year 1969

The year 1969 bore some resemblances to 1968—in the dull, wet May, very mild October and cold November: it lacked, however, the striking contrast between a sunny, warm, rather dry summer in the north and west and a dull wet summer in the south and east; this was the most memorable feature of the weather in 1968. The summer of 1969 might be described as good average for most parts of Britain.

From October to November, at Alice Holt (see Table 21) there was a drop of no less than 8 degrees in the mean monthly maximum temperature, of nearly 6 degrees in mean minimum. Like October, September was dry (albeit dull) and, collectively, the two months showed a large rainfall deficit. All districts had warm, dry sunny periods in June and July, but there was no prolonged summer drought and May provided plentiful moisture at the start of the growing season.

In the fortnight ending 10th May, Aberdeen logged 16·7 hours sunshine, Whitby 15·6 hours. By contrast, in the brilliant week ended 14th June (with slightly longer days, it is true), most lowland stations (including Aberdeen) enjoyed 84 hours sun or more (12 hours daily), London had 96 hours and many west coast places more than 100 hours.

Among the many facets of the year's weather which affected foresters, special interest in 1969 was given to the weather prevailing during the Forestry Commission's Jubilee displays held in all parts of the country. In general these were favoured by plentiful sunshine and little rain, although South-east England was unlucky at Bramshill on 23rd June. The wisdom of holding these open air exhibitions early in the summer, still in the drier part of the year, was vindicated.

While an agreeable impression of midsummer sunshine remained, the year as a whole was not oustandingly sunny, except perhaps in the English Midlands. Among several relatively dull months, December in eastern England is worth mention: some stations (e.g. Santon Downham, 11 hours) had remarkably low total sunshine values. It has been suggested that the lack of sunshine in our winters contributes, with relatively high temperatures and short days, to the discomfiture of Norway spruce (*Picea abies* Karst.), in some maritime regions.

The year 1969 was not distinguished by spread of the top dying disease of Norway spruce, but there were many reports, from most parts of the country, of discoloration, loss of foliage and sometimes death of young evergreen conifers. Douglas fir seems to have been affected most, but Western hemlock, the cypresses, Grand fir and other species were often reported on. This damage may perhaps be ascribed to the rather abrupt change from very mild weather in January to cold weather, accompanied by desiccating easterly winds, in February, continuing all through March. A somewhat similar cause, but on a diurnal time cycle, is invoked for injuries to several deciduous species (London plane, sycamore, lime), mainly in towns, during the same period. The suggestion that the alternation of frosty nights with bright sunshine by day, causing rapid thawing, is the reason for these injuries is being followed up experimentally in the Pathology Section, to whose staff I owe this information about winter cold damage in 1969.

TABLE 22

YEARLY AGGREGATE FREQUENCY OF GALES AT 40 WELL-DISTRIBUTED COASTAL AND INLAND WEATHER STATIONS IN BRITAIN

Year:	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
Gales:	321	568	405	686	829	653	602	695	735	1,054	764	585

Table 22 shows a trend towards greater storminess over recent years which seems to have been halted in 1968 (after the catastrophic mid-January gale in the central valley of Scotland) and 1969: this may be reflected in windthrow statistics.

Exclusion of the stormy month of January would bring the 1968 figure down to 598 occurrences. Mean daily run of wind at Alice Holt was 103 km (64 miles) in 1968, 78 km (48·5 miles) in 1969.

Garnier Gauges

As in former years, records have been kept of losses by evaporation from two gauges: the monthly totals in millimetres appear in Table 21 below the precipitation figures. On three days in June and 17 days in July, when the irrigated turf was moist at 9 hours, while the surround was free from dew, advected heat may have augmented the measured loss by evaporation (oasis effect).

J. M. B. BROWN

FOREST GENETICS

Seed Crops

Scots pine produced moderate to heavy crops in the older seed orchards in east and south-west England and in central and north-east Scotland; crops in managed seed stands throughout the country were considerably lighter. Corsican pine, Douglas fir and coastal Lodgepole pine crops were generally poor throughout Britain whereas "inland" Lodgepole pine provenances had moderate crops in many parts of eastern Scotland; Alaskan Lodgepole pine coned prolifically in Shetland, Orkney and south-east Scotland with somewhat lighter crops in Caithness.

Both Sitka spruce and Japanese larch produced heavy crops in small pockets in south Scotland and more generally on south-facing slopes in the more coastal mid-western regions of the Highlands. These heavy crops are probably a direct consequence of the hot and dry summer of 1968, coupled, perhaps, with root injury following the severe January gale of the same year. Large-scale and relatively inexpensive cone collections were made from especially felled selected heavily-coning dominant trees of both species.

A heavy beech crop occurred throughout south-west Scotland and north-west England; heavy beech fruiting was also reported from most parts of Ireland.

The Breeding Register

In the *Report* for 1966 (p. 66 and Plate 5) mention was made of a new Abbreviated Breeding Register, the information for which was stored on punched paper tape suitable for processing by the Sirius computer at Alice Holt. The processing time was slow, and for this reason the information was transferred on to 80-column punch cards for storage, using up to three cards for recording the following data on each Plus tree: location; whether vegetatively propagated and in a tree bank or not; number of clonal seed orchards in which it occurs; breeding history and each progeny-test site location and performance information. At the same time the opportunity was taken to extend the range of recorded information. The punch-cards can be updated at any time with obvious advantages to the punching operators. Information changes are made manually and the cards are processed at the Edinburgh Regional Computing Centre on either an IBM 360/50 or an ICL 4/75 computer. Any number of copies of the Register can be produced at a cost of under £2 per copy. When further facilities become available in a few years time, the data will be transferred on to magnetic tape for storage.

The Formation of Tree Banks

Continuing difficulties in establishing grafts and generally poor growth of successful plants in the Douglas fir tree bank at Newton Nursery in Moray provided good reason for transferring the Bank to an alternative and more sheltered site at Silk Wood, adjoining the Westonbirt Arboretum in Gloucestershire.

Rootstocks were first planted on the new site in 1966 (*Report* for 1969, p. 102) and continued in 1967, by which time nearly 3·2 ha (8 acres) of root-stocks had been planted. The rootstocks are planted in closely spaced groups of three at a between-group spacing of 9·1 m × 2·2 m (30 ft × 7½ ft). By 1969 at least two of the rootstocks in each position were suitable for grafting.

On-site grafting began on the 28th April 1969. On this date most of the root-stocks were at IUFRO Flushing stage I and II (slight bud-swelling, activity visible). In three days 116 clones on 807 rootstocks were grafted by a team of four men. A further 93 rootstocks were grafted under-glass to fill blank positions at a later date. Compared to the 1962 Clanna grafting (*Report* for 1969, p. 102) the rootstocks were smaller and a very good match was obtained between the stocks and scions. More than 90 per cent were grafted on the terminal shoot using the apical side-veneer method but leaving two or three vegetative buds on the stock immediately opposite the union. Weaker and top-damaged stocks were grafted on second-year wood, using a side-veneer grafting method, but again leaving two or three sap-drawing branches at the same heights as the scion bud. There was little sign of blast-damage to the foliage during the first winter.

An assessment of the survival of the grafts at the end of August 1969 showed that only 70 (8·6 per cent) of the 807 grafts had died. Losses were not attributable to the work of individual propagators. This new bank will be extended over a period of years and the groups will be singled when four to five years old.

Rooting of Cuttings

A broad study of the rooting capacity of a number of conifers has been started using mist-propagation facilities kindly lent by the University of Edinburgh. Previous experience has shown that Western red cedar and Lawson cypress cuttings can usually be rooted easily, while success with Leyland cypress and *Sequoia sempervirens* has been variable. It has also been possible to propagate a few selected clones of Sitka spruce by this method.

One of the problems in this field is the large number of variables involved. Some forty variables have been identified and incorporated into an " initial details sheet ", on which the age and condition of the stock plant, and the size and other features of the shoots used as cuttings are noted. Treatment with hormones or other chemicals is also recorded together with the propagating conditions.

Eight species and three hybrids have been successfully rooted to date. Much of the initial work was done using Western red cedar as a test plant. This species has been used to study the variability of the propagation bed, and also the effects of size of cutting, hormone interactions, etc., and was chosen because large stock plants of an easy-rooting clone were readily available. The clone in question, 139: Ardgoil, is one of the most promising of all the Plus trees of the species; it appears to root most rapidly and strongly with 0·5 per cent napthalene-acetic acid plus 0·5 per cent indole-butyric acid—the auxin being dissolved in absolute methyl alcohol and applied by the quick-dip method. Cuttings 25-30 cm (10-12 in) in length

can be rooted and potted in 6-10 weeks with 90-100 per cent success, using mist and a bed temperature of approximately 24°C. Such plants quickly resume rapid shoot growth, and are ready for planting-out a month later.

Considerable success has been achieved in rooting Sitka spruce cuttings taken from fairly young stock plants. In one case, a 5-year-old tree produced a large number of small shoots in response to pruning, and 3 cm (1¼ in) cuttings from this showed 70 per cent rooted in 5½ weeks ; 90 per cent were suitable for potting-up after 10 weeks. Similarly, a 15-year-old stock plant which had been grazed by deer yielded cuttings of which 73 per cent were potted after 9 weeks. An interesting point is that only 28 per cent of cuttings without a terminal bud were suitable for potting by the same date, suggesting a possible promotive effect of the buds. In both experiments these small buds were " post-dormant " (i.e. their chilling requirements had already been met), and they generally flushed at the same time that roots were being initiated.

Cuttings and grafts of spruce taken from older " mature " stock plants frequently make a single, short " flush " of growth and also exhibit a plagiotropic, i.e. branch-like, habit. The cuttings from the 5-year old tree are continuing shoot-extension growth under the long-days of the greenhouse ; the terminals are mainly vertical, and are showing the " continuing " type of growth found in first-year seedlings. This has two very important implications ; firstly, it should be possible to grow the cuttings to a size suitable for planting-out in a much shorter time than " mature " cuttings. Secondly, it may perhaps be that a reversion to a seedling habit of growth could be induced in mature stock plants. A somewhat analogous situation has been found in *Sequoia sempervirens* cuttings, where the cutting itself is strongly plagiotropic, but shoots arising from minute buds at the base grow vertically and are generally radially symmetric.

The possibility of propagating pines from needle fascicles is an attractive one since, if they were easily rooted, the multiplication of desirable individual trees would then be easy. Fascicular buds may be formed between the needles particularly if the ordinary buds are damaged, and such budded fascicles, including a small portion of the main stem, have been rooted in *P. contorta* and *P. jeffreyi*. In the former species, 50 per cent of these small cuttings were potted, and some are making renewed shoot growth after a period of short-days (" autumn ") and chilling (" winter ").

Where rooting is difficult there is much to be said for attempting to stimulate the initiation of roots *before* a cutting is detached from the stock plant ; this avoids the need to keep cuttings in the propagation beds for long periods and the subsequent deterioration in condition which inevitably occurs. Such methods, known as pre-severance treatments, are similar to the techniques of layering and air-layering, though much simpler. It has been found that complete stem " ringing " (girdling) of birch seedlings produced roots above the ring in 41 out of 42 plants so treated. The roots, which even emerged into the moist air, were produced up to 15 cm (6 in) above the ring, and some trees had produced 40 or more roots. Birch is by no means an easy species to root with normal techniques, and if these methods prove effective with other difficult species they could be used for multiplying selected individuals. A preliminary trial with Douglas fir has yielded two rooted

cuttings after six months. In this case the pre-severance treatment consisted of an oblique cut made below the cutting three months previous to its removal from its stock plant.

Flowering

Breeding work on tree species is often hampered because flowering is sparse or irregular in occurrence ; there is also great variation in the reproductive behaviour of individual trees. Some control over flowering is therefore needed, both to enable series of controlled pollinations to be planned, and to allow sustained seed production by seed orchards. The aim of the current series of physiological studies is to develop methods of control arising from investigations into the effects of external and internal factors on flowering.

The formation, or initiation, of cones or inflorescences occurs in most tree species during the spring or summer before the time of flower emergence and pollination, and attention is at present concentrated on these early stages in the flowering process. A variety of experimental treatments has been applied and first results indicate that branch ringing (girdling) stimulates flower initiation in a number of species. The effect is generally most marked when a complete ring of bark is removed (at the basal end of the branch), with a smaller effect when two half-rings are used. Previous studies have generally involved treating the main stem, where complete ringing has been considered too drastic ; in some cases the results have been inconclusive because of the variability of the material. Greater precision has been possible in the present investigation because the treatments were applied to branches of similar size and position in each tree, and because of the availability of vegetatively propagated clonal material from " mature " trees instead of " younger " trees of seedling origin.

In Scots pine, a " shy " flowering clone has been stimulated to abundant male flowering by completely ringing five- or six-year-old branches ; the male buds also appear to be unusually large. In Western red cedar, over 90 per cent of all branches given the same treatment produced female cones, up to a 100 or more in some cases, whereas the whole of the untreated parts of the trees were virtually without flowers. In other species, such as Douglas fir and Norway spruce, the effect of ringing treatments will not be seen until the buds open in spring 1970.

Several aspects are being considered in larch where it was already known that flowering could be stimulated by ringing and by pulling branches into a horizontal or downwardly directed position. In addition to effects upon the proportion of vegetative and flowering buds, attention is focused on the percentage of female buds, which are usually a small proportion (approximately 0·5 per cent to 3 per cent) of all flowers in untreated trees. Attempts are being made to alter the sex ratio by gravimorphic and ringing treatments and by applying growth substances to potential flower buds before the cone initials have been formed. Another important feature in larch is the time of flower-bud opening: Japanese larch usually flowers much earlier than European larch. It now seems that the time of flowering may be affected by previous treatment ; assessments in spring 1969 on Japanese and hybrid larch progenies at Clanna (Forest of Dean) showed that male and probably

also female cones were at a more advanced stage on trees which had been previously partially ringed on the main stem. It will be of interest to see whether any of the branch treatments in the present series of experiments has also advanced the time of flower emergence in European larch, since this would enhance the prospects for the commercial production of hybrid seed.

Ancillary problems on which work has started include the training and pruning of seed orchard trees and the selection of branches for ringing to permit repeated flowering with a minimum risk of breakage at the point of ringing. By repeated collection and dissection of buds it has been shown that flower initiation in European larch near the Northern Research Station had reached the early stages of microsporophyll and bract primordia formation by early August 1969.

A more difficult problem concerns the ability of young trees to produce flowers. It is generally assumed that young trees of seedling origin are juvenile, in the sense that they lack what has been termed "ripeness-to-flower" (Blühwilligkeit). Studies of potted seedlings of *Betula pubescens,* grown rapidly under greenhouse conditions, have now shown that flower formation can be induced when the trees are less than 8 months old. Since this can be done merely by ringing the main stem completely, it seems that there may, perhaps, be no true juvenile, non-flowering phase in this species, though the precise effect of the ringing has still to be clarified.

Flowers of both sexes have been initiated under greenhouse conditions on small, one-year-old cuttings of *Metasequoia glyptostroboides* originating from a fourteen-year-old cutting. Female cones on this species are uncommon in Britain and the male cones have not been recorded here previously. Pollen from the male flowers has been used to pollinate female cones on the same plant; if fertile seeds are obtained they will be the first to have been produced in Britain.

Sitka Spruce Population Study

Sitka spruce is the most important commercial conifer in cultivation in Britain and most of the seed used has been obtained from the Queen Charlotte Islands off the coast of British Columbia. In general, trees from this source are acceptably straight and frost-hardy under most British conditions and the wood is highly prized for pulping and is used for sawmilling. Vigour is good—but lower than that of trees of the same species from more southerly sources.

Population studies are needed to provide data for quantitative work on the inheritance of measurable characters, and for this reason the opportunity was taken of collecting seed from 150 parent trees of Queen Charlotte Island origin growing in a 43-year-old plantation in South Strome Forest in north-west Scotland. Because the cone crop was heavy it was easy to arrange collections of 50 cones from each of the trees covering the full range of size-classes including the smallest subdominants. A check was kept during the selections to ensure that all size-classes were equally represented. Seed extraction has been satisfactorily completed and the open-pollinated seeds were sown in spring 1970.

To provide basic data on the variation within the stand, detailed measurements of the following characters are being made; height, girth, crown diameter, crown length, angle of branching, diameter of branches, and number of branches per whorl. This data will be used to demonstrate offspring-parent tree relationships. In addition a 10-cone sample from each tree will be used as the basis for data on cone and seed morphology. Wood anatomy and wood density information will be obtained from 12 mm increment cores taken at breast height.

CONTROLLED POLLINATIONS

Sitka Spruce Inter- and Intra-Species Crossings

Sitka spruce has a large natural distribution and hybridises naturally with White spruce (*Picea glauca*). Only a few previous attempts have been made to produce artificial hybrids between Sitka spruce and other species; successful crosses with Serbian spruce (*P. omorika*) have proved interesting. To study the possibilities of obtaining other inter-specific hybrids artificial crosses were made at Roseisle, Moray, using Sitka spruce of Queen Charlotte Island, British Columbia, provenance as the female parent and *Picea likiangensis, P. abies, P. maximowiczii, P. asperata* and *P. koyamai* as males; an inter-provenance cross with Washington provenance as the male parent was also made. Only the inter-provenance cross and the inter-species cross with *P. likiangensis* produced viable seed.

Lodgepole Pine Inter-provenance Crossings

The crossing programme described in the 1969 *Report* was extended using the Section's provenance collection at Saltoun, Stenton Forest (East Lothian). Emphasis was placed on crossing six widely-separated inland British Columbian provenances, two from Oregon and one each from Alberta, Saskatchewan and Washington. Each of these eleven inland provenances was crossed with pollen from a coastal Washington provenance. In addition, trees from two northern coastal sources, namely, Skagway, Alaska and Queen Charlotte Islands were also artificially crossed using coastal Washington pollen. To provide experimental control material, coastal Washington trees were crossed with trees from Tidewater, Oregon, and a mixture of trees from all the inland sources with pollen from Shuswap, British Columbia.

Seed yields from the 1968 Lodgepole pine intra-specific crossing programme were very satisfactory. Seed from the 1968 and 1969 crosses will be sown in a single experiment in spring 1971.

Early-Testing

Sitka Spruce

The 7×7 diallel cross reported in the 1969 *Report* (p. 104) provided sufficient seed and plants to occupy the whole of the main glasshouse at Alice Holt. 56 progeny lots were obtained, i.e. the 7 trees used as both male and female parents including "selfs" and wind-pollinated lots from the same parents. Forty seedlings from all but two of the progeny lots were potted-up; these were arranged in five-plant line plots and replicated eight times. Seeds were sown in early February, and in order to extend the growing-period supplementary heating for the whole experiment and supplementary

lighting over half the experiment was provided until the end of September. The supplementary heating raised the soil temperature to 24°C, and the air temperatures to 13–15°C, for part of the period. The artificial lighting provided a minimum 15-hour day from April to September. Plants were hardened-off by terminating the extended photoperiod and gradually reducing the supplementary heating over a one-month period. After a further month in the glasshouse with no additional heat or light, the plants were transferred to a plunge-bed in the open-nursery for a period of 5 weeks of winter-chilling. The experiment will continue in the glasshouse in 1970 using one out of every five plants potted-up into larger pots. Surplus plants will be distributed to other research centres for growing on, and to provide research material for further studies.

Twelve characters were assessed at the end of the first growing-season, and since the extended photoperiod was only applied to half the greenhouse it was decided to treat the data as two separate experiments. During the first growing-season several interesting points were noticed, in particular one parent (H) responded strongly to the extended day-length.

The Statistics Section is making a study of variation in growth characteristics due to local environmental effects in the greenhouse. This is being done by using the computer to calculate and display, in map form, the residual deviations for a range of experimental designs. This should enable any of the more disturbing environmental effects to be taken into consideration in future experimental designs.

Cone Harvesting by Mechanical Shaker

In November 1968, a preliminary trial of an "Evans Tree Shaker" (see Plate 10) showed promise as a possible means of dislodging cones from Scots pine, Douglas fir and Sitka spruce, but not from larch or Norway spruce. These trials were conducted later than the normal harvesting time for all the species other than Scots pine, and it was noted that cones of Sitka spruce and Douglas fir had already started to absciss. In consequence a more comprehensive series of tests was carried out in South Strome Forest (Ross), during autumn 1969, concentrating the effort on a 19–23 m (65–75 ft) tall Sitka spruce crop, with additional trials on Noble fir, Western hemlock and Douglas fir. Scots pine in an 18 m (60 ft) tall seed stand in Culbin Forest (Moray), and on 6 m (20 ft) tall grafts in the National Scots pine tree bank at Newton (Moray) were also used to determine the suitability of the machine.

The shaker has a hydraulically operated clamping device, the jaws of which are fitted with deformable rubber roller-shaped cushions which are held loosely in place by a detachable rubber sling. The jaws are mounted on the end of a 3 m (10 ft) long arm which is suspended by metal hinges from the main frame. For the trials, the machine was mounted on a steel frame fixed to the three-point linkage of a Ford County Super-4 tractor to give an operating height 2·1 m (7 ft) above ground. The frequency of shake is controlled by the engine-speed of the tractor, and the amplitude by adjustable weights on a rotating head fixed at the end of the shaker-arm. Trials on Sitka spruce started in mid-September and were continued at intervals into early October.

Results showed that, on average, approximately 50 per cent of the cone crop was removed in mid- or late-September, but only 25 per cent by the end of the first week of October. This suggests that the effectiveness of the system is dependent on the weight of the cones; as the cones ripen and become lighter they become progressively more difficult to dislodge. Trees varied greatly in their ability to yield cones; the percentage catch of the total crop per tree varied from 0–90 per cent. Most of the trees suffered some damage to the upper crown and the loss of leading shoots was common; damage to the main stem seldom occurred below a 5 cm (2 in) diameter. Cones were more readily removed from the upper third of the crown.

Only one Douglas fir tree, with a long crown, was shaken ; this yielded almost half its cones very readily. This adds some confirmation to American reports that Douglas fir is a suitable subject for machine harvesting. Almost all the cones came from the upper third of the crown, but the main stem snapped at 5 cm (3 in) diameter. The machine failed to dislodge cones from Noble fir, Western hemlock and Scots pine.

On the evidence obtained from the 1969 trials, it seems highly unlikely that the machine will provide an effective substitute for the traditional methods of harvesting cones from the more commonly used commercial conifers.

R. FAULKNER

A. M. FLETCHER

K. A. LONGMAN

R. C. B. JOHNSTONE

FOREST PATHOLOGY

Death and Decay Caused by Fomes annosus

Deaths of Pines on Alkaline Sites: Stump Removal Studies

Studies of the costs and benefits of stump removal as a method of eradicating *Fomes annosus* from infected pine plantations on alkaline sites prior to replanting were completed during the year. Three methods of removing stumps were compared (see *Report* for 1969):

1. *"Volvo whole tree"*

   Whole trees, with root systems attached (instead of normal clear felling) were pushed over and extracted using the Volvo LM 840 tractor with a grapple attachment.

2. *"Challenger"*

   Stumps were pushed out after normal clear felling using a Challenger 33 tractor with a grubber blade.

3. *"Volvo lift"*

   Stumps were dug out after normal clear felling using the Volvo LM 840 tractor with lifting tongs.

The Work Study Section calculated that the costs per acre of removing stumps were as follows:

Method 1	£36
Method 2	£32
Method 3	£39

It should be noted that using Method 1, the stumps of standing trees are removed but thinning stumps remain in the ground as potential sources of infection. This method of stump removal could only be used if the compartment had not been thinned for at least six years, thus allowing the inoculum in these stumps to become depleted.

The proportion of roots removed by all three methods was considered to be adequate to give good control of the disease in the replanted crop. Assessments of the proportions of roots removed indicated that Method 3 was better than Method 2, which in turn was better than Method 1. Because of the difficulties and breakdowns encountered during the removal of large stumps it was felt, however, that the Volvo lift method (Method 3) was not suitable for this task, and on the basis of cost and overall effectiveness of the three methods it was concluded that Method 2 was to be preferred.

The Planning and Economics Branch calculated that the extra discontinued revenue which would accrue in the crops following stump removal was between £28 and £35 per acre. These benefits were derived from an assessment of the losses caused by *F. annosus* which occurred in a Pathology experiment with and without stump removal treatments.

Thus the costs and benefits of stump removal directly related to the control of *F. annosus* were similar in the crop concerned here.

The decision of the forest manager on whether to apply this treatment in practice is clearly a difficult one. There may be additional benefits associated with stump removal, such as cheaper and better establishment of the replanted crop, and it may be prudent to try this treatment on a pilot scale at this stage.

Deaths on Alkaline Sites : Survey of Clear-fell Pine Areas

It is important in Thetford Chase to determine which areas on replanting are likely to suffer severe losses from attack by *F. annosus*. Every compartment included in the clear-felling programme for the past two years has been surveyed by Pathology staff before felling, and this work is currently being extended by Conservancy staff.

A systematic survey is being made in each compartment, general crop and site information noted, and the following detailed records made:

Number of standing trees showing crown symptoms of attack by *F. annosus*.

Number of standing trees killed by *F. annosus*.

Number of thinning stumps infected by *F. annosus*.

Number of healthy trees per acre.

pH of the soil.

In the earliest replanting experiment assessments were made to include the factors mentioned above and a formula was devised to relate them to the losses which occurred after replanting. This formula is being used as a guide to predict future losses on areas currently being clear felled.

As the experimental evidence in support of these calculations is limited, two more subjective assessments of expected losses are made, one based on the proportion of infected stumps left after clear felling and the other based on a rating of various important factors.

If the losses are likely to be high on the basis of all three of these calculations, then alternative areas are allocated for clear felling and infected crops are left standing. The future of these crops will depend on the success of remedial treatments currently being considered.

Butt Rot

The preliminary study into the relative susceptibility of Grand fir and Western hemlock to staining and decay caused by *F. annosus* was completed during the year. It was concluded that Western hemlock was susceptible and on heavily invested sites up to 30 per cent of the volume of 40-year-old trees was affected. Grand fir was relatively resistant and very small losses were incurred in stands up to about 40 years of age. No crops above this age were available for examination. The number of sites where comparative studies could be made was strictly limited, and confirmation is required of the degree of resistance shown by Grand fir.

After the completion of the above study, three sites were found where significant decay in Grand fir caused by *F. annosus* has been identified. Investigations are being undertaken to elucidate this apparent breakdown in resistance and to determine its significance.

Biological Control

A preliminary assessment of the biological stump treatment experiment on Sitka spruce stumps was made (see *Report* for 1969). One of the fungi being tested showed marked ability to decay the stumps under forest conditions. However, no assessment of its competitive activity against *F. annosus* could be made as the inoculum of the latter failed to develop even on the untreated controls. A final assessment of the experiment will be made in 1970 and further trials will be laid down including the most promising treatments.

Treatment of pine stumps with the competitive fungus *Peniophora gigantea* is being extended to more forests. Eighteen forests, mainly in East England and East Scotland, are now using *P. gigantea* for routine stump protection against *F. annosus*. Until recently *P. gigantea* was made up in tablets which had to be soaked overnight in a jar of water. It is now produced as a liquid formulation in small glass phials, the contents of each of which can be mixed immediately and readily, together with a marker dye, in 4·5 litres (1 gal) of water.

Disease Survey in Scotland and Northern England

Hitherto we have relied largely upon field staff to draw our attention to disease occurrences, although some special surveys of particular diseases or disorders have been carried out. The survey now in progress will provide an overall picture of disease incidence in northern forests, and while some information from it will be directly useful to management, its main function will be to identify those disorders requiring research. The survey is at present restricted to Forestry Commission forests.

Two techniques are employed. In one, the Sampling Survey, a statistically based assessment of a systematically selected 10 per cent sample of Scots pine, Lodgepole pine, Japanese and Hybrid larch, Norway spruce, Sitka spruce, Douglas fir and Western hemlock crops is carried out. In the other, the Observation Survey, the surveyor checks, summarizes and records the observations of local staff.

Younger crops less than twenty-five years old, where access and inspection are not always feasible, and small blocks of woodland less than five acres in extent, where normal stand conditions cannot be expected, are excluded from the sampling survey. The crop selected for inspection is first viewed from a vantage point using a pair of binoculars. Then, from within the stand, each individual in a sample of four hundred trees is closely inspected. Particular attention is paid to stocking, leader behaviour, needle colour and retention, and any variation from normal health and vigour for that species on that site is noted and investigated.

The Sampling Survey has now been completed in the West and East Scotland conservancies. A summary is given in Table 23.

TABLE 23

INCIDENCE OF UNHEALTHY CROPS

	Tota	West Scotland							East Scotland						
		Scots pine	Lodgepole pine	Japanese and Hybrid larches	Norway spruce	Sitka spruce	Douglas fir	Western hemlock	Scots pine	Lodgepole pine	Japanese and Hybrid larches	Norway spruce	Sitka spruce	Douglas fir	Western hemlock
No. of crops sampled ...	601	13	3	12	96	142	6	3	139	11	25	62	82	7	0
Per cent affected ...	33	23	66	8	40	28	50	100	60	60	4	40	25	56	—

Although about 30 per cent of the crops sampled are recorded as "affected", a large proportion of these records signify only the presence,

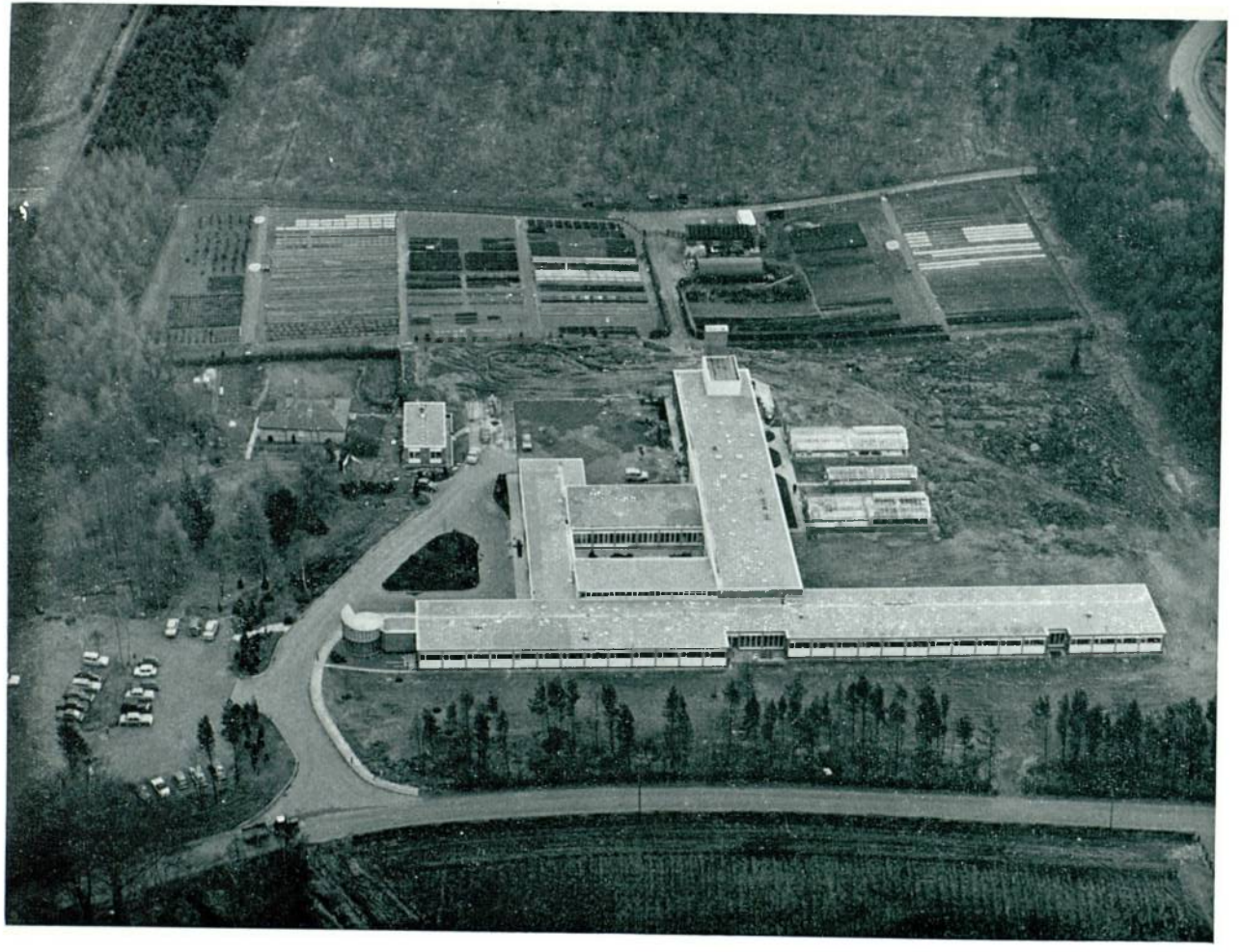


PLATE 1:

Introduction (p. 1)

Aerial view of Northern Research Station. B5634.

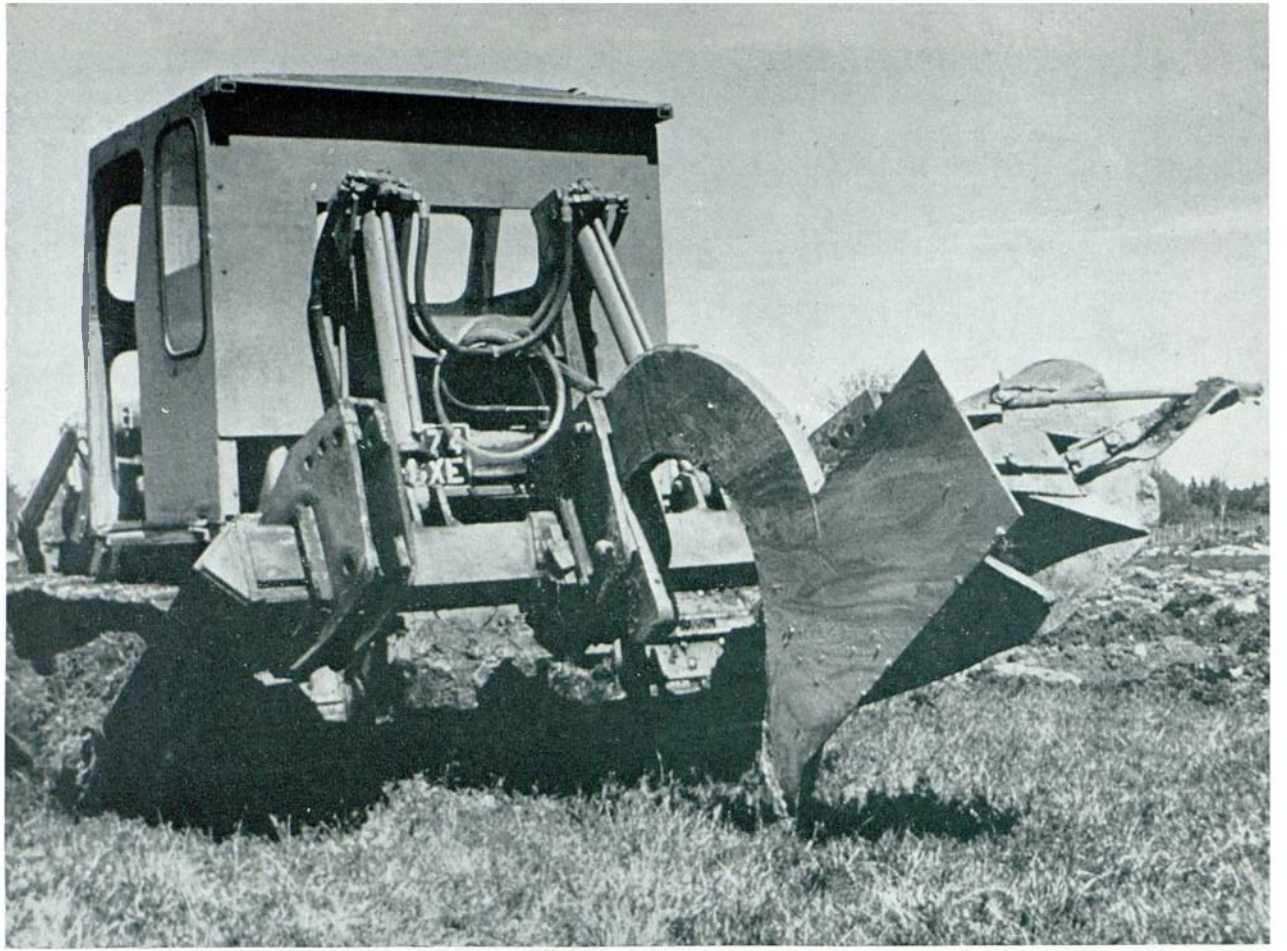


PLATE 2. Cultivation (p. 94)
Proto-type deep cultivation "Sickle" plough developed for research purposes to investigate tree response on indurated heathland soils. The tractor is a Fowler, Challenger 33, normally used for bulldozing or rock ripping on civil engineering operations. A4209.

PLATE 3. Cultivation (p. 94)
Part of Towy Forest, Experiment 11, showing some of the combinations of cultivation intensity and drain spacing. B5635.

Planning and Economics (p. 141)

Replicated Line Thinning Experiment, Corsican pine, Compartment 87.

Kings Beat, Thetford Forest, East Anglia.

PLATE 4 (*left*)

Plot 1648. Removal of one row in two. A4210.

PLATE 5 (*below*)

Plot 1649. Removal of three rows in four. A4211.

PLATE 5:
Removal of three rows in four.
(*See above*).

PLATE 6. Work Study (p. 147)
An experimental front-mounted brushcutter designed and built in the Research and Development Workshops at Alice Holt. A4208.

PLATE 7. Work Study (p. 149)
A "Hydrostatic" skidding tractor designed by the Research and Development engineer at Alice Holt. C4733.

PLATE 8: Work Study (p. 147).
A variable width grass roller powered by a narrow gauge Massey Ferguson 135 "Vinyard" tractor. It was designed and built by the Research and Development Workshops, Alice Holt. A4207.

PLATE 9: Work Study (p. 150).
Hydraulic Tongs ("Hydratongs") for extraction, designed by Work Study Branch, used on a Massey Ferguson 135 agricultural tractor. C4734.

PLATE 10:

Genetics (p. 112)

The Evans Tree Shaker, used experimentally for cone collection. D6436.

frequently on less than 5 per cent of the crop trees, of such minor disorders as drought crack and salt spray damage, and of minor diseases such as those caused by the fungi *Chrysomyxa* species and *Cucurbitaria piceae*. The "affected" percentage is further swelled by the large number of Scots pine crops attacked by *Peridermium pini* in an area of East Scotland where it has long been known and recognised as an influence on management.

Extraction damage, and damage caused by deer, were very common on Norway spruce. Killing by *Fomes annosus* in pine, though seldom serious, also occurred more frequently than had been expected. The most commonly noted disorder, however, was "check" in Norway and Sitka spruce.

The Observation Survey covers crops of all species and of all ages. Particular attention is paid to butt rot, and to disease incidence in crops less than 25 years old, which were not covered by the Sampling Survey. This part of the survey has only recently been started. An early finding concerns infection by *F. annosus* in pine crops which are likely to be replaced by a butt-rot-susceptible species. Stumps were sampled in six forests in East Scotland where first-rotation crops had been thinned before stump protection was introduced. An average of 22 per cent of the stumps was infected. This represents a serious threat if a butt-rot-susceptible species is used in the next rotation.

Dieback of London Plane

A more detailed investigation of this recurrent problem in the cultivation of this leading ornamental tree, *Platanus acerifolia*, was undertaken during the year.

The most common and striking initial symptom of the disorder is extensive death of buds, apparently before, during, and a little after, bud-break. Severely-affected branches produce little or no foliage in spring, and leaves produced later in summer tend to be sparse and chlorotic. From limited observations, this bud failure is not commonly preceded by any extensive death of live parts elsewhere in affected trees. Later, and apparently related, symptoms on some affected trees are interveinal chlorosis and marginal scorch of some expanded leaves.

This dieback has been recorded in Central London in 1955, 1963, 1968 and 1969, following unusually cold but sunny winter periods, particularly in February. The chances of such periods occurring have increased following an increase in winter sunshine consequent on enforcement of the Clean Air Act.

A survey in areas of Central London where damage was known to occur was carried out during 1969.

The incidence of damage was greatest on roadsides facing between south-east and south, and least inside parks and gardens. The most likely cause of damage appeared to be over-rapid thawing of twigs and small branches. The greatest damage occurred where the combined heat from traffic and from morning sunshine on trees and on stone, concrete and tarmac surfaces in their vicinity would cause the earliest and most rapid thawing after cold nights. Least damage occurred where trees were away from traffic and from surfaces likely to be much warmed by sunshine.

The population of London plane was found to consist of morphologically varied individuals and clones, and evidence of wide variations in susceptibility

to dieback was found. One parent of London plane, Occidental plane, the North American *Platanus occidentalis,* has largely failed in Britain, apparently through lack of winter hardiness; the other parent, Oriental plane, *P. orientalis* from Asia Minor, is hardy in this country. It seems likely that susceptibility to dieback is inherited from Occidental plane.

Control of this dieback may ultimately be achieved by planting resistant clones.

Advisory work

The Advisory Service received 637 enquiries during the year, 515 at Alice Holt and 122 at the Northern Research Station. One hundred and sixty-four of these were Forestry Commission queries and 473 came from non-Forestry Commission sources. Three hundred and forty-one related to woods and plantations, 268 to parks, gardens, roadside trees and other ornamental plantings. The number of visits paid to deal with enquiries was 182, of which 128 were made from Alice Holt and 54 from the Northern Research Station.

Diseases caused by fungi and bacteria accounted for 210 of the solved problems, *Armillaria mellea* remaining by far the most commonly occurring parasite in the south and *Fomes annosus* was the most frequent in the north.

Notable Features

Cryptodiaporthe populea (Sacc.) Butin, the perfect state of *Dothichiza populea* Sacc. & Briard, was recorded for the first time in Great Britain in January 1969, on Lombardy poplar nursery stock in Gloucestershire.

Severe outbreaks of *Didymascella thujina* in a nursery in Norfolk and another in Hampshire in the spring of 1969 were apparently the result of unusually heavy infections in the previous autumn, probably during the outstandingly wet September and mild October period. An unusual feature of the outbreaks was the large amount of dieback resulting from girdling injuries, a type of damage apparently hitherto undescribed for the disease.

A remarkable increase in damage to Corsican pine by *Brunchorstia pinea* in some northern forests became evident early in 1969, and there was a sudden severe outbreak in a previously healthy stand in Lincolnshire. A similar new outbreak in healthy trees in East Anglia followed the bitter 1963 winter; February 1969, the coldest since then, may have favoured the disease last year.

The cold February was preceded by a remarkably mild January, milder, in fact, than March. It was presumably these winter conditions which led to the widespread death of needles and shoots of various conifers, notably Douglas fir, which became apparent during March and April in the southern half of Britain, and to diebacks in London plane (referred to above), Common lime *Tilia europaea,* and *Acer* species. In some of this injury, over-rapid thawing on a number of brilliantly sunny days in the first half of February appeared to have been involved. The dieback of hardwoods was markedly worse on roadsides, possibly because of the additional warming effect of road surfaces and morning traffic, as has been noted above in connection with dieback of London plane.

The wet, dull and thundery May produced several cases of waterlogging and soil compaction damage in nurseries. At about this time, in Norfolk, some 250 pole-stage Scots pine in a group were killed by lightning.

In early summer, *Fomes annosus* spreading from Scots pine stumps was found killing three quite large cedars in a Hampshire garden ; a similar instance affected a small greengage tree in Surrey.

Inoculation of *Juniperus communis* with a *Phomopsis* species isolated from girdling branch cankers on *Juniperus sabina* ' Tamariscifolia ', which had been imported from Holland, reproduced the symptoms of the disease, and the same fungus was re-isolated from the inoculated plants. The damage resembled that on *Juniperus virginiana* in North America caused by *Phomopsis juniperovera,* but the fungus differs from this in several respects. Isolates of a similar *Phomopsis* from cankers on *J. communis* from Teesdale and from *J. sabina* ' Tamariscifolia ' from North Wales also reproduced the symptoms when inoculated into *J. communis* test plants.

In July, *Coryneum cardinale* Wag., a serious bark pathogen of Monterey cypress (*Cupressus macrocarpa*), known to cause serious damage in California and elsewhere, was discovered for the first time in this country in Surrey, and since then long-standing infections have been found causing considerable damage to Monterey cypress in Dorset, Hampshire, Kent and Hertfordshire. Preliminary inoculation tests indicate that the *C. macrocarpa* × *C. nootkatensis* hybrid, *Cupressocyparis leylandii* (Leyland cypress) is susceptible to the disease, a possibility that had apparently not been investigated before.

The fine summer probably served to enhance symptoms of Elm disease (caused by *Ceratocystis ulmi*) and other disorders. The sharp increase in Elm disease queries, particularly from Kent, Essex and Worcestershire, confirmed the indications of the previous two years that the disease is passing through one of its periodic unexplained aggressive phases.

During the winter months of 1969/70, *Phytophthora cambivora* was isolated from the roots of dying 5-year-old beech from Lincolnshire and dying pole stage beech from Northamptonshire. A species of *Phytophthora,* still unidentified, was isolated from dead roots of large horse chestnut (*Aesculus hippocastanum*) in Norfolk and, for the first time in this country, what appears to be *Phytophthora cactorum* was isolated from necrotic, slime-fluxing bark of a horse chestnut from Surrey.

One of the last investigations of the year concerned top dying of Norway spruce in a gappy, young, Christmas tree plantation in Hampshire. The outbreak appeared to be associated with the remarkably mild January of 1969.

General

A number of changes in the Pathology Section staff took place during the year, as recorded in the Introduction to this *Report* (page 5). Mr. H. Preston of Brunel University worked in the section for six months on Beech bark disease.

The fourth meeting of the British Forest Pathology Group was held in Eire in September 1969. Field excursions to see forest pathological problems in various Irish forests were arranged by Mr. G. J. de Brit and his colleagues.

A power-driven Pressler borer was developed for detecting decay within standing trees. This machine and a sample of the cores that it extracts, are illustrated on the front cover of this *Report.*

D. A. BURDEKIN

FOREST ENTOMOLOGY

Pine Looper Moth, Bupalus piniarius

The annual Pine Looper survey carried out in the winter 1969/70 covered fifty pine forests. In general this year the majority of pupal populations have gone down or changed little. Cannock Chase has a *highest compartment mean* of 9·6 per square yard, but is displaced on *overall forest mean* by Montreathmont in East Scotland with 3·39, compared with Cannock's 2·57. Sherwood III and Tentsmuir, both mentioned in last year's *Report,* now have forest means of 1·20 and 1·05 respectively. Speymouth Forest although showing an increase on highest compartment mean from 4·0 to 7·6 has dropped in its overall mean from 3·43 to 2·06.

The Hambleton and Allerston Forests in the North Riding of Yorkshire are the dramatic exceptions to this general picture. Here the two units regularly surveyed show very large increases, Ampleforth (Hambleton) having a highest compartment mean count of 0·8 in 1969 rising to 12·8 pupae per square yard in 1970, and Dalby (Allerston) 5·2 in 1969 and 27·3 this year. At Allerston Forest three new units have been surveyed. These are Wykeham where serious defoliation occurred last season and this year gave a count of 196·8 pupae per square yard in one compartment, Cropton with 7·2 and Langdale with 20·4.

The present population in Wykeham threatens complete defoliation throughout the 400 hectares or so of this block. Failing unforeseen natural control, the situation will call for insecticide treatment if the crop is to be saved. The *circa* 50 hectares defoliated in 1969 are at present being salvage-felled to preclude the build-up of a large population of *Tomicus piniperda,* with the possibility of subsequent attack on the remaining part-damaged and highly susceptible crop.

Pine Shoot Beetle, Tomicus piniperda

Log spraying with BHC

In experiments in previous years, spraying logs after attack with a mixture of BHC in water and in diesel oil resulted in a significant reduction in the numbers of emerging adults. Careful examination of the bark has shown that in some cases the larvae were killed in the innermost layers but in others it was suspected that the adults were killed as they were emerging, having eaten their way through the treated bark.

It was desirable to know whether this apparent variation was due to the differential penetration of the chemical or to some other cause. During 1969 two small experiments were carried out to determine the behaviour of BHC applied to logs in water and in diesel oil. No attempt was made at this stage to correlate results with bioassays. Logs were treated with BHC solution at the rate of 4·91/10m^2 (1 gal/100 ft^2) of bark surface and samples were taken with a disc cutter at intervals of one month and two months. In addition, samples were divided into inner and outer layers. Determination of BHC residues was carried out by the Government Chemist, using gas liquid chromatography. The total initial deposit of BHC did not differ significantly,

whether it was applied in water or in diesel oil, but after two months weathering the total BHC residues in bark sprayed with the diesel mix was very significantly greater than in the water mix, where the loss was of the order of 50 per cent of the initial deposit. Penetration of BHC into the inner bark was much better initially when mixed with water, but after one month's exposure there was no significant difference between the two treatments. The percentage of the total deposit penetrating to the inner bark was of the order of 15 per cent.

Control of the Large Pine Weevil, Hylobius abietis, and Bark Beetles, Hylastes species

In 1965 a series of observations were started in Thetford Chase to study the life cycle of *Hylastes ater* Payk. These observations, which finished in 1968, indicated that populations of *H. ater* build up rapidly on clear-felled pine areas and persist at a high level for two years. After this, available breeding material is usually exhausted by a combination of drying, fungal invasion and the breeding of *Hylastes* and *Hylobius* so that populations drop dramatically. This information provided a basis for an experiment started in March 1967 on two sites at Thetford to test the control of *Hylastes,* by dipping whole plants in 1·6 per cent " Gammacol " (a water-based fine suspension of lindane), and to check the effectiveness of this treatment against *Hylobius.* The results showed that satisfactory control was obtained of both *Hylobius* and *Hylastes* species for two years.

It was decided in 1967 to investigate the life cycle of *Hylastes cunicularius* Er. in cleared spruce forest at Kielder. By late 1968 it was obvious that the life history and population build-up of this bettle was more protracted than that of *H. ater* in pine. In fact, populations can persist for up to four years after felling. Since " Gammacol " dipping had only been tested over two years in the relatively dry conditions of East Anglia, it was necessary to check the effectiveness and persistance of this insecticide under wetter conditions. An experiment was laid down in April 1969, at Kielder, involving whole dipping of plants in (a) 1·6 per cent " Gammacol ", (b) 2·5 per cent " Didicol " (a water-based fine suspension of DDT) and (c) only top-dipping of plants in 5 per cent " Didimac " (a liquid formulation of DDT). This experiment aims to test the length of time over which these treatments provide its protection against *Hylastes* and *Hylobius.* Results for the first year gave significant differences between treatments and control, but not between treatments.

During 1968 and 1969 a short investigation was carried out in Tentsmuir Forest, Fife, to study the life cycle of *Hylastes brunneus,* which replaces *H. ater* in pine in the north. Here the life cycle of *H. brunneus* is slightly more protracted than that of *H. ater.* Conditions were not suitable to judge the damage potential of *H. brunneus.*

In 1970, trials will be laid down to test alternative materials which do not have the extreme persistance in the soil of the organochlorine insecticides.

Green Spruce Aphid, Elatobium abietinum

Host Plant Susceptibility

Laboratory techniques for handling and identifying amino-acids in xylem extracts have now been worked out. Preliminary observations have indicated that differences between certain trees can be detected in this way. It is thought

that changes brought about by cultural treatments in plantations and hence changes in the sap, may influence the aphid populations. Work along these lines is planned. (See also page 52, under *Choice of species*.)

Attack Forecasting

E. abietinum is one of the few aphids in this country that overwinters as immature or adult pathenogenetic females on the aerial parts of trees. Past observations have clearly shown that this species is susceptible to winter cold, and certain weather sequences probably bring about greater mortalities than others. Laboratory investigations are being made on aphids reared under known regimes with a view to defining the range of conditions which would be lethal. Early results indicate that a cold-hardiness mechanism may operate in aphids reared in cooler conditions. The degree of protection that this affords is being investigated.

Conifer Aphids, Cinarinae

Further information on the distribution and hosts of these common, yet little studied, aphids has been collected over the past seasons. Their life cycles and methods of overwintering have been followed where possible. Flight of the winged forms occurred mainly during June and July in 1969 but the numbers at Alice Holt were few compared with recent years. Several isolated infestations of *Cinara piceae* were reported from England and Wales in the autumn. This is a much later occurrence than in previous seasons.

Life Cycle Studies on Adelgids

The studies made in previous seasons on the life-cycle patterns and phenology on a number of species have been continued on a reduced scale. The project has been concentrated on one or two species that have deserved special attention and on situations such as larch die-back. Several forests have been visited with symptoms of this disorder, and from further investigations, coupled with controlled experiments at Alice Holt, it is hoped to be able to measure what effects adelgids have on shoot growth of larch.

Control of Adelgids

Winter Washes

In experiments over the past few years tar oil and DNOC petroleum washes applied in spring have given promising control of *Adelges* species on European larch, Scots pine, Douglas fir, *Abies nordmanniana* and *A. cilicica*. The aim was to apply the washes in early spring while the trees were still dormant, although applications were sometimes later than intended. Five per cent DNOC/Petroleum applied to *Abies cilicica* on 21st April 1967 caused considerable scorch. Application of the same material to Douglas fir at 7·5 per cent on 25th March 1968 resulted in some damage to 1967 foliage. However, tar oil applied at this time caused no damage, but was not so effective in controlling *Adelges*. On the other hand, in an earlier experiment, DNOC/petroleum applied to Scots pine at the beginning of May, when buds still had the scales on but were elongating rapidly, produced no ill effects.

In order to be able to make a general recommendation about the use of these materials as winter washes, more information was clearly needed about safe periods for application to a range of species. Winter wash materials might also be used as summer washes, perhaps at a lower concentration, utilising their ovicidal properties, which are lacking in insecticides normally used against active stages. A knowledge of the phytotoxic effects from spraying at any month in the year was desirable. In March 1969 an experiment was started to test the phytotoxic effects of DNOC/petroleum and tar oil applied monthly right round the year, at concentrations normally recommended for winter use. It is likely that summer applications at these concentrations may cause serious damage and if this proves to be so, further investigation of phytotoxicity at lower concentrations will be necessary.

Gamma BHC

The recommended spring application of BHC sprays in seed orchards against *Adelges cooleyi* has sometimes given poor control. This is probably due to the delay caused by bad weather, so that when spraying was carried out the susceptible over-wintering nymphs had been replaced by the resistant adults and egg stages. It was thought that by extending the application period into the winter months these difficulties would be overcome. A trial was therefore made in November 1968 using Gamma BHC, that is BHC with DNOC, for comparison against a heavy infestation of adelgids. Results showed that both treatments were very effective and that there was no significant difference between them. Although the experiment was not repeated in the spring, the control obtained was as good as that achieved on many occasions by satisfactory treatment in the spring.

Factors Affecting Growth and Survival of Young Crops

The two projects dealing with this subject have now run for two of the five years planned, and assessments show that they have some mortality factors and insect pests in common. The sample sites are all in the early stages of establishment and are spread over England, Scotland and Wales.

New Planting Survival

This investigation is confined to Scotland. Black game, hares, deer, frost, drying winds and weed competition continue to be the major factors involved in losses and damage amongst young trees. The incidence of insect attack was in the region of 5 per cent and in most cases not serious. However, suppression of the trees can occur where weed competition is great and at the same time is associated with loss of leader growth due to the feeding of certain micro-moth larvae.

Twenty species of moth have been identified to date. It is expected that this number will increase when the insects collected for study, and at present overwintering, emerge in the spring. The most important of the species found, in terms of damage and numbers, are:—*Clepsis senecionana* Hübn., *Syndemis musculana* Hübn., *Amelia viburnana* Schiff and *Argyrotaenia pulchellana* Haw.

Neodiprion sertifer Geoff. was present in fairly large numbers on Lodgepole pine, causing considerable needle loss. In some cases where the tree was very small, part of the current year's growth had been eaten. *Elatobium*

abietinum Walk. was insignificant in both numbers and damage. The aphid *Cinara pinicola* Kalt. was present in fairly large numbers. This insect is found on the tender young shoots of Sitka spruce. The damage caused does not appear to be lasting but will be more fully assessed during 1970.

Effects of Fertilisers

This project is concerned with effects of fertiliser applications and certain silviculture measures on the relative incidence of insect species, and with a view to correlating the data with growth performance.

The insects which occur in sufficient numbers to be worth recording are as follows:—*Elatobium abietinum* Walk., *Cinara piceae* Panzer, *Cinara pinicola* Kalt., *Schizolachnus pineti* Fab., *Eulachnus agilis* Kalt., *Pineus pini* Gmelin, *Adelges cooleyi* Gillette, *Eucosma tedella* Clerk, *Coleophora laricella* Hübn., *Evetria purdeyi* Durr., *Otiorrhynchus picipes* Fab., *Tomicus piniperda* Linn., *Pristiphora abietina* Christ., *Neodiprion sertifer* Geoff., certain *Cercopids*, and the mite *Oligonychus* (*Paratetranychus*) *ununguis* Jacobi. The moths so far identified include:—*Pitycholoma lecheana* Linn., *Pandemis cinnamoneana* Treits., *Spilonota laricana* Hein., *Archips rosana* Linn., *Ceramica pisi* Linn. and *Lycophotia varia* Vill. All these were found on Sitka spruce, but the last mentioned insect, which suffered attack by a natural virus disease, was found doing damage to Lodgepole pine.

Populations have been too small to show significant differences between different fertiliser treatments. However, aphids and adelgids appear to be most numerous in plots with highest nutrient application, while no aphids were found in plots with nutrient deficiencies such as occur at Wilsey Down Forest in Cornwall. Sites treated with herbicides carry higher numbers of *Lepidoptera* larvae.

Observations on the effect of shade from an overhead crop of Japanese larch show that populations of *Elatobium abietinum* Walk. increase as shade increases. It is just the reverse in the case of *Adelges cooleyi* Gillette on Douglas fir. Larvae of the moth *Coleophora laricella* Hübn. have been found feeding on all conifer species planted beneath Japanese larch.

Studies continue in an older crop of Scots pine at Cannock where an excess of nutrients is applied each year. The insect being observed here is the Pine looper moth, *Bupalus piniarius* Linn. Treatment has resulted in an increase in nitrogen and potassium in the host tree, with a depressior of phosphorus, but so far as can be judged from a study of pupal data no significant effect on the insect has been found.

Enquiries

There were 52 written enquiries in the south and 35 in the north from the Forestry Commission, and 110 in the south and 8 in the north from private sources during the year.

D. BEVAN

JOAN M. DAVIES

MAMMALS AND BIRDS

Grey Squirrels

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

Trials of Warfarin poison against grey squirrels were carried out during the period April–July 1969 in five forests. A longer period of bait presentation and a modified hopper design were tested using whole grain wheat bait coated with " Warfarin " at concentrations of 0·005 per cent or 0·025 per cent. All trials were preceded and succeeded by cage-trapping and searches were made for dead bodies.

The results confirmed that it should be possible to exclude all animals except squirrels from the hoppers. However, both the siting and the design of the hoppers could be improved. Dead squirrels were found on all areas but it is possible that the 0·005 per cent " Warfarin" concentration may have taken a little longer to produce an effect than the 0·025 per cent concentration. A six-week poison period was tried: it seemed that in conditions of non-isolated woodland some squirrels continued to be poisoned throughout the period. On one site, damage to young beech occurred at the end of the poison period.

Deer

The tagging of red deer calves has continued in Galloway, South Scotland. Thirty calves were marked in 1969, bringing the total since 1965 to 152. For the first time calves from two tagged hinds were caught and marked.

Calves more than one day old when caught were marked by freeze-marking with dry ice. Two of the seven calves so marked were seen in winter 1969/70 showing white hair growth over the marking sites on the haunches. However, another calf when shot had only partially unpigmented hairs on the freeze-site.

The freeze-marking technique was also tested on roe and fallow. Both dry ice and liquid nitrogen were tried on a young fallow buck and while both techniques produced some white hair growth, the dry ice method is easier to apply and has a less critical application period.

Trials of various roe deer trap designs have been begun.

Starling Roost Dispersal

The season's work on starling roost dispersal confirmed that the size of the woodland area available for the roost and access for the dispersal team are the important limiting factors to the success of the operation.

It had been found that a 12-bore shot-gun was not entirely satisfactory for the bird-scaring cartridges, but a 1½-inch Verey pistol with a 12-bore sleeve adaptor proved an adequate substitute.

Chemical Repellants

Two new chemical repellants were available for tests in the 1969/70 seasons. The first, "Rotan R-55", was an American petroleum by-product for which success as a rodent repellant was claimed. However, it failed dismally against fallow deer browsing Scots pine. The second candidate was an un-named material of European origin. This has shown some promise as a repellant for a limited period but phytotoxicity tests have yet to be completed.

Fencing

The development of "Preformed" wrap guy links for terminating line wires, and of "Preformed" line splices for joining line wires, has speeded up fence erection and reduced costs. These items can be used instead of ratchets and knots respectively. "Preformed" lashing rods have been developed as a more robust method than clips of attaching woven field netting to line wires; they are not, however, designed for fixing hexagonal mesh netting. As all three items are applied manually, no additional tools are required in a fencing kit.

A comparison of the decay rates of a variety of wires and wire netting materials has been begun at Alice Holt Forest, Hampshire (which is little affected by atmospheric pollution), Hope Forest, Derbyshire (which is subject to industrial pollution) and Newborough Forest, Anglesey (subject to coastal pollution by blown sea salt).

Damage

The extensive survey of bark-stripping damage by red deer, roe deer and feral goats in forests of the Galloway region of South Scotland is nearing completion.

A comparison has been made of vegetation in a fallow deer enclosure in the New Forest from half of which deer and other grazing animals have been excluded for six years. This has shown up the very marked decrease in species present and in regeneration under a regime of intensive grazing and browsing.

Squirrel Questionnaire

The annual questionnaire for red and grey squirrels for the year ended September 1969 showed little change in the distribution of either species. Damage by grey squirrels was considerably more extensive than in recent years: no damage by red squirrels was reported.

JUDITH J. ROWE

STATISTICS AND COMPUTING

General

A major staffing problem was resolved by the appointment, in May 1969, of Dr. D. R. Causton as Statistician at the Northern Research Station.

Training of the Section's junior staff continued mainly through day-release courses. A few of the special short courses available have also been used as opportunities occur. Three members of the Section have now attended a short course on technical report writing.

During the winter months the Section ran a Statistics and Computing course for Research Foresters. This was organized as five two-day sessions at monthly intervals with course-work between sessions. It was largely experimental and further consideration needs to be given to consolidation of the students' improved understanding of statistical and computing methods.

The new building for the Section at Alice Holt was finished on time and the move of personnel, computers and other equipment was completed by May 1969. Fortunately the computers seemed to suffer no lasting effects of their short ride over difficult terrain, and they have taken well to their new temperature-controlled environment. The building was designed by EDP Roomplan Ltd. and built by J. E. Lesser Ltd., and has continued to give satisfaction.

Negotiations with manufacturers and bureaux on the question of replacing the Sirius computers have reached an advanced stage. In the north, most of the computing continues to be done through the Edinburgh Regional Computing Centre, but use of a teletype terminal to a GE 430 is being tried until the ERCC's own conversational facility has been developed.

Service Work

The main work of the Section has continued to be in providing a statistical and computing service to the Research and Management Services Divisions and this work is generally reviewed under appropriate headings elsewhere in Part I of this year's *Report*. Mention will be made here of only a few projects.

With the appointment of an Operations Manager to supervise data preparation and computing aspects of the work at Alice Holt, readier access to the computers has been possible for other Sections and both familiarity and expertise appear to be spreading.

The main job of processing the data from the census of private woodlands has been completed. In retrospect it can now be concluded that the task was ill-suited to our own computers, but it can certainly be argued that keeping the whole process under close control within the Section obviated the risks and costs of liaison with an external bureau on such a large individual job.

For Work Study, the production of standard-time tables for forest operations has been systematized more fully than before, and turn-round of these jobs has been much improved.

The system for updating the Plus Tree Register for the Genetics Section has been transferred from the Sirius computer to the IBM 360/50 at the Edinburgh Regional Computing Centre, and further development of this system is in progress.

The computing necessary for the revision of Forestry Commission Booklet 5, *Conversion Tables for Research Workers in Forestry and Agriculture* (HMSO), was accomplished ahead of schedule by means of a single general program.

In the north, work has been concentrated on building up a library of Fortran programs, but some use of the Edinburgh language Imp continues to be made.

Research and Development

Audio Data-Capture

This investigation is into one method of data handling. The final system envisaged is one in which data are recorded in the forest by means of a portable magnetic band recorder, the bands are then sent to the research centre for conversion to computer-legible form by means of a transcription machine which plays back to the machine operator through earphones. A comprehensive computer program will then process the data and enter them into a "data bank" on magnetic tape files and output a summary of the data.

So far, comparative trials of selected tape recorders have been undertaken, and the IBM 224 has been chosen as the most suitable. A practical field system has been evolved for recording data from experiments, and development of the computer program has begun.

Statistical Methods

Little progress has been made during the year on either the revision of the Code of Assessments for Forest Experiments or the revision of the tables of exact probabilities in 2 × 2 contingency tables.

A computer program written a few years ago to fit the Richards function to growth data has been considerably modified and extended. This function is defined by the differential equation

$$\frac{dW}{dt} = \frac{kW}{nA^n}(A^n - W^n),$$

where W may be the weight of an organism at time t, and A, k and n are constants. Fitting is based on the method of least squares in an iterative non-linear regression algorithm, and instability in the convergence of the procedure is sometimes encountered. A study is now being made of the properties of the least squares estimators of the function to determine the best placing of a small number of data points for the fitting process, as well as to gain some insight into the conditions giving rise to divergence during the iteration process. Using the data of investigations by Causton and Wareing (1966, 1967) a study is also being made of the growth of the parts of a plant in relation to one another.

The nursery stock-taking procedure adopted by the Commission a few years ago is now being revised as part of the metrication programme. The opportunity is being taken to improve, and if possible simplify, the procedure. To this end an analysis of the most recent stock-taking data from all the Commission's major nurseries is being made.

R. S. HOWELL
D. H. STEWART
D. R. CAUSTON

REFERENCES

CAUSTON, D. R., and WAREING, P. F. (1966). Influence of leaf characters and growth habit on the production of dry matter in forest trees. *Rep. Forest Res., Lond.* 1966.

CAUSTON, D. R., and WAREING, P. F. (1967). Influence of leaf characters and growth habit on the production of dry matter. *Rep. Forest Res., Lond.* 1967.

RESEARCH WORKSHOP

A galvanized steel version of a two-man High Seat for controlled shooting of deer has been completed and tested. The experimental unit was designed in conjunction with the Wildlife Forester, Forest Management Division, and made at Alice Holt. Ten kits of parts have been made, together with instructions for assembling the kits. These have been made available to the Conservancies to enable field staff to assess the merits of this " Alice Holt Movable High Seat ". Two experimental one-man seats are also under test.

A hot-wire cutter, made to cut expanded polystyrene sheet, proved extremely useful for making large maps and display boards for the exhibitions at the Bush Estate near Edinburgh, and at Alice Holt. It has also been used to cut sections of polystyrene for relief maps. An audio-visual quiz unit was made in which buttons could be used to link slides of animals and birds with tape recordings of their sounds. This unit was used successfully at the Commission's Jubilee Exhibition at the Bush Estate, and at open days at Alice Holt. For these and other exhibitions a large rotating Forestry Commission symbol was made, and this and the quiz unit are now being operated by the Show Unit of the Commission's Information Section.

Details of a plastic caliper, developed to measure the diameter of small trees, were published late in 1969, as an FAO note, and also in the *Journal of Agricultural Engineering Research* (Stickland 1969). To date, enquiries have been received from fourteen countries and a United Kingdom horticultural sundries supplier is interested in marketing the caliper commercially.

In connection with the impending change to the metric system of measurement, the workshop supplied various items of special-purpose metric measuring equipment during the year. Included were:

100 ½-metre scales

50 2-metre scales

18 sets of height rods

20 assessment frames

Details of this equipment will be written up this year.

A calibration unit for aligning the Blume Leiss hypsometer was designed and made. The change-over of the hypsometer scales to metric measurement has been carried out in the workshop (by staff of Planning and Economics Branch) using this unit.

To test the new metric measuring tapes a simple test rig was developed. The tests carried out on this rig revealed several problems, and as a result the tape manufacturers were asked to seek solutions.

A lightweight shoot-sampling tool was made in aluminium alloy to enable shoot samples to be taken from trees 10 to 15 metres high.

In addition, many small items, including bark-sampling tools, freeze-marking equipment and random samplers have been made, and normal engineering service facilities have been maintained.

Over 7,000 engraved labels were produced, and work on new labelling techniques is continuing.

R. E. STICKLAND

REFERENCES

STICKLAND, R. E. (1969). *Caliper for nursery measurements.* For. Equip. Note (FAO) A 59 69.

STICKLAND, R. E. (1969). A caliper for measuring plant diameter: **14** (3), 290–291.

Journal of Agricultural Engineering Research.

PHOTOGRAPHY

General

The year can be divided into two parts. During the first half our work was mainly in connection with the Jubilee celebrations and their aftermath, and in the second with the re-arrangement and re-classification of the Photographic Collection.

As a result, practically no field work was done and the number of new photographs added to the Collection was few.

Jubilee

For a time, the Section was almost fully committed to work for the Jubilee to the virtual exclusion of all else. Two thousand and fifty-nine monochrome and three hundred and two colour prints or transparencies of exhibition quality were supplied for display. In addition, the large Photographic Exhibit used at the Forestry Exhibition at Bramshill Forest in 1964 was re-furbished for further use. Other services provided included wild life recordings, photographic material for numerous articles appearing in the press and periodicals as well as in the Commission's own publications and a large quantity of lettering work.

Photographic Collection

For some time past, there has been a pressing need to re-organize the Collection. The retrieval system, based on the Oxford Decimal Classification (ODC), had almost broken down, as the associated card index had become too large for manual sorting.

Since October, work on the reclassification and re-organisation of the colour transparency and monochrome collections has proceeded in parallel. A much simpler direct-access system based on self-evident keywords has been adopted. By this means the prints and transparencies themselves constitute the index, thereby eliminating the need for cards. Being much less sophisticated it does not provide the depth of cross-referencing of the previous system, but has the merit of bringing together as a unit all the photographs of a particular subject. This not only speeds selection, but gaps in the coverage of the collection are more readily identified, and the " weeding " of out-dated material is made easier.

As a safeguard against loss or damage no original transparency will in future be loaned out, so transparencies for loan are now being duplicated at a rate of 500 per week. During the change-over period it has not been possible to make selections of slides to meet individual needs and this has meant unavoidable inconvenience to borrowers. As a stop-gap measure several copies were made of two basic slide sets—one on general forestry, the other on wildlife and recreation. These sets have been more widely accepted than we dared hope, and we plan to continue to make them available as required.

Despite the difficulties, the number of slides loaned during the year increased slightly, to 10,726. Four hundred and sixteen films were also distributed on loan.

I. A. ANDERSON

PUBLICATIONS

The following ten 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-ninth Annual Report of the Forestry Commissioners, 1967/69 (HC 171, Session 1968/69) (11s. 0d.).

Report on Forest Research for the year ended March, 1969 (22s. 6d.).

Bulletin

No. 39. Use of Land for Forestry within the Proprietary Land Unit, by D. C. Nicholls (17s. 6d.) .

Forest Records

No. 69. Guide to Site Types in Forests of North and Mid-Wales, by D. G. Pyatt, D. Harrison and A. S. Ford (8s. 0d.).

No. 70. Imports and Consumption of Wood Products in the United Kingdom 1950/67, with Forecasts to 1980, by A. J. Grayson (6s. 0d.).

No. 72 Experiments on Drying and Scaling Close-Piled Pine Billets at Thetford, by J. R. Aaron and J. J. Pruden (3s. 6d.).

Booklets

No. 23. Timber! Your Growing Investment, by H. L. Edlin (6s. 6d.).

No. 25. Forests of Central and Southern Scotland, by H. L. Edlin (12s. 6d.).

No. 27. Metric Guide for Forestry. A Guide to the Introduction of the Metric System in British Forestry (3s. 0d.).

Guide

Kilmun Arboretum and Forest Plots, by J. E. Kirby (2s. 0d.).

In addition twelve priced publications sold by Her Majesty's Stationery Office were reprinted after varying degrees of revision.

Three new unpriced publications for the general public were issued during the year, namely: *See Your Forests, Forestry Employment,* and *The Forestry Commission and Conservation.* Twelve others were revised and reprinted.

H. L. EDLIN

RESEARCH INFORMATION

Library

Increasing use of the library is reflected in the new record of 3,300 loans for the year. Items requested from other libraries amounted to 522. We acquired 239 new books, subscribed to a further 11 periodicals, and commissioned 34 translations.

Preparatory work has been completed on a new library catalogue, which will shortly be ready for the printers.

A further addition to the Commonwealth Forestry Bureau's Card Index on Microfilm was purchased, giving us an author catalogue up to 1969, with a further 150,000 references. This means that in addition to our own library card index, we have on microfilm reference cards to Forestry Abstracts amounting to 600,000.

The Open Day arrangements at Alice Holt involved the complete reorganisation of the journals and reference parts of the library. After the event, however, a better arrangement of shelving and furniture was achieved, although it is still necessary to have bookshelves in the entrance hall of the Lodge.

Information Services

A *Keyword Index to Selected British Forestry Literature,* covering all the Forestry Commission's technical publications with some of the more immediately useful of the recent articles appearing in forestry journals published in Great Britain, was produced during the year. This is essentially a document for Forestry Commission field staff, intended to give them an index to the literature likely to be found on a forester's bookshelf in this country.

Preparation of this index was computer-assisted, with the co-operation of the Statistics Section staff, as was another project to produce an " Interest Register " of all the scientific and technical staff in the Division. Currently, work is being carried out on a project to produce computer-printed reference cards covering the " interests " for each individual member of staff. This development promises to increase the "alerting " service we already provide, which at present involves the selective dissemination of more than 40 items of information each day.

Current Awareness

In the 1967 *Report* reference was made to the development of " current awareness " aspects of the Section's work. This is being achieved by the following features :

Library Review. This not only lists new books, periodicals, translations, Forestry Commission publications, and articles by staff members, but also includes notes on new forms of literature, summaries of reports, and guidance on information handling techniques. It is produced regularly three times a year.

Current Information Notes. These contain short, single-sheet, easily readable details of the latest developments in research, with the researchers' names and references to relevant literature. Issued on average once a month, they have been well received by field staff.

Periodicals on Display. Approximately half of all the periodicals received in the library are put on display in the reading room. Each week the contents of the latest arrivals are screened and the titles of articles of interest to Alice Holt staff are listed on a single sheet. This is distributed to Research and Headquarters staff, and also to individual members of the field staff at their request.

Assistance with General Reading. A sheet similar to the above, listing relevant articles in those journals likely to be seen by field staff, is issued each quarter. Two hundred and thirty-four copies are sent to Conservancy staff who have asked to receive this service.

Courses. A five-year programme of courses for Assistant Conservators and District Officers to deal mainly with research appreciation was completed in February 1970. The future of these courses, with their strong current awareness aspect, is under review and it is possible that some courses may now be held at the Northern Research Station as well as at Alice Holt Lodge.

Users

In addition to the increase in loans, the number of enquiries dealt with by the Section has risen very considerably. During the year, in addition to a large number of telephone enquiries, 345 written enquiries needing detailed investigation were received.

Short introductory courses have been held for new members of the station staff to help them take advantage of the library services.

A detailed questionnaire on library services produced a good response from station staff, and showed that only 10 per cent were not satisfied with the service. Closer investigation of this minority revealed that many of the problems are due to misunderstanding or problems of communication.

O. N. BLATCHFORD

MANAGEMENT SERVICES DIVISION

Though Planning and Economics and Work Study are branches of the Management Services Division, the research and development aspects of their work are reported here with those of the Research Division.

PLANNING AND ECONOMICS

Introduction

The research aspects of the work of the Planning and Economics Branch for the period 1st April 1969 to 31st March 1970 are reported under three main heads. These are:—

(a) Policy and Corporate Planning

(b) Aids to Management and Planning

(c) Surveys and Data Processing.

D. R. JOHNSTON

POLICY AND CORPORATE PLANNING

Research Evaluation

An evaluation of the costs and benefits associated with different levels of seed orchard research and investment has been carried out for a number of species. The evaluation involves assumptions on long-term total planting programmes and species usage. These have been based on the judgment of a number of "informed" persons, the final assumptions being in the form of probability distributions. Other assumptions include those on seed orchard establishment cost and progeny testing, the value of the extra revenue obtained from improved seed, seed orchard production of seed and the number of acres plantable per pound of seed. The results were tested against two criteria, namely "net discounted revenue" and "discounted benefits/discounted cost" ratio. Sitka spruce emerges as clearly the best candidate for further seed orchard research and investment, although the overall financial benefits of seed orchard investment are not outstandingly impressive, partly because of the long time-intervals involved before the benefits are reaped.

All the assumptions in this work are subject to a great deal of uncertainty and a number of separate evaluations are required to determine the sensitivity of the result to different assumptions. It has therefore been considered worthwhile programming this work for calculation on a computer. This has the added advantage that the research manager himself can easily carry out further evaluations if better information becomes available on which to base his assumptions.

J. F. MORGAN

AIDS TO MANAGEMENT AND PLANNING

Forest Management Studies

Further work has been done on the simulation programme referred to in the last *Report* which has been prepared for the investigation of the quantities and costs of resources required for different programmes of work in the national forestry enterprise. This programme enables us to assess the economic, financial and manpower implications of various management practices and policies.

Work has been done on a variety of problems, including revision of guides on logging road density, assessment of the economic merits of treatments required to release crops from " check ", and decision rules for premature felling of crops liable to windthrow.

A. J. GRAYSON

Fire Studies

More concentrated work has been started on an investigation of fire incidence and loss. Fire is one of the more spectacular and obvious causes of damage to plantations but managerial decisions in this field are difficult, not because of any lack of data, but because of the inherent variability in the situation. This variability either masks the real changes which may be taking place or, conversely, leads to the identification of apparent trends when in reality they are merely random events in an otherwise stable situation. The work done so far has involved the analysis of available data in an attempt to draw conclusions of management significance. Such conclusions as may be drawn at any given time may not remain valid in a dynamic situation, so a further aim has been to devise methods that management might use to monitor the situation.

Cumulative sum techniques (Woodward and Goldsmith 1964) have been used in order to try and detect changes in the fire situation over the last fifteen years or so. In real terms fire expenditure has decreased fairly sharply over the last ten years. This decrease in real expenditure has not been associated with any significant change in the reported number of *fire starts** per annum (excluding railway fires) or in the average area of plantations burnt.

Figures for the period 1965/69 indicate that there are regional differences in the number of fire starts. There are obvious differences in fire start frequencies between forests, but useful generalisations cannot be made unless forests are classified into " fiery " and " non-fiery " forests. If forests are so classified then useful generalisations can be made about the expected number of fire starts and the frequency of fire starts per year for " non-fiery " forests. This is shown in Table 24. Over 60 per cent of the total forest area of the Forestry Commission falls into the " non-fiery " category.

In relation to acres burnt per fire, as opposed to fire starts, the same general distribution is found over most of the Forestry Commission's estate. It is virtually independent of size of forest and whether it is in the

* A *fire-start* is defined as an ignition that may or may not develop into a damaging fire.

TABLE 24

THE DISTRIBUTION OF FIRE STARTS IN "NON-FIERY" FORESTS

Size, class of forest, acres (1 acre = 0·405 hectare)	Maximum number of fire starts over 5 years for forest to qualify as "non-fiery"	Expected fire starts per annum	Relative frequency of "n" fires where n =		
			0 %	1 %	2 or more %
0–999	3	·12	89	10	1
1,000–1,999	4	·21	81	17	2
2,000–2,999	4	·27	76	21	3
3,000–3,999	5	·30	74	22	4
4,000–4,999	6	·31	73	23	4
10,000–14,999	6	·35	70	25	5
15,000–99,999	6	·58	56	32	12

" fiery " or " non-fiery " category. This distribution is summarised in Table 25 together with the proportion of the total planted acres burnt caused by different sizes of fire. A few fires cause a large proportion of the damage.

TABLE 25

DISTRIBUTION OF FIRE STARTS AND FIRE LOSSES BY "ACRES BURNT"

Planted acres burnt per fire	0—·99	1·0—9·99	10·0 or more
Relative frequency of fire starts	79%	17%	4%
Proportion of total damage caused by fires in given category	7%	33%	60%

The analyses carried out should help management to achieve a better relative allocation of resources between Conservancies. It should also enable a rational assessment to be made of the relative efficiency of pre-suppression and standby measures in " nonfiery " forests. Comparisons of the Forestry Commission data with available private woodland data enable some informed speculation to be made on the probable overall losses resulting from a decrease in the level of protection expenditure.

Industrial quality-control techniques are being used to devise reasonably efficient methods of monitoring the key parameters in the fire situation. These parameters are the average number of fire starts per annum and the mean acres burnt per fire. This should help management to determine any effects arising from changes in protection policy and also to detect changes in the overall fire situation.

Further work is being done on the short-term forecasting of fire starts.

J. F. MORGAN

Recreation Studies

A report has ben prepared on the findings of a survey carried out in the summer of 1968 in all Conservancies apart from North-East England, the Forest of Dean and the New Forest. This survey attempted to provide an estimate of the total numbers of visits to car parks and picnic places on Forestry Commission land during the period of June 1st to September 30th 1968. The results give some indication of the order of magnitude of recreational day use, even though use of all sites on all days cannot be accurately estimated and a large error term has to be attached to the figures.

TABLE 26

ESTIMATED USE OF CONCENTRATED USE SITES ON FORESTRY COMMISSION LAND

(Great Britain, all days, 1st June to 30th September 1968)

Concentrated use sites	Number of day visits, millions	Standard error
Week-ends	1·86	±0·54
Week-days	3·97	±1·35
Total	5·83	±1·83

TABLE 27

ESTIMATED WEEK-END USE OF ALL SITES ON FORESTRY COMMISSION LAND

(Great Britain, week-ends—including Bank Holidays between 1st June and 30th September 1968)

Week-end Use	Number of day visits, millions	Standard error
Concentrated use sites	1·86	±0·54
Lesser use sites	0·63	±0·19
Road-side verges	6·26	±3·23
Total	8·75	±3·28

The figures shown in Tables 26 and 27 are estimates of *visits* to the forest and not the numbers of *visitors*. No attempt was made to measure how often people visit the forests either on the same or subsequent occasions. The figures include an estimate for North-East England Conservancy, but do not include a further 2·2 million visits paid to the Forest of Dean, the New Forest, and the arboreta at Westonbirt and Bedgebury. The nearest approximation to a total estimate of visits to Forestry Commission land over the whole period is between 10 and 18 million, the low end of this range almost certainly being an under-estimate to the extent that week-day use of the lesser-used sites and road-side verges is not included.

The attendance at road-side verges is of interest even though this is the least reliable result from the survey. The extent of this type of use, where provision of facilities is at a minimum, deserves further study. The survey has been helpful in exploring the techniques of extensive survey and provides a basis for planning improved censuses of recreational use of forests. Recent work has concentrated on designing methods of survey which incorporate the use of running records, mechanical means of counting vehicles and the estimation of length of stay of visitors.

R. M. SIDAWAY

SURVEYS AND DATA PROCESSING

Topographic Survey and Inventory

Work continued on the country-wide metric revision and updating of area and yield class data. By the end of the year 82 per cent of the programme had been completed, accounting for 561,000 ha (1,386,000 acres) of plantations. This project will be completed by June 1970 when topographic survey work will be resumed along with periodic assessments for purposes of valuation.

Towards the end of the year some topographic survey work was carried out and new survey work was completed on 20,700 ha (51,200 acres), while resurvey covered 4,300 ha (10,700 acres).

R. T. BRADLEY

A. M. MACKENZIE

L. M. SIMPSON

Site Survey

Soil surveys were carried out on 27,400 ha (67,750 acres) in six Conservancies. The development of windthrow in relation to soil types was plotted in two Welsh forests, Crychan and Glasfynhyd (Brecon and Carmarthenshire).

In Scotland the relationship between " checked " growth and soil type was investigated at Montreathmont Forest (Angus and Kincardineshire), and an intensive analysis of growth rates, soil types and vegetation types was made at Glen Garry Forest (Inverness-shire) in order to define the site factors associated with " checked " crops on the Central Highland Moine region. Fieldwork has been completed and the data will be analysed in 1970.

The use of panchomatic aerial photographs as an aid to rapid soil survey of plantable reserves is being investigated at Fiunary (Argyll), Portclair (Inverness-shire), and Glen Garry Forests, and appears a promising development which will be confirmed by further work in 1970.

Two courses were run in 1969 for Research Foresters on the identification and description of soils and in the use of the Forestry Commission soils classifications. Regional soil guides are in preparation for the North York Moors, the Moray Firth Sandstone region, the Central Highland Moine region and the East Dalradian region. The provisional peat classification is being tested further by vegetation sampling and peat analyses before its final publication in 1971.

D. B. PATERSON

Mensuration

The work of the Mensuration Section has again been dominated by the impending change to the metric system of measurement which takes place in February 1971. Most of the work in preparing the more essential tabular aids for publication has now been completed.

A modest start has been made to the extension of sample plots on the poorer upland sites, and in the less important commercial species.

A new replicated line thinning experiment has been established in Corsican pine at the King's Section of Thetford Chase Forest in East Anglia. The major aim of the experiment is to examine the effect on increment of varying weights of first thinning by the removal of complete rows. The treatments are :

1 row removed in every 3 rows (33 per cent volume removed)
1 „ „ „ „ 2 „ (50 „ „ „ „)
2 rows „ „ „ 4 „ (50 „ „ „ „)
2 „ „ „ „ 3 „ (66 „ „ „ „)
3 „ „ „ „ 5 „ (60 „ „ „ „)
3 „ „ „ „ 4 „ (75 „ „ „ „)
Control (no thinnings)

In the thinning treatments *all* trees are released to some degree. There are three replications. (See Plates 4 and 5).

G. J. HAMILTON

REFERENCE

WOODWARD, R. H., and GOLDSMITH, P. L. (1964) *Cumulative sum techniques.* I.C.I. Monograph No. 3, Oliver and Boyd.

WORK STUDY

I. FOREST MANAGEMENT STUDIES

General

Semi-circular spade planting was further developed and some time spent on step and notch planting, and on tubed seedlings. Development work on the Lokomo plough was concluded and the emphasis shifted towards further work on the Parkgate deep draining plough and drains maintenance. Weed control studies centred on tractor mounted and ultra-low volume mistblowers, tree injectors and the development of a front-mounted brushcutter. Nevertheless a residue of hand weeding remains and standard times for this operation were revised. The somewhat erratic delivery of fertiliser given by various distributors was investigated. Respacement studies were undertaken.

PLANTING

Planting with Semi-Circular Spade

The semi-circular spade has been long established as a planting spade on the Border forests of North-East England. Micromotion studies on skilled planters allowed a simple standard method to be devised, which could readily be taught. This tool is recommended for ploughed peat where exposure is not too severe. Under these conditions outputs in excess of 300 plants per hour can be expected. The spade can also be used on other soil types, though outputs are lower, and is useful for planting through branches lying on clearfelled areas. At this stage of the investigation it is not possible to define with accuracy the range of sites over which this method can be used without the trees suffering to some degree from exposure.

At the end of the first season during which the semi-circular spade had been used in two Conservancies, daily outputs of trees planted were raised from 1,300 and 800 respectively at the start of the season to 1,600 and 1,500. This compared with an average of 1,200 per day by the conventional methods.

Step and Notch Planting

It was clear that the semi-circular spade was unlikely to have much application on exposed sites. Hence in North Scotland, where large areas are affected by exposure, a rapid study was made of the step and notch planting already generally used there. Its object was to provide a guide to likely outputs from step and notch planting rather than present full tables of standard times. Nevertheless it was possible to take account of site variations during the study.

Tubed Seedlings

Work has concentrated on devising a tool suitable for planting tubed seedlings. Satisfactory designs for two cheap tools each costing about £1 were produced, and outputs of up to 500 plants per hour seem achievable. Work continues in close co-operation with Research Division.

Finn Forester Tree Planter

In 1968 this machine was shown to be suitable for replanting clearfelled areas at Thetford Chase, East Anglia. Subsequently it was decided to modify a machine for planting on spaced furrow ploughing. First results have been encouraging and trials are continuing. Thus far outputs of 800–1,000 plants per hour for a three-man team are indicated.

PLOUGHING AND DRAINAGE

Outputs of Ploughing Outfits

Data collected prior to 1969 has proved difficult to analyse because of complex interactions between terrain and equipment. However, there are three main situations in the study areas:

Steep slopes ploughed by tractor-mounted hydraulic tine ploughs.

Deep peats ploughed by trailed ploughs.

Thin peat over mineral soil usually ploughed by a trailed plough and tine head.

Within these three broad categories it appears that slope plays a major part in controlling the rate of ploughing but there are many other factors. Work is proceeding with a view to producing an output guide.

Prototype "Step-Cutter"

A prototype step-cutter mounted on the packer of a Cuthbertson mouldboard has been designed and made and is going for trials. The object is to produce a step, 15 cm (6 in) high and equally broad, in the side of a single furrow.

Lokomo Plough and BTD 20 Tractor

Development work on this Finnish deep-draining plough and the associated powerful tractor have been completed. The total length of drain ploughed to date is in the region of 200 km (125 miles), over two-thirds of this total in East Scotland Conservancy. The sites being tackled in Scotland are fragogleys (a type of surface water gley), indurated ironpan soils and peaty gleys. The risk of bogging is considerably reduced on these soil types but the wear on the plough—especially in the stony soils—has been greatly increased. This has particularly resulted in increased wear of the point of the plough (the sock) and this has resulted in a fall-off in the drain depth. Modifications to the sock have been made and the most recent innovation by East Scotland Conservancy has been the use of replaceable toes.

The main conclusions from the studies are:

(a) The BTD 20 tractor has a bearing pressure of 0·46 kg/cm^2 (6½ lb in^2) which limits it to reasonably firm ground conditions.

It is unlikely that widening of the tracks would extend the range of working sites to include risk-free travelling on deep peats.

(b) Recommended site types are:

(1) Peaty gleys with peat depths not exceeding 46 cm (18 in).

(2) Surface water gleys including the frago-gleys of East Scotland.

(3) Other firm site types requiring drainage, e.g. peaty podsols or indurated ironpan soils which are gleyed above the pan.

(c) A minimum programme of 10 km (6 miles) is considered necessary before use of the equipment is justified. Long straight runs are necessary for efficient working and consideration of turning points at the end of the runs is important to minimise crop damage. Where these conditions are met outputs of 302–402 m (15–20 chains) per hour nett are possible, i.e. outputs of 2000 m (100 chains) plus per day. The equipment will plough drains in early thicket-stage crops, but it is even more essential to have well-marked, fairly straight lines for the tractor to follow.

(d) The system of winching and the winch itself have worked satisfactorily. Strain gauge tests gave maximum pulls in the region of 24 tonne (93 per cent of the quoted maximum bare drum figure for the winch). However, the fall-off in pull associated with the build-up of the rope on the drum has limited the drain depth.

(e) Drain depth varies according to soil type: 76 cm (2 ft 6 in) or more is attained in pure peat, with 69 cm (2 ft 3 in) in peaty gleys falling to just over 61 cm (2 ft) in the tough gleys and the harder indurated soil types.

(f) The drain itself is, in peaty gleys, of similar depth to that produced by the Humpy plough, but about twice the cross-sectional area and should be more stable. The cost advantage lies with the Humpy drain which costs only half as much as the Lokomo. The Humpy is more suitable and is the obvious choice for peaty and easy peaty gley conditions, with the Lokomo fitting into the harder ground types.

(g) The backacting digger is the alternative on these soils. A clean drain to the required depth is possible but it will cost about twice as much as Lokomo ploughing. An average cost for Lokomo work would be £37 per km (£60 per mile).

(h) Limited trials in North Wales indicated that the equipment has possibilities for ploughing drains in clear felled areas. Further trials are planned.

Oja-Viska Ditch Digger

Lacking the appropriate machinery, drainage maintenance has generally been a manual task. We are seeking to mechanise the operation and, as a start, an Oja-Viska Mk II Rotary Ditcher was purchased and fitted to a County Super 4 (Model 754) tractor. The initial feasibility work has been carried out in the Borders by Research and Engineering Divisions. At an early stage the standard size wheels were replaced by Sea Horse tyres to give improved manoeuvrability. Even so it appeared that the unit would be restricted to relatively easy terrain without soft peat cover. When cleaning

old ditches, one pass of the tractor cleared most of the blockage from the waterway although the profile was ragged. The unit was incapable however of following anything other than gentle bends in the ditch line: the result was a series of partially cleared straights with intervening stretches of partially cut new ditch, the latter of insufficient depth to permit free water flow ; a second pass was therefore necessary.

At the same time as this work was proceeding it was shown that maintenance may often be successfully undertaken by a conventional single mouldboard plough drawn by one crawler tractor. Evaluations are continuing. Meanwhile it seems that easily transported rotary ditchers may find an application in small areas where it would not pay to transport a plough. Indications are that the Super 4 will need to be replaced by a more powerful machine.

FERTILISING

Fertiliser Distributors

In co-operation with Research Division three types of distributor have been investigated:

Type and Principal Makes Studied

Trailer: Atkinson Mk I/VI Double Spinner.
Blower: Metsa-Viska Mk II.
Blower: Metsa-Agra 450.
Blower: Metsa-Agra 1500.
Tractor mounted: Vicon.

It quickly became apparent that the distribution of the unground mineral phosphate used was erratic in the trailer and blower types but reasonable for the Vicon. Shallow catch-traps were used to measure the distribution, and scores varied from *nil* to the equivalent of 1,215 kg per hectare (½ ton per acre). The intended application rate was 375 kg per hectare (3 cwts per acre). Whilst it is clear that complete accuracy is neither achievable, nor wanted, it was felt that acceptable limits should be set and these were 375 ± 125 kg per hectare (3 ± 1 cwt per acre). Preliminary studies with a granulated fertiliser suggested that distribution patterns could be greatly improved when granulated phosphate became available. This is now being tested.

Although more work will be needed before full cost comparisons can be made it seems that the blowers and the Vicon will do the job for about £6·6 per hectare (£2·75 per acre). The trailer model costs a little more but the differential was not conclusively demonstrated and depends largely upon the machine charges attributed to this model. The Vicon has the advantage of ploughing at the same time as fertilising, and this is an obvious cost-saving advantage even though logistical problems will have to be resolved. One may conclude that the costs indicated tentatively by this study are not very different from those of aerial fertilisation and may, indeed, be somewhat lower.

WEED CONTROL

"Pharos" Herbicide Sprayer

This development is complete but initial machines supplied have shown two faults which have now been corrected.

Tractor Mounted Mistblowers

The machine tested was French—the Vermorel No. 211. This is no longer made but an alternative is being purchased for testing. the main conclusions are:

(a) Pre-planting treatment (cut stump) using 2,4,5-T in diesel oil. 16·9 litres, 2,4,5-T in 337 litres of diesel per hectare (12 UK pints in 30 UK gallons per acre) gave good control of woody weeds and savings of about £24 per hectare (£10 per acre) were secured.

(b) Foliar spraying of bramble under standing Scots pine with 2,4,5-T in water. This was very effective and cost savings of more than £9·10 per hectare (£4 plus per acre) were obtained as compared with knapsack mistblowing. This represents savings of more than 50 per cent.

(c) Foliar spraying of coppice with 2,4,5-T in water (in Norway spruce planted in 1960, and Corsican pine planted in 1969). Degree of control about the same as aerial spraying and likely to be at lower cost (a locally quoted figure for aerial spraying was £3·4 per acre all in; tractor mounted mistblowing did not exceed £2·5 per cent all in). Cost saving compared with a knapsack mistblower was £2·4 plus per hectare (£1 plus per acre) representing a saving of more than 30 per cent. Rate of coppice-kill was not high but growth was severely checked—probably for as long as two years; planted trees were very little affected.

Ultra Low-volume Sprayers

Two hand-held ULV sprayers have been obtained, one operated by batteries and one powered by a small two stroke engine. Initial trials in cooperation with the Research Division have begun.

Tree Injectors

The use of 2,4,5-T ester in diesel fuel oil applied to the basal bark, or in a frill girdle, is a well established technique for the control of unwanted woody growth. But it can be a messy, unpopular job and, if substantially less expensive than cutting with hand tools, is still not cheap. The development of tree injectors, mainly in the USA, with which neat, or nearly neat, herbicide can be placed in direct contact with inner bark and sapwood has therefore been watched with interest, and a number of treatments and tools have been tried in Britain. Definitive recommendations as to herbicide, dosage, species susceptibility or seasonal effect have not yet emerged from trials. *Provisionally,* the specification is "1 ml per cut of a mixture made up of equal quantities of 2,4,5-T ester and diesel oil in cuts at 8 cm (3 in)

centres on birch and at 5 cm (2 in) centres on moderately resistant species such as hazel and oak. (Meanwhile ash and hawthorn should not be treated)." A suitable bespoke tool for the job is the Jim-Gem marketed by Forestry Supplies Inc., 205 West Rankin Street, Jackson, Miss., USA. This consists of a chisel bit attached to the base of a 1·22 m (4 ft)—long reservoir tube. The weight empty is 5·4 kg (12 lb). Price is about £25, including import duty, shipping charges etc. Alternative and generally preferred tools are a 0·45 kg (1 lb) hatchet and a Fickningsspruta obtainable from Skogsmaterial AB, Box 12-199, Stockholm 12, at about £2. This is a water-pistol type tool connected by a plastic tube to a 0·57 litre (1 pt) reservoir hung on the belt. The jet as supplied should be drilled to 0·16 cm (1/16 in).

Chlorthiamid Application

A number of distributors for the weed-killer chlorthiamid have been investigated, and both the knapsack and tractor-mounted applicators produced by Horstine Farmery, Ltd. appear to be the most suitable.

The advantages of spot treatment over strip treatment are clear. Some small modifications have been made to the equipment and trials continue.

Front-mounted Brush Cutter

A heavy duty brush cutter (Plate 6) has been built in the Research and Development Workshop and mounted on an International 523 tractor. The tractor controls have been reversed so that the cutter precedes the tractor. The blades of the cutter are hydraulically powered, cutting down shock damage to the tractor power-take-off shaft. A flexibly mounted cutting head will also decrease shock loading.

Grass Rollers

An advanced design roller has been built (Plate 8) and has undergone its initial tests. It consists of two water-filled rollers in tandem which can be separated hydraulically to give widths varying from 1·2 to 1·8 m (4 ft to 6 ft).

Each of the two rollers can be angled, again by hydraulics, to give a varying tearing action. During initial trials some modifications proved necessary and the narrow gauge, MF 135 tractor will be given a greater ground clearance. Good grass control is achieved for about £2·4 per hectare (£1 per acre).

Long-term Weeding Plots, East England

Work has now been concluded on plots, set up in 1966/67, to compare the costs of hand, chemical and mechanical weeding over the period of establishment. Although techniques have changed over the period of the study, the result confirmed what is very generally the case ; machine weeding was cheapest and hand weeding dearest.

The figures for additive weeding costs are given in Table 28.

TABLE 28

WEEDING COSTS

Rockingham Forest (FYs 66–68 inclusive)

Plot:	A	B	C	D	E	F
Treatment	Hand	Chemical	Machine	Hand	Machine	Chemical
Cost	£108 ha (£45/acre)	£70 ha (£29/acre)	£55 ha (£23/acre)	£103 ha (£43/acre)	£55 ha (£23/acre)	£72 ha (£30/acre)

Hazelborough Forest (FYs 67, 68)

Plot:	A	B	C	D	E	F
Treatment	Chemical	Machine	Hand	Chemical	Hand	Machine
Cost	£26 ha (£11/acre)	£12 ha (£5/acre)	£55 ha (£23/acre)	£19 ha (£8/acre)	£53 ha (£22/acre)	£17 ha (£7/acre)

In these particular plots it was not necessary to undertake heavier preparation of ground for mechanical weeding than for hand or chemical weeding. Where this is necessary the advantage of mechanical weeding lessens or may disappear. By subtracting the costs of mechanical from those of chemical weeding an idea is given of the extra costs which could be considered for outlay on more preparation of ground to allow brush cutters etc. to operate.

FENCING

High Tensile Spring Steel Fencing

Methods of fence erection developed by Research Division have been studied. In this job the sequence of operations is important and can vary with different fencing situations. Standard times are being prepared.

BRASHING

Brashing Using Chainsaws

Until recently the weight of chainsaws has precluded their use in brashing, but the arrival of a saw whose operational weight was only about 3·6 kg (8 lb) suggested a trial. Initial work in Sitka spruce showed that damage to bark and cambium were excessive if branches were cut reasonably close to the tree. To keep the chain clear of the bark, half moon strips of 1·25 cm × 1·25 cm ($\frac{1}{2}$in × $\frac{1}{2}$ in) aluminium were screwed to each side of the bar. This enabled branches of up to 2·5 cm (1 in) diameter to be cut; the strips stopped short of the tip by 7·6 cm (3 in) to allow larger branches to be severed. Although about 20 per cent faster than hand brashing with a 51 cm (20 in) blade, the cost was very similar because of machine charges. It was concluded that, whilst the machine was closer to a practical tool for

brashing than earlier chainsaws, it was not suitable for the job ; it is designed essentially for timber felling and vibration was not damped, making it undesirable both ergonomically and physiologically.

At about the same time a prototype brashing attachment for a 7·3 kg (16 lb) chainsaw became available. The chain-drive sprocket had been replaced by a pulley which drove a 23 cm (9 in) diameter, fine-tooth, circular saw blade through a pulley belt. The blade was protected by a guard fitted with a protruding arm which fed the branch into the saw. The time for brashing was 50 per cent greater than for hand brashing, and weight and vibration were excessive. There were other design faults but the quality of brashing was very good. Whilst the prototype could not be recommended the principle remains of interest.

Respacement

Calculation by the Chief Economist, and work overseas, suggested that the early removal of a proportion of trees from closely-planted areas would have economic advantages. As part of the project, trees of various ages have been removed to various patterns using light-weight chainsaws. Although studies are incomplete it appears that the cost of felling the trees and leaving them where they lie is remarkably low. Sitka spruce 3·7 m (10 ft) in height cost 1d (£0·004) per tree.

II. HARVESTING STUDIES

General

Work proceeded at three levels: first, the design and production of new equipment ; secondly, the testing of commercially available equipment ; lastly, method study and work measurement of operations. Important progress was also made in the various Industrial/Forestry Commission joint working parties. In co-operation with the Technical Training Officer and medical men advances were made in the resolution of the problem of chainsaw vibration. An expert on fully mechanised harvesting systems, Mr. Ross Silversides, visited us from Canada and gave valuable advice on the sorts of system we might consider introducing over the next decade.

MACHINERY DESIGN

Forest Tractors

In co-operation with outside industry we have developed a 75 BHP skidding tractor (Plate 7). This is a ruggedly-constructed machine specially designed for forest use. It is an articulated frame-steering tractor, with four wheel drive, a small turning circle and high ground clearance, combined with a low centre of gravity. Since it is hydrostatic, there are no clutches, gears or axles, etc. but only an engine driving a variable-flow hydraulic pump from which fluid is piped to hydraulic ball motors in each wheel. This provides an infinitely-variable drive between stationary and maximum speed. The machine is fitted with two hydraulic winches, fairleads, back plate, log-rolling blades etc.

A brief specification is:

Brake horse power: 75 gross.

Maximum steering angle: 45°.

Maximum articulation angle: 30°.

Kerb-to-kerb turning circle: 8·23 m (27 ft).

Winch pull 4,990 kg (11,000 lb) bare drum.

System hydraulic pressure: 210 kg cm^2 (3,000 lb per in^2) for drive.

System hydraulic pressure: 140 kg cm^2 (2,000 lb per in^2) for winches.

Tyres 356 mm × 610 mm (14·00 × 24) 8 ply, earthmover.

Much has been learned from the trials and the final design for the Mark II model is in hand.

From detailed enquiry it has further been determined that there is likely to be a demand for a smaller hydrostatic skidder and designs have been drawn up.

Hydraulic Tongs

Manually-operated timber tongs, fitted to Massey Ferguson tractors, have long been in use at Thetford Chase Forest, East Anglia, and have played an important part in the extraction system. We have now produced a series of hydraulically-operated tongs, tested them and developed a production model (Plate 9). The indications are that, in Thetford conditions, the cost of extraction will be reduced by between 20 and 30 per cent as compared with manually operated tongs. This is largely a reflection of the increased loads which are carried. The so-called "Mark IIB" tongs will shortly be available commercially.

Meanwhile the general principles of tong or grapple loading (as opposed to multiple chokering) have been considered. The larger and more expensive, rear-mounted grapples certainly require pre-bunching of loads under most circumstances whilst smaller and cheaper tongs or grapples may economically be able to collect their own loads together for the main haul. Large grapples are now commercially available but we are constructing an intermediate size which should be suitable for larger tractors than the MF 135. This particular grapple will have some lateral movement to enable trees to be picked up more readily.

Cable Crane Trailer

One of the problems associated with efficient working of cable cranes is to keep the site around the tractor and winch clear. Machine time is lost owing to the need for restacking and/or resorting of the extracted poles. There are also instances where the material needs to be transported to a stacking or conversion bay some distance away. An estimated 200/300 hours extra use per year may be gained from each outfit if satisfactory equipment can be designed and put into operation. With this in mind a trailer has been designed and made. Trees, extracted in the length, are dropped direct on to a swivelling bolster mounted at the front of the trailer; the trailer is set more or less parallel with the road and the bolster set at the

best angle to receive material from the rack; thus the poles rest with one end on the bolster and the other end on the road; when about 3 tonne have been so gathered the poles are winched up skids on to the trailer using a tractor with winch; the tractor then proceeds to remove the trailer to landing after first placing an empty trailer beneath the skyline.

Mark II trailers have now been built incorporating the lessons learned from the prototypes. The towing tractor is to be equipped with a suitable front-end loader so that material may be expeditiously off-loaded at the landing, sorted and stacked after conversion.

Nose Cones for Ground Skidding Winches

In cooperation with South Scotland and North West Conservancies further studies have been made of ground skidding winches. One particular outcome has been the development of an improved nose cone in conjunction with a Longtown blacksmith. The device is of two-part, angle-iron construction; the lower part of the nose cone is provided with spikes, rather like a meat dish, on which the pole rests; the upper part is joined to the lower by two pairs of hinges: when the chain, attached to the upper part, is tightened the upper part moves forward and downwards on its hinges and clamps the pole firmly in position and is winched out in this way. At the winch end, the pole is released easily by moving the upper part of the nose cone upwards and backwards.

MACHINERY TRIALS

Massey Ferguson Treever 2200

This timber forwarder was tested at Thetford and Kielder. Since that time two machines have been purchased. Main conclusions are:

(a) The machine handled well and travelled well over Border conditions. As usual a brash "carpet" was provided to aid movement.

(b) As designed, it is a pulpwood carrier and cannot transport saw timber. We have modified the trailer to improve this situation and provided the grapple with a simple "heel" so that timber may be lifted away from its centre of gravity.

(c) Compared with the Massey Ferguson Robur, the Treever has a lower carrying capacity (Robur 6 tonne approximately under Border conditions, Treever 4 tonne maximum). Despite this the Treever should reduce extraction costs by 14d to 28d per cubic metre ($\frac{1}{2}$d to 1d per hoppus foot) depending upon length of haul. As the haul increases in length so the Robur becomes progressively more competitive.

(d) Wheeled forwarders are more manoeuvrable than $\frac{3}{4}$-track machines and coped as well or better with soft terrain.

Hough Paylogger

Studies undertaken on this frame-steering skidding tractor between February 1967 and July 1968 have been brought together in a report. The main conclusions from the studies are:

(a) The potential of this type of machine will not be realised unless there is a programme available in excess of 7,200 cubic metres (200,000 hoppus feet) per year. Clearly unit costs are least if the programme is in a compact area, but composite programmes from more than one adjacent forest need not be ruled out.

(b) Numerous alternative machines are available on dry, flat or moderately sloping ground and in such conditions the frame-steering principle is of little advantage. Conversely the machine is inappropriate in steep country, especially if the ground is also wet. The place for it is essentially on flat and moderately sloping sticky clays and shallow peats, provided the latter are covered with brash.

(c) On such terrain, load sizes in the band 2·2–3·2 cubic metres (60–90 hoppus feet) can be anticipated with a modest mean of 2·5 cubic metres (70 hoppus feet).

(d) Terminal costs per cubic metre increase with smaller tree size but large loads can be collected from well-presented clear falls of relatively small trees and low densities (eg Kielder, 3·1 cubic metres (85 hoppus feet) loads from 0·2 cubic metre (5·4 hoppus feet) trees at about 178 cubic metres per hectare (2,000 hoppus feet/acre)).

(e) Large conversion/stacking sites, or rapid despatch of produce, are essential to efficient working.

(f) Given a total cost per minute in the order of 12·04d the ratio between machine charges (57 per cent), driver + oncost (22 per cent) and chokerman + oncost (21 per cent) continuously emphasises the need to keep the machine in operation. The full potential will only be realised with:

(i) Careful planning
(ii) Appropriate felling
(iii) A well-trained driver and substitute
(iv) A skilled chokerman
(v) Rapid and experienced attention to breakdowns.

(g) A highly generalised mean can be taken as 70d per cubic metre (2½d/hoppus foot) terminal cost plus 23d per cubic metre per 100 metres. (¾d/hoppus foot per 100 yards) movement cost.

Volvo Loaders

A Volvo LM 840 loader, developed in Sweden, was used in a Research Division experiment at Thetford. The object was to compare its cost and efficiency with other machines for removing stumps for the control of *Fomes annosus*. The opportunity was taken to study the value of this sort of machine in harvesting operations. Studies included the smaller Volvo LM 640, and this machine was preferred on cost grounds, although for any full tree work the extra stability of the LM 840 may be required. Compared with current systems the LM 640 showed the cost advantages given in Table 29.

TABLE 29

COSTS: VOLVO LOADERS COMPARED WITH OTHER EQUIPMENT

Operation	LM 840 Volvo	LM 640 Volvo	10 Ton Lorry/Hydraulic Grapple	Massey Ferguson 135 with chains	Combined Massey Ferguson 135 and 10 ton Lorry
Move logs from heaps in clearfelling to stock-pile at rideside.	84d/m³ (3d/h ft.)	48d/m³ (1·7d/h ft.)	—	70/dm³ (2·5d/h ft.)	—
Move logs from heaps in clearfelling and load lorry at rideside.	92d/m³ (3·3d/h ft.)	67d/m³ (2·4d/h ft.)	—	—	95d/m³ (3·4d/h ft.)
Load logs on to lorry from piles within 10 m.	(Not available for this study)	48d/m³ (1·7d/h ft.)	56d/m³ (2·0d/h ft.)	— —	— —
Load poles on to lorry from stock-pile at rideside.	14d/m³ (0·5/h ft.)	(Not available for this study)	28d/m³ (1·0d/h ft.)	—	—

Agria Drabant Skidder

The Drabant skidder is a light, tracked machine developed in Norway Its weight with single drum winch is 825 kg (1820 lb), length 2·45 m (7 ft 9 in) width 1·20 m (47 in), height 1·30 m (51 in) and ground clearance 25 cm (10 in). The machine proved successful for line thinning but appeared to have no advantage over more conventional skidders for routine thinnings or clear-fellings.

Cable Cranes

Work has centred on the study and development of skyline systems. The main needs appear to be for a 300-metre line with up to 1·5 tonne load capacity and a 600-metre line with up to 0·5 tonne capacity. Work has concentrated on the former. In particular, studies have been made of the British Smith Winch. A main feature of this equipment is that the haul-in and haul-back drums are mounted along the longitudinal axis of the tractor and lie between the rear and front wheels. A skyline drum is mounted on the opposite side of the tractor. The longitudinal mounting of the drums allows the tractor to be placed along, rather than across, the road and this allows more stacking space. A locking skyline carriage is another feature of the equipment. Studies have confirmed the earlier promise of this equipment. Safety aspects for this and other skylines have been considered in detail with the Commission's Engineering Division, and electronic strain gauges have been used to determine forces acting along the ropes.

The following modifications are under discussion:

(a) A torque-limiting device which will not allow a greater pull to the equipment than it is designed to take.

(b) A hydraulic ram to tension the skyline coupled with a hydraulic accumulator in circuit so that, within the design limits, a nearly constant tension is maintained in the skyline. This can be pre-set to avoid overloading.

(c) Tower design to be checked by experimental stress analysis.

(d) A device to permit the skyline to be dropped as a safeguard against a runaway locking carriage.

OTHER HARVESTING STUDIES

Random Length Pulpwood

A detailed study was made to compare the costs of harvesting a standard length product with a conjectured random length specification of 4·9-7·3 m (16-24 ft). Taken into account were differential conversion losses between the two specifications and also the difference in work content and cost of the felling, snedding, crosscutting, extracting, loading and transportation elements. The conclusion was that the standard product would be cheaper to produce in most situations.

Harvesting Systems, Depots and Road Improvements

In cooperation with outside industry a series of studies was undertaken at Kielder to determine the best harvesting system using two criteria: cost and

labour requirement. Both shortwood and tree length systems were studied in relation to the provision of conversion or transfer depots, and the possible roading improvements which certain systems would require. The study included reference to the possible place of feeder lorries and their relationship to road status and main haul lorries. The possible combinations of harvesting system, depots, road status and layout, feeder and main haul lorry are, theoretically, infinite, and operational research techniques would be required to find the optimum solution. In practice one may achieve much by selecting a few likely combinations and comparing them in economic terms. For this particular study a score of system combinations were compared and the results were:

(a) The best of the shortwood and tree-length systems were not significantly different in cost.

(b) Tree-length systems are somewhat less labour-intensive than shortwood systems. Since labour costs are increasing relatively more sharply than machinery costs, there are indications that tree length systems will be increasingly favoured. However, shortwood systems based upon timber forwarders (such as the Massey Ferguson Treever) are effective, particularly for small trees up to about 0·108-0·144 cubic metres (3-4 hoppus feet) and are likely to be only slowly phased out.

(c) Tree-length systems not only reduce the total amount of labour required but allow it to be partly redisposed in more controlled depot conditions. This should result in less time being lost through adverse weather.

(d) Conversion depots would vary in size and degree of mechanisation, depending upon throughput and product mix. More study is required on this aspect.

Scottish Windblow

The Scottish gale of January 1968 gave the opportunity to produce provisional standard times for the clearance of windblown-spruce. These were based upon the average volume of the blown trees—obviously a difficult figure for the supervisor to get. Nevertheless the tables have made a useful impact. Attempts to convert the tables so that payments could be made by end-product were not successful, since the payment for end-products depended upon the average size of tree from which these products came. Further work is being carried out in the attempt to resolve this problem.

Payment by Standing Tree Volume Versus End-product Payment

Most standard time tables for felling/thinning and processing are based upon one or more of the following parameters: average tree size, tariff number and average number of whorls. Recently there has been an inceasing demand for tables to be expressed in terms of end-product, and a short project has been started so that the whole matter may be clarified.

Standard Times for Clear Felling

Provisional standard times have been issued for clear felling Sitka spruce ; data for Norway spruce, Japanese larch and Douglas fir are being worked up. Similar data for anticipatory clear felling of spruce in the Borders have been prepared.

Line Thinning

At the beginning of the year, work was concluded on the felling phase of line thinning in the spruces. Results of this work showed that there was no significant difference in the felling time between selective (brashed) thinning, unbrashed line thinning, and thinning in 50 per cent partially-brashed stands. It followed that where line thinning is applicable and no brashing is done the total cost of brashing is saved. Studies on extraction of line thinnings followed using the Holder tractor, Unimog 411, Agria Drabant skidder, Cundey winch and Thetford hydraulic tongs. Results of these studies did not yield information upon which universal recommendations might be based, since it was not possible to demonstrate in any generalised way how effective the extraction of line thinnings was in relation to selective thinning extraction. The difference in crop and topography, both within and between sites, suggests that realistic comparisons between these methods will only be obtained by carrying out costings on a wide scale. There is some promise that, with the correct systems, the cost of extraction may be similar to that of conventional early thinnings. The results of this project are now being written up. In addition, studies have been carried out in different parts of the country and in different species to build up standard times for felling of line thinnings.

III. PROCESSING STUDIES

Bark Processing

Since markets for pulverised bark appeared to be available we were requested to help develop a suitable machine for bark processing for use in the Brandon Depot at Thetford Chase in East Anglia.

The equipment consequently produced was coupled directly to the mobile Cambio peeler bark outlet. Bark is ducted to a 60 cm × 30 cm (24 in × 12 in) Christy and Norris hammer-mill, powered by a Bedford 300 cubic-inch Diesel engine. This also drives the blower which transports pulverised bark to an adjacent trailer. The degree of pulverising can be varied by changing the hammer mill screens. There have been many teething troubles associated with the selection of appropriate screen sizes for Scots and Corsican pine bark respectively, and the varying moisture contents of the bark. It may prove necessary to break the continuous process and separate bark processing from peeling logs.

Hydraulic Lifting Device for Sawbenches

Lifting poles to sawbenches for crosscutting has always been hard work and has sometimes resulted in operators suffering from back strains.

This part of the work may be mechanised in several ways. At Brandon depot, Thetford Chase, a number of independent loading systems was studied, but each had disadvantages. A hydraulic lifting device was therefore developed as an integral part of the saw. It consists of a table mounted on 51 cm (20 in) wheels, with a capacity of about 20 poles, 2 cubic metres (50 hoppus feet). Lifting arms pivoted on the leading edge of the table raise the poles to table height ; the poles are then pulled forward, one at a time, by one of the two operators ; they are supported on rollers during crosscutting. A disadvantage of the equipment has been that the lifting arms have to be loaded manually ; although this is an easier task than raising poles to bench level, it remains an undesirable operation. Current work is concentrated on perfectly a fully automatic lift.

More recently the Mechanical Engineer of South East England Conservancy has designed and made a device for lifting billets to a Cundey TRCP peeler. We have been handed this useful equipment for study and for a few modifications.

IV. OTHER STUDIES

Roads

Studies have concentrated on the economics of pre-planting roads (i.e. roads constructed before plantation establishment begins). Monetary values were placed upon the difficulties which a " no-road " situation creates in all significant establishment operations, and these values were set against road construction and maintenance costs. Discounted cash flow techniques were used, and the effects of varying discount rates explored. Both intensive and extensive forest management systems were considered. This detailed exercise indicated the way in which the problem might be tackled, and the method has been tested in several specific areas and shown to be workable. These tests are, in their turn, leading towards the formulation of a " drill book " approach which will allow managers to solve their problems without extensive calculations. This part of the work is being carried out jointly with the Chief Economist.

As part of this study, data has been obtained on a full range of cross-country vehicles and short studies have been made on several of them.

Chainsaw Vibration

Extension work on this problem has largely fallen to the Technical Training and Safety Officer. In cooperation with the National Institute of Agricultural Engineering, and medical men, vibration levels of various saws have been tested and the effect of Raynauds Phenomenon (" white finger ") explored. The superiority of saws fitted with anti-vibration handles has been demonstrated, and there is no doubt that the use of such saws will become general. Other precautions against white finger, such as the use of gloves, the preservation of whole body warmth and the taking of appropriate rest periods, or periods of other work, throughout the day, have been considered and recommended.

Communications

The role of radio equipment in harvesting operations has been examined and preliminary studies made of ultra-high frequency and very-low frequency equipment. The former shows particular promise, being light, relatively cheap and less liable to interference. We are also developing a one-way system of sonic communication which should be relatively cheap and particularly suitable for ground skidding double-drum winches (e.g. the Cundey winch). The choker man will be equipped with a sonic tone unit which emits a tone when the button is pressed. At the winch end a suitable receiver will convert the tone into a visual signal of command.

Steps have been taken to arrange for the conversion of mobile radio sets to 12·5 KHZ channel spacing, in accordance with Post Office rulings. The change is to be completed by 1973 and will be met partly by conversion and partly by routine replacements.

Earlier work on deer-tracking transmitter equipment resulted in an improvement of eight times in the effective tracking range, and an extension by 30 per cent of the battery life. Further work is now in hand, including improvements to the receiver.

L. C. TROUP

HARVESTING AND MARKETING DIVISION

TIMBER UTILISATION

Use of Bark in Horticulture

Most of the development work involved the growing of a wide range of horticultural crops in a "potting compost" made from seven parts bark, three parts sand and one part loam. Boxes of seedlings were obtained from local growers and transferred to pots containing this mixture ; they were then fed on a high-nitrogen liquid fertiliser.

The following plants were included in the trials:

Coleus species

Trailing *Lobelia*

African marigold (*Tagetes*)

Geranium (*Pelargonium*)

Fuchsia

Fibrous-rooted begonia (*Begonia semperflorens*)

Cineraria

At the same time a commercial grower near Newbury produced the following ornamental shrubs in a mixture of equal parts of sand and bark :

Shrubby *Potentilla* ' Moonlight '

Cornus elegantissima

Cornus spathia

Prunus cistina

Prunus ' Pissardii '

In both series of crops there was good root and shoot development, and the plants were displayed on a " Bark in Horticulture " exhibit at the Royal Show and at the Commission's Jubilee Exhibition near Edinburgh. Subsequently, pulverised bark was used with considerable success for bulb forcing with daffodils, hyacinths and tulips. However, an attempt to germinate *Calceolaria* seeds in the bark/sand/loam mixture was a failure.

At the Luddington Experimental Horticultural Station of the National Agriculture Advisory Service, near Stratford-on-Avon, trials were also undertaken with the use of potting composts based on bark. In one experiment Leyland cypress was grown out of doors in a medium made from three parts bark and one part sand. Another experiment involved the growing of *Begonia semperflorens* in a mixture of three parts sand and one part grit in a glasshouse. Both trials resulted in the production of saleable plants, but confirmed the need for readily available nitrogen at all stages of growth. The *Begonia* trials also pointed to the possibility of damage to young seedlings by volatile substances if freshly pulverised material is used for the potting compost. This could indicate that either weathering of the bark prior to use, or the addition of a medium to the compost to absorb the volatiles, may be desirable.

The results to date have indicated that using pulverised bark without further elaboration is probably the most promising of the horticultural outlets considered so far. When used in this way it is solely the physical properties of the bark which are exploited as a rooting medium, and there is no suggestion that the bark can make a contribuion to the plant's nutrition. This project has now reached the stage where market development work should take over, provided that further information is obtained on the addition of nitrogen to bark-based composts, and on the rate of its release to the plant.

Other work involved a forest nursery trial at Wareham Forest in Dorset, in which a top-dressing of ammoniated bark was compared with one of spent hops.

The development of a pulveriser at Brandon Depot of Thetford Chase, to produce horticultural bark, is reported in the Work Study Section on p. 156.

Prevention of Needle Fall in Christmas Trees

A market survey undertaken in 1966 on Christmas trees reported that one of the main objections to the natural Christmas tree was its tendency to shed needles before the end of the Christmas period. The consultants who carried out the survey suggested that research into treatments to inhibit needle fall would help to reduce the replacement of natural by artificial trees.

Accordingly an experiment was undertaken at Tair Onen Nursery, where a number of small unrooted Norway spruce trees were given a range of different treatments as follows:

(0) Controls—No treatment.
(1) Butts continually immersed in wet gravel, no treatment of foliage.
(2) Fresh cut surface of the butts sealed with warm bitumen, no treatment of foliage.
(3) Foliage dipped in 1.25 per cent solution of Epsom salts.
(4) Foliage dipped in a proprietary plastic compound.
(5) Foliage sprayed with a proprietary latex compound.
(6) Foliage dipped in a 1 per cent solution of proprietary preparation of alginate.

The trees were randomly arranged during the pre-Christmas period in a shed which had been lined with polythene to improve its heat insulation. Over a period of nearly five weeks, three electric fan heaters and a "Jet air" gas burner were used so that the temperature could be raised to a level of 23°C for three hours daily, in an attempt to simulate living-room conditions.

Assessments were made by giving the butt of each tree a sharp tap and collecting the needles shed 15, 21, 24, 27 and 30 days after treatment; both the fresh weight and the oven-dry weights of the needles were recorded.

The results, which indicate that the immersion of the butts in wet gravel, or dipping the foliage in alginate, are probably the most effective ways of reducing needle fall, are given in Table 30.

The sealing of the butt with bitumen has also shown some promise, and a repeat trial using this method is under consideration; conversely it will be seen that an Epsom salt dip does not inhibit needle fall, and might even accelerate it.

TABLE 30

MEAN NEEDLE LOSS, OVEN DRY WEIGHT IN GRAMMES

Treatment on 16/12/69	Date					
	30/12/69	6/1/70	9/1/70	12/1/70	15/1/70	Total
Control	0·24	0·31	0·42	1·1	3·0	5·1
Immersed butts	0·19	0·18	0·16	0·2	0·2	1·0
Sealed butts	0·15	0·25	0·35	0·7	1·5	3·0
Epsom salts dip	0·45	0·69	1·05	2·8	3·1	8·1
Plastic dip	0·10	0·15	0·26	0·9	1·8	3·2
Latex spray	0·13	0·23	0·41	0·8	1·1	2·7
Alginate dip	0·02	0·07	0·16	0·2	0·5	1·0
Standard Error	0·096	0·128	0·180	0·733	0·822	1·75

Fence Post Trials

The annual assessments at the 20 experimental farms continued. For Scotland, where the 9 sites were set up in 1957, the results were as shown in Table 31.

TABLE 31

PERCENTAGE POSTS REMAINING AFTER TWELVE YEARS: SCOTLAND

	Untreated	Water-borne Treatment*	Creosoted
Sitka spruce	30	67	100
Birch	3·5	64	99·3

* With the use of a water-borne preservative, no longer marketed in Britain for use in contact with ground.

It is of interest to note that most of the survivals of the untreated Sitka spruce posts are at infertile peaty sites at Achany Farm in Sutherland and Lephinmore in Argyll; elsewhere survivals are usually below 13 per cent.

For England and Wales, where 11 sites established in 1958 are under observation, the results to date are given in Table 32.

Results are available also from a further series from three sites which were set up in 1963. In these the service of untreated Scots pine and Douglas fir is being compared with similar posts which have been treated with an

TABLE 32

PERCENTAGE POSTS REMAINING AFTER ELEVEN YEARS: ENGLAND AND WALES

Species	No. of sites (out of 11)	Treatments			
		Untreated	Waterborne preservative	Creosote	Charring
Scots pine	11	6	89	100	—
European larch	1	75	93	100	—
Japanese larch	1	44	100	100	—
Ash	3	Nil	29	83	Nil
Birch	5	12	51	100	—
Elm	2	6	22	94	—
Oak	1	Nil	56	94	—
Sweet chestnut	1	75	75	100	62
Sycamore	2	12	75	93	—

improved waterborne preservative (which is recommended for use in contact with the ground). So far, 11 per cent of the untreated Douglas fir and 12½ per cent of the untreated Scots pine posts have failed; there have been no failures in the treated posts in this series in either species.

J. R. AARON

THE JOINT PROGRAMME ON HOME-GROWN TIMBER:

FOREST PRODUCTS RESEARCH LABORATORY AND FORESTRY COMMISSION

The Joint Programme of Work on home-grown timber, carried out by the Ministry of Technology's Forest Products Research Laboratory at Princes Risborough and by the Forestry Commission, has been continued in an effort to meet the Commission's need for further information on the properties of home-grown wood.

The following is an account of the work done under this Joint Programme. It should be remembered that some of the projects referred to in the 1969 *Report*, for example, "Work Study of Sitka Spruce from Wykeham and Bush Provenance Plots", and "Examination of Pruned Logs from Windblown Material", have reached the stage at which the practical work has been completed, and the results are being processed and analysed prior to the preparation of a report on the work.

Effect of Vigour on Young-growth Sitka Spruce

The success of Sitka spruce in British forestry can be attributed to its ability to grow on a wide range of sites, often under poor conditions, and to have a stem form and vigour of growth such that its yields generally exceed those of other species. Timber production of spruce is increasing rapidly. By 1975 it is estimated that it will amount to about 28.8 million hoppus feet (roughly

1 million cubic metres) out of a total production of 57.7 million hoppus feet (2 million cubic metres) from Commission forests. During the succeeding decade both figures will almost double (Holtam, 1966). The timber is sought after for both lumber and pulp production, but it is a feature of much home-grown spruce timber that it is light in weight and its market performance would be improved by an increase in density. A programme of tree and timber selection is being undertaken for Sitka spruce in order to recognise, and in due course to breed from, those trees that combine high yield and good timber quality. However, in order to make an effective selection, it has already been shown (Brazier, 1967) that a clearer understanding is required of the relation between vigour of growth and those factors affecting density in young Sitka spruce. Such an understanding is essential, too, in appraising the effects of forest management practices which, by influencing vigour of growth, affect wood quality. This is especially important in a species such as Sitka spruce, which sometimes produces timber that nearly falls below the acceptable density limit for certain industrial uses.

A study of the effect of vigour on the within-ring components of young, plantation-grown Sitka spruce has been made as a contribution to a more effective selection of timber having superior timber yields, and to appraise the likely effect of forest management practices which, by influencing vigour of growth, affect wood quality.

It was found that as ring-width in Sitka spruce increases:

(a) There is an increase in early-wood width without a corresponding increase in late-wood and therefore a greater proportion of early wood.

(b) There is a reduction in the average density of the early wood component of the rings.

(c) Because of the combined effects of (a) and (b), there is a reduction in wood density as vigour of growth increases.

(d) There is a lower minimum early-wood density.

The significance of these observations on the growth and technical performance of Sitka spruce timber is considered in a detailed paper on this work (Brazier, 1970). Also in this paper, the possibility of appraising adult wood characteristics on the basis of juvenile wood performance is examined, and the scope for assessing fibre length and density of adult wood from an examination of wood laid down at about six years from the pith is demonstrated.

A Study of the Effects of Spacing on Wood Density and Wood Yields of Sitka Spruce

The objects of this study were:

(a) To examine the effects of spacing on wood yields, both in quantitative and qualitative terms, in young plantation-growth Sitka spruce.

(b) To examine the relationship between wood density of a breast-height boring and the mean density of the stem.

Material for the investigation was obtained from the spacing plots laid down at the Forest of Ae, in Dumfriesshire, in 1935. Initial plantings were

at four spacings, 3 × 3, 4½, 6 and 8 feet, and plots were subject to one of two experimental thinning régimes, " P " treatment when thinning was carried out to minimise the effects of differences in the initial spacing, and " Q " treatment when thinning was used to maintain or accentuate the effects of the initial spacing. Sampling was on the basis of a random selection within stratified basal areas in each plot. Stratification was introduced in order to examine the effects, on the final crop trees, of the removal of stems of different size-classes in the first thinnings.

This study indicated that, for young-growth Sitka spruce, planting distances have little effect on crop yields and where yields of wood substance, as, for example, for pulp production, are the primary concern of management, a wide initial spacing is justified. However, where timber quality is important, as, for example, in saw-timber production, the low density of some of the trees on sites planted at wider spacings must be considered a disadvantage, if not unacceptable; there is evidence, too, that the proportion of the crop having a very low and possibly unacceptable density for purposes where strength is important tends to be higher in the 8-foot spacing, as compared with that in the 6-foot spacing plots. At all planting distances considered there is a marked difference between the average density of the largest trees compared with the smaller trees, with the largest trees producing a high proportion of the low density timber of uncertain value for saw-timber production. The removal of these largest trees in early thinnings can be expected to yield a better financial return, whether they are used at that stage for some form of sawn timber use or converted to pulp, compared with that obtained from the extraction of a large number of smaller trees. The trees left can be expected to receive a stimulus to growth, but this is laid down on a core of wood of generally acceptable density. The character of the wood, from pith to bark, in the final-crop trees, can be expected to be more nearly uniform compared with that in the largest trees if these are left to produce the final crop, and, although some trees of very large size will be missing from a final crop, this might be expected to be more uniform in character, especially size. Finally, there is some evidence, based on the differences between the free-growing Q trees at wider spacings and the more restricted growth with the P treatment, that favouring slower-growth trees tends to a better stem form, which, in turn, should yield a better return of sawn timber. (*See also : Planting, Spacing* on page 50 of this *Report.*)

The Stress Grading of Home-Grown Softwoods to Determine their Suitability for Building

The development of factory prefabrication of structural components is likely to result in a wider use of stress-graded timber in building. While stress-grading may be undertaken by visual inspection, this is a slow process requiring skilled personnel; furthermore it tends to underrate the strength of timber.

These disadvantages can be overcome by use of stress-grading machines, and recent tests carried out at the Forest Products Research Laboratory have shown that the Australian Computermatic machine is well suited for use in Britain.

Further advantages in using a stress-grading machine are that each piece of wood is marked with its grade rating, and that the grade is in no way dependent on individual interpretations of grading rules.

Grading machines depend for their operation on the relationships between the various strength properties of wood and modulus of elasticity. These relationships have been established for a number of imported timbers, and are particularly significant for bending strength.

A programme of work is in hand to determine the relationship between bending strength and modulus of elasticity for timber sawn from samples of home-grown Scots pine, Sitka spruce and Douglas fir saw-logs. The Computermatic stress-grading machine is being used in these trials in order to arrive at an assessment of the quantities, and proportions, of sawn timber suitable for structural use in building obtainable from these three species. It is expected that the application of machine stress-grading to these species will result in a substantial increase in their stress rating as compared with visual stress-grading.

Blue-Stain Experiments at Thetford

A detailed account of the work summarised in last year's *Report* has been published (Savory *et al.*, 1970).

The continuation experiment, using only untreated control logs, has confirmed that the peak of staining occurs in Thetford Chase in March- to July-felled timber. There was, however, the usual but unaccounted-for decline in the amount of stain present in the logs felled in May.

Laboratory trials have been carried out, using aqueous solutions of the sodium salts of tribromophenol and of pentachlorophenol on wet and dry Scots pine billets, and supplementary forest trials have been initiated.

Preservation of Home-Grown Timbers by Diffusion

Work on this subject has been mainly confined to studies of the rate of leaching of " Timbor " (a sodium polyborate) from treated timber, in order to assess the possible reduction in protection due to a period of exposure out-of-doors, but not in contact with the ground.

Studies on lateral leaching have been carried out on unprimed Scots pine, Sitka spruce and Western hemlock. Under rainfall conditions corresponding to about six months' exposure, leaching was confined to a depth of about 6 mm, but even in this layer the loading remained above the required toxic level.

Further studies have been made of leaching from the end-grain of primed and unprimed Scots pine treated by the " Timborising " process. In samples exposed to six months' natural weathering, depletion of boron salt occurred up to 37–44 mm from the end grain in the unpainted samples and up to 25–30 mm in the painted samples. There is evidence that most of the " Timbor " from the leached area diffused deeper into the wood rather than being washed out of it. The extent of re-diffusion from the unleached to the leached areas, on further storage under cover, is being investigated.

A Comparison Between Two Methods of Log Conversion

For the sawmilling process to be an economic and viable operation it is essential that the most efficient conversion pattern is employed to suit the quality, size and shape of the logs available and the particular end-products required.

There are a number of methods by which round softwood logs, tapering along their lengths and possibly containing sweep, can be sawn into square-edged material, but the two most common systems involve sawing either parallel-to-the-pith or parallel-to-the-bark, referred to as the " cant method " and the " taper sawing method ", respectively. With the cant method slabs including the log taper are removed from the outside of the log, yielding a parallel-sided cant which can be sawn into battens. The slabs are cross-cut to give boards of shorter lengths. With the taper sawing system the log is sawn through-and-through parallel to the bark, leaving a wedge which includes the pith and which can be cross-cut to yield shorter-length boards.

Recently these two particular conversion patterns were compared at Timberlab on the basis of the processing times, the quantity and quality of sawn material produced, and the overall economics of the two systems (Maun, 1969). For the comparison, two consignments of home-grown Douglas fir similar in size, shape and quality were converted into 2-inch (50 mm) battens, and 1-inch (25 mm) and $\frac{3}{4}$-inch (19 mm) boards.

This comparison, although limited in scope, showed that, *for the particular log saw used,* the cant method of sawing is economically superior to the taper sawing technique.

Generally it could be economic to use the taper sawing system only when straightness of grain is of great importance, as, for example, when high value material is required for ladder sides and scaffold boards.

Properties of the More Important Minor Species

Work has commenced on a programme to examine the timber properties of Western hemlock, Grand fir, Noble fir and Western red cedar, the possible importance of which in future planting programmes is being considered.

Specific gravity and moisture content determinations have been made in order to arrive at a preliminary assessment of the effects of site and other factors on timber properties. Sawmilling trials on Western hemlock and Grand fir have been completed and the results are being analysed.

T. HARDING,
Forest Products Research Laboratory.

REFERENCES

BRAZIER, J. D. (1967). Timber improvement I. A study of the variation in wood characteristics in young Sitka spruce. *Forestry* **40** (2), 117-128.

BRAZIER, J. D. (1970). Timber improvement II. The effect of vigour on young growth Sitka spruce. *Forestry* (in the press).

HOLTAM, B. W. (1966). *Home-grown roundwood. A survey of estimated industrial requirements 1965-80 compared with potential production.* Forest Rec., Lond. **52** (HMSO 4s. 6d.).

MAUN, K. W. (1969). A comparison between two methods of log conversion. *Suppl. Timb. Trades J.* October, pp. 22-24.

SAVORY, J. G., NASH-WORTHAM, J., PHILLIPS, D. H., and STEWART, D. H. (1970). Control of blue-stain in unbarked pine logs by a fungicide and an insecticide. *Forestry* (in the press).

PART II

Research undertaken for the Forestry Commission at Universities and other Institutions

NUTRITION AND FOREST SOILS

NURSERY AND FOREST EXTENSION EXPERIMENTS IN TREE NUTRITION

By BLANCHE BENZIAN and S. C. R. FREEMAN

Rothamsted Experimental Station, Harpenden, Herts

Copper Deficiency in Conifer Seedlings

" Needle tip-burn " of Sitka spruce (*Picea sitchensis*) was identified as a sign of copper deficiency in 1955 and shown to be preventable by spraying seedlings with solutions of copper salts. The symptoms commonly appear during hot dry spells and were much more in evidence at Wareham this year than for some years. However, they occurred only on plots not previously sprayed, and seedlings on plots treated as long ago as 1965 were free from the symptoms. Seedlings are small when they are sprayed, so that much of the solution reaches the soil and residues remain. Seedlings with symptoms had 2·4 ppm Cu in dry matter of tops (similar to the amount found in 1955). Where sprays were applied in 1960-65 (with none since) the plants had 4·0 ppm, and where sprayed in 1967 and 1968, 5·8 to 6·4 ppm of Cu. (Benzian and Freeman, with Hill, Biochemistry Department) (Extract from *Rothamsted Report* for 1969.)

Nitrogen Concentrations in Conifer Transplants and Subsequent Growth in the Forest

To see whether increasing nitrogen concentrations of trees in the nursery benefits them after planting in the forest, green healthy conifer transplants were grown in 1968 at Wareham and Kennington Extension nurseries, with uniform inorganic fertilizers supplying N, P, K, Mg. The species were: at Kennington—Sitka spruce (*Picea sitchensis*) (South Coastal, Washington State), and at Wareham—Sitka spruce, Norway spruce (*Picea abies*) (St. Viet/Pongau, Austria), Grand fir (*Abies grandis*) (Nanaimo, British Columbia) and Western hemlock (*Tsuga heterophylla*) (Nanaimo, British Columbia).

During early September, when top growth had nearly ceased, half the plots were top-dressed with extra " Nitro-Chalk " at either 7 g.N/m^2 (rate 1) or 14 g.N/m^2 (rate 2). Whilst the trees without late top-dressings of N retained their healthy green appearance, those with extra N turned a still darker green. Table 33 shows that N treatments increased N concentrations in all species, the double rate giving increases of between 28 and 44 per cent

TABLE 33

NITROGEN IN TRANSPLANTS OF FOUR CONIFER SPECIES AND SUBSEQUENT GROWTH IN THE FOREST

Transplants grown at	Nursery 1968		Forest 1969						
	N given Sept. 5 g/m²	N in crop* November Percentage in dry matter	Bud scores† end May/early June			Assessments November			
			T	L	T	Ht(cm.)	Dia(mm.)	Ht(cm.)	Dia(mm.)
Kennington:			*Rheidol*		*Aberhirnant*	*Rheidol*		*Aberhirnant*	
Sitka spruce	None	0·81	1·1	1·7	2·2	31·6	4·1	30·0	4·5
Picea sitchensis	7	1·23	1·4	2·0	2·6	36·0	4·5	33·4	5·3
	14	1·50	1·8	2·4	2·7	38·7	4·7	34·2	5·4
						SE±0·78	0·07	0·63	0·13
Wareham:									
Sitka spruce	None	1·14	1·5	2·0	2·0	33·1	4·5	28·3	4·7
Picea sitchensis	7	1·46	1·6	2·4	2·2	35·4	4·7	32·5	5·4
	14	1·60	1·8	2·6	2·2	37·1	4·9	30·4	5·1
						SE±1·18	0·15	0·68	0·17
					Bedgebury			*Bedgebury*	
Norway spruce	None	1·43	0·9	1·7	2·8	25·7	4·4	22·5	4·2
Picea abies	7	1·82	1·1	2·0	3·2	25·4	4·6	23·8	4·6
	14	1·83	1·0	1·7	3·1	26·9	4·6	23·1	4·1
						SE±0·66	0·17	0·96	0·21
Grand fir	None	1·30	0·7	1·9	2·3	20·9	4·6		
Abies grandis	7	1·56	0·7	2·2	2·6	24·7	5·2	crop failed	
	14	1·69	0·9	2·4	2·5	26·3	5·2		
						SE±1·13	0·21		
Western hemlock	None	1·22	1·1	1·5	2·4	32·5	3·7	28·3	4·9
Tsuga heterophylla	7	1·66	1·7	2·1	2·5	35·5	3·8	27·5	5·3
	14	1·75	1·8	2·2	2·8	34·1	4·1	29·4	6·0
						SE±1·31	0·18	1·72	0·27

Notes: * tops plus roots. † the more advanced the bud, the higher the score. T=terminal. L=lateral.

at Wareham and about 85 per cent at Kennington. After lifting in November, the trees were stored in polythene bags at 2 to 4°C—a method commonly used in practice. To increase the precision of the forest experiments, about 20 per cent of the nursery trees were discarded (i.e. the shortest and tallest and, within each height class, those with the smallest and largest diameters).

Sitka spruce were planted during April 1969 in Aberhirnant Forest (North Wales), an exposed site at 1,700 feet, and in Rheidol Forest (Central Wales), a sheltered site at 800 feet regarded as a frost hollow. The three other species (also planted in April) were tested at Rheidol and at Bedgebury Pinetum (Kent), where frost damage of susceptible species is common. All three forest sites received basal P after planting.

During the first season in the forest, the nursery nitrogen treatments speeded up bud development in all experiments (except of Norway spruce at Rheidol) and decreased needle cast and needle browning of Western hemlock at Bedgebury. Nitrogen increased height and diameter with Sitka spruce, Grand fir and Western hemlock (but not Norway spruce) at Rheidol, and with Sitka spruce at Aberhirnant.

The only clear effect at Bedgebury was a diameter increase of Western hemlock. There were some losses among Norway spruce and Western hemlock at Bedgebury, and most of the Grand fir died ; the cause of the losses is uncertain, but nitrogen treatments had no effect.

Shoot growth (which could only be measured with the spruces) shows still more clearly the great improvement from nursery nitrogen at the Welsh forests (Table 34). Sitka spruce from Kennington Extension gave the biggest effects, those with the largest N concentrations producing shoot increases of 70 per cent over the untreated ones at Aberhirnant and of 85 per cent at Rheidol.

TABLE 34

ONE-SEASON SHOOT GROWTH (CM)

Nurseries and treatments:	*Rheidol* Sitka spruce	*Rheidol* Norway spruce	*Aberhirnant* Sitka spruce
Wareham			
none	8·0	9·6	6·9
rate 1	11·5	10·7	8·5
rate 2	13·2	11·2	8·4
	SE±0·51	0·31	0·55
Kennington			
none	7·1	—	5·9
rate 1	11·2	—	8·8
rate 2	13·1	—	10·1
	SE±0·38	—	0·47

These results, if confirmed by later experiments, could have important practical implications by disproving a widely accepted opinion that a large N content is a disadvantage on frosty or exposed sites.

RESEARCH ON FOREST SOILS AND TREE NUTRITION

By H. G. MILLER and B. L. WILLIAMS
Macaulay Institute for Soil Research, Aberdeen

TREE NUTRITION

Nitrogen Nutrition of Pines

As described in previous *Reports* (1965 to 1969) a study has been made of the uptake and release of nutrients in a stand of Corsican pine at Culbin Forest (Moray). This stand, like much of the rest of the forest, had entered a phase of declining growth rate upon reaching middle-age, a condition that was found to be due to an increasingly severe deficiency of nitrogen resulting from the continuing immobilisation of this nutrient in the newly developing humus layer (Miller, 1969). In order to investigate some of the factors controlling the transformations of nitrogen in coniferous mor humus, and the uptake of nitrogen by trees, a new experiment has been laid out in a nitrogen-deficient 40-year-old crop of Scots pine at Culbin. In 1968 this experiment was treated with 250 kg of elemental nitrogen per ha applied as fertiliser forms of ammonium sulphate, sodium nitrate, ammonium nitrate and urea, these nitrogen treatments being partially factorialised with applications of triple superphosphate (to supply 100 kg phosphorus per ha) and ground limestone (2·5 tonnes per ha). The nitrogen treatments were re-applied in the spring of 1969, but no further applications of phosphorus or lime have been given.

By the end of the first growing season clear differences existed between the plots receiving the various forms of nitrogen. Needle weight and needle nitrogen concentration were highest in those plots given ammonium nitrate (29 mg and 2·5 per cent N, as against 20 mg and 1·4 per cent N in untreated trees) and both these parameters were significantly greater in the ammonium nitrate plots than in those given either sodium nitrate or urea (24 mg and 1·8 per cent N), with ammonium sulphate occupying an intermediate position (25 mg and 2·0 per cent N). After the second growing season, however, the differences in nitrogen concentration were very much reduced, the urea treatments, in particular, having shown a marked increase over the intervening twelve months. At this stage the needle nitrogen concentration was still highest in the ammonium nitrate treated trees (2·5 per cent N), followed by urea (2·3 per cent N), ammonium sulphate (2·25 per cent N) and sodium nitrate (2·15 per cent N). Phosphorus and lime had no significant effect on needle nitrogen concentration, at least over the first two years following application, but did tend to increase needle weight at any one foliar nitrogen level.

Humus samples were taken from this experiment for incubation studies in May 1969, prior to the second application of nitrogen fertiliser, and again late in the following August. The results of these studies are reported below.

Nutrient Content of Sitka Spruce

During the year a new study was initiated to determine the amount and distribution of dry matter and nutrients within a stand of 21-year-old Sitka spruce growing on thin hill peat at Fetteresso Forest (Kincardineshire). Preliminary work has been concerned with developing satisfactory means of sampling and subsampling this species, the gross morphology of which is so different from that of pine that it has proved necessary to make extensive modifications to the techniques originally developed with Corsican pine. A small-scale trial sampling, taking only four trees, has been made to determine the degree and pattern of variation likely to be encountered in both the distribution of foliage and the foliar nutrient concentrations in these trees.

The weight values obtained from these four trees suggest that Sitka spruce carries a larger amount of foliage than does pine, possibly about 18 000 kg per ha in this experimental crop as against 14 000 kg per ha found on fast growing Corsican pine in a previous investigation. Maximum crown development consistently occurs in the region of internodes 4 to 7, numbering from the top, there apparently being little difference in this between tree sizes. As might be expected the concentrations of nitrogen, phosphorus, potassium and sodium in the foliage were found to decrease with increasing age of needle at any fixed level in the crown, whereas that of calcium increased. For any given age of needle, calcium concentration varied little down the length of the crown whereas the concentrations of nitrogen, phosphorus, potassium and sodium tended to decrease. However, at the very bottom of the crown there were marked increases in the concentrations of phosphorus, potassium and sodium, and a decrease in the concentration of calcium. Variations in magnesium concentrations showed no consistent trend.

A full-scale and intensive sampling of this crop is now under-way.

Effect of Shade on Nutrient Uptake

A short duration study has been initiated to check continental reports that shading of certain coniferous species results in increases in foliar nutrient and chlorophyll concentrations. Starting in November 1969, samples of foliage have been taken at monthly intervals from young Lodgepole pine, Sitka spruce, Douglas fir, Grand fir and Western hemlock planted beneath five densities (approximately 0, 100, 200, 300 and 500 stems per ha) of middle-age larch at Drumtochty Forest (Kincardineshire). At each sampling the concentration of chlorophyll has shown a marked and consistent increase with increasing shade, at least up to 300 stems per ha. Variations in nutrient levels are not so well defined but with some elements, particularly potassium, a distinct pattern appears to be developing with the approach of the growing season. The effect of increasing shade on the size of individual needles, in terms of their length, area and weight, varied with species, maximum values occurring beneath an over-canopy of 500 stems per ha with Douglas fir, beneath 300 stems per ha with hemlock, beneath 100 stems per ha with both spruce and Grand fir and in the open with pine. However, a microscopic examination of cross-sections of these needles gave no suggestion that any of these species is producing morphologically specialised "shade-needles" under the range of shade intensities being considered.

Mineralisation of Nitrogen in Peat and Humus

A new series of studies has been initiated to examine some of the factors, particularly those of the chemical environment, that affect release of

mineral nitrogen from coniferous mor humus and deep acid peats. Both mor humus and acid peats contain large quantities of organic nitrogen, yet the trees they support may become severely nitrogen-deficient. Preliminary investigations have been concerned with developing satisfactory incubation techniques to quantify, at least on a relative scale, the effect of various treatments on the rate of net production of inorganic nitrogen in these two forms of accumulated organic debris.

Incubations have been carried out at 30°C on samples of humus taken in early May and late August from the Scots pine experiment at Culbin described above. In May, just prior to the second application of nitrogen fertiliser to this experiment, between 0·2 and 4·4 per cent of the total nitrogen in the humus was in the inorganic form and therefore could be extracted with 2N KCl, whereas by late August inorganic nitrogen had risen to between 0·5 and 15·7 per cent of the total. On both occasions the higher values occurred in samples from those plots that had been given nitrogen fertiliser, and these were also the samples that gave the highest net production of additional mineral nitrogen on incubation for nine weeks. In samples from plots that had received nitrogen fertiliser, the quantity of mineral nitrogen present after incubation varied with form of nitrogen applied and tended to increase in the order: sodium nitrate <ammonium sulphate <ammonium nitrate <urea. The effect of lime, whether applied alone or in combination with phosphorus, was to depress net mineralisation in any nitrogen treatment. The response to phosphorus without lime, however, was variable, but at least in the May samples phosphorus tended to have a stimulatory effect on mineralisation.

Samples of peat for incubation studies were taken in September 1969 from drainage experiments on a raised bog at Achray Forest (Stirlingshire) and hill peat at Inchnacardoch Forest (Inverness-shire). The amounts of mineralised nitrogen in fresh samples was found to be very variable, the trend at both sites being an increase in inorganic nitrogen (almost wholly ammonium) with increasing moisture content of the peat. However, the quantities found in samples of the very poorly decomposed *Sphagnum* peat from the raised bog at Achray tended to be lower than the quantities of inorganic nitrogen found in samples of the more highly decomposed *Sphagnum-Trichophorum* hill peat of Inchnacardoch Forest. During incubation of samples from these two sites mineral nitrogen accumulated very slowly. The rate was particularly slow in samples from unfertilised peat at Inchnacardoch Forest: furthermore, mineralisation in these samples showed no relationship to the imposed drainage treatments. However, in samples from sections of the same plots that had been fertilised with N P and K the quantity of mineral nitrogen that could be extracted after incubation for nine weeks was greater and was found to increase with the decreases in moisture content brought about by the drainage treatments. Mineralisation in the samples from the experiment at Achray Forest showed little relation to drainage, but here again there was some evidence that an increased application of P and K could stimulate the net production of mineral nitrogen under the conditions of incubation used in this study.

REFERENCE

MILLER, H. G. (1969). Nitrogen nutrition of pines on the sands of Culbin Forest, Morayshire. *J. Sci. Fd Agric.* **20,** 417–419.

FOREST PATHOLOGY

CONIFER SEEDLING PATHOLOGY

By G. A. SALT

Rothamsted Experimental Station, Harpenden, Herts

The "Psychrophilic Seed Fungus"

Experiments begun in 1968 at Wareham and Kennington nurseries to measure the effect of this fungus on the emergence of Sitka spruce (*Report* for 1969, p. 147) were continued to test whether the fungus had survived in dead seed or soil. A central band 16 cm wide, containing most of the seeds killed by inoculum placed there in 1968, was left undisturbed by cultivation, and Sitka spruce seed was broadcast over the whole area. There was no evidence of inoculum surviving because as many seedlings emerged in the central strip as in the rest of the plot. There were small randomly distributed patches where seedlings did not emerge, but with broadcast seed patchy emergence could result from patchy sowing in addition to attack by pathogens. However, dead seeds recovered from the patches yielded cultures of the seed fungus, showing that infection was from new inoculum in the broadcast seed and not from inoculum surviving from the previous season.

As precision spacing of seed becomes more important (*Report* for 1969, p. 33) losses are easier to measure, and it becomes increasingly necessary to understand and prevent them. At Kennington a seed-bed that had been treated with formalin to kill soil-borne pathogens was sown with precisely spaced seeds of two Sitka spruce provenances, 61(7972) from Washington State, USA, and 66(6111) from Queen Charlotte Island (Q.C.I.), British Columbia, both of which contained about 2·5 per cent of naturally infected seed. The seed was mounted in rows between two sheets of absorbent tissue 45 cm wide, tightly crimped together, with 2·5 cm between rows and between seeds. The tissue was rolled in 20 m lengths which were unrolled on the seedbed and covered with quartz grit. Before sowing, 8, 32 and 64 autoclaved seeds infected with the fungus were stuck, evenly spaced, on 0·9 m (1 yd) lengths. This corresponded to 1·2, 5 and 10 per cent of the seed sown, and therefore exceeded the range, 1 to 5 per cent of infection usually found in seed samples.

Spread from naturally infected seeds presumably accounted for only 48 per cent and 35 per cent of viable seed of Washington and Q.C.I. provenances respectively emerging in uninoculated controls, and the fungus was recovered from 60 per cent of seeds that failed to emerge. Adding the three proportions of inoculated seed further decreased emergence respectively of Washington by 29, 26 and 54 per cent and of Q.C.I. by 8, 24 and 64 per cent.

The losses in uninoculated seed were greater than in seed of the same two provenances broadcast on a nearby plot without formalin fumigation, where an average of 56 per cent emerged. In Petri dishes the radial spread of the fungus on unsterilized absorbent tissue was no greater than on Kennington soil, and it is improbable that the tissue provided the fungus with extra

nutrient. However, in nursery seedbeds the physical conditions within the tissue might well have been more favourable to fungus growth than normal soil. Thiram seed dressings control this fungus and should therefore be included in any method designed to increase precision in the spacing of seedlings.

Although naturally infected seed has been found only in Sitka spruce imported from North-west America, inoculation of plots with a pure culture of the fungus growing on autoclaved Sitka spruce seed decreased the emergence of other conifer species. Worst affected were Sitka spruce, Western hemlock, Lodgepole pine, Douglas fir and Japanese larch. Dead seeds of these species were recovered from the plots and yielded cultures of the fungus (cf. *Report* for 1969, p. 147). In addition the fungus was isolated from dead seeds of Norway spruce and Scots pine, but not from Grand fir, European larch or Corsican pine. As the fungus seems not to survive our relatively mild winters, it is unlikely to be a serious pathogen of other conifer species in our nurseries.

ROLE OF LOPHODERMELLA SPECIES IN PREMATURE DEATH OF PINE NEEDLES IN SCOTLAND

By C. S. MILLAR

Department of Forestry, University of Aberdeen

This report relates to an investigation into the causes of premature browning and death of needles of Corsican pine (*Pinus nigra* var. *maritima* (Aiton) Melville) at Culbin Forest, Moray, and Scots pine (*Pinus sylvestris* L.) at Glenlivet Forest, Banffshire. Browning had been observed for several years at both sites but, although several secondary fungi had been isolated from browned needles, the primary cause had not been established.

The investigation, which has recently been supported by a travel and subsistence grant from the Forestry Commission, started in 1967. It has shown that, at both sites, the fungus *Lophodermella* (*Hypodermella*) *sulcigena* (Rostr.) v Höhn is the primary parasite causing extensive browning of current year's needles. Fructifications (hysterothecia) of *L. sulcigena*, which are conspicuous in July on one-year-old browned needles, release clavate ascospores which infect the bases of the new growing needles, causing browning by October of the same year. Further details of *L. sulcigena* and related fungi can be obtained from Darker (1932 and 1967) and Terrier (1944).

Availability of Ascospores

A Burkard volumetric spore trap was used to sample the air in a Corsican pine stand at Culbin from early June 1968 to September 1969. *L. sulcigena* ascospores were trapped from 20 June to 20 August in both years. Their deposition on the vaselined tape was normally preceded by periods of three or more hours of humidity over 90 per cent with or without rain. During July and early August rain invariably produced some spores but in each year the main peak of spores deposited occurred between 7–15 July with secondary peaks in late July or early August depending upon the incidence of rain, fog and low temperatures. The deposition of spores other than *L. sulcigena* is currently being investigated.

Symptom Development

Corsican pine needles normally emerge from the fascicular sheath about 10 June at Culbin, elongate steadily throughout July and August and stop growing in late September. Thus spores are deposited during needle growth. Controlled inoculation experiments have shown that *L. sulcigena* infects only at the base of the growing needle, within the 5 mm zone immediately above the fascicular sheath. Macro-symptoms appear about one month after infection, by which time the needle has usually grown about 4 cm so that, because pine needles grow from a basal meristem, the infection spot is in effect, carried away from the base of the needle. Examination of

populations of naturally infected needles shows that infection spots (translucent resinous bands) appear on the needles in positions corresponding to the base of the needle at the time of peak spore release.

Progressive discoloration away from the initial infection spot occurs until, by the end of October, the needle is browned to within about 1 cm of the sheath. One or both of the needles in a pair may be infected. Studies are now in progress to describe, in more detail, the nature of the site and mechanism of infection.

Control

Preliminary measurements on Corsican pine have shown that in years of severe infection girth increment was up to 25 per cent lower in trees heavily infected with *L. sulcigena* as compared with nearby apparently resistant trees. Needle browning has been reduced by using one of two fungicides, " Dithane " and " Bordeaux Mixture ", at weekly intervals during the sporing season and eliminated by enclosing the growing shoots in Terylene pollination bags. A singe dip in " Dithane " effectively prevented infection in the dry July of 1967 (23·4 mm rain) but several dips achieved only incomplete control in 1968 (116·8 mm) and 1969 (42·3 mm).

High rainfall in July presumably increases the chances of infection in three ways: (1) by releasing spores more or less continuously ; (2) by ensuring moist conditions for spore germination ; (3) by washing off fungicide applied to the foliage. In this connection it must be emphasised that, on any needle, a new infection site (needle base) is steadily available throughout the sporing season so that successful control by surface application of fungicides will depend entirely on an ability to define the conditions for peak spore release.

Secondary Organisms

In Corsican pine, *Hendersonia acicola* Tubeut readily infects needles already infected with *Lophodermella sulcigena* but does not infect healthy needles. The relation between *Lophodermium pinastri* (Schrad. ex Hook) Chev. and *L. sulcigena* is not yet clear. Needles protected during the limited sporing season of *L. sulcigena* are not infected by *L. pinastri* in the first year but may become infected later.

In Scots pine current year needles are also often infected by *H. acicola* and *L. pinastri*. *Naemacyclus niveus* (Persoon ex Fries) Saccardo, a fungus not yet found on Corsican pine, occurs rarely on first year needles and then only on needles already infected by *Lophodermella* or *Lophodermium*. However, *N. niveus* is particularly important since it invades most second-year needle pairs previously infected by *L. sulcigena*, causing premature fall.

Second-year Needles

In Corsican pine many needles which remained healthy during their first year of growth showed symptoms, early in their second year, of another hypodermataceous fungus, *Lophodermella conjuncta* Darker. This fungus, which has not yet been studied in detail, can apparently infect needles at any point along their length causing, initially, brown lesions with a conspicuous

yellow margin. Mature hysterothecia appear soon after the infection becomes noticeable and persist throughout the winter, shedding ascospores in wet conditions. By the end of the second year most needles on susceptible trees are infected and completely brown but may be retained on the tree throughout the third year. Browning caused by *L. conjuncta* was particularly severe in 1969/70. Further studies on this and other fungi affecting older living needles are proposed.

Thus, where these hypodermataceous fungi prevail, severe premature loss of photosynthetic tissue can occur. The two species of *Lophodermella* described are instrumental in predisposing the needles to attack by other fungi which accelerate the needle tissue degradation. Trees which are resistant to *L. sulcigena* may or may not be suspectible to *L. conjuncta* and *vice versa.*

Summary

Premature death of needles has been studied in Corsican pine at Culbin Forest, Moray, and in Scots pine at Glenlivet Forest, Banffshire. At both sites the fungus *Lophodermella* (*Hypodermella*) *sulcigena* is the primary parasite causing extensive browning of current year needles. Ascospores of *L. sulcigena* are available for the whole of July, and infection, which occurs only at the base of growing needles, is markedly influenced by high humidity or rain during this period. Control by fungicides is complicated by the fact that new infection sites (needle bases) are available throughout the sporing season.

A number of fungi, notably *Hendersonia acicola, Lophodermium pinastri* and, on Scots pine, *Naemacyclus niveus,* may secondarily invade the young infected needles accelerating needle-cast. In the absence of infection by *L. sulcigena,* Corsican pine needles may be infected by *Lophodermella conjuncta* in their second year with a subsequent severe premature browning of the older foliage.

References

Darker, G. D. (1932). The Hypodermataceae of conifers. *Contr. Arnold Arbor.* **1,** 1–131.

Darker, G. D. (1967). A revision of the genera of the Hypodermataceae. *Can. J. Bot.* **45,** 1399–1444.

Terrier, C. A. (1944). Über zwei in der Schweiz bisher wenig bekannte Schüttepilze der Kiefern: *Hypodermella sulcigena* (Rostr.) v. Tub. und *Hypodermella conjuncta* Darker. *Phytopath. Z.* **14,** 442–449.

VIRUS DISEASES OF FOREST TREES

By P. G. BIDDLE

Commonwealth Forestry Institute, University of Oxford

Three virus-like conditions are now recognized in conifers in Britain. The most distinct of these is apparently the same as that described as spruce virosis by Čech *et al.* (1958). On both Sitka and Norway spruce, needles on some, or all, of the shoots show a vivid yellow or yellowish-white chlorosis, usually over the whole needle although the base may remain green. The chlorotic needles tend to be distributed on the underside of the shoot, or frequently one side of the shoot is chlorotic while the other is normal. The chlorotic needles tend to fall by mid-June, resulting in severe defoliation.

This defoliation complicates the separation of the condition of spruce virosis from an apparently distinct defoliation which affects Sitka and Norway spruce. Symptoms include defoliation of the previous year's needles, extending into the current year's needles at the end of the season. Needles may show distinct chlorotic banding before falling. The terminal internodes are usually shortened and deformed. The symptoms caused by the Green Spruce aphid, *Elatobium abietinum*, are frequently similar to this, and the relationship of this aphid to the condition is under investigation.

A third quite distinct symptom is " bushy stunt " of Scots pine. Affected trees exhibit multiple leaders giving a brooming appearance on both the main stem and side branches. The brooms are up to six inches diameter, comprising as many as twenty-five shoots, one of which usually re-establishes as a leader in the following year.

All these conditions are apparently associated with rod-shaped particles similar to those described by Čech *et al.* for spruce virosis. Three distinct particle sizes can be distinguished with diameters of 15, 25 and 36 nm. However the 36 nm particle is clearly not associated with any pathogenic condition. Investigations while on leave of absence at the University of California, Berkeley, have shown that this particle is ubiquitous in the genus *Pinus*, and that they are primarily or entirely of terpene composition. Further investigations are being made on the extraction and composition of the other two sizes of particles in order to elucidate their relationship to the anomalous conditions in the spruce and Scots pine.

It must be emphasised that at present there is no proof that the spruce chlorosis and defoliation, and the Scots pine " bushy stunt ", are attributable to virus infection, and so current work is aimed at understanding the cause and nature of the conditions and to establish whether they are pathogenic. In the belief that they may be of virus origin, graft and insect transmissions are being attempted, using seedlings and clonal cuttings as the stock material. The insect transmissions are being made using the Brown spruce aphid, *Cinara pilicornis*, described by Pintera (1955) as transmitting the chlorotic virosis of Norway spruce, and the Green spruce aphid, *Elatobium abietinum*. The implication of a virus could explain the problem of the non-density dependent defoliation occasionally caused by *Elatobium*.

Investigations are also continuing into viruses of hardwood species. Particular emphasis is being given to the possibility of the "stem pitting" of beech being caused by a virus, and its relationship to the "beech snap" syndrome.

References

ČECH, M., KRÁLÍK, O., and BLATTNÝ, C. (1961). Rod-shaped particles associated with virosis of spruce. *Phytopathology* **51,** 183–185.

PINTERA, A. (1955). Pokos o přenos žloutnutí jehlic korovincí *Sacciphantes abietis L.* (Experiment with the transmission of yellowing of spruce trees by the aphid *Sacciphantes abietis* L.). *Acta Soc. ent. čsl* **52,** 113–115.

FOREST ENTOMOLOGY AND ZOOLOGY

STUDIES ON INSECT VIRUSES

By J. F. LONGWORTH

Insect Pathology Unit, Commonwealth Forestry Institute, University of Oxford

Mrs. J. Underwood left the Unit in December, and her place was taken by Mrs. K. Coppin. The following investigation continued.

Pieris brassicae

Inclusion bodies of the granulosis virus of *Pieris brassicae,* the Large White Butterfly, were dissolved in alkali and three components were obtained, inclusion body protein, virus particles and the inclusion body membrane. These were separated by gel chromatography and density gradient procedures. The inclusion body protein had a repeating structure different from the protein lattice of the inclusion body.

Serological tests showed that two proteins were present in solutions of inclusion body protein. Both of these were present at the surface of the inclusion body but only one of these, protein B, was present at the surface of the enveloped virus particle.

The two proteins were separated by gel chromatography and were shown to be serologically unrelated. Amino-acid analyses confirmed that the two proteins were different. The isoelectric point of protein A was rH 5·8 and of B rH 3·5.

Protein A was " typical " inclusion body protein ; protein B, present both at the surface of the inclusion body and the enveloped virus particle, has different properties. This may well affect the validity of previous serological comparisons between granulosis viruses.

The antigenic properties of the virus particles are now being further examined.

These studies are being extended to include the granulosis virus of *Melanchra persicaria,* the Dot moth, and the nuclear polyhedrosis virus of *Lymantria dispar,* the Gypsy moth.

RESEARCH ON THE GREEN SPRUCE APHID ELATOBIUM ABIETINUM

By W. H. PARRY

Department of Forestry, University of Aberdeen

The study of the population dynamics of *Elatobium abietinum* at Forest of Deer (Aberdeenshire) was continued during 1969. During this period there occurred what might be described as a moderate infestation of the aphid, which contrasted with the severe outbreak of 1967 and the almost complete absence of aphids during 1968. As in 1967, peak aphid numbers were obtained in mid-June when values of between 20 and 30 aphids per 100 needles were observed in the unsprayed plots. Again, one spraying operation with malathion in early April proved sufficient to eradicate *E. abietinum* completely from the sprayed plots. While some noticeable defoliation did take place in the unsprayed plots the values obtained were not significantly higher than those from the two sprayed plots. The aphid population showed considerable variation between trees, most trees being lightly infested, but a few heavily infested trees showed a marked defoliation. However, at the mean aphid infestation level obtained, the overall defoliation effects were small and probably of very little significance if, as in this case, they did not immediately follow a severe outbreak of the aphid.

One of the aims of this study has been to attempt to obtain a method whereby severe outbreaks of *E. abietinum* can be predicted sufficiently early for preventive measures to be taken. Some work has already been carried out on the continent in relation to the effects of winter temperatures on the severity of aphid attack during the succeeding summer (Petersen, 1962). In the absence of such data it was considered possible that outbreak levels could be predicted on the basis of aphid numbers alone using known infestation levels from previous years.

Using the formula:

$$\frac{W_2 \times S}{W_1} = E$$

where W_1 is the observed overwintering aphid level in a year with a known succeeding spring or summer population peak, S, and W_2 is the observed overwintering aphid level in the year for which the peak level E is required, attempts were made to predict the 1969 summer population peak (Table 35).

These initial values give some possibility of predicting summer population peaks with sufficient accuracy for preventive measures to be confidently undertaken during early spring. However, more observations of a similar nature are required before any definite conclusions can be drawn as to the reliability of this method.

TABLE 35

OBSERVED AND PREDICTED ELATOBIUM ABIETINUM LEVELS IN THE UNSPRAYED PLOTS AT FOREST OF DEER

(Aphids per 100 Needles)

Plot No.	W_1	S	W_2	Expected peak aphid value (E)	Observed peak aphid value
10	1·115	54·12	0·74	35·90	25·26
3	3·35	47·36	1·83	25·87	27·11

In contrast to the rapid population summer decrease which occurred in 1967 (Parry, 1969), the decrease in 1969 was much more protracted and aphids were still present in mid-August, compared to mid-July in 1967. *Aphidecta obliterata* and all other predators were virtually absent in 1969 and parasitism remained at the same low level previously recorded. Alate formation again occurred only in a minor proportion of the population so that emigration only accounted for a small part of the total decrease. This gives further evidence in favour of the conclusions of Parry (1969) that, in the absence of severe defoliation, density-independent qualitative food shortage appears to be the main cause of the population decline at this time.

No conclusive reason for the population fall which occurs in mid-summer has been advanced, although the most commonly accepted hypothesis is that the amino-acid levels in the plant sap are mainly responsible (Parry, 1969). To test this hypothesis the amino-acid levels of Sitka spruce needles are being quantitatively assessed throughout the year. To date, 19 and 20 amino-acids have been isolated from Sitka spruce and Norway spruce respectively. These are, for both species, tryptophan, phenylalanine, leucine, iso-leucine, troosine, valine, alanine, threonine, glycine, serine, asparagine, glutamine, arginine, lysine, proline, glutamic acid, aspartic acid, cysteic acid and cystine, with histidine being additionally isolated from Norway spruce. In Sitka spruce needles showing *Elatobium* damage, tryptophan, phenylalanine, tyrosine, glycine and cysteic acid were apparently absent, while histidine and probably hydroxyproline were additional compounds isolated.

To obtain some measure of the relative number of alate aphids of all species flying within a Sitka spruce crop, six sticky aphid traps were set up in a small isolated plot of Sitka spruce in the Countesswells Section of Midmar Forest, Aberdeenshire. Two main peaks of flight activity were recorded, the first during May and June, the second during late September and early October. Alate *Elatobium abietinum* captures were confined to the first peak, the main flight period occurring from 10th June to 3rd July and the last winged individual being trapped in the week ending 17th July. The pattern of spruce aphid flight seems basically similar to that recorded in 1968 at Alice Holt Lodge, Surrey (*Report* for 1969), but the flight peak occurs at a later period and the last alates were trapped a month later at Countesswells. Therefore, the period of flight activity exhibits an appreciable time-lag in comparison with the south of England.

Further investigations have been carried out on the effects of aphid feeding on spruce needles. A method is being evolved which uses the time taken for damage symptoms to appear as a measure of the tolerance level of Sitka spruce to *E. abietinum*. It is hoped that this will be of value in estimating the tolerance level of known Sitka spruce clones or individual trees suspected of possessing tolerance.

REFERENCES

PARRY, W. H. (1969). A study of the relationship between defoliation of Sitka spruce and population levels of *Elatobium abietinum* Walker. *Forestry* **42** (1), 69–82.

PETERSEN, B. BEIER (1962). Peak years and regulation of numbers in the aphid *Neomyzaphis abietina* Walker. *Oikos* **13**, 155–168.

STUDIES ON TIT AND PINE LOOPER MOTH POPULATIONS AT CULBIN FOREST

By MYLES CROOKE

Department of Forestry, University of Aberdeen

Routine assessments of Coal tit breeding densities and of Pine looper pupal numbers were made in the two permanent study plots in 1969. The census of Coal tits revealed that there were 26 breeding pairs in Plot 1 as compared with 19 pairs in Plot 2 so that the provision of supplementary winter feeding in the form of peanuts in Plot 1 seems again, as in 1968, to have increased the breeding density therein as compared with the unfed, control Plot 2. The differential, at one third more than the control, is not, however, as substantial as it was in 1968 when the breeding population was doubled by artificial feeding during the previous winter.

Two new study plots were established during 1969, one of these being 36 ha (89 acres) and the other 39 ha (96 acres) in extent. The smaller of these is being managed by the provision of nest boxes and winter food in an effort to increase Coal tit breeding densities whilst the larger remains untreated to act as a control, with the pair acting as replicates of the original two plots.

An intensive tit ringing programme is in progress in both the fed plots, the birds being caught in mist-nets at the feeding tables and being ringed with both BTO rings and colour rings in various codes. To date 426 birds have been ringed, and subsequent observation and/or trapping will yield information on tit dispersion in the plots and throughout the surrounding plantations. Monthly winter flock counts have also been made and these indicate that, as anticipated, there are significantly larger numbers of birds in the fed plots as compared with the control plots. Other work in hand includes flock tracking to determine winter feeding range, and the capture and ringing of roosting birds.

A start has been made with sampling of the various growth stages of the Pine looper with the objective of constructing survivorship curves, but the low population levels of the insect are posing sampling difficulties. The pupal densities in the Plots 1 and 2 were only 0·5 and 0·3 per square yard in 1969 as compared with 1·2 and 1·7 per square yard in 1968.

FISH POPULATIONS IN FOREST STREAMS

By D. H. MILLS

Department of Forestry and Natural Resources, University of Edinburgh

The study of a trout population in the Glentress Burn (Peeblesshire) was continued during the year. The stream has a dense slow-growing population of brown trout with a rather low production and a low ratio of production to summer standing crop.

The movements of trout in this stream are affected by stream "jams" caused by felled trees and cuttings during thinning operations. Further stream blockages have been caused during work to remove trees blown down during the severe gale early in 1968. Silting behind these "jams" is heavy.

The results of this study are being written up for publication.

HYDROLOGY

HYDROLOGICAL RELATIONS OF FOREST AND MOORLAND VEGETATION

By L. LEYTON, E. R. C. REYNOLDS and F. B. THOMPSON

Department of Forestry, University of Oxford

Research continues on certain aspects of vegetation hydrology including water uptake from the soil and root patterns in time and space (Reynolds, 1970), the interception and evaporation of rainfall by forest and moorland vegetation, the quantitative measurement of sap flow (Leyton, 1970) and the stomatal control of transpiration by different species. One line of new work includes the effect of different levels of water supply on the production and death of fine roots and their distribution in a stand of Douglas fir. Another line deals with stomatal and cuticular resistances of tree seedlings of certain species from the Mediterranean region, in relation to water loss under different environmental conditions.

Continuing our practice of reporting a recent experiment in more detail, we have selected one on the effect of the deciduous habit on rainfall interception (Thompson, 1970). Although the interception loss by deciduous species might be expected to be considerably less during the leafless period, the literature reveals conflicting results. In some cases little difference has been found between leafy and leafless periods, and this has been generally attributed to seasonal climatic differences. A direct comparison of interception loss by leafy and leafless canopies under the same climatic conditions, and also of the effect of summer and winter climates on interception loss by leafless canopies, was made on a stand of coppice oak (*Quercus robur*), which had not been cut over for about sixty years. Four adjacent 12·1 m square plots were laid out with 3·1 m guard zones and in two of these, all trees were frill-girdled and poisoned with 2, 4, 5–T (in paraffin). In each plot, throughfall was measured by 5 randomly placed 5 in. standard rain gauges and stemflow was measured on 6 random stems. The gross rainfall was measured in a nearby open area. In the untreated control plots, budburst began in early May, and leaf fall in October, continuing into December ; no foliage was produced by the treated trees.

The results for the year 1969 are summarized in Table 36. The interception loss is the difference between gross and net rainfall (the sum of throughfall and stemflow).

Over the year, poisoning of the trees has resulted in a decreased interception loss of 42·9 mm (6·7 per cent of the gross rainfall) of which 23·9 mm is accounted for during the full leaf period, June to September inclusive, and a further 13·0 mm during May, October and November when the trees were partly in leaf. Despite the fact that interception losses by

TABLE 36

GROSS RAINFALL (mm.), INETRCEPTION LOSS (%) AND STANDARD ERRORS OF THROUGHFALL (%)

1969	Gross Rainfall (mm.)	Interception Loss (%)		Standard error of Throughfall (%)	
		Control trees	*Treated trees*	*Control trees*	*Treated trees*
January	89·1	10·9	10·6	4·4	5·6
February	38·2	5·8	6·1	4·4	5·8
March	48·4	5·9	2·6	4·5	8·7
April	39·9	4·5	3·1	6·8	5·8
May	122·1	20·6	12·8	8·0	5·3
June	20·0	8·8**	3·1	9·7	4·5
July	54·0	11·7*	5·2	9·1	4·0
August	91·4	20·7*	13·9	10·4	4·8
September	56·9	12·7	7·8	15·0	9·3
October	5·9	3·2	1·4	21·8	6·8
November	49·0	9·6*	6·2	5·4	4·6
December	57·8	7·5	6·2	10·5	4·8
Total ...	672·7	121·9	79·0	—	—

Significant differences: ** 1 per cent. * 5 per cent.

the control trees were almost invariably higher than the treated trees, the differences were only significant during the summer months, June to August, when the trees were in full leaf, and also in November, when about half the foliage was still present. The failure to establish significant differences during other leafy months, in particular, September and October, is almost certainly due to the very high standard errors of the throughfall estimates for these months. As might have been expected, the standard error of the throughfall estimates for the control plots increases during the leafy period as a result of increasing heterogeneity in the throughfall pattern ; in contrast, the standard errors for the treated trees remain more or less constant during this period, indicating that the guard zones were large enough to prevent interference from surrounding leafy trees. It follows that in the measurement of throughfall under deciduous crops, attention must be paid to the need to allow for seasonal changes in the throughfall pattern.

The effect of seasonal climate on interception losses by the treated trees was small. For the two periods corresponding to the leafless (January–April, December) and full leaf months (June to September) with gross rainfalls of 273·4 and 222·3 mm respectively, the interception losses were 28·6 mm (10·5 per cent of the gross rainfall) and 30·0 mm (13·5 per cent). In contrast, the combined effect of season and leaf state, as shown by the control plots, resulted in interception losses during the same two periods of 34·6 mm (12·7 per cent) and 53·9 mm (24·2 per cent) respectively. Clearly,

in this stand and under the climatic conditions prevailing in 1969, the increased summer interception loss was very largely determined by the presence of leaves which increased the canopy storage capacity from about 0·4 mm for the leafless period to 1·0 mm ; the canopy storage capacity of the treated plots remained at about 0·3 mm during both periods (for the determination of canopy storage capacity see Leyton *et al.*, 1967).

Acknowledgement. The authors have pleasure in acknowledging the support by the Forestry Commission for a technical assistant, Mr. E. A. S. Ogden.

REFERENCES

LEYTON, L. (1970). Problems and techniques in measuring transpiration from trees. In *Physiology of Tree Crops*. London: Academic Press (in press).

LEYTON, L., REYNOLDS, E. R. C., and THOMPSON, F. B. (1967). Rainfall interception in forest and moorland. In *Forest Hydrology* (ed. W. E. Sopper and H. W. Lull), pp. 163–177. Oxford: Pergamon Press.

REYNOLDS, E. R. C. (1970). Root distribution and the cause of its spatial variability in *Pseudotsuga taxifolia* (Poir.) Britt. *Pl. Soil* (in press).

THOMPSON, F. B. (1970). Seasonal rainfall interception by oak coppice (*Quercus robur, L*). in the leafy and leafless state in Southern England. In *Aspects of Forest Climates,* Symp. agric. Met. **13,** Aberystwyth.

FIRES

THE RATE OF SPREAD OF HEAD FIRES IN THE NEW FOREST, HAMPSHIRE

By P. H. THOMAS

Ministry of Technology and Fire Offices' Committee
Joint Fire Research Organization, Boreham Wood, Herts

In the past few years, teams from the Fire Research Station have attended some controlled head fires in heather, gorse and grass, in the New Forest and measured various features of their spread including the heat transfer rates to the unburnt fuel ahead of the fire front. The data have been reported by Woolliscroft (1968 and 1969) and Woolliscroft and Law (1967), who made some heat balance calculations for the heating of the unburnt fuel. These have since been studied further and it now appears possible :

(i) to correlate the data in broad terms with previous laboratory experiments.

(ii) to interpret some features of the data in terms of a heat balance for the unburnt fuel.

The importance of the bulk density of fuel in still air fires in the laboratory has previously been established. In wildland fires, however, the fuel bed is not homogeneous and thick fuel tends to be only partially burnt, so there is some uncertainty as to what bulk density controls the spread.

The amounts of fuel were obtained by weighing samples, and the size distribution of the unburnt and burnt heather, gorse and grass, on the various plots was also measured ; estimates were then made from these of the bulk density ρ'_b of the burnt fuel and ρ'_b of the initial fuel. The greater variability of the samples of burnt fuel made estimates from the direct weighing of a few samples somewhat unreliable. Estimates of ρ'_b were therefore based on changes in the size distribution.

Figure 7 shows the mass rate of spread $R\rho'_b$ where R is the linear rate of spread for the various wind speeds U. One fire 1967/2* was reported as burning sporadically, having to be relit at various times because of the non-uniform fuel coverage ; the data for fire 1966/4 have been calculated on the assumption that only the grass content of the fuel was burning. Woolliscroft (1966) has shown that the flame length of this fire was consistent with this view.

The data roughly follow:

$$R\rho'_b = 0{\cdot}07\,(1+U) \qquad (1)$$

where R and U are in m/s
and ρ'_b is in kg/m^3.

* The numbers, e.g. 1967/2, refer to the year 1967 and the test No. 2 in the reports by Woolliscroft.

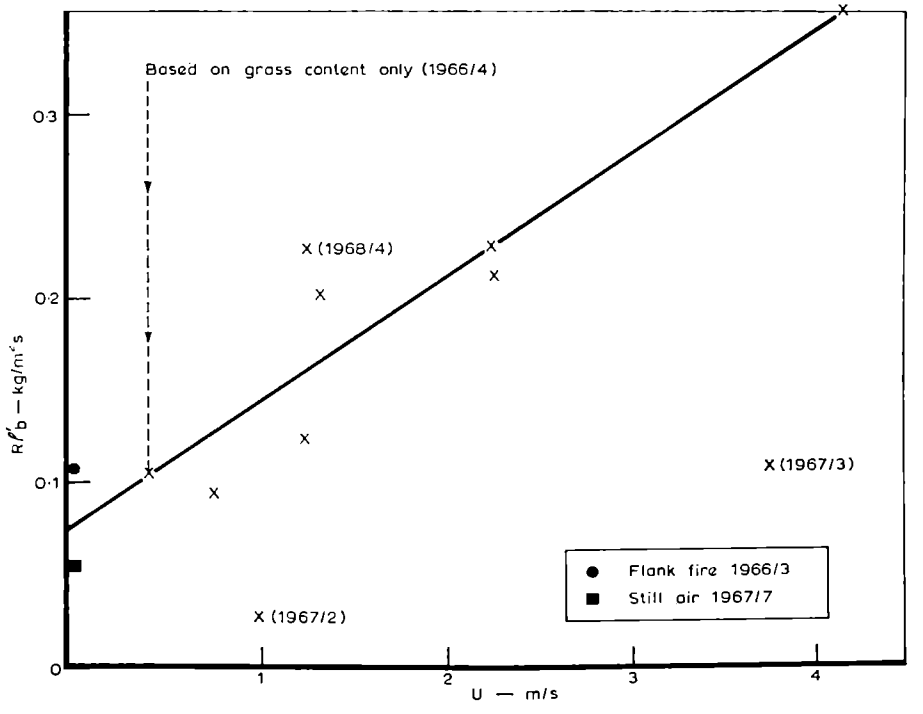


Figure 7: Effect of wind on fires.

The mean value of ρ'_b/ρ_b was found to be 0·45 and the ratio decreases systematically with increasing moisture. However, there are presumably other effects of moisture which prevent these data being combined to predict that R increases with increasing moisture content! One such factor is the enthalpy $\triangle H$ required to raise unit mass of fuel to ignition which, according to theory, should appear as $R\rho'_b\triangle H$. The increase in $\triangle H$ with moisture content would oppose the reduction in ρ'_b.

The fact that increasing moisture decreases the likelihood that any source of ignition would lead to a propagating fire and increases the safety of wildland, does not imply that it would have as large an effect on the rate of spread if spread did take place. For the time being one should regard ρ'_b/ρ_b as 0·45 in equation (1).

One effect of moisture, which tends to oppose those reducing the rate of spread, is that it increases the time taken to consume a piece of fuel (the " residence time "). This leads to a thicker flaming zone and perhaps more emissive flames. Values of D, the length of the flame zone in the direction of travel, were obtained from photographs of the fire and the ratio D/R is the effective " residence time ", t . Figure 8 shows the marked increase of t with moisture for these fires.

Byram *et al.* (1964) have reported data for the effect of wind on crib fires in the laboratory. They used cribs made of $\frac{1}{4}$ in (6·3mm) sticks of *Abies concolor* at various horizontal spacings S and showed that the data follow:

$$R \propto S^{0.9}(U_o + U)$$

where U_o is a constant.

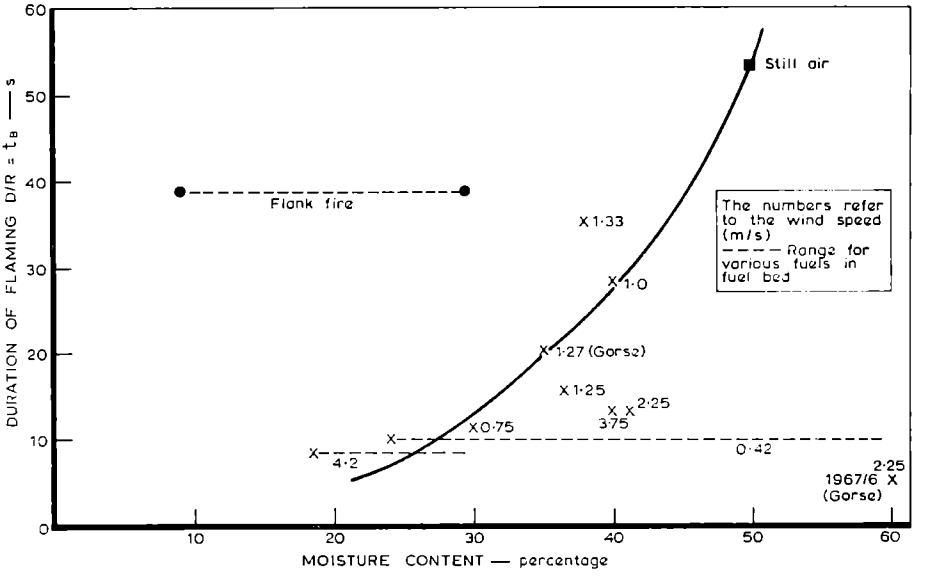


Figure 8: Duration of flaming (residence time) of a head fire, in relation to the percentage moisture content of fuel.

A recalculation of data in terms of ρ_b appears in Fig. 9, and

$$R\rho_b \simeq 0{\cdot}05\ (I + U)$$

for a range of 6:1 in ρ_b.

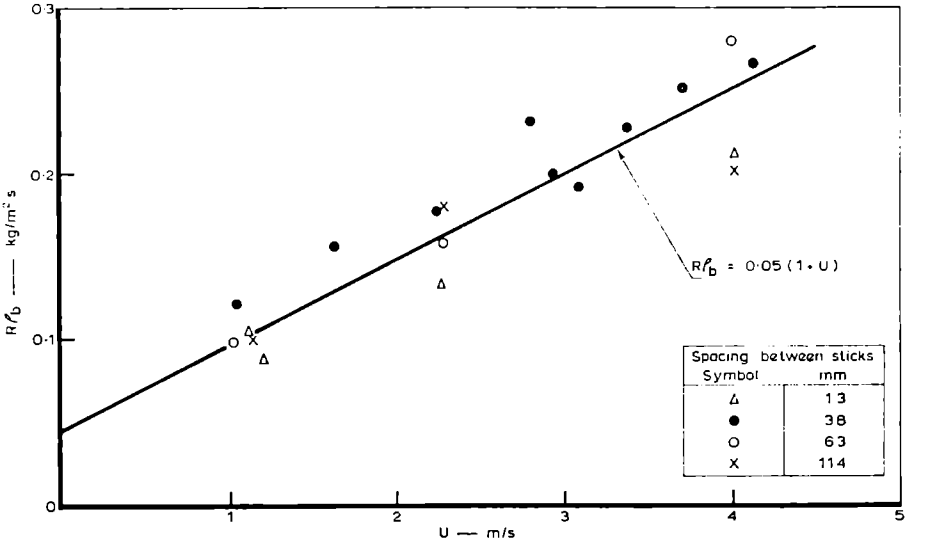


Figure 9: Correlation of crib data (calculation from data of Byram *et al*).

They do not report the value of the fuel residue in detail but it would appear to have been relatively small ($<$ 10 per cent), so that the two sets of data are probably within 50 per cent of each other, a better agreement between laboratory and field data than would be expected taking into consideration the non-uniform character of real fuels, though it is the similarity between the forms of the relationships rather than between the constants that is the more significant, since the cribs were considerably drier than wildland fuel. Byram's data are for cribs without any cover over their sides. Earlier experiments reported by Thomas and Pickard (1961) showed that covering the sides of the cribs to represent wide uniform fuel beds reduced the effect of increasing wind, the rate of spread appearing to reach a constant value as winds exceeded 4-5 m/s.

In other experiments with cribs having no side walls, rates of spread similar to those recorded by Byram *et al.*, but some up to twice as high, have been measured. The reasons for the differences are not clear but the field data lie in the middle of the whole range of crib data and, perhaps being in non-uniform fuel, correspond to cribs with partly open, partly closed, sides.

Theoretical analysis suggests that the variation of R with U may not necessarily be linear at higher speeds, and that the increase is partly due to an increase in flame radiation as flames are deflected by the wind and partly due to convection.

In estimating flame radiation a value of flame emissivity ϵ_f, and its variation with D, is required.

By analogy with vertical flames it was assumed that ϵ_f could be expressed as:

$$\epsilon_f = 1 - e^{-KD}$$

ϵ_f being calculated from measurements of the radiation flux and the flame temperature and correlated with D. For most of the head fires K could be taken as approximately 0·1 m^{-1}.

Flame lengths were on average about 25 per cent less than those calculated from:

$$L = 18{\cdot}6\,(R\rho_b' h)^{2/3}$$

derived from theory and laboratory data (Thomas, Pickard and Wraight, 1963) where h is the height of the fuel and $\rho_b' h$ is the burnt part of the fuel loading.

A heat balance similar to that described elsewhere (Thomas, 1967), but including a term to represent convection, shows that the form of Fig. 7 can be adequately interpreted by allowing for radiation through the fuel bed from the heated solids, radiation from the flames, and a convection flux proportional to U. The flame radiation increases with U and there are some difficulties in precisely estimating the relative importance of the latter two components, which both increase with wind speed but neither of which can be neglected.

The theoretical heat balance shows that there are conditions in which some fires can spread in two ways: a "slow" spread and a "fast" spread (Thomas, 1967). It is interesting that only for fire 1967/72 was a "slow"

spread impossible according to the theory and it was this fire which spread sporadically, having to be relit from time to time. A full report of this analysis is available (Thomas, 1969).

Differences between different types of vegetation, and different mixtures, the role of moisture, the effect of slope, etc., require further study and more data but the theoretical considerations involved in the above interpretation provide the basis for choosing the data to be reported on. In particular, bulk density rather than fuel loading per unit ground area is the most important property of the fuel bed. The time of burning of real vegetation, i.e. t_B, is largely characteristic of the fuel itself and could be determined independently of any real fire.

It is now necessary therefore to pursue the study of wildland fires by acquiring statistical data using this and other studies as the framework.

REFERENCES

BYRAM, G. M., *et al.* (1964). *An experimental study of model fires.* Tech. Rep. SEast Forest Exp. Stn **3,** Macon, Georgia, USA.

THOMAS, P. H. (1967). Some aspects of the growth and spread of fire in the open. *Forestry* **40** (2), 139–64.

THOMAS, P. H. (1969). *The rate of spread of head fires in gorse and heather.* Fire Res. Note Jt Fire Res. Orgn **796/1969.**

THOMAS, P. H., and PICKARD, R. W. (1962). Fire spread in forest and heathland materials. *Rep. Forest Res., Lond.* 1961, pp. 105–8.

THOMAS, P. H., PICKARD, R. W., and WRAIGHT, H. G. H. (1963). *On the size and orientation of buoyant diffusion flames and the effect of wind.* Fire Res. Note Jt Fire Res. Orgn **516/1963.**

WOOLLISCROFT, M. J. (1968). *A report on forest fire fieldwork (New Forest, March 1966).* Fire Res. Note Jt Fire Res. Orgn **693/1968.**

WOOLLISCROFT, M. J. (1969). *Notes on forest fieldwork (New Forest, 1967).* Fire Res. Note Jt Fire Res. Orgn **740/1969.**

WOOLLISCROFT, M. J. (1969). *A report on forest fieldwork (New Forest, March, 1968).* Fire Res. Note Jt Fire Res. Orgn **744/1969.**

WOOLLISCROFT, M. J., and LAW, MARGARET. (1967). *A report on forest fieldwork (New Forest, March 1965).* Fire Res. Note Jt Fire Res. Orgn **647/1967.**

APPENDIX I

Main Experimental Projects and Localities

(*See Maps, page 225, for situations*)

SILVICULTURE AND SOILS

PRODUCTION OF PLANTING STOCK

Benmore Nursery, near Dunoon (Argyll)
Bush Nursery, near Edinburgh (adjacent to Northern Research Station)
Fleet Nursery, Gatehouse of Fleet (Kirkcudbrightshire)
Headley Nursery, Alice Holt Forest (Hampshire and Surrey)
Inchnacardoch Nursery, near Fort Augustus (Inverness-shire)
Kennington Nursery, near Oxford
Newton Nursery, near Elgin (Moray)
Sugar Hill Nursery, Wareham Forest (Dorset)
Tulliallan Nursery, Devilla Forest (Fife and Clackmannanshire)

PROVENANCE EXPERIMENTS

Scots pine:	Black Isle Forest, Findon (Ross-shire) Thetford Chase (Norfolk and Suffolk)
Corsican pine:	Bowland Forest (Lancashire) Brighstone Forest (Isle of Wight) Cotswold Forest (Gloucestershire) South Yorkshire Forest Thetford Chase (Norfolk and Suffolk) Wareham Forest (Dorset)
Lodgepole pine:	Achnashellach Forest (Ross-shire) Allerston Forest, Wykeham (Yorkshire) Beddgelert Forest (Caernarvonshire) Black Isle Forest, Millbuie (Ross-shire) Brendon Forest (Somerset) Ceiriog Forest (Denbighshire) Clocaenog Forest (Denbighshire and Merioneth) Forest of Deer (Aberdeenshire) Glen Trool Forest (Kirkcudbrightshire and Ayrshire) New Forest (Hampshire) Shin Forest (Sutherland) Taliesin Forest (Cardiganshire and Montgomeryshire) Thetford Chase (Norfolk and Suffolk) Towy Forest (Cardiganshire, Brecon and Carmarthenshire)
Jack pine:	Allerston Forest (Yorkshire)
Sitka spruce:	Clocaenog Forest (Denbighshire and Merioneth) Coed Morgannwg (Glamorgan) Glendaruel Forest (Argyll) Glen Trool Forest (Kirkcudbrightshire and Ayrshire) Kielder Forest (Northumberland) Loch Goil Forest (Argyll) Mynydd Du Forest (Brecon and Herefordshire) Radnor Forest (Radnorshire and Herefordshire) Ratagan Forest (Ross-shire and Inverness-shire)

PROVENANCE EXPERIMENTS—*contd.*

	Taliesin Forest (Cardiganshire and Montgomeryshire) Wark Forest (Northumberland) Wilsey Down Forest (Cornwall)
Norway spruce:	The Bin Forest (Aberdeenshire) Brendon Forest (Somerset) Cannock Chase (Staffordshire) Drummond Hill Forest (Perthshire) Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire) Halwill Forest (Devon and Cornwall) Minard Forest (Argyll) Newcastleton Forest (Roxburghshire and Dumfriesshire) Salisbury Forest (Wiltshire)
European and Japanese larches:	Allerston Forest (Yorkshire) Clashindarroch Forest (Aberdeenshire) Drummond Hill Forest (Perthshire) Fetteresso Forest (Kincardineshire) Mortimer Forest (Herefordshire and Shropshire) Plym Forest (Devon) Savernake Forest (Wiltshire and Berkshire) Walcot Forest (Shropshire)
Douglas fir:	Culloden Forest, Ferness (Inverness-shire and Nairnshire) Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire) Glentress Forest (Peeblesshire) Land's End Forest, St. Clement (Cornwall) Lynn Forest, Shouldham (Norfolk) Mortimer Forest (Herefordshire and Shropshire) Newborough Forest (Anglesey) Rheidol Forest (Cardiganshire)
Western hemlock:	Allerston Forest, Wykeham (Yorkshire) Benmore Forest (Argyll) Brecon Forest (Brecon) Brendon Forest (Somerest) Clocaenog Forest (Denbighshire and Merioneth) Loch Goil Forest (Argyll) New Forest (Hampshire) Rheidol Forest (Cardiganshire) Thetford Chase (Norfolk and Suffolk) Wareham Forest (Dorset)
Western red cedar:	Alice Holt Forest (Hampshire and Surrey) Benmore Forest (Argyll) Cannock Chase (Staffordshire) New Forest (Hampshire) Radnor Forest (Radnorshire and Herefordshire) Thetford Chase (Norfolk and Suffolk)
Silver fir, Abies alba:	Drummond Hill Forest (Perthshire) Lael Forest (Ross-shire) Radnor Forest (Radnorshire and Herefordshire) Thetford Chase (Norfolk and Suffolk)
Silver fir, Abies lowiana/concolor:	Brendon Forest (Somerset) Honiton Forest (Devon and Somerset) Mortimer Forest (Herefordshire and Shropshire)

PROVENANCE EXPERIMENTS—*contd.*

Oak :	Forest of Dean, Penyard (Gloucestershire, Herefordshire and Monmouthshire) Dymock Forest (Gloucestershire and Herefordshire)
Beech :	Queen Elizabeth Forest (Hampshire and Sussex) Savernake Forest (Wiltshire and Berkshire) Wendover Forest (Buckinghamshire)

CHOICE OF SPECIES FOR AFFORESTATION

Species and mixture trials on peat soils :	Achnashellach Forest (Ross-shire) Beddgelert Forest (Caernarvonshire) Borgie Forest, Strathy (Sutherland) Eddleston Water Forest (Peebleshire) Glen Trool Forest (Kirkcudbrightshire and Ayrshire) Inchnacardoch Forest (Inverness-shire) Kielder Forest (Northumberland) Kirroughtree Forest (Kirkcudbrightshire) Naver Forest (Sutherland) Rumster Forest, Watten (Caithness) Shin Forest (Sutherland) Wauchope Forest (Roxburghshire)
Species and mixture trials on gley soils :	Forest of Ae (Dumfriesshire) Alice Holt Forest (Hampshire and Surrey) Allerston Forest (Yorkshire) Beddgelert Forest (Caernarvonshire) Black Isle Forest (Ross-shire) Blairadam Forest (Fife and Kinross-shire) Bowland Forest, Gisburn (Yorkshire) Brendon Forest (Somerset) Clocaenog Forest (Denbighshire and Merioneth) Forest of Deer (Aberdeenshire) Drumtochty Forest (Kincardineshire) Elibank and Traquair Forest (Selkirkshire and Peebleshire) Fetteresso Forest (Kincardineshire) Garadhban Forest, Lennox (Stirlingshire and Dunbartonshire) Gwydyr Forest (Caernarvonshire and Denbighshire) Hamsterley Forest (County Durham) Kielder Forest (Northumberland) Land's End Forest (Cornwall) Loch Ard Forest (Perthshire and Stirlingshire) Rockingham Forest (Northamptonshire) Rosarie Forest (Banffshire and Moray) Taliesin Forest (Cardiganshire and Montgomeryshire) Wilsey Down Forest (Cornwall)
Species and mixtures on ironpan soils :	Allerston Forest (Yorkshire) Clashindarroch Forest (Aberdeenshire) Devilla Forest (Fife and Clackmannanshire) Hambleton Forest (Yorkshire) Monaughty Forest, Newtyle (Moray) Teindland Forest (Moray)
Species and mixtures on freely drained soils :	Alton Forest (Hampshire) Bedgebury Forest (Kent and Sussex) Bodmin Forest (Cornwall)

CHOICE OF SPECIES FOR AFFORESTATION—*contd.*

	Bradon Forest (Wiltshire) Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire) Exeter Forest (Devon) Honiton Forest (Devon and Somerset) Hursley Forest (Hampshire) Land's End Forest (Cornwall) Micheldever Forest (Hampshire) Mortimer Forest (Herefordshire and Shropshire) New Forest (Hampshire) Plym Forest (Devon) Thetford Chase (Norfolk and Suffolk) Tintern Forest (Monmouthshire) Wareham Forest (Dorset)
Trials of species on other soils:	Brighstone Forest (Isle of Wight) Chilterns Forest (Buckinghamshire, Oxfordshire and Hertfordshire) Cranborne Chase (Dorset and Wiltshire) Exeter Forest (Devon) Friston Forest (Sussex) Queen Elizabeth Forest (Hampshire and Sussex)
Trial plantations on difficult sites:	Beddgelert Forest (Caernarvonshire) Borgie Forest (Sutherland) Clocaenog Forest (Denbighshire and Merioneth) Deudraeth Forest (Merioneth) The Garraries (Kirkcudbrightshire) Glencoe Forest (Argyll) Glen Garry Forest, South Laggan (Inverness-shire) Glen Trool Forest (Kirkcudbrightshire and Ayrshire) Hafren Forest (Montgomeryshire) Hoy Experiments (Orkney Islands) Land's End Forest (Cornwall) Lewis Experiments, Isle of Lewis and North Uist (Ross-shire) Myherin Forest (Cardiganshire) Mynydd Du Forest (Brecon and Monmouthshire) Naver Forest (Sutherland) The Queen's Forest (Inverness-shire) Radnor Forest (Radnorshire and Herefordshire) Rumster Forest (Caithness) Shetland Experiments (Shetland) Shin Forest (Sutherland) South Yorkshire Forest Torrachilty Forest (Ross-shire) Wareham Forest (Dorset)
Trial of species having specialised cultural requirements:	Alice Holt Forest (Hampshire and Surrey) Bagley Wood, St. John's College Estate, near Oxford Bedgebury Forest (Kent and Sussex) Blandford Forest (Dorset) Bradon Forest (Wiltshire) Cannock Chase (Staffordshire) Chilterns Forest, Wendover (Buckinghamshire) Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire) Land's End Forest (Cornwall) Lynn Forest (Norfolk)

CHOICE OF SPECIES FOR AFFORESTATION—*contd.*

Quantock Forest (Somerset)
Queen Elizabeth Forest (Hampshire and Sussex)
South Yorkshire Forest
Stenton Forest (East Lothian, Midlothian and Berwickshire)
Thetford Chase (Norfolk and Suffolk)
Wareham Forest (Dorset)
Wentwood Forest (Monmouthshire)
Westonbirt (Gloucestershire)
Wynyard Forest (County Durham)

ARBORETA

Crarae, Minard Forest (Argyll)
Kilmun, Benmore Forest (Argyll)
National Pinetum, Bedgebury (Kent)
Westonbirt Arboretum (Gloucestershire)

CONTAINER PLANTING

Alice Holt Forest (Hampshire and Surrey)
Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Farigaig Forest (Inverness-shire)
Glen Garry Forest (Inverness-shire)
Gwydyr Forest (Caernarvonshire and Denbighshire)
Naver Forest (Sutherland)
Selm Muir Forest (Midlothian and West Lothian)
Shin Forest (Sutherland)
Thetford Chase (Norfolk and Suffolk)
Tighnabruaich Forest (Argyll)
Towy Forest (Cardiganshire, Brecon and Carmarthenshire)

NUTRITION

Allerston Forest (Yorkshire)
Arecleoch Forest (Ayrshire)
Clocaenog Forest (Denbighshire and Merioneth)
Culbin Forest (Moray and Nairnshire)
Eddleston Water Forest (Peeblesshire)
Exeter Forest (Devon)
Inchnacardoch Forest (Inverness-shire)
Kielder Forest (Northumberland)
Mabie Forest (Kirkcudbrightshire and Dumfriesshire)
Selm Muir Forest (Midlothian and West Lothian)
Shin Forest (Sutherland)
Speymouth Forest (Moray and Banffshire)
Tarenig Forest (Cardiganshire and Montgomeryshire)
Teindland Forest (Moray)
Towy Forest (Cardiganshire, Brecon and Carmarthenshire)
Wareham Forest (Dorest)
Wilsey Down Forest (Cornwall)

FOREST WEED CONTROL

Abinger Forest (Surrey)
Alice Holt Forest (Hampshire and Surrey)
Alton Forest (Hampshire)
Bedgebury Forest (Kent and Sussex)

FOREST WEED CONTROL—*contd.*

Forest of Bere (Hampshire)
Bodmin Forest (Cornwall)
Chiddingfold Forest (Surrey and Sussex)
Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Durris Forest (Aberdeenshire and Kincardineshire)
Exeter Forest (Devon)
Friston Forest (Sussex)
Glentress Forest (Peeblesshire)
Hursley Forest (Hampshire)
Lleyn Forest (Caernarvonshire)
Neroche Forest (Somerset)
New Forest (Hampshire)
Rockingham Forest (Northamptonshire)
Rogate Forest (Sussex)
Taliesin Forest (Cardiganshire and Montgomeryshire)
Thetford Chase (Norfolk and Suffolk)
Wareham Forest (Dorset)

DRAINAGE

Achray Forest (Perthshire)
Forest of Ae (Dumfriesshire)
Allerston Forest (Yorkshire)
Bernwood Forest (Oxfordshire and Buckinghamshire)
Clocaenog Forest (Denbighshire and Merioneth)
Crychan Forest (Brecon and Carmarthenshire)
Hafren Forest (Montgomeryshire)
Halwill Forest (Devon and Cornwall)
Inchnacardoch Forest (Inverness-shire)
Kershope Forest (Cumberland)
Kesteven Forest (Lincolnshire and Rutland)
Kielder Forest (Northumberland)
Lennox Forest (Stirlingshire and Dunbartonshire)
Montreathmont Forest (Angus and Kincardineshire)
Naver Forest (Sutherland)
Newcastleton Forest (Roxburghshire and Dumfriesshire)
Orlestone Forest (Kent)
Rumster Forest (Caithness)
Shin Forest (Sutherland)
Towy Forest (Cardiganshire, Brecon and Carmarthenshire)

CULTIVATION

Achnashellach Forest (Ross-shire)
Allerston Forest (Yorkshire)
Black Isle Forest (Ross-shire)
Clashindarroch Forest (Aberdeenshire)
Clocaenog Forest (Denbighshire and Merioneth)
Dornoch Forest (Sutherland)
Exeter Forest (Devon)
Fetteresso Forest (Kincardineshire)
Hallyburton Forest (Angus and Perthshire)
Hambleton Forest (Yorkshire)
Inshriach Forest (Inverness-shire)
Speymouth Forest (Moray and Banffshire)
Taliesin Forest (Cardiganshire and Montgomeryshire)
Teindland Forest (Moray)
Towy Forest (Cardiganshire, Brecon and Carmarthenshire)

REGENERATION, NATURAL AND ARTIFICIAL

Forest of Ae (Dumfriesshire)
Alice Holt Forest (Hampshire and Surrey)
Allerston Forest (Yorkshire)
Bernwood Forest (Oxfordshire and Buckinghamshire)
The Bin Forest (Aberdeenshire and Banffshire)
Brendon Forest (Somerset)
Coed Morgannwg, Michaelston (Glamorgan)
Cranborne Chase (Dorset and Wiltshire)
Culbin Forest (Moray and Nairnshire)
Culloden Forest (Inverness-shire and Nairnshire)
Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Drumtochty Forest (Kincardineshire)
Garadhban Forest, Lennox (Stirlingshire and Dunbartonshire)
Glenbranter Forest (Argyll)
Hursley Forest (Hampshire)
Kielder Forest (Northumberland)
Kirkhill Forest (Aberdeenshire)
Newcastleton Forest (Roxburghshire and Dumfriesshire)
Portclair Forest (Inverness-shire)
Radnor Forest (Radnorshire and Herefordshire)
Rannoch Forest (Perthshire)
Thetford Chase (Norfolk and Suffolk)

STABILITY OF CROPS

Forest of Ae (Dumfriesshire)
Allerston Forest (Yorkshire)
Clocaenog Forest (Denbighshire and Merioneth)
Coed Morgannwg, Margam (Glamorgan)
Hamsterley Forest (County Durham)
Hartland Forest (Devon and Cornwall)
Kielder Forest (Northumberland)
Newcastleton Forest (Roxburghshire and Dumfriesshire)
Redesdale Forest (Northumberland)
Teindland Forest (Moray)
Wark Forest (Northumberland)
Wauchope Forest, Whitrope (Roxburghshire)

GENETICS

PROPAGATION CENTRES

Alice Holt Forest (Hampshire and Surrey)
Bush Nursery, near Edinburgh
Grizedale Nursery (Lancashire)

TREE BANKS

Alice Holt Forest (Hampshire and Surrey)
Alton Forest (Hampshire)
Bush Nursery, near Edinburgh
Chiddingfold Forest, Witley (Surrey and Sussex)
Newton Nursery, near Elgin (Moray)
Teindland Forest (Moray)
Wauchope Forest (Roxburghshire)
Westonbirt (Gloucestershire)

SEED ORCHARDS

Alice Holt Forest (Hampshire and Surrey)
Bradon Forest (Wiltshire)
Craigvinean Forest (Perthshire)
Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Drumtochty Forest (Kincardineshire)
Glenalmond Forest, Keillour (Perthshire)
Glenalmond Forest, Ledmore (Perthshire)
Lynn Forest (Norfolk)
Newton Nursery, near Elgin (Moray)
Westonbirt (Gloucestershire)
Whittingehame (East Lothian)

PROGENY TRIALS

Alice Holt Forest (Hampshire and Surrey)
Allerston Forest (Yorkshire)
Ardross Forest (Ross-shire)
Aultmore Forest (Banffshire)
Benmore Forest (Argyll)
Bramshill Forest (Berkshire and Hampshire)
Brendon Forest (Somerset)
Chillingham Forest (Northumberland)
Clocaenog Forest (Denbighshire and Merioneth)
Coed Sarnau (Radnorshire)
Coed y Brenin (Merioneth)
Craigvinean Forest (Perthshire)
Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)
Elchies Forest (Moray)
Farigaig Forest (Inverness-shire)
Garcrogo Forest (Kirkcudbrightshire)
Glendaruel Forest (Argyll)
Glenlivet Forest (Banffshire)
Gwydyr Forest (Caernarvonshire and Denbighshire)
Inchnacardoch Forest (Inverness-shire)
Kershope Forest (Cumberland)
Kilmichael Forest (Argyll)
Kilmory Forest (Argyll)
Laurieston Forest (Kirkcudbrightshire)
Monaughty Forest (Moray)
Speymouth Forest (Moray and Banffshire)
Stenton Forest (East Lothian, Midlothian and Berwickshire)
Teindland Forest (Moray)
Thetford Chase (Norfolk and Suffolk)
Tighnabruaich Forest (Argyll)
Towy Forest (Cardiganshire, Brecon and Carmarthenshire)
Wauchope Forest, Whitrope (Roxburghshire)
Westonbirt (Gloucestershire)

PATHOLOGY

FOMES ANNOSUS

The Bin Forest (Aberdeenshire and Banffshire)
Bramshill Forest (Berkshire and Hampshire)
Clocaenog Forest (Denbighshire and Merioneth)
Dartmoor Forest (Devon)
Kerry Forest (Montgomeryshire, Shropshire and Radnorshire)

FOMES ANNOSUS—*contd.*

Lael Forest (Ross-shire)
Radnor Forest (Radnorshire and Herefordshire)
Thetford Chase (Norfolk and Suffolk)

ARMILLARIA MELLEA

Alice Holt Forest (Hampshire and Surrey)
Bramshill Forest (Berkshire and Hampshire)
Chiddingfold Forest (Surrey and Sussex)
Westonbirt (Gloucestershire)

POLYPORUS SCHWEINITZII

Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire)

ELM DISEASE TRIALS

Alice Holt Forest (Hampshire and Surrey)

BACTERIAL CANKER OF POPLAR

Blandford Forest (Dorset)

TOP DYING OF NORWAY SPRUCE

Coed Morgannwg (Glamorgan)

ENTOMOLOGY

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)

ADELGES SPP.

Alice Holt Forest (Hampshire and Surrey)

PINE SHOOT BEETLE: TOMICUS PINIPERDA

Bramshill Forest (Berkshire and Hampshire)

BLACK PINE BEETLE: HYLASTES SPP.

Alice Holt Forest (Hampshire and Surrey)
Thetford Chase (Norfolk and Suffolk)

LARGE PINE WEEVIL: HYLOBIUS ABIETIS

Alice Holt Forest (Hampshire and Surrey)
Kielder Forest (Northumberland)
Ringwood Forest (Dorset and Hampshire)
Thetford Chase (Norfolk and Suffolk)

DOUGLAS FIR SEED WASP: MEGASTIGMUS SPERMOTROPHUS

Brendon Forest (Somerset)
Culloden Forest (Inverness-shire and Nairnshire)
Mortimer Forest (Herefordshire and Shropshire)
New Forest (Hampshire)
Thornthwaite Forest (Cumberland)

LARCH SAWFLY: ANOPLONYX DESTRUCTOR

Drumtochty Forest (Kincardineshire)

PINE LOOPER MOTH: BUPALUS PINIARIUS

Cannock Chase (Staffordshire)

EFFECT OF FERTILISERS

Achray Forest (Perthshire)
Aeron Forest (Cardiganshire)
Arecleoch Forest (Ayrshire)
Borgie Forest, Strathy (Sutherland)
Brendon Forest (Somerset)
Cannock Chase (Staffordshire)
Clocaenog Forest (Denbighshire and Merioneth)
Clwyd Forest (Denbighshire and Flintshire)
Coed Morgannwg (Glamorgan)
Dartmoor Forest (Devon)
Eddleston Water Forest (Peeblesshire)
Exeter Forest (Devon)
Halwill Forest (Devon and Cornwall)
Mabie Forest (Kirkcudbrightshire and Dumfriesshire)
Neroche Forest (Somerset)
Selm Muir Forest (Midlothian and West Lothian)
Shin Forest (Sutherland)
Tarenig Forest (Cardiganshire and Montgomeryshire)
Towy Forest (Cardiganshire, Brecon and Carmarthenshire)
Wareham Forest (Dorset)
Wilsey Down Forest (Cornwall)

NEW PLANTING LOSSES

Arecleoch Forest (Ayrshire)
Aultmore Forest (Banffshire)
Craik Forest (Roxburghshire, Selkirkshire and Dumfriesshire)
Glenerrochty Forest (Perthshire)
Glen Garry Forest (Inverness-shire)
Glenorchy Forest (Argyll)
Kirroughtree Forest (Kirkcudbrightshire)
Leanachan Forest (Inverness-shire and Argyll)
Rannoch Forest (Perthshire)

NEW PLANTING LOSSES—*contd.*

Rumster Forest (Caithness)
Selm Muir Forest (Midlothian and West Lothian)
Shin Forest (Sutherland)
Tornashean Forest (Aberdeenshire)

MENSURATION

The following are experiments in which permanent sample plots are used as assessment units and for growth and yield studies. Forests with replicated experiments are marked with an asterisk (*).

SPACING

Scots pine :	Black Isle Forest, Findon (Ross-shire) Ebbw Forest (Monmouthshire) Roseisle Forest (Moray) Thetford Chase (Norfolk and Suffolk) Tintern Forest (Monmouthshire)
Corsican pine :	Aldewood Forest (Suffolk)
Lodgepole pine :	Slaley Forest (Northumberland and County Durham)
Sitka spruce :	Allerston Forest (Yorkshire) Brecon Forest (Brecon) Clocaenog Forest (Denbighshire and Merioneth) Coed Morgannwg, Rheola (Glamorgan) Gwydyr Forest (Caernarvonshire and Denbighshire)
Norway spruce :	Clocaenog Forest (Denbighshire and Merioneth) Clunes Forest (Inverness-shire) Coed Morgannwg, Rheola (Glamorgan) Glenlivet Forest (Banffshire) Kerry Forest (Montgomeryshire, Shropshire and Radnorshire) Monaughty Forest (Moray)
European larch :	Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire) Fleet Forest (Kirkcudbrightshire) Mortimer Forest (Herefordshire and Shropshire) Radnor Forest (Radnorshire and Herefordshire)
Japanese larch :	Brechfa Forest (Carmarthenshire) Caeo Forest (Carmarthenshire) Coed Morgannwg, Rheola (Glamorgan) Crychan Forest (Brecon and Carmarthenshire) Dalbeattie Forest (Kirkcudbrightshire) Drumtochty Forest (Kincardineshire) Ebbw Forest (Monmouthshire)
Douglas fir :	Allerston Forest (Yorkshire) Brechfa Forest (Carmarthenshire) Ystwyth Forest (Cardiganshire)
Poplar :	Alice Holt Forest (Hampshire and Surrey)

THINNING

Scots pine :	Aldewood Forest (Suffolk) Black Isle Forest, Millbuie (Ross-shire)* Cannock Chase (Staffordshire) Crown Estates, Fochabers, near Speymouth Forest (Moray and Banffshire) New Forest (Hampshire) Thetford Chase (Norfolk and Suffolk)
Corsican pine :	Aldewood Forest (Suffolk) Culbin Forest (Moray and Nairnshire) New Forest (Hampshire) Pembrey Forest (Carmarthenshire) Sherwood Forest (Derbyshire, Yorkshire and Nottinghamshire)* Thetford Chase (Norfolk and Suffolk)*
Sitka spruce :	Forest of Ae (Dumfriesshire)* Ardgartan Forest (Argyll) Brendon Forest (Somerset) Dovey Forest (Merioneth and Montgomeryshire)* Glen Trool Forest (Kirkcudbrightshire)*
Norway spruce :	Bowmont Forest (Duke of Roxburgh's Estate, Roxburghshire)* Cairn Edward Forest, Bennan (Kirkcudbrightshire) Kershope Forest (Cumberland) Monaughty Forest (Moray) Tintern Forest (Monmouthshire)
European larch :	Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire) Murthly Estate (near Strathord Forest, Perthshire)
Japanese larch :	Bodmin Forest (Cornwall) Brechfa Forest (Carmarthenshire) Coed Morgannwg, Rheola (Glamorgan) Drumtochty Forest (Kincardineshire) Glentress Forest (Peebleshire) Stourhead Estate (Wiltshire)
Douglas fir :	Alice Holt Forest (Hampshire and Surrey)* Gwydyr Forest (Caernarvonshire and Denbighshire) Mynydd Du Forest (Brecon and Monmouthshire) Wensum Forest (Norfolk)
Noble fir :	Dovey Forest (Merioneth and Montgomeryshire)
Picea omorica :	Bedgebury Forest (Kent and Sussex)
Oak :	Forest of Dean (Gloucestershire, Herefordshire and Monmouthshire) Hazelborough Forest (Buckinghamshire and Northamptonshire) Micheldever Forest (Hampshire) Wensum Forest (Norfolk)
Beech :	Hampden Estate (Buckinghamshire) Nettlebed Estate (Buckinghamshire)

UNDERPLANTING

Corsican pine, underplanted with Grand fir:	Thetford Chase (Norfolk and Suffolk)
European larch, underplanted with various species:	Dymock Forest (Gloucestershire and Herefordshire) Exeter Forest (Devon)
Oak, underplanted with Western hemlock:	Micheldever Forest (Hampshire)

MIXTURES

Sitka spruce / Lodgepole pine: *Sitka spruce / Japanese larch:*	Beddgelert Forest (Caernarvonshire)
Oak / beech:	Tintern Forest (Monmouthshire)

APPENDIX II

Publications by Staff Members

Reprints of several of the papers listed are available on application to the Librarian. Priced publications issued by the Forestry Commission are available from H.M. Stationery Office at addresses shown on back cover.

AARON, J. R. (1969). Metrication in forestry and the home timber industry. *Timb. Grow.* **34**, 20–25.

Discusses the implication of the change in the light of Government policy, and outlines the advantages which metrication holds for the forestry industry. The reasons behind the Commission's decision are explained, together with the proposed methods of metric measurement for standing and felled timber. Mention is also made of the arrangements for staff training in metrication.

AARON, J. R. (1969). Pros and cons of pruning in conifers. *Q. Jl For.* **63**(4), 295–304.

Pruning in relation to consumer requirement is discussed and the case for and against the practice is argued. The advantages and disadvantages of pruning various species of trees are discussed and the cost of the operation is analysed.

AARON, J. R. (1970). Experiments on drying and scaling close-piled billets at Thetford. *Forest Rec., Lond.* **72** (HMSO 3s. 6d.)

Studies on the effect of species, diameter, season and presence of or absence of a roof were made on close-piled billets of Scots pine and Corsican pine. The main conclusions were that the drying characteristics of the species are quite dissimilar, especially during the late autumn and winter months when virtually no drying occurs in Corsican pine. Volume measurements showed that any " losses " in the solid content of stacked volume are attributable to " setting down " in transit and not to diametric shrinkage.

AARON, J. R. (1970). The future for timber. *Field,* 29th January, p. 182.

Describes how the loss of traditional markets for wood is being more than compensated for by the development of " bulk " markets by the new wood consuming industries, as well as by new uses for solid wood.

ALDHOUS, J. R. (1969). Aerial spraying of forests—Notes for landowners. *Q. Jl For.* **63**(2), 152–155.

While many landowners and their forest staff will be thoroughly familiar with the use of weedkillers applied by knapsack, they are unlikely to have used aircraft as a means of applying weedkillers. Nevertheless, aerial spraying has advantages of speed, and in some circumstances, lower cost.

This paper does not go into details of which chemicals to use; this is discussed fully in Forestry Commission Leaflet 51 (2nd edition 1969 H.M.S.O. 4s.). However, it may help landowners to avoid some of the pitfalls for the inexperienced.

ALDHOUS, J. R. (1969). Aircraft and British forestry. *Q. Jl For.* **63**(2), 105–113.

Aircraft are selected for operations in forestry where wheeled or tracked vehicles cannot get in either because of steep or soft terrain, or because of obstruction by the growing crop, helicopters being used where there are no convenient landing strips for fixed wing aircraft.

Aircraft have until recently played a small part in British forestry. However, between 1967 and 1969 fertilisers will have been spread by helicopter on approximately 50,000 acres of forest.

The need to control insects from the air occurs rarely in British forests, but sizeable blocks are treated at one time when control becomes necessary.

The area of weeds controlled from the air has varied annually from a few hundred to two thousand acres in the last decade but has been made up of many small blocks.

Fence materials have been lifted to inacceessible places on more than a dozen occasions.

There has been no place in British forestry for aerial fire control or commercial aerial photography.

ALDHOUS, J. R. (1969). *Chemical control of weeds in the forest.* Leafl. For. Commn, **51**, 2nd ed. (revised) H.M.S.O. 4s.

Prescriptions are given for the control of herbaceous and woody weeds using 2,4,5–T, 2,4–D, paraquat, diquat, dalapon, ammonium sulphamate, chlorthiamid, maleic hydrazide and dicamba.

Appropriate safety precautions are recommended, with some details of suitable equipment.

ALDHOUS, J. R. (1969). Looking forward. What timber shall we grow and where? *Suppl. Forestry*, pp. 93–98.

A review of current silvicultural and marketing considerations leading to the view that no more than six species ought to be grown for commercial timber production.

ATTERSON, J. (1969). Fertiliser research in Scottish nurseries and forests. *J. Sci. Fd Agric.* **20**(7), 415–416.

The use of fertilisers, particularly slow-release nitrogen fertilisers, in forest nurseries is discussed. In forests, trials have shown unforeseen interactions between applied fertilisers and unforeseen effects of different constituents of particular fertilisers. Future requirements of phosphate rock, phosphate-potash, and urea, the main fertilisers used, are considered.

BEVAN, D. (1969). Philosophy of forest insect control in Britain. *J. Sci. Fd Agric.* **20**(8), 505–506.

It is concluded that, on economic grounds, prevention of infestation by amelioration of the site and improvement in the vigour of the trees is more likely to be practical than remedial spraying of infested trees.

BINNS, W. O. (1969). Fertilisers in forestry—the future. *J. Sci. Fd Agric.* **20**(7), 424–426.

In forestry the long interval between investment in fertilisers and any pay-off, particularly for treatment at planting, means that responses have to be large to pay for the interest accrued; this colours all considerations of crop improvement.

Phosphatic fertilisers are still the only ones used widely; potassium gives useful responses only on deep peats and its relative importance will depend on the amount of this site type afforested in the future; nitrogen is only used experimentally at present, though some promising responses suggest wider future use, especially in the last years of the rotation.

Making sweeping assumptions about the responsiveness of different species and the planting pattern of the future, it is estimated that by the end of the century the Forestry Commission will be using, each year, about 9,000 tons of phosphate rock (5,000 at planting) and 5,000 tons of urea (all on established crops).

BINNS, W. O. (1970). Forests, rainfall and run-off. In *Association of River Authorities Year Book* 1969, pp. 19–23. London.

Foresters are criticized both for wasting water and for causing floods. Forest drains, designed to remove excess water, cause a temporary increase in "flashiness", but careful design and spreading drainage over several years can reduce this. Major floods in Britain are not caused by forest operations, but the forester should always act carefully when draining or cultivating in the uplands. A complete forest cover certainly uses more water than grass does (a) by increased interception of rain and (b) by greater transpiration due to greater foliage area and canopy roughness; the extra energy needed is brought in by the airmass. Where forest replaces grass there will eventually be a slightly reduced quantity of better quality water.

BROWN, R. M. (1969). Herbicides in forestry. *J. Sci. Fd Agric.* **20**(8), 509–512.

This is a review paper on the present use and future potential of herbicides in forestry. After discussing the necessity for weeding, expenditure on weeding and some basic requirements of forest herbicides, the weed problems in Great Britain are broken down into major weed types. These main types are then considered for their importance in forestry and the availability of herbicides to control them.

BURDEKIN, D. A. (1969). The use of cycloheximide for the control of *Didymascella thujina* on Western red cedar (*Thuja plicata*). *Proc. 5th Br. Insectic. Fungic. Conf.*, pp. 558–562.

Didymascella thujina causes a serious needle blight in nursery stock of Western red cedar. The use of cycloheximide to control this disease was reported in 1962. Experiments since that time have been directed towards determining the optimum times and rates of application of this fungicide.

It has been concluded that cycloheximide should be applied at a concentration of 85 ppm of active ingredient and at a rate of 100 gal/acre. Two applications, one at the end of March and the other at the end of April, give excellent control except in nurseries on the west side of the country where a third application in mid-June may be necessary.

(BYROM, N. A. and) BURDEKIN, D. A. (1970). British Records 101. *Drepanopeziza punctiformis* Gremmen. *Trans. Br. mycol. Soc.* **54**(1), 139–141.

Drepanopeziza punctiformis Gremmen, perfect state of *Marrsonina brunnea* (E. & E.) Magn., was recorded for the first time in 1968 in Britain.

CARTER, C. I. (1969). An intermediate form of *Elatobium abietinum* (Walker) (Hem., *Aphididae*) found during the winter in Scotland. *Entomologist's mon. Mag.* **105**, 200.

This short paper records and describes specimens of this aphid found on Sitka spruce that were intermediate between alatae and apterae. The occurrence of these forms together with a developing alate in February 1967 suggests that the photoperiod is unlikely to be the determining factor for the production of winged forms of this species, since in normal seasons the production of winged forms is confined to May and June.

CARTER, C. I. (1969). Three species of adelgids (*Homoptera, Adelgidae*) new to Britain. *Entomologist's mon. Mag.* **105**, 167–169.

Adelges viridana (Cholodkovsky), *Pineus pineoides* (Cholodkovsky) and *P. orientalis* (Dreyfus) have been found to be established in Britain. *A. viridana* appears to be widespread on Japanese and Japanese-type hybrid larch feeding on the stems in the winter and on the long extension shoots in the summer. The connection between *A. viridana* and the bark exfoliation recorded by Crooke (1952) in *Forest Rec., Lond.* **17** is discussed. *P. pineoides* and *P. orientalis* are less common. Details of their host plants, feeding sites, distribution and life cycles are given.

CAUSTON, D. R. (1969). A computer program for fitting the Richards function. *Biometrics* **25**(2), 401–409.

A method is described for fitting Richard's generalization of the logistic function by the method of least squares. The solution of the equations obtained requires the use of an iterative process from given starting values, and these are obtained in the first part of the program by a procedure based on Hartley's method of "internal least squares".

EDLIN, H. L. (1969). Fifty years of forest parks. *Commonw. For. Rev.* **48**(2), 113–126.

Since its foundation in 1919 the Forestry Commission of Great Britain has been continually concerned with the administration of forest parks and similar areas of public access, and it has gained a longer experience of the values and problems involved than any comparable organisation in the country. Its fiftieth anniversary forms a fitting occasion for a review. There are now seven Forest Parks and, with the New Forest, they hold 484,000 acres (188,500 hectares or 752 square miles), roughly one-sixth of all land held by the Commission.

EDLIN, H. L. (1969). 50 years of forestry. *Trees, Lond.* **32**(3), 9–19.

A general account of the Forestry Commission's history and achievements from its formation in 1919 to its Jubilee in 1969.

EDLIN, H. L. (1969). The Forestry Commission in Scotland 1919–1969. *Scott. geogr. Mag.* **85**(2), 84–95.

A popular account of the Forestry Commission's work in Scotland from 1919 to 1969, intended as background reading for teachers and students of geography.

EDLIN, H. L. (1969). *Timber! Your growing investment.* Bookl. For. Commn. **23.** (HMSO 6s. 6d.)

A comprehensive summary of the Forestry Commission progress from its foundation in 1919 to its fiftieth anniversary. Fully illustrated with photographs, maps and graphs.

EDLIN, H. L. (1969). *What wood is that? A manual of wood identification.* Thames & Hudson 42s.

Gives identification features, properties and uses of forty leading timbers on the European and North American markets. Includes actual samples as small veneer sheets of the timbers concerned.

EDLIN, H. L. (1969). Woodland notebook: Catkins in spring. *Q. Jl For.* **63**(2), 113–121.

A review of the inflorescences known as catkins, borne by many common broadleaved trees. The general pattern is for male and female catkins to be separate structures, fairly inconspicuous because they are wind-pollinated, while most open early when trees are leafless. Exceptions occur, as in Sweet chestnut, *Castanea sativa,* which bears conspicuous bisexual catkin, pollinated in part by insects, around midsummer. Male catkins are basically short-lived organs for efficient scattering of pollen. Female catkins, much smaller, develop after fertilisation into distinctive fruits. Northern trees have numerous small fruits and seeds; those native further south may have large, edible seeds, fewer in number.

EDLIN, H. L. (1969). Woodland notebook: Leaves in summer Q. Jl For. **63**(3), 227-236.

The shapes, characters and colours of tree leaves are related to their functions and particular environments. Conifer needles and the leathery-textured, waxy-surfaced leaves of evergreen broadleaved trees are designed to retain water and restrict transpiration. Such trees can withstand both hot sunny summers and cold winters when temperatures limit water intake. Deciduous broadleaved trees transpire water freely, and their thin, soft leaves have varied outlines, many being lobed or compound.

EDLIN, H. L. (1969). Woodland notebook: Broadleaved fruit and seed in autumn. Q. Jl For. **63**(4), 346–355.

Every autumn the broadleaved trees produce a rich crop of fruits and seeds, infinitely more numerous than seems necessary to reproduce their kind. The structure and size of seeds vary remarkably from one species to another, and so do the methods of dispersal. Patterns of nuts, succulent fruits, seed-pods and winged seeds are described, and their significance for the tree-grower is discussed.

EDLIN, H. L. (1970). Woodland notebook: Evergreen broadleaves. Q. Jl For. **64**(1), 49–59.

The British climate is mild enough in winter for certain broadleaved trees to hold functional leaves throughout the year. Only one, the holly, is a common native, but we also claim a woody-stemmed climber, the ivy. Two small evergreen broadleaves, box and strawberry, are native too, but rare, with very restricted natural distributions. All these trees have very hard, dense, even-grained timbers. Arboriculturists have introduced many evergreen broadleaved trees from the Mediterranean region, but none has succeeded as a timber producer. The Mediterranean evergreen oak is used only as an ornamental, or for seaside shelter. Landscape planters have enriched shrubberies with many evergreen bushes, which readily become naturalised. One, the common rhododendron, can become a rampant forest weed, almost impossible to eradicate. Season-linked shade tolerance, whereby these shrubs utilise winter sunlight below a leafless canopy of tall broadleaved trees, gives them effective competitive power.

FRASER, A. I. (1969). Some investigations of the relative development of the crown, stem and root of trees growing on shallow peat soils in Britain. (In Finnish, with English summary). *Suo* **20**, 1–8.

The root system of a tree, while performing the necessary functions of extracting water and nutrients from the soil, and of supporting the tree against wind pressures, comprises a substantial proportion of the total matter in the tree. If the management objective for a forest is to grow and harvest timber then it is desirable that the maximum quantity of material in a tree should be in its stem.

During an investigation into the relative stability against wind forces of trees growing on a range of soil types in Britain, measurements of the fresh weights of the crown, stem and roots of each sample tree were made.

A preliminary analysis of this data, to compare the relative sizes of crown, roots and stem of trees on shallow peat and brown earth soils, has yielded some interesting results. Their value is somewhat limited by the limited objectives when collecting the data, but since there is a lack of comparable information from other sources they may serve a useful purpose in stimulating more detailed investigations.

The better growth of trees growing on brown earth soils as compared with peaty gleys appears to be almost entirely confined to the stem. The average weight of the roots and crowns of samples of the same age are very similar, whereas the stems on the brown earths are frequently more than 50% heavier than those on peaty gleys.

FRASER, A. I. (1969). The use of automatic data loggers in forest research. *Appl. Statist.* **18**, 78–81.

The paper describes a data logging system which has been developed by the Forestry Commission to enable detailed measurements of the forest environment to be recorded directly onto punched paper tape. The conclusion is that modern automatic data loggers are suitable for field recording and are not expensive by comparison with alternative methods when the cost of handling the data is taken into account.

It is considered wise to design a fully integrated system from sensor through data logger to computer, as this reduces the risk of errors and allows variation in the characteristics of the sensors to be handled by the computer rather than by additional electronics.

A number of practical recommendations are made with regard to the operation of such a system.

FRASER, A. I. (1970). The influence of climatic factors on the development of plantation forest structure. In *Aspects of Forest Climates* (ed. J. A. Taylor), *Memo. Dep. Geogr. Univ. Coll. Aberystwyth.* **13**.

The paper describes detailed measurements of the growth of a large number of trees and associated measurements of various climatic factors, including solar radiation, wind and temperature. The results show that the relative growth of individual trees in the stand is influenced as much by climatic factors, as it is by the growth of its neighbours. As a result, different types of canopy structure are developed in different environments.

GRAYSON, A. J. (1969). *Imports and consumption of wood products in the United Kingdon 1950–1967, with forecasts to 1980.* Forest Rec., Lond. **70** (HMSO 6s.)

The values represented by wood products consumed and imported by the United Kingdom are large and growing steadily. The total value of deliveries of wood products from wood manufacturing firms and traders is of the order of £800 millions per year and imports, which have amounted to more than £500 millions since 1964, reached more than £650 millions in 1968. The roundwood supplied from British woodlands accounts for only 8% of the volume of roundwood used in total consumption.

This paper presents statistics on the volume, value and price of deliveries and imports of wood products between 1950 and 1967, and shows how the quantities of deliveries and imports can be related to national income and stock-building in

the economy. On the basis of these relationships and certain assumptions about the effect of price on consumption it is possible to build forecasting models. Forecasts of deliveries and imports are calculated on the basis of two rates of increase in national income and assuming a continuation, but at a lower rate, of the fall in price (in real terms, that is after adjusting for the falling value of money) experienced since 1951.

HAMILTON, G. J. (1969). The dependence of volume increment of individual trees on dominance, crown dimensions, and competition. *Forestry* **42** (2), 133–144.

A study of the volume increment of individual trees over one growing season in a 23-year-old stand of Sitka spruce (*Picea sitchensis* Carr.), indicated that narrow crowned trees were more efficient producers of increment. Other factors being constant, trees of greater girth at breast height were found to be inherently better producers. Trees of the upper canopy were generally more efficient than those of the lower canopy under varying conditions of competition. Shorter periods of growth were recorded in lower canopy trees and with trees under conditions of greater competition.

HOLMES, G. D. (1969). Future trends in forest research. *Suppl. Timb. Trades J.* May, pp. 39–47.

A popular review written on the occasion of the Commission's jubilee, which speculates on the nature of future research particularly that done by the Commission, and the technological changes which could follow. The prospects for increasing productivity both in terms of wood output by improving trees, site, and protection methods, and labour output by systems development and mechanisation, are briefly explored.

KERNAHAN, K. A. (1969). Chemical weeding with "Pharos". *Suppl. Timb. Trades J.* October, p. 24.

A small pump mounted on a sledge enables up to four men to spray herbicides through live reels. They are thus relieved of the burden of carrying heavy knapsack sprayers. The machine can also be used for pumping liquid up to 200 feet up a hillside.

LINDLAY, D. K., and STEWART, D. H. (1969). Data processing in forestry with the aid of Lector. *Appl. Statist.* **18**(1), 98–100.

Lector is a machine which scans data recorded as pencil marks on special forms and punches them onto paper tape ready for computing. The authors record trials and errors made during the 1965 census of woodlands and various other jobs. They conclude that Lector can be used most economically when processing long runs of data of uniform layout.

LINES, R. (1970). Notes on provenance of coniferous forest tree seed for use in Scotland. *Scott. For.* **24**(1), 10-13.

Provenances which are generally suitable, and others which are unsuitable are given for Sitka and Norway spruce, Scots and Lodgepole pine, Douglas fir, European and Japanese larch, Western hemlock and Grand fir, together with brief notes and some references to more detailed papers.

LONGMAN, K. A. (1969). The dormancy and survival of plants in the humid tropics. *Proc. Symp. Soc. expl. Biol.* **23**, pp. 471–478.

Discusses the factors controlling bud dormancy in forest trees and those influencing seed dormancy of certain weed species which colonise open, disturbed ground. Distinct differences were found in the growth habits and responses to photoperiod of budded (grafted) plants and seedlings of *Cedrela odorata*, the former responding more quickly to changes in day-length. The presence or absence of leaves also affected bud-break under long-days and natural days of about 13 hours.

From observations it was noted that older trees have short periods of shoot growth which do not generally coincide with the wettest period.

Dormancy mechanisms of tropical weed species was found to be complex and very different in three species which were investigated.

MASLEN, N. R. (1969). *Cinara brauni* Börner (Homoptera, Aphididae). A new British record. *Entomologist* **102**, 228.

Details are given of a pine feeding aphid (previously known only from central and eastern Europe) which was collected in an insect suction-trap at Alice Holt Lodge in 1968.

MITCHELL, A. F. (1969). Bosnian—the pine for gardens on lime soil. *Gdnrs' Chron.* **166**(15), 12-13.

A short article stressing the unusual merits of this tree (*Pinus leucodermis*) for general planting in gardens. These are its wide tolerance of soils from limestone to thin peats, its resistance to drought and good growth in heavy rainfall, its clean grey bark, neat shape and the brilliant blue-purple cones.

MITCHELL, A. F. (1969). The growth of Grand fir in Britain. *Suppl. Timb. Trades J.* October, pp. 26-27.

A resumé of the growth of the oldest, biggest and most vigorous trees of Grand fir, *Abies grandis*, to show the exceptional rapidity of growth in a wide range of conditions. The one original tree surviving from Douglas' seed of 1831 and another possible original are given with recent dimensions, and examples of great increase in size of a number of trees measured in the early years of the century and in 1931 and recently.

PHILLIPS, D. H. (1969). Fungicides in forestry in Great Britain. *J. Sci. Fd Agric.* **20**(8), 503-504.

In Great Britain, fungicides are used in the forest only for the control of root and stem rot, caused by *Fomes annosus*. In forest nurseries they are employed on a small scale to control damping-off, grey mould (*Botrytis cinera*), needle-cast of pine caused by *Lophodermium pinastri*, needle-cast of larch caused by *Meria laricis*, needle blight of Western red cedar (*Thuja plicata*) caused by *Didymascella thujina* and oak mildew (*Microsphaera alphitoides*).

PHILLIPS, D. H. (1970). A review of *The Biology of Mycorrhiza* by J. L. Harley (Leonard Hill, 1969). *Jl R. hort. Soc.* **95**(3), 138.

PLATT, F. B. W. (1969). Extraction by hydraulic tongs. *Suppl. Timb. Trades J.* October, p. 25.

Light weight agricultural tractors have been used in the pine forests of E. Anglia fitted with manually operated "tongs" for extracting sawlogs and poles. The introduction, experimentally at present, of hydraulically operated tongs has increased the load size, reduced costs and enabled produce to be extracted over greater distances.

PLATT, F. B. W. (1969). Loading sawbench by hydraulics. *Suppl. Timb. Trades J.* October, p. 41

To reduce sick leave caused by sawbench operators lifting the increasing size poles at the produce depot in Thetford Forest, an experimental hydraulic lift has been constructed. Further work to perfect the picking-up mechanism is under way.

PYATT, D. G., HARRISON, D., and FORD, A. S. (1969). *Guide to site types in forests of North and Mid-Wales.* Forest Rec., Lond. **69** (HMSO 8s).

The site classification is applicable to a region comprising slaty rocks of the Cambrian, Ordovician, Silurian and Devonian systems. This region encompasses some 110,000 hectares (275,000 acres) of Forestry Commission land. The site classification is based on soil types, and is presented in the form of three tables. Table 1 lists the soil, topographic and vegetational characteristics of each site type. In the assessment of windthrow hazard pertaining to each site type (Table 2) consideration is given to soil depth and drainage status, and to the degree of topographic exposure of the site. On the most hazardous sites (high hazard) windthrow is expected to be a serious management problem before crops reach 18 metres (60 feet) top height. Table 3 rationalises for each site type the best current practices for cultivation, drainage, choice of major species, fertilisation at planting and as later top-dressing, treatment of weeds and thinning regime.

Fourteen soil/site types are recognised including five shallow soil phases. An estimate of the relative extent of soils in the region as a whole by the four major groups is as follows: brown earths 50 per cent, ironpan soils and related intergrades 20 per cent, surface-water gleys and peaty gleys 25 per cent, deep peats 5 per cent.

ROWE, Judith J. (1969). Research on fencing for forest protection. *Deer* **1**(10), 419, and *J. chart. Ld Ag. Soc.* **69**(2), 56-57.

Research on forest fencing has shown that considerable savings in the material and labour costs of erection can be achieved by using spring steel line wires instead of conventional mild steel line wires. A higher tensile strength is among the properties which give spring steel its ability to retain tension: this reduces the amount of supporting woodwork required. It is also suggested that the most satisfactory specification for deer fencing consists of three line wires carrying woven field netting of hexagonal mesh wire netting. Synthetic fibre netting is not a suitable alternative, particularly since animals can readily become entangled in it.

STEWART, D. H. (1968). Data capture in forestry research. *Statistician* **18**(4), 377–411.

Techniques and instruments which could mechanise and simplify the input of data to computers have been examined by the Forestry Commission's Research Division. This paper reviews some experience gained with commercially-produced devices, both portable and static.

Included as sections are: a list of aims for a modern data-capture system, some notes on progressive mechanisation and automation, a general comparison of continuous and discontinuous recording media, an outline of an experiment designed to test instruments, some comments on bureau working and some guesses at future developments.

Four inferences are made: (1) that familiarity with the organisation's needs and with available equipment logically precedes efficient system design and instrument selection; (2) that the details of acceptable instruments derive from acceptable systems, e.g. that, with the Commission's policy of responsibility for data at source, the forester needs to be able to examine a clear record of any assessment he has encoded; (3) that limited markets for data-capture devices have often precluded their production; (4) that a strong, organised group of statistical users might help to break such deadlocks.

STEWART, D. H. (1969.) Portable magnetic-tape encoders for computer data. *Appl. Statist.* **18**(1), 89–98.

This is a note of some early experiments in which portable dictating machines were used successfully by the Forestry Commission to record computer data for later copy punching. It describes some of the newer portable digital magnetic-tape encoders.

STICKLAND, R. E. (1969). *Caliper for nursery measurements.* For. Equip. Note (FAO) A 59 69.

STICKLAND, R. E. (1969) A caliper for measuring plant diameter. *J. agric. Engng Res.* **14**(3), 290–291.

The above two papers describe a caliper developed to measure the diameter small plants and trees.

THORNE, C. A. (1969). Recording numerical data on Port-a-punch cards. *Appl. Stat.* **18**(1), 88–89.

The uses of Port-a-punch cards as a means of recording numerical data for subsequent machine processing, together with their advantages and disadvantages, are discussed. Port-a-punch cards are the same size as 80-column cards, but have holes in 40 columns embossed for easy removal by means of a stylus.

WARDLE, P. A. (1970). Weather and risk in forestry. In *Weather Economics* (ed. J. A. Taylor), pp. 67–82. Pergamon Press.

Windthrow and fire losses are taken as examples of weather-related risks to forestry investment. The varied incidence of windthrow and fire losses in British Forestry Commission forests is described. In both cases the incidence of damage can be affected

by the management of the crops. In the case of windthrow, investment in drainage long in advance of the time when the trees are susceptible reduces the liability of the crops to be blown. In the case of fire, investment in various types of equipment and barrier and the employment of lookouts, patrols and "fire brigades" increases the likelihood of controlling the spread of a fire. Investment in fire protection can be timed to coincide much more closely with the period when the crop is at risk. The paper discusses methods of assessing the size of investment that is worthwhile, and the weather information which will be useful in making such an assessment.

WINTER, T. G. (1969). Some early and late Lepidoptera. *Entomologist's Rec. J. Var.* **81**(5), 148.

The early appearance of two species of Lepidoptera and the late appearance of five others is recorded. All but one were taken at light at Alice Holt.

WINTER, T. G. (1970). Notes and observations: *Parascotia fuliginaria* (Linnaeus) (Lep., Noctuidae) in Hampshire. *Entomologist's Gaz.* **21**(1), 1.

This moth, regularly taken in the summer of the four years 1966–1969 of light trapping at Alice Holt, was also taken in October 1969. This indicated a second generation in that year. Numbers taken are given together with dates.

WITTERING, W. O. (1969). Grass control by roller. *Suppl. Timb. Trades J.* October, p.21.

The principle of rolling chemical-resistant grasses is being tested. A variable width roller has been built for trial in 1970.

YOUNG, C. W. T. (1969). *Larch canker and dieback.* Leafl. For. Commn **16,** revised (HMSO 1s 6d).

Canker and dieback of European larch, attributed primarily to frost in previous revisions of this Leaflet, are separate disorders. The primary agent in larch canker is the fungus *Trichoscyphella wilkommii* (Hart.) Nannf., and there is reason to suspect that adelgids are a primary cause of epidemic dieback. The disorders are indirectly related in that provenances resistant or susceptible to one disorder are similarly resistant or susceptible to the other. Control is best achieved by planting the least susceptible provenances. Provenances of Sudeten larch give the best combination of resistance, form and volume production. Scottish provenances, which were previously recommended, are unreliable.

(PAWSEY, R. G., and) YOUNG, C. W. T. (1969). A reappraisal of canker and dieback of European larch. *Forestry* **42**(2), 145–164.

Evidence from the assessment of two large European larch provenance experiments replicated on a number of sites in England, Wales and Scotland, and from other observations, suggested that: (a) Larch canker was not caused by frost, but was probably due to primary infection by the fungus *Trichoscyphella willkommii* (Hart.) Nannf. (b) Scottish provenances of European larch were more susceptible to canker and dieback than were Carpathian provenances. (c) Canker and epidemic dieback of European larch were unrelated phenomena, although the relative susceptibility of the provenances examined was similar for both conditions. (d) Dieback appeared to be associated with attacks by *Adelges laricis* Vall.

APPENDIX III

Staff Engaged in Research and Development

As at 31st March, 1970

The main centres for research and development are:

FORESTRY COMMISSION RESEARCH STATION

Alice Holt Lodge,
Wrecclesham,
Farnham, Surrey. Tel. 0420-4 2255

FORESTRY COMMISSION

Northern Research Station,
Roslin,
Midlothian,
Scotland. Tel. 031-445 2176.

Some staff engaged in research and development (or controlled by Director Research) are also stationed at:

FORESTRY COMMISSION

25 Savile Row,
London W1X 2AY. Tel. 01-734 0221.

Research on timber and other forest products is not carried out by the Forestry Commission but by the Ministry of Technology's Forest Products Research Laboratory, Princes Risborough (Tel. 3101), Aylesbury, Buckinghamshire. The Forestry Commission keeps in close touch with this work, some of which is done jointly by the two organisations.

RESEARCH DIVISION

Director	. G. D. Holmes, B.Sc. (*Alice Holt*)
Administration and Finance Officer	. G. H. Bowers (*Alice Holt*)
Director's Secretary	. Mrs. V. O. C. Lampard (*Alice Holt*)
Chief Research Officer (South)	. D. H. Phillips, M.Sc., Ph.D., F.I.Biol. (*Alice Holt*)

(With general responsibilities for research in the Southern areas, and with special responsibilities for research in seed, ecology, pathology and entomology, and for seed supply, publications and photographic services.)

SEED (*Alice Holt*)

G. M. Buszewicz, Mgr. Eng. (For.), Head of Section

Laboratory :	D. C. Wakeman: Mrs. L. S. Elgy, Miss R. E. Crumplin, Miss E. Hart-Dyke
Seed Store and Extractory :	M. D. Witts (Research Forester): T. A. Waddell, L. Crumplin
Office :	Mrs. B. P. Hartley, B.A.

ECOLOGY (*Alice Holt*)

J. M. B. Brown, B.Sc., Dip. For., Head of Section

Research Forester: P. Marsh

PATHOLOGY

Alice Holt

D. A. Burdekin, B.A., Dip.Ag.Sci., M.I.Biol., Head of Section
C. M. Brasier, B.Sc., Ph.D., M.I.Biol.
J. N. Gibbs, M.A., Ph. D.

Research Foresters: C. W. T. Young: B. W. J. Greig, J. E. Pratt, R. G. Strouts, P. J. Webb
Laboratory: E. J. Parker: Miss A. Trusler
Office: B. D. Higgins: Mrs. B. A. Reynolds (Typist)

Northern Research Station

D. B. Redfern, B.Sc., Ph. D.
Research Foresters: J. D. Low: M. Cruickshanks

ENTOMOLOGY

Alice Holt

D. Bevan, B.Sc., Head of Section
Miss J. M. Davies, B.Sc.
Miss J. J. Rowe, B.Sc. (Mammals and Birds)
C. I. Carter, M.Sc., M.I.Biol.
T. M. Scott, B.Sc.

Research Foresters: R. M. Brown, L.I.Biol., L. A. Tee (Mammals): A. R. Barlow*, D. J. Billany, D. Elgy (Mammals), C. J. King, H. M. Pepper (Mammals), P. R. Ratcliffe (Mammals), C. Walker
Laboratory: T. G. Winter: M. Jukes, P. S. Recardo, T. J. Smith
Office: J. Ellison

Northern Research Station

Research Forester: R. C. Kirkland

PHOTOGRAPHY (*Alice Holt*)

I. A. Anderson, F.I.I.P., Head of Section
Mrs. T. K. Evans, F.R.P.S.
Miss H. J. Turner
R. W. Genever (Head Forester)
I. S. D. Hay, Dip.A.D., L.S.I.A. (Illustrator)
Miss M. Trusler
Office: J. G. Jackman

RESEARCH WORKSHOP (*Alice Holt*)

R. E. Stickland
H. G. W. Bodkin, M. F. Johnston, C. H. Bodkin

PUBLICATIONS (*London*)

H. L. Edlin, M.B.E., B.Sc., Dip.For., Head of Section
P. A. Mayne
Mrs. L. D. Piggott

Chief Research Officer (North) . . . B. W. Holtam, B.Sc. (*Northern Research Station*).
(With general responsibilities for research in the Northern areas, and with special responsibilities for research in silviculture, soils, genetics and physiology.)

---

* On unpaid leave at Aberdeen University.

SILVICULTURE (NORTH) (*Northern Research Station*)

D. T. Seal, B.Sc., Head of Section
R. Lines, B.Sc.
A. J. Low, B.Sc., Ph.D.
J. M. Mackenzie, B.Sc.
S. A. Neustein, B.Sc.
G. G. M. Taylor, B.Sc.

Research Foresters		
	N. P. Danby	Northern Research Station
North Scotland Region	A. Macdonald	Fort Augustus
North Scotland Area	A. A. Green, M. K. Hollingsworth	Fort Augustus
North East Scotland Area	G. Bartlett: A. McInnes, N. MacKell	Mid-Ardross, Ross and Cromarty
Central Scotland Region		
Central Scotland Area	E. R. Robson: E. A. Crofts, W. G. Paterson	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: J. B. McNeill	Bush Nursery, Roslin, Midlothian
Mearns Area	J. C. Keenleyside: M. Rodgers	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: W. Brown, J. D. McNeill	Mabie, Dumfriesshire
North England Region		
North East England Area	K. A. S. Gabriel: T. C. Booth*, P. Priestley, J. E. J. White	Wykeham, Scarborough
Borders Area	G. S. Forbes: J. D. Lindsay, A. H. Reid, D. L. Willmott	Kielder by Hexham, Northumberland
North West England Area	D. S. Coutts	Grizedale, nr. Hawkshead, Westmorland

SILVICULTURE (SOUTH) (*Alice Holt*)

R. M. G. Semple, B.Sc., Head of Section
J. R. Aldous, B.A.
R. M. Brown, B.Sc.
J. E. Everard, B.Sc.
A. I. Fraser, B.Sc.
J. Jobling, B.Sc.
A. F. Mitchell, B.A., B.Agric.(For.)

Office : L. W. Thomas: Miss A. Davidge, Miss E. Burnaby, Mrs. V. K. Sims

		Centre
Research Foresters		
South East England Region	R. Hendrie	Alice Holt
South East England Area	P. W. W. Daborn, J. B. H. Gardiner, M. L. Pearce, I. H. Blackmore, H. C. Caistor, D. W. H. Durrant, P. D. Howard	Alice Holt

* On unpaid leave at Aberdeen University.

Research Foresters		*Centre*
Wareham Area	L. A. Howe: G. F. Farrimond, 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: D. J. Rice	Exeter
Dean and South Wales Area	F. Thompson: A. J. A. Graver, R. M. Keir, F. R. W. Stevens	Dean
Westonbirt Area	E. Leyshon: C. W. Webber	Westonbirt Arboretum
North Wales Region	G. Pringle	Betws y Coed
North Wales Area	G. A. Bacon: D. Downs	Betws y Coed
Mid-Wales Area	D. G. Tugwell: P. A. Gregory, C. J. Large	Knighton, Radnor
East England Region		
Kennington Area	F. S. Smith	Kennington, nr Oxford
East England Area	R. M. Ure: R. E. A. Lewis, K. Mills, D. J. Williams	Santon Downham, nr Thetford

SOILS

Alice Holt

W. O. Binns, M.A., B.Sc., Ph.D., Head of Section
W. H. Hinson, B.Sc., Ph.D.
G. P. Moffatt, M.Sc.

Research Foresters: D. F. Fourt, L.I.Biol: A. E. Coates: I. G. Carolan

Laboratory: R. Carnell: Miss S. A. Dabek, E. Darlington, Mrs. C. Y. Haggett, Miss C. E. Spinney

Northern Research Station

D. G. Pyatt, B.Sc.

Research Forester: T. E. Radford

GENETICS

Northern Research Station

R. Faulkner, B.Sc., Head of Section
A. M. Fletcher, B.Sc., Ph.D., A.I.W.Sc.

Research Foresters: C. McLean (Bush Nursery, Roslin, Midlothian), M. T. T. Phillips (Newton, Elgin): D. S. Coutts (Grizedale, Lancs).

Alice Holt

R. C. B. Johnstone, B.Sc.For., M.Sc.

Research Foresters: I. J. M. Dawson: R. B. Collins, G. Simkins, G. C. Webb (Westonbirt, Glos.)

Laboratory: Miss L. S. Devereux

Office: F. H. Khawaja

PHYSIOLOGY

Northern Research Station

K. A. Longman, B.Sc., Ph.D., Head of Section

Research Forester: J. Howarth

Laboratory: D. F. Sangster

---

* On detached duty at Forest Products Research Laboratory, Princes Risborough.

STATISTICS

Alice Holt

R. S. Howell, Head of Section
D. H. Stewart, B.Sc., M.I.Biol.
R. C. Boswell, B.Sc.
C. J. Ashton
Miss C. M. Ironside

Assistants: C. A. Thorne: I. D. Mobbs, I. Pollock, M. H. M. Webb (Research Foresters): Mrs. R. J. F. Glynn, Miss E C. Bridger, Mrs. E. Butler, Mrs. S. D. James, Mrs. S. M. Nicholls (Machine Operators)

Office: N. A. Trollope: Mrs. U. Schofield (Typist)

Northern Research Station

D. R. Causton, B.Sc., M.Sc., Ph.D.
Mrs. J. M. Boyd

Assistants: J. Baird (Research Forester): Miss F. M. K. Farquharson (Machine Operator): Miss L. Lennon (Machine Assistant)

RESEARCH INFORMATION SECTION (*Alice Holt*)

O. N. Blatchford, B.Sc., A.I.Inf.Sc., Head of Section
S. H. Sharpley
F. C. Fraass
Miss A. M. Welch
Mrs. L. D. Birchall (Typist)

ADMINISTRATIVE STAFF

Alice Holt

Deputy Administration and Finance Officer:	W. D. Wardrop
Establishment:	P. H. Hamilton: Miss B. Parfitt, Mrs. A. C. Vandeleur-Boorer: Miss H. J. Crooks
Finance:	J. J. Richardson: Miss G. B. Hayden, Miss P. A. M. McCunnin, A. R. Taggart
General Services:	Miss S. B. Page: J. M. Littler: Mrs. M. Butt
Typists:	Miss M. Hopkin (Superintendent): Mrs. J. G. Anderson, Mrs. E. L. Allen, Mrs. A. M. Clements, Mrs. B. E. Dickinson, Mrs. J. Richardson, Mrs. E. A. Walters
Photoprinter:	Mrs. S. A. M. Bridger
Telephone Operator:	Mrs. E. A. R. Empson
Messengers:	Mrs. M. Greenwood, Mrs. J. M. Plant
Gardens:	H. Farr
Workshop:	R. H. Butt, R. D. Butt: E. V. Tattam

Northern Research Station

Office:	P. Hunter: M. Abrahams, Miss M. E. Grant: Mrs. E. M. Hiddleston
Typists:	Miss A. J. Henderson, Miss S. M. Taylor, Mrs. R. J. K. Webber
Telephone Operator:	Mrs. A. A. Martin

MANAGEMENT SERVICES DIVISION

Director of Management Services . . . . J. Q. Williamson, B.Sc. (*London*)
Deputy Director of Management Services. . . D. R. Johnston, M.A. (*Alice Holt*)

(With special responsibilties for Planning and Economics.)

PLANNING AND ECONOMICS (*Alice Holt*)

D. R. Johnston, M.A., Head of Branch
R. T. Bradley, M.A.
A. J. Grayson, M.A., B.Litt.
G. J. Hamilton, M.Sc.
G. M. L. Locke, B.Sc.
A. M. Mackenzie (*Edinburgh*)
J. F. Morgan, B.Sc.
D. B. Paterson, B.Sc. (*Northern Research Station*)
R. M. Sidaway, M.A.
L. M. Simpson, B.Sc.
P. A. Wardle, B.Sc.
E. R. Adams, B.Sc.

Foresters: Based on Alice Holt: J. McN. Christie, G. M. Haggett, G. D. Spiller: P. Bond, J. Dickinson, E. J. Fletcher, M. A. Mitchell, R. Q. Oakes.

Based on Edinburgh: J. Armstrong.

Working Plans and Mensuration:

Field Staff (Foresters)—England and Wales

R. F. E. Bartlett, D. D. G. Davies, A. C. Dover: C. R. Alpe, A. Beardsley, D. A. Bell, P. E. Cliffe, M. A. Colley, J. S. Conduit, E. B. Cordery, M. W. Davies, D. M. Dymond, D. Ellis, I. C. Embry, G. G. Green, P. Green, E. R. Hall, G. E. Harrison, D. R. Hornby, P. Hutchinson, G. I. Jones, E. J. Jury, C. E. G. Lawes, G. H. MacGowan, R. McKinley, A. C. Miller, P. J. Noot, D. W. Price, J. J. Pruden, J. L. Read, J. B. Richards, R. J. Rogers, K. G. Shuker, R. N. Smith, L. G. Starling, W. B. Sturges, F. G. Thurlow, R. C. B. Vines, P. C. Westley, M. D. Whitlock, M. R. Wigzell, J. L. Williams.

Field Staff (Foresters)—Scotland

J. Straiton: J. C. Anderson, D. A. Beaton, J. R. Boyd, A. R. Brown, N. C. Bunyan, W. Elger, K. Fryer, A. N. Gordon, P. J. Humphries, C. R. Liversidge, J. Livingstone, P. J. Lodge, I. D. Macdonald, R. J. A. MacDuff, L. D. Macrae, D. Main, F. H. Millwood, I. M. Parrott, J. C. Phillipson, A. A. J. Rees, P. G. Risby, P. L. W. Simon, A. E. Surman, F. G. O. Thom, B. Thompson, J. J. Waddell, G. A. Watson, P. J. Williams.

Soil Survey (Foresters)

J. Davidson, D. A. T. Douglas, A. S. Ford, J. S. Innes, G. N. Kearns, W. Thomson, F. Webster.

Office

J. Empson: Mrs. M. E. Douglas

WORK STUDY (*Alice Holt*)

L. C. Troup, B.Sc., Head of Branch
J. V. St. L. Crosland, B.Sc.
T. W. G. Coulson, B.Sc. (*Langholm*)
A. A. Cuthbert, B.Sc. (*Dumfries*)
J. A. Drummond, B.Sc. (*Kilmun, Argyll*)
D. M. Hughes, B.Sc. (*Dolgellau*)
J. S. Oakley, B.Sc. (*Inverness*)
A. H. A. Scott, B.Sc. (*Brockenhurst*)
A. R. Sutton, B.Sc. (*Brecon*)

D. H. Wallace, B.Sc. (*Inverness*)
A. Whayman (*Hawick*)
W. O. Wittering

Machinery Research and Development:

R. B. Ross, A.M.I.Mech.E.
K. A. Kernahan
W. S. Mackenzie

Roads Research and Development:

K. T. Davidson, B.Sc., A.M.I.H.E. (*Inverness*)

Communications:

D. E. W. Blandford (*Bristol*)

Foresters:

A. A. Lightly (*Communications, Bristol*), D. J. Morris (*Brecon*), D. M. Percy (*Brockenhurst*), F. B. W. Platt (*Santon Downham, Suffolk*), R. J. Reid (*Brecon*), E. V. Rogers (*Olney, Bucks*), P. Wood (*Santon Downham, Suffolk*): D. J. Amer (*Communications, Perth*), C. E. Allison (*Brockenhurst*)*, St. J. G. D. Bland-Flagg (*Brockenhurst*), J. Campbell (*Inverness*), C. F. Dampney (*Brockenhurst*), P. P. Davis (*Dolgellau*), M. J. Day (*Santon Downham, Suffolk*), P. Featherstone (*Kielder*), J. Grieve (*Kilmun, Argyll*), M. J. R. Ingoldby (*Olney, Bucks*), G. H. Ivison (*Byrness*), P. W. Lansdown (*Brockenhurst*), R. S. MacInnes (*Ae*), A. S. Rawlinson (*Inverness*), I. Richardson (*Dolgellau*), T. R. Sawyer (*Brecon*), G. O. Smith (*Kilmun, Argyll*), B. D. Symes (*Langholm*), W. Trotter (*Kilmun, Argyll*), K. E. Wallis (*Ae*), V. Williams (*Brecon*).

Office:

R. D. Duncan: R. Powell

HARVESTING AND MARKETING DIVISION

J. R. Aaron, M.A., M.Sc., A.I.W.Sc. (*London*)
J Meechan (Forester) (*Alice Holt*)

* On secondment to FAO, Zambia.

APPENDIX IV

Metric Equivalents of Values used in this Report

The following conversion factors are taken from the basic units of the Système International (S.I.) (British Standard 350: Part 1: 1959). Exact factors are marked with an asterisk.

Length

1 inch (in) = 2·5400 centimetres (cm)*
1 foot (ft) = 0·3048 metres (m)*
1 yard (yd) = 0·9144 metres (m)*
1 chain = 20·1168 metres (m)*
1 mile = 1·609344 kilometres (km)*

Area

1 square inch (in^2)	= 6·4516 square centimetres (cm^2)*
1 square foot (ft^2)	= 0·09290 square metres (m^2)
1 square foot quarter girth (ft^2 qg)	= 0·1183 square metres (m^2)
1 square yard (yd^2)	= 0·8361 square metres (m^2)
1 acre	= 0·4047 hectares (ha)
1 square mile	= 259·0 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 bushel	= 0·0363687 cubic metres (m^3)

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)	= 0·0890916 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 (litres/ha)

Weight/Volume

1 pound per gallon (lb/gal)	= 0·09976 kilogrammes per litre (kg/litre)
1 ounce per bushel (oz/bushel)	= 0·804490 kilogrammes per cubic metre (kg/m^3)

Linear Velocity

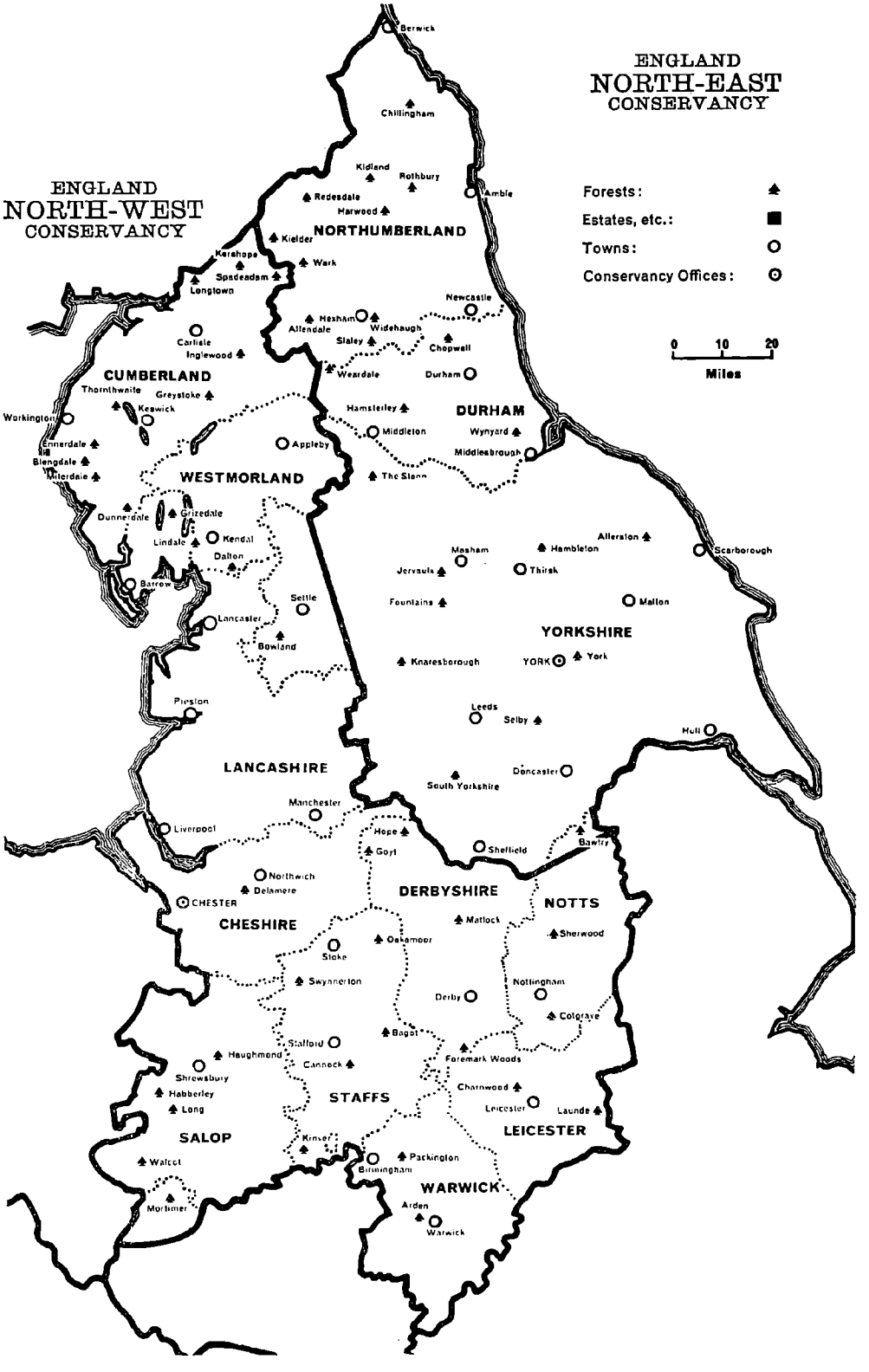
1 foot per second (ft/s) = 0·3048 metres per second (m/sec)*

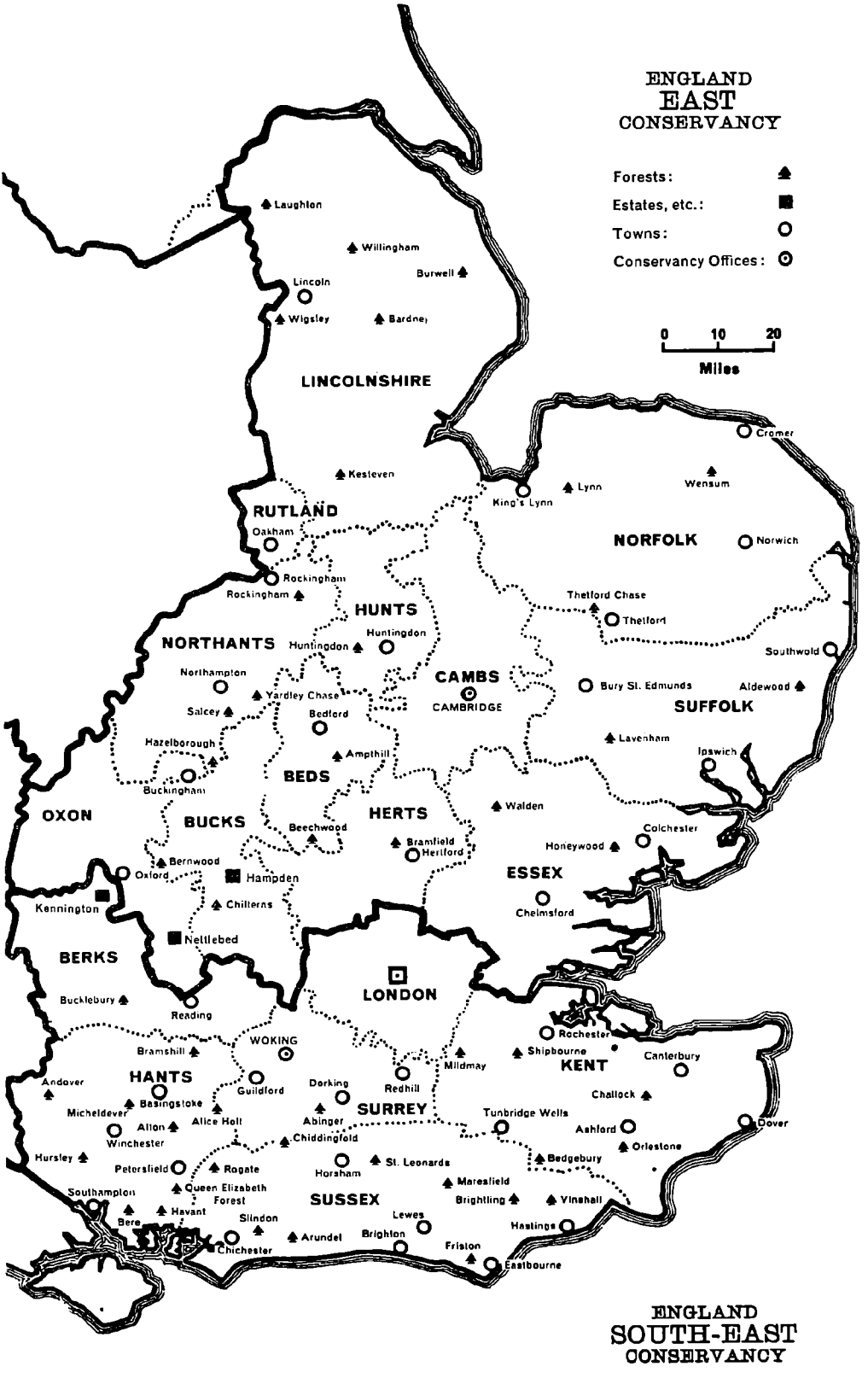
Note. Forestry Commission Booklet 5. *Conversion Tables for Research Workers in Forestry and Agriculture* (HMSO 1960, 6s. 6d.) gives a more comprehensive series of equivalents, with reciprocals.

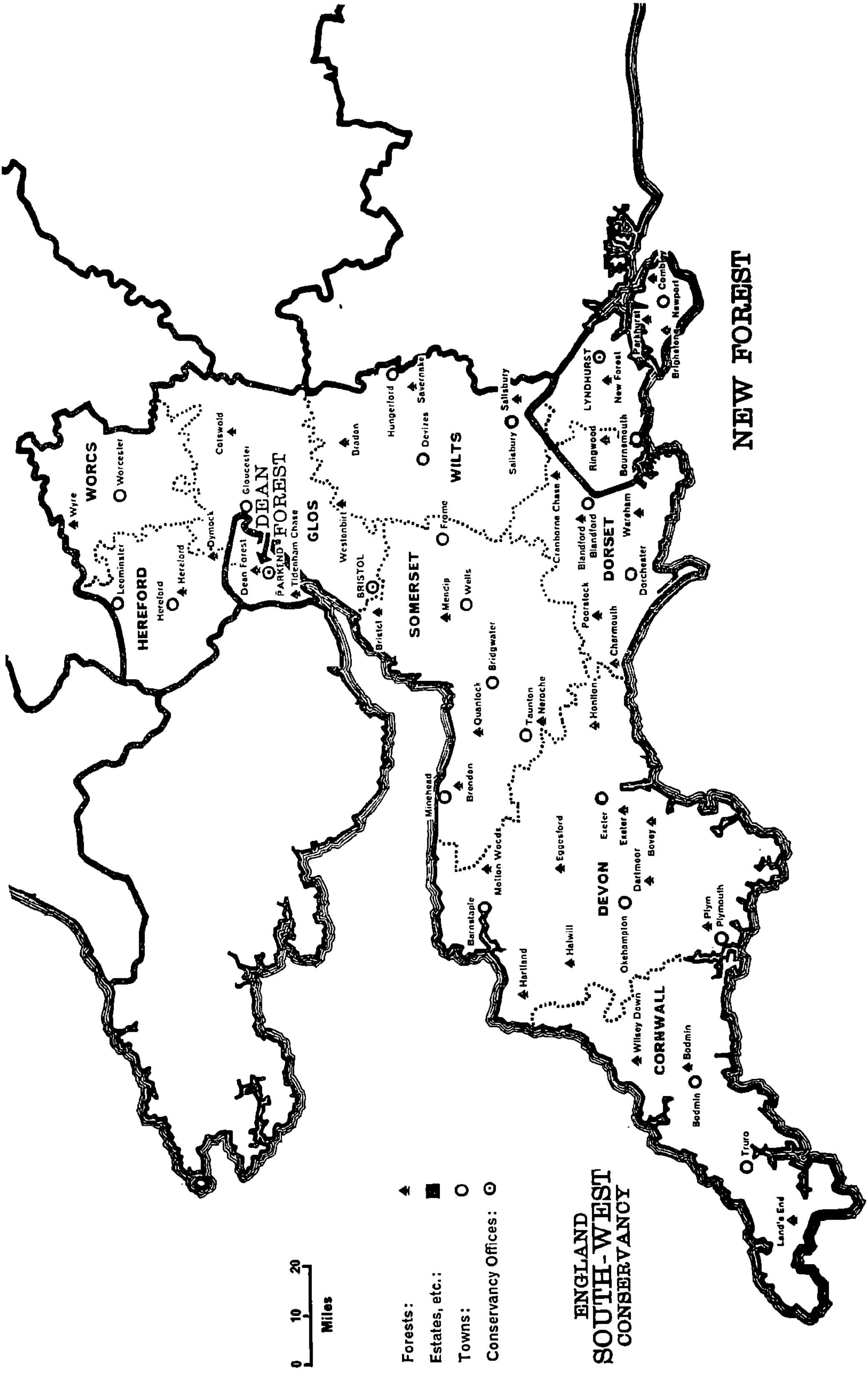
Booklet 30, *Metric Conversion Tables and Factors for Forestry*, is in the press.

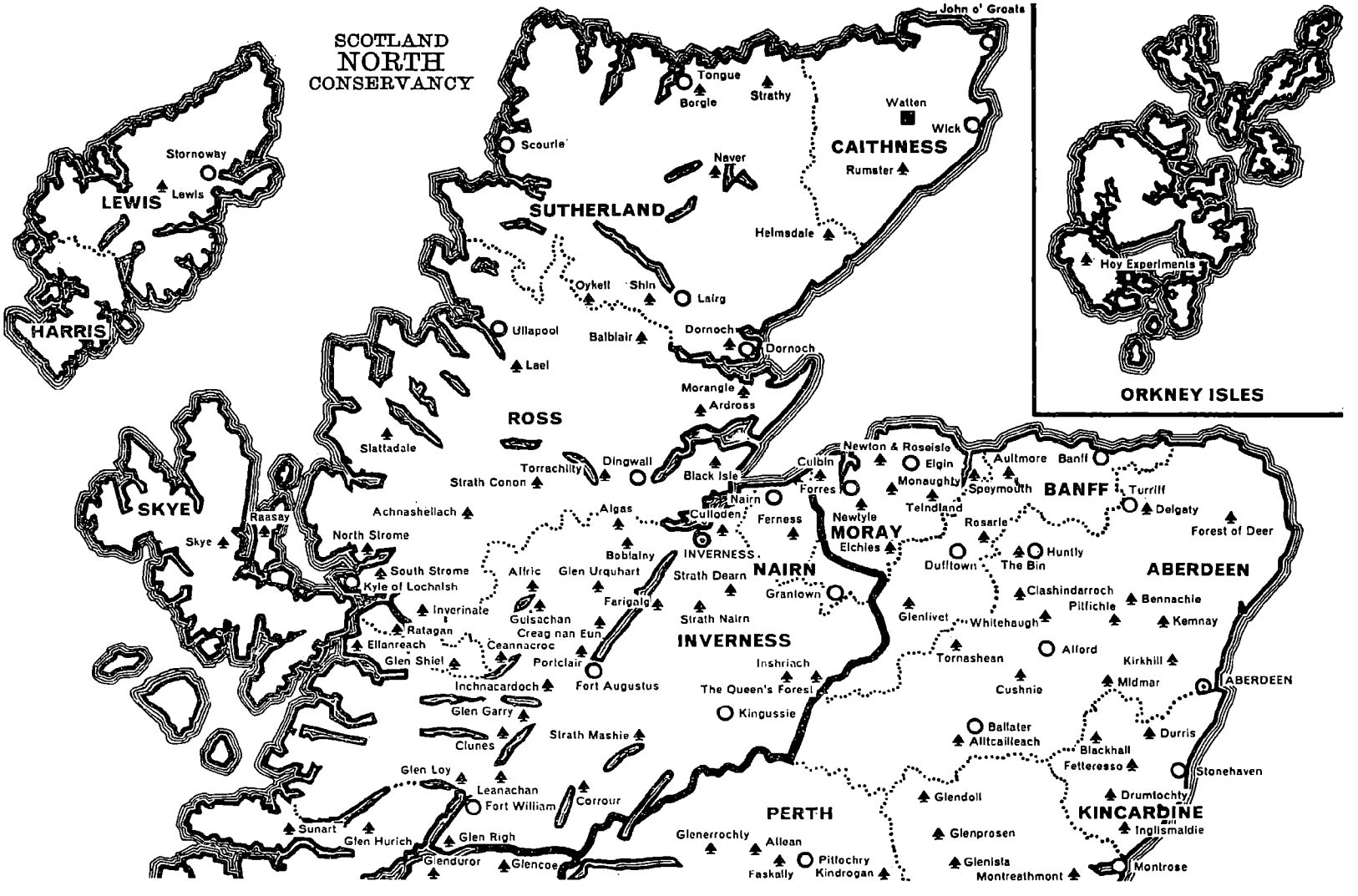
MAPS

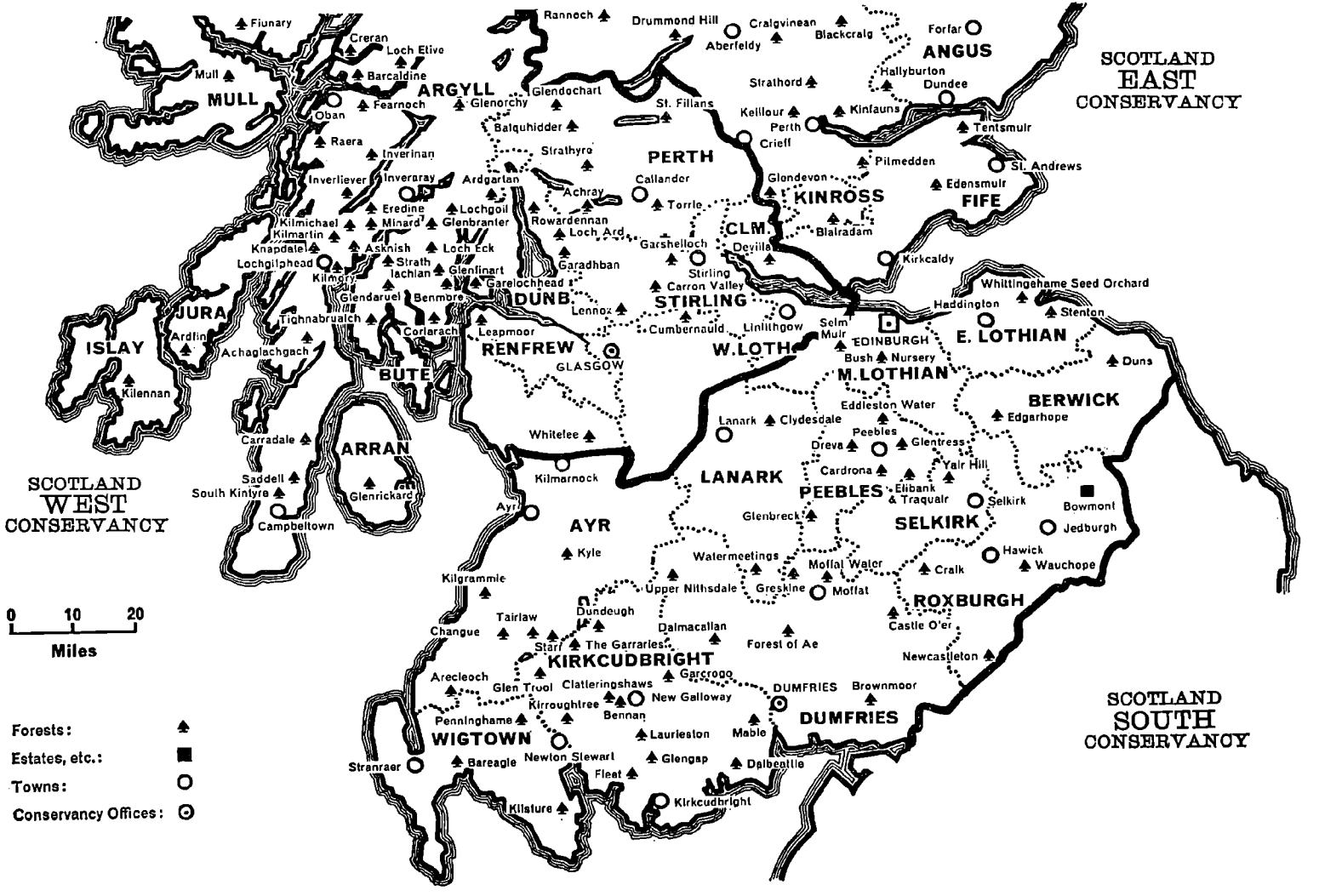
Showing situations of Commission Forests and Experimental Projects listed in Appendix I.

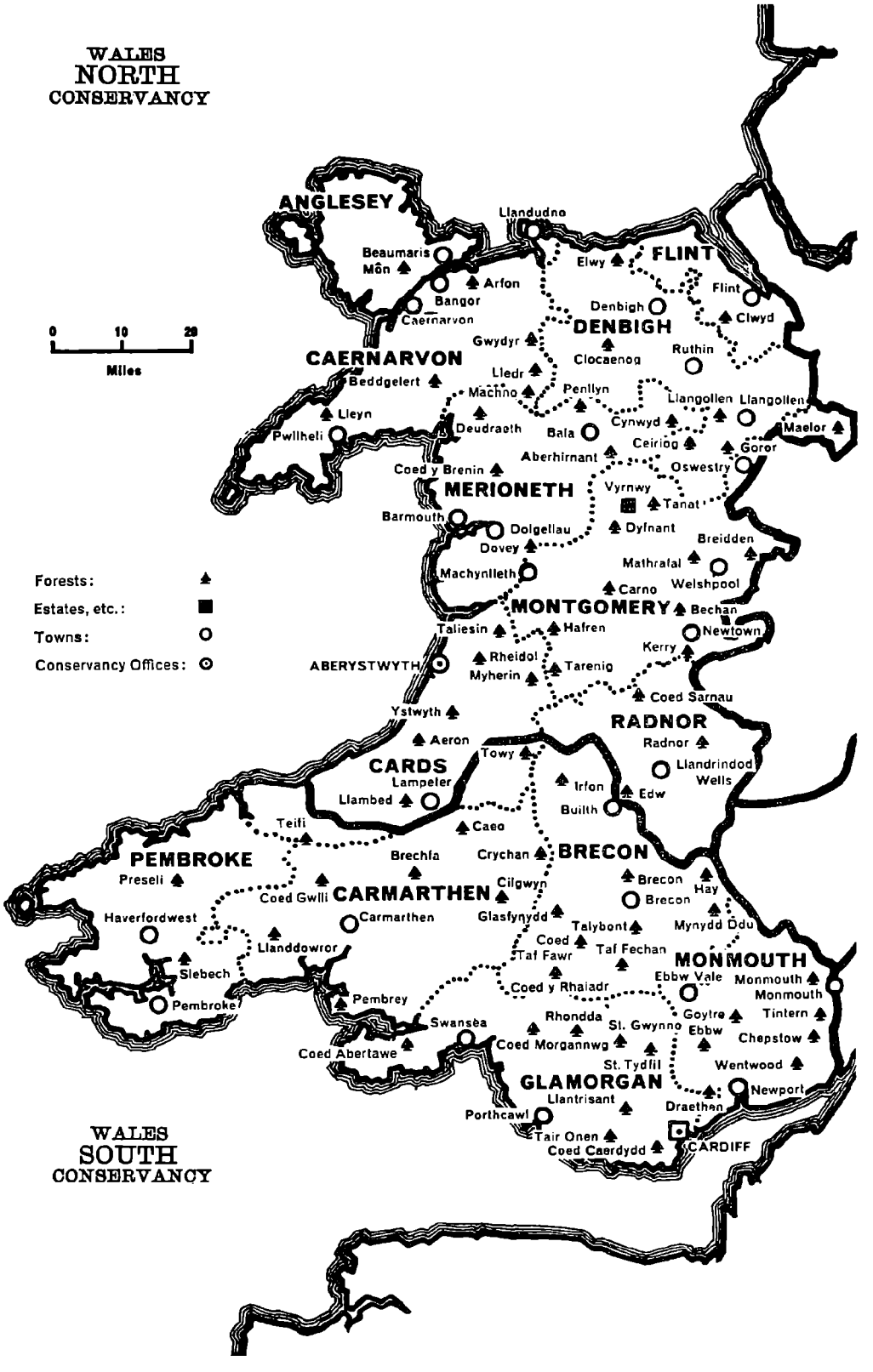

ENGLAND
NORTH-EAST
CONSERVANCY
Forests:
Estates, etc.:
Towns:
Conservancy Offices:
0 10 20
Miles
ENGLAND
NORTH-WEST
CONSERVANCY
Berwick
Chillingham
Kidland
Rothbury
Amble
Redesdale
Harwood
Kielder
NORTHUMBERLAND
Wark
Kershope
Spadeadam
Longtown
Newcastle
Hexham
Allendale
Widehaugh
Slaley
Chopwell
Carlisle
Inglewood
Weardale
Durham
CUMBERLAND
Thornthwaite
Greystoke
Keswick
Workington
Hamsterley
DURHAM
Middleton
Wynyard
Middlesbrough
Ennerdale
Blengdale
Miterdale
Appleby
The Slenn
WESTMORLAND
Dunnerdale
Grizedale
Lindale
Kendal
Dalton
Barrow
Alleraton
Scarborough
Masham
Hambleton
Jervaulx
Thirsk
Settle
Fountains
Malton
Lancaster
YORKSHIRE
Bowland
Knaresborough
YORK
York
Preston
Leeds
Selby
Hull
LANCASHIRE
Doncaster
South Yorkshire
Manchester
Liverpool
Hope
Goyt
Sheffield
Barnsley
Northwich
Delamere
CHESTER
DERBYSHIRE
NOTTS
CHESHIRE
Matlock
Sherwood
Oakamoor
Stoke
Swynnerton
Nottingham
Derby
Colonaye
Bagot
Stafford
Haughmond
Cannock
Foremark Woods
Shrewsbury
Charnwood
Habberley
Long
STAFFS
Leicester
Launde
LEICESTER
SALOP
Kinver
Packington
Birmingham
Walcot
WARWICK
Mortimer
Arden
Warwick


ENGLAND
EAST
CONSERVANCY
Forests:
Estates, etc.:
Towns:
Conservancy Offices:
0 10 20
Miles
Laughton
Willingham
Burwell
Lincoln
Wigsley
Bardney
LINCOLNSHIRE
Cromer
Kesteven
Lynn
Wensum
King's Lynn
RUTLAND
Oakham
NORFOLK
Norwich
Rockingham
Rockingham
Thetford Chase
HUNTS
Thetford
Huntingdon
NORTHANTS
Huntingdon
Southwold
Northampton
CAMBS
Bury St. Edmunds
Aldewood
Yardley Chase
CAMBRIDGE
Salcey
Bedford
SUFFOLK
Hazelborough
Lavenham
Ampthill
Ipswich
BEDS
Buckingham
OXON
BUCKS
HERTS
Walden
Beechwood
Colchester
Bramfield
Hertford
Honeywood
Bernwood
Oxford
Hampden
ESSEX
Kennington
Chilterns
Chelmsford
Nettlebed
BERKS
LONDON
Bucklebury
Reading
Rochester
WOKING
Shipbourne
Canterbury
Bramshill
Mildmay
KENT
Andover
HANTS
Guildford
Dorking
Redhill
Challock
Basingstoke
Micheldever
Alice Holt
Abinger
SURREY
Tunbridge Wells
Alton
Ashford
Dover
Winchester
Chiddingfold
Orlestone
Hursley
Bedgebury
Petersfield
Rogate
Horsham
St. Leonards
Maresfield
Queen Elizabeth
Forest
Brightling
Vinehall
Southampton
Havant
SUSSEX
Lewes
Hastings
Bere
Slindon
Arundel
Brighton
Friston
Chichester
Eastbourne
ENGLAND
SOUTH-EAST
CONSERVANCY


ENGLAND
SOUTH-WEST
CONSERVANCY
NEW FOREST
DEAN FOREST
Forests:
Estates, etc.:
Towns:
Conservancy Offices:
0 10 20
Miles
WORCS
HEREFORD
GLOS
WILTS
SOMERSET
DORSET
DEVON
CORNWALL
BRISTOL
LYNDHURST
PARKEND
Wyre
Worcester
Leominster
Hereford
Dymock
Gloucester
Cotswold
Dean Forest
Tidenham Chase
Westonbirt
Bristol
Hungerford
Savernake
Devizes
Bradon
Salisbury
Frome
Mendip
Wells
Bridgwater
Quantock
Taunton
Neroche
Brendon
Minehead
Mellon Woods
Barnstaple
Hartland
Halwill
Eggesford
Exeter
Bovey
Dartmoor
Okehampton
Plym
Plymouth
Wilsey Down
Bodmin
Truro
Land's End
Honiton
Charmouth
Poorstock
Dorchester
Blandford
Wareham
Cranborne Chase
Ringwood
Bournemouth
New Forest
Parkhurst
Brighstone
Newport
Combley


SCOTLAND
NORTH
CONSERVANCY
John o' Groats
Tongue
Borgie
Strathy
Watten
Wick
CAITHNESS
Rumster
Scourie
Naver
SUTHERLAND
Helmsdale
Oykell
Shin
Lairg
Stornoway
LEWIS
Lewis
HARRIS
Ullapool
Lael
Balblair
Dornoch
Dornoch
Morangie
Ardross
ROSS
Slattadale
Torrachilty
Dingwall
Strath Conon
Black Isle
Culbin
Forres
Nairn
Culloden
Ferness
Newton & Roseisle
Elgin
Monaughty
Teindland
Aultmore
Banff
Speymouth
BANFF
Turriff
Delgaty
Forest of Deer
Rosarie
Huntly
The Bin
Dufftown
Newtyle
MORAY
Elchies
Achnashellach
Algas
Bobialny
INVERNESS
Raasay
Skye
SKYE
North Strome
South Strome
Kyle of Lochalsh
Alfric
Glen Urquhart
Strath Dearn
NAIRN
Granlown
Farigaig
Strath Nairn
INVERNESS
Inverinate
Gulsachan
Creag nan Eun
Ratagan
Ellanreach
Ceannacroc
Glen Shiel
Portclair
Fort Augustus
Inchnacardoch
Glen Garry
Clunes
Strath Mashie
Inshriach
The Queen's Forest
Kingussie
Glenlivet
Whitehaugh
Tornashean
Alford
Clashindarroch
Bennachie
Pitfichie
Kemnay
Kirkhill
Cushnie
Mldmar
ABERDEEN
ABERDEEN
Ballater
Alltcailleach
Durris
Blackhall
Fetteresso
Stonehaven
Glendoll
Drumtochty
KINCARDINE
Inglismaldie
Glenprosen
Glenisla
Montreathmont
Montrose
Glen Loy
Leanachan
Fort William
Corrour
Sunart
Glen Hurich
Glen Righ
Glenduror
Glencoe
PERTH
Glenerrochly
Allean
Pitlochry
Faskally
Kindrogan
Hoy Experiments
ORKNEY ISLES


SCOTLAND
WEST
CONSERVANCY
SCOTLAND
EAST
CONSERVANCY
SCOTLAND
SOUTH
CONSERVANCY
MULL
ARGYLL
ANGUS
PERTH
KINROSS
FIFE
CLM.
STIRLING
DUNB.
RENFREW
W.LOTH
E. LOTHIAN
M.LOTHIAN
BERWICK
JURA
ISLAY
BUTE
ARRAN
LANARK
PEEBLES
SELKIRK
AYR
ROXBURGH
KIRKCUDBRIGHT
WIGTOWN
DUMFRIES
EDINBURGH
GLASGOW
Fionary
Creran
Loch Etive
Mull
Barcaldine
Oban
Fearnoch
Glenorchy
Glendochart
Rannoch
Drummond Hill
Craigvinean
Aberfeldy
Blackcraig
Forfar
Hallyburton
Dundee
Strathord
Kellour
Perth
Crieff
Kinfauns
Tentsmuir
St. Fillans
Balquhidder
Strathyre
Raera
Inverinan
Inverliever
Inverawe
Ardgartan
Achray
Callander
Torrie
Glendevon
Pilmedden
St. Andrews
Edensmuir
Eredine
Lochgoil
Glenbranter
Kilmichael
Minard
Kilmartin
Knapdale
Asknish
Loch Eck
Lochgilphead
Kilmory
Strath Iachlan
Glenfinart
Garelochhead
Rowardennan
Loch Ard
Garadhban
Garshelloch
Stirling
Carron Valley
Deville
Blairadam
Kirkcaldy
Whittingehame
Seed Orchard
Haddington
Stenton
Glendaruel
Benmore
Tighnabruaich
Corlarach
Leapmoor
Lennox
Cumbernauld
Linlithgow
Selm Muir
Bush Nursery
Duns
Ardfin
Achaglachgach
Kilennan
Carradale
Whitelee
Eddleston Water
Lanark
Clydesdale
Peebles
Edgarhope
Dreva
Glentress
Cardrona
Yair Hill
Elibank & Traquair
Selkirk
Bowmont
Jedburgh
Hawick
Wauchope
Cralk
Saddell
South Kintyre
Campbeltown
Glenrickard
Kilmarnock
Ayr
Glenbreck
Kyle
Watermeetings
Moffat Water
Greskine
Moffat
Kilgrammie
Upper Nithsdale
Dundeugh
Tairlaw
Changue
Dalmacallan
Forest of Ae
Castle O'er
Newcastleton
Start
The Garraries
Garcrogo
Arecleoch
Glen Trool
Clatteringshaws
Kirroughtree
New Galloway
Bennan
Brownmoor
Penninghame
Laurieston
Mable
Stranraer
Bareagle
Newton Stewart
Glengap
Dalbeattie
Fleet
Kirkcudbright
Kilsture
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
Clwyd
DENBIGH
Gwydyr
Clocaenog
Ruthin
CAERNARVON
Lledr
Beddgelert
Machno
Penllyn
Llangollen
Llangollen
Lleyn
Pwllheli
Deudraeth
Bala
Cynwyd
Ceiriog
Maelor
Goror
Aberhirnant
Oswestry
Coed y Brenin
MERIONETH
Vyrnwy
Tanat
Barmouth
Dolgellau
Dyfnant
Dovey
Breidden
Mathrafal
Machynlleth
Welshpool
Carno
MONTGOMERY
Bechan
Taliesin
Hafren
Newtown
Kerry
ABERYSTWYTH
Rheidol
Myherin
Tarenig
Coed Sarnau
Ystwyth
RADNOR
Aeron
Radnor
Towy
CARDS
Lampeter
Llandrindod
Wells
Irfon
Llambed
Edw
Builth
Teifi
Caeo
PEMBROKE
Brechfa
Crychan
BRECON
Preseli
Coed Gwili
CARMARTHEN
Cilgwyn
Brecon
Hay
Brecon
Haverfordwest
Carmarthen
Glasfynydd
Talybont
Mynydd Ddu
Coed
Taf Fechan
Llanddowror
Taf Fawr
MONMOUTH
Slebech
Ebbw Vale
Monmouth
Monmouth
Coed y Rhaiadr
Pembroke
Pembrey
Rhondda
Goytre
Tintern
Swansea
Sl. Gwynno
Ebbw
Chepstow
Coed Morgannwg
Coed Abertawe
St. Tydfil
Wentwood
GLAMORGAN
Newport
Llantrisant
Draethen
Porthcawl
Tair Onen
Coed Caerdydd
CARDIFF
WALES
SOUTH
CONSERVANCY

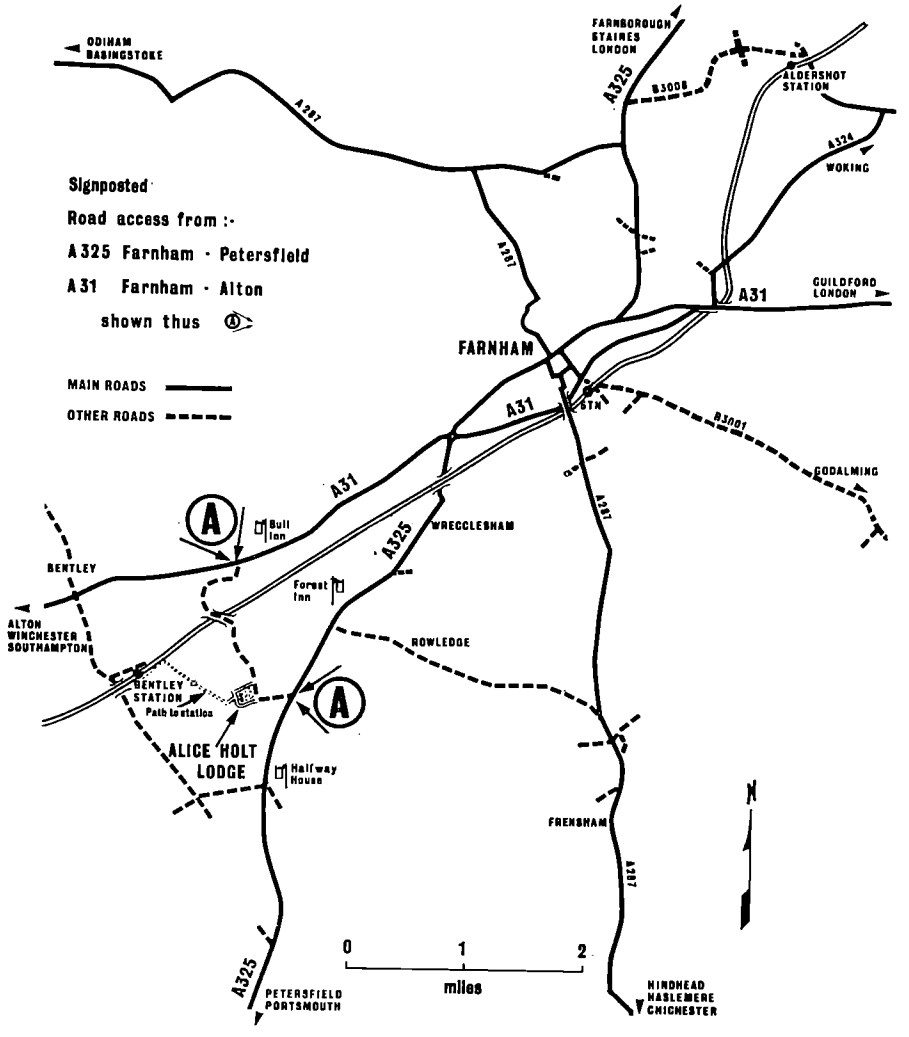


FIGURE 10: Approaches to Alice Holt Research Station, which lies 3½ miles south west of Farnham, Surrey, between the Farnham–Winchester road, A31, and the Farnham–Petersfield road, A325—A and A mark signposted approach roads. Postal address: Alice Holt Lodge, Wrecclesham, near Farnham, Surrey, England. Telephone: 0420-4 2255.

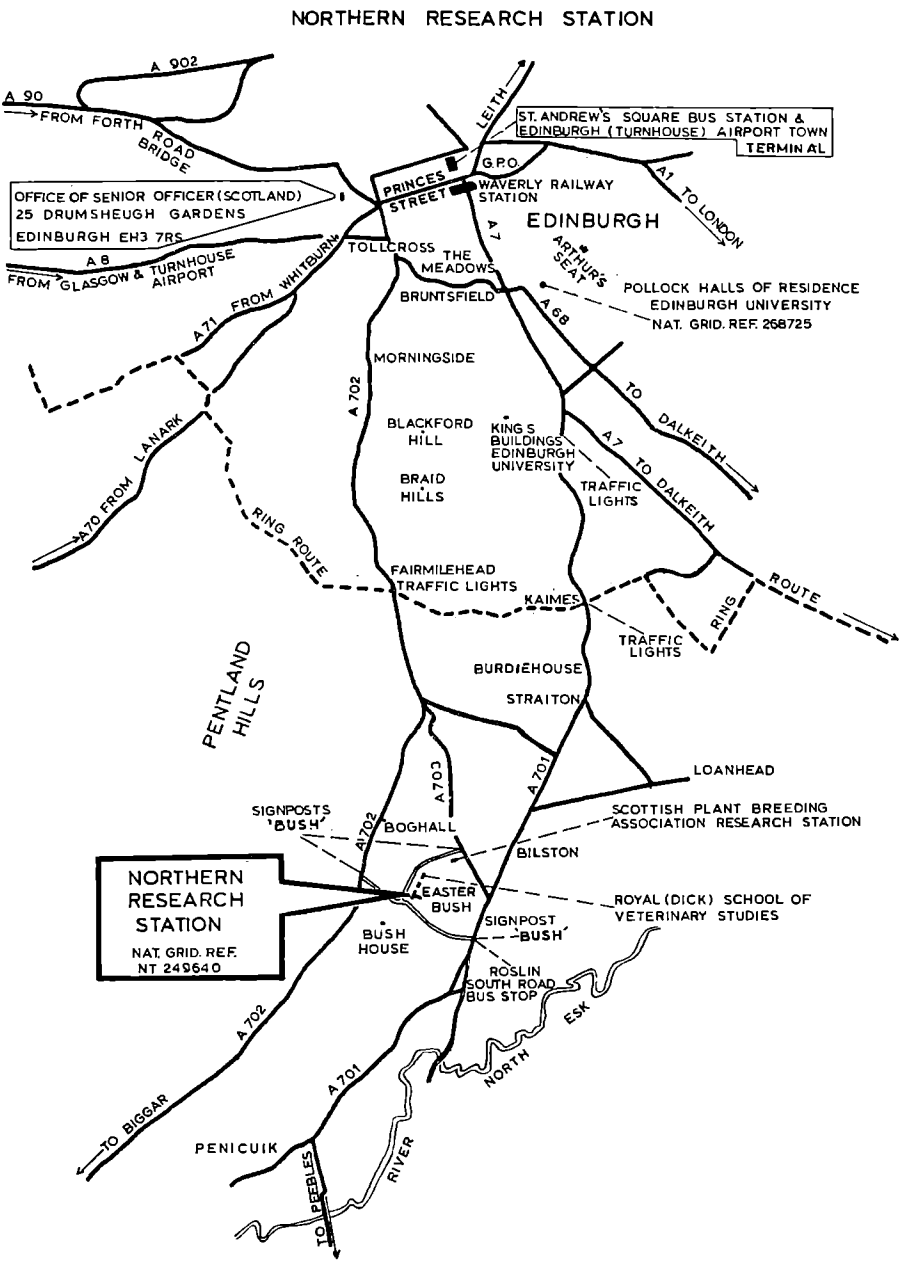


FIGURE 11: Approaches to the Northern Research Station, which lies between the main roads A702, Edinburgh–Biggar and A701 Edinburgh–Penicuik, six miles south of Edinburgh.

Postal address: Forestry Commission, Northern Research Station, Roslin, Midlothian, Scotland.
Telephone: 031-445 2176.

INDEX

Printed in England by Her Majesty's Stationery Office
at St. Stephen's Parliamentary Press

(880191) Dd. 501345 K30 10/70 St.S.

FORESTRY COMMISSION PUBLICATIONS

RECENT ISSUES

REPORTS

Annual Report for the Period 1st October 1967—31st March 1969	11s. 0d. (11s. 6d.)
Report on Forest Research for the Year ended March 1969	22s. 6d. (23s. 8d.)
Census of Woodlands, 1965–67	12s. 0d. (13s. 0d.)

FOREST RECORDS

No. 69 Guide to Site Types in Forests of North and Mid-Wales	8s. 0d. (8s. 4d.)
No. 70 Imports and Consumption of Wood Products in the United Kingdom 1950–67	6s. 0d. (6s. 4d.)
No. 72 Experiments on Drying and Scaling Close-piled Pine Billets at Thetford	3s. 6d. (3s. 10d.)
No. 73 Ploughing Practice in the Forestry Commission	4s. 0d. (4s. 4d.)

LEAFLETS

No. 50 Grey Mould in Forest Nurseries (Revised 1969)	3s. 6d. (3s. 10d.)
No. 51 Chemical Control of Weeds in the Forest (Revised 1969)	4s. 0d. (4s. 4d.)

BOOKLETS

No. 6 Forest Parks (Revised 1969)	3s. 6d. (4s. 0d.)
No. 15 Know Your Conifers (Revised 1970)	6s. 0d. (6s. 10d.)
No. 26 Metric Volume Ready Reckoner for Round Timber	7s. 0d. (7s. 4d.)
No. 27 Metric Guide for Forestry	3s. 0d. (3s. 4d.)

GUIDES

New Forest (Revised 1969)	7s. 0d. (7s. 8d.)
Bedgebury Pinetum and Forest Plots (Kent) Short Guide (Revised 1969)	9d. (1s. 1d.)

(Prices in brackets include postage)

Published by Her Majesty's Stationery Office and obtainable from the Government Bookshops at the addresses on back cover overleaf (post orders to P.O. Box 569 London S.E.1), or through any bookseller.

Printed and published by
HER MAJESTY'S STATIONERY OFFICE

To be purchased from
49 High Holborn, London WC1V 6HB
13a Castle Street, Edinburgh EH2 3AR
109 St Mary Street, Cardiff CF1 1JW
Brazennose Street, Manchester M60 8AS
50 Fairfax Street, Bristol BS1 3DE
258 Broad Street, Birmingham 1
7 Linenhall Street, Belfast BT2 8AY
or through any bookseller

SBN 11 710109 5