REPORT ON

FOREST RESEARCH

1973

FORESTRY COMMISSION

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Cover pictures, Left: Grey squirrel.

Right: Damage by Grey squirrel to the bark of a pole-stage beech tree.

FORESTRY COMMISSION

REPORT ON FOREST RESEARCH

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INTRODUCTION

By G. D. HOLMES
Director of Research

Research Aims

At the time of writing this *Report* the Forest Policy Review, proposals for which are given in *Forestry Policy* (HMSO, 1972, 18p), is still at the consultative stage, so it is premature to comment in detail on its implications for research. However, two features are quite obvious at the present time:

(i) All financial considerations relating to wood production emphasise the importance and value of the existing forest growing stock.

(ii) The high and increasing values of forests and trees in terms of the human environment.

In terms of research aims and activities, these points are having an important effect on our thinking and the deployment of research effort to best meet the needs of those concerned with managing trees and forests. Thus, new stress is being placed on the problems of established trees and forest crops aimed at improving their productivity and their protection against pests, diseases and wind; and the pursuit of operational efficiency, especially in relation to harvesting operations remains important. Also, there is increasing emphasis on research and development projects relating to recreation, landscape and amenity trees.

In recreation, links are being formed with other bodies, including the Countryside Commission and investigations so far have been mainly into visitor use patterns and preferences, and study of the recreation potential of forests. This includes sponsored research at three University centres. On the biological side, our interests are mainly in how best to develop sporting, and for the future in better understanding the management of wildlife as a resource, i.e. for natural history values.

Research projects relating to landscaping have so far consisted mainly of enquiries into the silviculture of broadleaved species of amenity value. One aspect of this work concerns problems of amenity trees outside forests and woodland areas. This is an increasingly important topic and includes arboricultural problems in rural, urban and industrial areas. The Commission already possesses considerable expertise as a result of its work in this and related fields and we are increasing our research on these problems where it is judged to be in the national interest. Also, we will continue to undertake contract research with other Government departments when this seems appropriate and facilities can be made available.

Research Review

In September 1972, a Visiting Group appointed by the Commission's Research Advisory Committee examined the work of our Genetics, Physiology and Seed Sections. The Group was chaired by Professor P. F. Wareing, F.R.S., and comprised Prof. R. Riley, F.R.S (Director, Plant Breeding Institute, Cambridge), Dr. P. S. Wellington, (Director, National Institute of Agricultural Botany, Cambridge), Prof. A. J. Rutter (Department of Botany and Plant Technology,

Imperial College), Prof. A. D. Bradshaw (Department of Botany, University of Liverpool), and J. A. B. McDonald, Esq. O.B.E. (formerly Conservator of Forests, South Scotland). In general, the Group was satisfied that the work is sound and necessary and their recommendations include the following points: (i) the need to speed up production of genetically improved seed for field use, (ii) the need for rapidly developing the technology of vegetative propagation to bring genetically improved stock into practical use more quickly, (iii) strong encouragement for our developing research programme on the control of the growth and form of tree *roots* in relation to the survival, growth and stability of trees. The Group's findings were most constructive and are being implemented.

Research Achievements

The whole *Report* is an account of progress on a wide selection of projects and is presented under more or less standard heads which should make items easy to find. Some of the individual reports are accounts of work done, while others summarise results and achievements. Much of the material adds up to a gradual accretion of new knowledge on a wide range of problems. I will comment on some of the trends and highlights.

Pests and Diseases

There were many developments, and the Dutch elm disease epidemic was the prominent feature. Important progress in understanding the nature of the latest epidemic was made when our Pathologists showed that a recognisable "aggressive" strain of the fungus is involved, and that this was almost certainly imported into Britain on elm logs from North America. Intensive efforts are being made to improve and develop control methods, and progress has been made with stem-injection techniques against the fungus, and in external use of selected insecticides against the beetle vector. There is close collaboration with workers in the Natural Environment Research Council's Institutes and Universities in research on the biology of this disease. There were also new findings on the incidence and causes of Beech bark disease affecting many pole stage beech in the south.

Grey squirrel numbers were down compared with 1971 but they continued to cause extensive damage to young broadleaved species in many parts of the country. New work on reproductive biology of this beast was started, but our main effort was concentrated on the development of a safe technique to permit the recent introduction of warfarin as an additional tool to control squirrel numbers.

There were three cases of localised outbreaks of insects which are potential pests, and two involve Sawfly defoliators. The Spruce sawfly (*Gilpinia hercyniae*) has affected 16,000 ha of Sitka spruce in North Wales, and its spread is being monitored. The Unit of Invertebrate Virology at Oxford is studying a naturally occurring insect virus, which shows considerable promise. A more limited outbreak of the Web-spinning sawfly (*Cephalcia alpina*) on Japanese larch in South Wales is being studied in relation to the large area of larch in that region. The third case is the European bark beetle (*Ips cembrae*) which was found in Scotland breeding on logs of Douglas fir, Scots pine and spruce as well as on larch. The latter two insects were first recorded in Britain as recently as 1959 and 1955 respectively and so merit close observation.

Wood Properties

The Forestry Commission is now a paying customer for research at the Princes Risborough Laboratory of the Department of the Environment, and this joint work has the following broad aims:

(i) To evaluate the properties and growth characteristics of home grown species and the influence of forest management practices so that the quality and yield of the forest output can be improved.

(ii) To study the processing of the forest output and the subsequent utilisation of the product so that the available material is used in the most efficient way.

In 1972 work was concentrated on assessing the effect of vigour of growth on wood density and strength and also in completing tests of mechanical stress-grading on home grown softwoods. Results showed improved yields of higher grades of timber compared with conventional visual grading systems.

Mechanical Development

The design and construction and trial of a new Mark III Hydrostatic Tractor designed for harvesting and timber handling, is a major feature of the logging research programme the prime aim of which is to develop means of minimising wood costs. An important new activity was the testing and further development of mechanical delimbing equipment for use at harvesting. Other specific achievements include improved ULV spraying equipment, tree injection tools and a mechanical aid to aerial photography.

Supply of Propagation Material

EEC directives require strict control of seed origin and quality and we have now completed a new register of seed stands to standards accepted within EEC. The seed control scheme will be operated by the Forestry Commission and one consequence will be that the Alice Holt Seed Laboratory will become the National Seed Testing Station for tree seed from July 1973.

New Hybrid larch seed orchards were established composed of clones with compatible flowering periods.

On the clonal propagation side, progress was made in improving methods for raising spruce from cuttings, initially for trial of clones of desirable characteristics including vigour, form, disease resistance and site adaptation.

Selection and Breeding

Particular attention was given to development of more rapid methods of progeny testing by intensive growing methods, and also the study of biochemical variation in Sitka spruce as a possible basis for forecasting future growth characteristics.

Environmental Factors and Tree Growth

A major share of resources are devoted to this field, particularly in work examining methods of treating sites and trees either to improve growth or wind stability. Many of the problems and obstacles are physical ones limiting rooting, and much of the research has taken the form of empirical experimentation in the

field testing drainage, cultivation and other methods on the gleys, clays and ironpan soils mainly involved. This has changed and a feature of present work is a more analytical approach involving teams of scientists both inside and outside the Division, notably from the Macaulay Institute and the Universities of Sheffield, Hull and St. Andrews. Our Physiology and Soils Sections are now equipped and developing methods to study and begin to sort out the effects of environment and genetic factors on *root* growth. This takes two principal forms, (i) the study of the effects of practical treatments on soil aeration and water movement and in turn on roots in the field, and (ii) experimental work on root growth under controlled conditions in the laboratory to provide some better understanding of root reaction to adverse factors such as waterlogging and compaction and to study the variation in tolerance of individual trees. The same applies to work on wind stability, and there is a report on studies of the dynamics of wind-sway of trees which helps predict and define the crop structures most vulnerable to wind damage.

Work on tree nutrition is not featured so prominently this year, but new work includes fertiliser studies on broadleaved species and a major new project at the Macaulay Institute to trace the fate of added nutrients in pole stage spruce crops.

Wildlife Conservation

There is a valuable new contribution from the University of Cardiff on songbird populations of forests.

Organisation

We have great value and stimulation from guest scientists and students working in the two Stations. There were four visiting scientists last year from Canada, New Zealand and the United States. In addition there are three research students from Reading, Imperial College and Edinburgh Universities working on Grey squirrel, Elm disease and the Physiology of Sitka spruce respectively.

Close collaboration with other research organisations is vital and at home the most important links were with the Princes Risborough Laboratory of the Building Research Establishment, Department of the Environment, the Institutes of Tree Biology and Terrestrial Ecology of the Natural Environment Research Council, and numerous University centres of research.

Dissemination of Information

This continues to be one of our prime functions and we were involved in consultation, advice and committee work and the writing of publications and advisory material on an unprecedented scale. These activities included meetings with the Timber Growers Organisation and the Scottish Woodland Owners Association on technical developments, and a substantial programme of promotion and advisory work with local authorities and the general public in connection with Dutch elm disease and grey squirrel control. We were also involved in Government Committees concerned with Codes of Practice, (e.g. noise, safety and health standards), and especially Plant Health and Seeds Regulations in relation to EEC.

There were over 176,000 visitors to our National tree collections at Westonbirt and Bedgebury.

The *Report* notes 15 new official publications via Her Majesty's Stationery Office. These include major works such as those by A. F. Mitchell on "Conifers in the British Isles" and J. R. Aldhous's bulletin on "Nursery Practice". Another feature was the number of guides and popular booklets relating to "Tree Planting Year" and elm replacement. In addition to this there were 54 items published in scientific and professional and other journals.

Conference and Courses

Participation in scientific meetings abroad included several International Union of Forest Research Organisations working parties, a IUFRO seminar on forestry and wildlife in Zurich, a conference in Norway on forest pests and diseases organised by IUFRO and EPPO (European Plant Protection Organization). Other notable overseas meetings were:

European Economic Community (EEC) and Organisation for Economic Co-operation and Development (OECD) meetings in Paris and Brussels on control of forest reproductive material moving in international trade.

The Food and Agriculture Organisation/Economic Commission for Europe/International Labour Office Study Group on organisation and methods for forest work at Geneva.

The 4th International Peat Congress in Helsinki.

The Elm Research Institute Conference in New York.

A conference on the genetics of the fungus *Phytophthora* in Italy.

A meeting in Holland of the British and Dutch Soils Science Societies.

At home, there are now so many symposia and seminars especially on matters relating to the environment, it is difficult to know which are important and which not. We took part in twenty-four conferences/symposia at home, including several organised by the Commonwealth Forestry Association (on wood quality), the Nature Conservancy (on lowland forestry and conservation), the Timber Growers Organisation (on recreation), the Association of Applied Biology (on plant breeding), the Institute of Advanced Architectural Studies (on landscape), the Society of Chemical Industries (pesticides use), and other symposia organised by the British Trust for Ornithology and the British Ecological Society. Staff also contributed to the annual meeting of the British Association for the Advancement of Science at Leicester, the 11th British Weed Control Conference, a Conference of Ministry of Agriculture, Fisheries and Food and the Agricultural Development Advisory Service on land capability, and to meetings of the Institute of Foresters.

Research personnel were also responsible for organising and conducting a variety of courses including courses on hydrology, on computer systems and technology, and courses on Dutch elm disease control.

Visits Abroad

G. D. Holmes was guest overseas speaker at the Silver Jubilee Celebrations of the Forest Research Station, Wageningen, Netherlands.

A. J. Grayson served as Consultant on Economics to the State Forestry, Forest and Wildlife Service, Department of Lands, Dublin.

J. Drummond to Norway to study Cable Crane and Skyline Equipment.

D. M. Hughes to see Draining and Ground Preparation Machinery in Finland.

W. O. Wittering visited Holland, Germany, Austria and Switzerland looking at Work Study Methods and Payment Systems.

A. Ray and G. D. Keighley were guests of the Oregon Chainsaw factory in America.

R. M. Sidaway went on a Western European Union Study Visit to Research Institutions in Holland to study recreation research.

J. Everard received a Western European Union Scholarship to visit State and Private Forest Research Organisations in France.

Dr. J. N. Gibbs visited the Department of Plant Pathology, University of Madison, and US Department of Agriculture Shade Tree and Ornamental Plant Laboratory, Delaware, Ohio to discuss Dutch elm disease research.

Dr. C. M. Brasier visited the Cocoa Research Institute of Nigeria, the International Institute of Tropical Agriculture, Ibadan, Nigeria, and the French Office for Overseas Scientific and Technical Research, Brazzaville, Congo, on a visit sponsored by the Cocoa, Chocolate and Confectionery Alliance to discuss *Phytophthora* diseases.

E. J. Parker visited the Laurentian Forest Research Centre, Quebec, for discussions on *Nectria* diseases, and the US Forest Service, Burlington, Vermont, to see Beech Bark Disease in the Forests.

C. I. Carter went on a 3-day Tour of Upland Plantings of Sitka spruce in Southern Ireland to gather information on Green Spruce Aphid.

Visitors

Two popular Open Days were arranged at Alice Holt in September to celebrate the 25th Anniversary of that Station and nearly 4,500 members of the public attended. Visitors to Alice Holt throughout the rest of the year numbered 598 from 25 countries and in addition some 110 overseas visitors were received at the Northern Research Station.

Staff Changes

Transfers in: N. E. Stutter (Senior Executive Officer) to Administration and Finance Officer from HQ Basingstoke. J. A. Dunford (Senior Executive Officer) to Work Study from West Scotland Conservancy. J. Dewar (District Officer II) to Planning and Economics from East England Conservancy. D. A. Thompson (District Officer II) to Silviculture North from South Scotland Conservancy.

New entrants: M. Anderson (Higher Scientific Officer) to Silviculture South. Dr. S. C. Gregory (Higher Scientific Officer) to Pathology. Miss A. Roberts (Scientific Officer) and Miss B. J. Smyth (Scientific Officer) to Statistics.

Transfers out: P. Merker (Principal, Organization and Methods) to HQ London. G. H. Bowers (Administration and Finance Officer) to North Wales Conservancy. A. A. Cuthbert (District Officer I, Work Study) to East Scotland

Conservancy. J. C. Keenleyside (Chief Forester, Silviculture North) to West Scotland Conservancy. G. M. Haggett (Head Forester, Planning and Economics) to East England Conservancy. A. MacInnes (Head Forester, Silviculture North) to West Scotland Conservancy.

Resignations: Dr. K. A. Longman (Principal Scientific Officer, Head of Physiology Section). K. A. Kernahan (Professional and Technology Officer II, Work Study). C. J. Ashton (Scientific Officer, Statistics). Miss C. M. Ironside (Scientific Officer, Statistics).

Retirements: J. M. B. Brown (Principal Scientific Officer, Ecology). A. MacDonald (Chief Forester, Silviculture North). S. H. Sharpley (Executive Officer, Library). F. C. Fraass (Clerical Officer, Library).

Obituaries: Sir Henry Beresford-Peirse, Director General of the Forestry Commission from 1962–68, a keen innovator and supporter of research in forestry.

Two retired Research Division members died during the year:

B. G. Howland who was Head Forester in the Ecology Section and

E. R. Parratt, Assistant Clerical Officer in Seed Section.

REVIEW OF THE YEAR'S WORK

By D. H. PHILLIPS, *Chief Research Officer (South), and*
B. W. HOLTAM, *Chief Research Officer (North)*

This Report gives in Part I some account of all research and development work done by the Forestry Commission, whether by its Research, Management Services or Harvesting and Marketing Divisions, or jointly with the Princes Risborough Laboratory of the Building Research Establishment, Department of the Environment, and in Part II of research undertaken for the Commission by universities and other organisations.

PART I

RESEARCH DIVISION

Forest Tree Seed

Much work has been done to revise our Seed Certification Scheme to accord with regulations made following our entry into the European Economic Community.

The home seed crop was again poor, and little seed was collected from our stands. Ways and means are, however, being sought to increase the collection of seed from our steadily increasing areas of mature plantation. Meanwhile our main seed stocks of most species are still imported.

It was found that storage of cones of Douglas fir for five weeks before extraction increased the germination of the seeds, but longer storage produced no further improvement. Similar storage of Scots pine cones from seed orchards, but in this case for a period of from two to four months, speeded up the opening of the cones, and so made extraction easier.

There were further studies to determine the causes of post-sowing seed losses for a number of tree species.

Investigations into the storage of sycamore seed showed that care should be taken to remove no more than the surface moisture before storing seed of this species. Further drying causes a loss of germination within three months.

Tests on samples of Sitka spruce seed either already in store or newly imported showed that the "psycrophilic seed fungus" (now called *Geniculodendron pyriforme*) was present on an increasing proportion of seed imported from western North America.

Plant Production

Additional information has been obtained on the effects of various pre-chilling treatments for improving germination in Sitka spruce. Moist pre-chilling, without the addition of sand, in a refrigerator for a three-week period is the recommended method, for seed of both high and low germination resistance. Early sowing and pre-chilling in mixture with sand are not recommended.

Irrigation of pre-chilled seed after sowing has not improved results. Moist seed can be carefully dried for machine sowing, with a considerable safety margin.

Experimental results continue to support the suitability of tubed seedlings for planting on upland peats as long as these are not subject to heavy weed growth or serious animal browsing. Dalapon treatments before the crop has flushed have given good control of moorland grasses, with no crop damage. Large-scale user trials of tubed seedlings continued in North Scotland, some 380,000 seedlings being planted—mainly Lodgepole pine of Alaskan and South Interior British Columbian provenances.

There has been continued progress with the development of plants in Paper-pots. Many of the problems associated with growing and handling of pots have been overcome, the means of preventing excessive root growth below pots being one of the principal problems receiving attention in the past year. The size of plants leaving the nursery appears to be critical for subsequent good growth; the best means of ensuring this is the chief remaining uncertainty.

With the increased interest in planting of broadleaved trees, especially to replace elms destroyed by Dutch elm disease, more work has been done on the vegetative propagation of alternative species. The principal species investigated in the past year was Grey poplar, a vigorous tree similar in crown form to elm but a species which is difficult to propagate on a large scale. Other species in preliminary trials included those *Nothofagus* species whose seed is in short supply.

Planting

A review of the influence of spacing of conifers at planting on their establishment, early growth and stability formed part of a more general study now almost complete. Direct evidence was rather incomplete, but it is tentatively concluded that there is no biological advantage in using closer rather than wider spacings, up to a limit of 2·4 m, at least as far as the establishment phase is concerned. There are obvious cost advantages in wider spacings, but these are somewhat confounded where even normal beating up is likely. In situations not subject to severe exposure a standard spacing of 2·1 m is therefore recommended as silviculturally satisfactory and likely to have the lowest overall establishment costs. On more exposed upland areas it is considered unwise to widen spacing beyond the standard 1·8 m × 1·8 m. No evidence was found of a relationship between initial spacing and crop stability up to the limit (2·4 m) of the range studied. Effects of spacing on yield are still under study and until these are resolved a maximum spacing of 2·1 m × 2·1 m is advocated.

Species and Provenance

Trials of Mountain hemlock, *Tsuga mertensiana*, established between 1960 and 1962 were reviewed. Slow early growth gives this species no place as a timber tree, even in conditions of severe exposure; nor is it the best choice under these conditions to add diversity of appearance to the crop. To develop a distinctive specimen tree it is best grown on fresh, fertile and seasonally sheltered sites, uncrowded by stronger competitors. Recent developments in the silviculture of broadleaf species are being reviewed; the review includes such techniques as the free growth of oak, and summaries of evidence from experiments

where broadleaf species have been planted on sites conventionally considered suitable primarily for conifers.

A collection of provenances of Sitka spruce has been assembled for sowing in Spring 1973. The seed was collected under the auspices of the Provenance Working Group of the International Union of Forest Research Organisations (IUFRO); those lots selected for sowing should supplement the evidence from existing collections, making data available from all useful parts of the range of this important species.

A review of results from a number of *Abies grandis* provenance experiments demonstrated differences of practical importance between provenances, clearly related to longitude and elevation. Results will be used in choosing further areas of collection by a IUFRO team under the direction of Dr. A. M. Fletcher in 1973.

Forest Weed Control

Contrary to previous experience granular atrazine has given, in a series of user trials, as good control of grass weed populations as the wettable powder formulations.

In the control of heather attempts to extend the use of 2,4-D into the dormant season gave some success only in April, and then only with double the standard dose. Low volume knapsack applications (110 to 225 litres/ha) using the standard rate of 2,4-D have given promising results in field trials and will be further tested; this could be a practical way of extending the spraying season, and could replace the mistblower.

Nutrition of Forest Crops

Analysis of foliar samples from conservancy crops in southern England and in Wales has again shown up nutrient deficiencies, particularly of phosphorus; deficiencies of nitrogen and potassium are much less common.

Relationships between nutrient concentrations in the foliage and tree growth are now being examined by plotting response surfaces, indicating which pair of nutrients (N P, N K, or P K) accounts for the most variation.

Experiments on northern hill peat have indicated that Sitka spruce takes up more phosphorus from applications after ploughing than from applications just before ploughing. There are suggestions that delaying applications of phosphate on deficient sites results in losses in increment which will not be made up. In contrast the growth of Lodgepole pine is not immediately affected by phosphate deficiency (as indicated by analysis), so timing of topdressing may be more flexible.

On raised bogs there is some evidence that nitrogen inputs for Sitka spruce will be required before ten years after planting to maintain the fast initial growth achieved by P K plus herbicide. But maximum and minimum growth patterns still have to be determined before the likely effects of nitrogen regimes can be estimated.

On peaty gley sites in Yorkshire Sitka spruce responds to the standard rate of phosphate (50 kg P per ha) applied as a topdressing, but much more dramatically in combination with heather control.

Foliar analysis indicates that while satisfactory uptake of potash can occur from applications in autumn and winter, the best uptake is in May and July. Subsequent effects on tree growth will determine whether new recommendations in timing of application of potash fertilisers can be made. In severe exposure, "luxury" fertiliser inputs have had no marked effect on height growth of spruce and pine after six years.

Experiments on the nutrition of newly-planted broadleaved trees, mainly oak and beech, have been started, since at present there is very little reliable information.

In the drier parts of the South, Corsican pine may reach Yield Classes 18 or 20, but *Pinus radiata* and *Pinus muricata* can grow much faster. Some work on these species is therefore being undertaken to see if their use is a practical possibility.

The number of samples of foliage for analysis continues to increase. A major change in methods of analysis for nitrogen and phosphorus has greatly speeded up the work.

Soil Studies

Studies of soil moisture contents in a drainage experiment in Sitka spruce on peaty gley at Kershope, Cumberland, have confirmed the small effects of drain depth and spacing, previously indicated by studies of water levels in open boreholes: indeed, the deeper drained treatments have *wetter* soil, and there is no effect of spacing.

In contrast, the effect of trees themselves on soil moisture content is, as might be expected, considerable. In three Scottish Border forests comparisons between soils under trees and in rides show a marked decrease in moisture content under the trees. More important perhaps, there is also a significant increase in bulk density, showing that the soil has subsided as it shrank; this may make deep rooting more, rather than less, difficult.

Some investigations on planting Corsican pine and beech on chalk downland have indicated that Nisula and Japanese Paperpot plants survive better than bare-rooted stock; this was in a year with abundant rainfall early in the growing season. Herbicide has worsened rather than improved survival.

Drainage

Vertical shrinkage of peat occurs in the turf only, during the first three summers after ploughing irrespective of whether a tree crop has been planted or not. Results show that intensive draining of clay subsoils is not to be recommended using present methods. As large-scale empirical drainage experiments have not yielded clear and positive results efforts have been made during the year to study soil and tree responses to draining at a more fundamental level. To this end co-operative work has been initiated with the Macaulay Institute for Soil Research to monitor water movement in deep peat and peaty gleys. Dr. R. M. M. Crawford of St. Andrews University, and our Physiology and Soils sections are involved in establishing the extent and effect on roots of anaerobic soil conditions.

Cultivation

The improvement of ironpan soils continues to dominate cultivation work in the north. Reduced increments on deep complete ploughing suggest that cultivation may have produced only a temporary response in terms of nutrient availability. However, that deep complete ploughing remains the best treatment is borne out by tentative results from a second experiment. A new experiment at Helmsdale Forest is to examine the degree to which mixing of soil is important during cultivation. Soil mixing is also the object behind the development of a new plough, the Rotary Mouldboard Plough, which will be undertaken in co-operation with the Scottish Section of the National Institute for Agricultural Engineering. The development of ploughing equipment and techniques for bare land and for replanting continues.

Crop Stability

Continued monitoring of thinning experiments has further indicated the correspondence between degree and type of thinning and incidence of windthrow as slight in no thinning treatments, considerable in normal thinning and very severe in line thinning.

A tree pulling study designed to compare stability of Sitka spruce on hand-prepared turves and on single furrow ploughing was conducted at three different dates in the year, giving contrasting levels of soil moisture, which were measured in each case. The greater root spread of spruce on hand-prepared turves gave significantly higher stability; on ploughed land roots had greater depth and weight, but less satisfactory distribution and spread and this last made for lower stability. Indications were obtained of lower stability with increasing moisture content; these were not statistically significant but merit further investigation under more precise experimental conditions.

A simple and rapid method of preparing topographic models was developed; in a wind tunnel test a model of part of Wauchope Forest gave excellent correspondence with actual readings from three years of extensive flag tatter work. Disappointingly the technique was much less successful in predicting the incidence of windthrow on another study site.

For the larger part of the year, Mr. A. J. C. Papesch, a New Zealander on sabbatical leave from the Mechanical Engineering Department of Christchurch University, undertook the writing up of the data accumulated by Dr. A. I. Fraser on the patterns of wind flowing over the forest edge at Redesdale, Northumberland. The results of this study are expected to be published shortly.

The dynamic behaviour of trees, and particularly tree sway and damping, has been studied partly to obtain a better understanding of the behaviour of trees in high winds, and partly to find a non-destructive technique for assessing the stability of trees on any given site.

Regeneration

The restocking of felled sites on gley soils continued to be the main subject of investigation. At Halwill (Devon) a range of alternative species (to Sitka spruce) gave good survival in the first year. At Kielder replanting of Sitka spruce on sites chosen to illustrate bad conditions gave convincing proof that such sites,

though not as amenable as newly ploughed ground present no insuperable difficulties; good plants, well handled and well planted in the slightly raised position near old stumps are, however, essential, as is protection from animal browsing.

Site Studies and Ecology

Studies of crop performance in relation to site factors have been extended in South Wales from the coalfield to other site types. Techniques for assessing sulphur dioxide pollution levels using lichens have been successfully applied in these studies.

A review was begun of the effects of current British forestry practice on aspects of the natural environment.

Forest Genetics

The first major revision of the National Register of Forest Tree Seed Sources was completed; 958 ha of selected seed sources are now registered. Forty hectares of new Douglas fir seed plantations were established.

The time has come to replace many of our earlier seed orchards. As this is done, use will be made of data now available to improve the average genotype of the new orchards, and increase the average yield of seed from each tree. Adjustment will also be made to relate the orchard acreage more closely to the present requirement of seed of the various species.

There is still a need to improve our techniques for the early testing of the genetic quality of new progenies. Various test methods are available, and experiments to evaluate these, with particular reference to their repeatability, were carried out with encouraging results. Artificial light to extend day length is needed to produce large plants for this early-test work as rapidly as possible. A new and improved sodium lamp with low heat emission was successfully used to raise in one growing season seedlings of Sitka spruce, Douglas fir and larch of a satisfactory size and form.

In 1970 a population study was begun of 150 trees of Sitka spruce of Queen Charlotte Island (British Columbia) origin in South Strome Forest, Ross-shire. In 1972 much detailed basic information was collected on each of these 150 parent trees. All the trees were felled to obtain accurate measurements of various characters and scions were collected for vegetative propagation.

A detailed investigation into the variation of polyphenols found in 2-year-old shoot samples collected from four widely separated provenances of Sitka spruce growing at four different sites in Britain was completed. It was hoped that if a good correlation existed between polyphenol content and vigour, polyphenol content could be used as a criterion in early-test procedures. The results indicated that it is highly probable that attempts to separate provenances by phenolic characteristics will be confounded by within-provenance variation in vigour. High polyphenol levels were associated with the most northerly provenances and at the least favourable sites for growth; this suggests that polyphenols accumulate after early cessation of growth and that they are therefore concentrated in a smaller volume of shoot. This may be because growth ceases early in the more northerly provenances and on the poorer sites, and photosynthetic

products synthesized after the cessation of growth may accumulate as polyphenols instead of being used for further cellular extension.

Physiology

Work on the breeding of trees is often hindered because flowering may be sparse or irregular, and vary greatly from tree to tree. Studies on flowering and seed production have therefore been continuing, and large increases in flowering of *Thuja plicata* have been achieved by supplying gibberellic acid solutions via a borehole in the main stem. If usable plants could be reliably produced from clonal cuttings such plants could be used to increase the precision of experiments, and might have possible future uses in the forest. Further work was therefore done on the rooting of cuttings of Sitka spruce and Lodgepole pine, using the growth hormones IAA and NAA at various rates. The rapidity of rooting and the number, type and size of roots produced were correlated with the weight of hormone applied, and the results will provide a clear guide for future investigations.

It is difficult to achieve the rooting of cuttings from mature trees, and work on this problem was intensified. It was found that in Sitka spruce epicormic shoots rooted more readily than cuttings taken from the crown.

Little is known about the effect of environmental factors on the growth of tree roots, and a programme to investigate the influence of both internal and environmental factors on the growth of roots of Lodgepole pine and Sitka spruce is being developed. In experiments on Sitka spruce in controlled environments using six soil temperatures varying from 6 to 26°C, root growth increased almost linearly up to 18°C. Other experiments have been started to study effects of mechanical stress, aeration and nutrition on root growth and survival.

Forest Pathology

In two underplanting trials in Thetford Chase, an assessment was made of the effect of the fungus *Fomes annosus* on trees of many species. Eight years after planting, few trees had been killed on an acid site but many were lost on an alkaline one. The heaviest losses were in Leyland cypress, Douglas fir, *Nothofagus obliqua*, Scots pine, Red oak and Hybrid larch.

Twenty-three sites throughout the country were studied to gather data on losses from butt rot caused by the same fungus. On many of the sites on which severe infection occurred, pines had formed an important part of the previous crop. Information on the volume of stain and decay in infected trees has been collected and is being analysed to provide data useful in the management of diseased crops.

Much work was again done on Dutch elm disease. A survey in 1972 showed that there were then many more trees affected by the disease than there had been in 1971, and it is estimated that about eight per cent of the elms in southern England and the Welsh borders have been lost since the present epidemic began.

The aggressive strain of the causal fungus *Ceratocystis ulmi*, can now be readily differentiated in culture from less aggressive ones. It much resembles some strains found in north America, and there is now evidence that it was introduced into this country on elm logs from Canada.

Of the two beetles that carry *C. ulmi* from tree to tree in this country, investigations have shown that *Scolytus scolytus* carries more spores than *S. multistriatus*, and also emerges earlier and is most active in June and early July when the elms are most susceptible to the disease.

In work on the control of the disorder a satisfactory method was devised for injecting trees with a solution of the systemic fungicide benomyl. Injecting trees in this way is relatively expensive, but if further work confirms its effectiveness it will be a valuable way of protecting trees of high amenity importance. Large-scale field trials to evaluate the method more fully are under way.

In further studies on diseases of trees caused by species of *Phytophthora*, various species of this fungus were found in association with damage to trees and shrubs of *Nothofagus*, *Populus*, *Prunus*, *Salix*, *Berberis*, *Viburnum* and *Tilia*.

Work continued on Beech bark disease (Plate 13), which appears to be caused by a species of the fungus *Nectria* (probably *N. coccinea*) following infestation by the Beech scale, *Cryptococcus fagi* (Plate 12). Surveys indicated that infestations by this scale are increasing in beech plantations in southern England. Inoculation studies confirmed the fact that the *Nectria* spp concerned can attack wounded beech stems. Experiments did not support the view that trees subject to moisture stress became more susceptible to the disease.

Further experiments on the dieback of London plane failed to support the hypothesis previously advanced that the disorder is connected in some way with the rapid thawing of frozen tissues. The cause of this malady therefore remains a mystery, and more work is needed to elucidate the matter.

Inoculation tests were made with mycelium and spores of an isolate of *Sirococcus strobilinus* (perhaps the same fungus as *Ascochyta piniperda*) from Lodgepole pine seedlings. Pathogenicity was tested on wounded and unwounded plants of Norway and Sitka spruce, as well as on Lodgepole pine. Results supported the view that the fungus is a wound parasite, and that provenances of Lodgepole pine may differ in their susceptibility to its attack.

Enquiries on diseases reached a record number. In the south, a great many of the queries concerned trees in parks and gardens. Most enquiries in the southern part of the country concerned Dutch elm disease, honey fungus (*Armillaria mellea*), anthracnose of Weeping willow (caused by *Marssonina salicicola*), species of *Phytophthora*, anthracnose of London plane (caused by *Gnomonia veneta*) and Beech bark disease. The willow anthracnose was much more severe than it has been for the past three years, and that of London plane caused widespread damage on trees throughout much of the south.

In the north, most enquiries were on honey fungus and willow anthracnose (as in the south), and also on *Lophodermella sulcigna* (a cause of needle blight in pines), and the root and butt rot fungus *Fomes annosus*. The aggressive strain of *Ceratocystis ulmi* was recorded for the first time as a cause of Dutch elm disease as far north as Newcastle on Tyne.

Forest Entomology

The sawfly *Gilpinia hercyniae* has continued to defoliate areas of Norway and Sitka spruce in part of north Wales, and work on its control by the use of a nuclear polyhedrosis virus has again been pursued in collaboration with the

Unit of Invertebrate Virology, Oxford. The possibility of introducing European parasites of the sawfly to assist in control is also being examined.

Further studies were also made on the Green spruce aphid, *Elatobium abietinum*, another major pest of spruce. Special attention was paid to the resistance of the aphid to cold, and to the activities of the beetle *Rhagonycha lignosa*, which was found preying on colonies of the aphid in southern England.

In experiments on the insecticidal control of pineapple galls caused by *Adelges abietis* on Norway spruce grown as Christmas trees, late autumn applications of contact insecticides showed promise.

Pupal counts of the Pine looper moth, *Bupalus piniarius*, showed a general rise in populations. The large populations now present in some areas suggest that spraying may be necessary in 1973 to prevent damage to crops. The matter will be kept under review, however, because Corsican pine, the species now mainly affected is relatively tolerant to Pine looper infestation, and some control is also possible by adjustment of felling programmes to include badly defoliated areas.

Promising results were obtained with fenitrothion applied in spring to control the European pine shoot moth, *Rhyacionia buoliana*, which was found to be causing severe damage to Lodgepole pine. Other insecticidal spray trials were made to improve the chemical control of the Pine shoot beetle. Good results were obtained with BHC and Dursban; this was so at a lower concentration than that normally used when spraying with BHC, though the best control was still given by spraying at the normal concentration (0·5 per cent) or a higher one.

A collection of parasitised larvae of the Larch casebearer, *Coleophora laricella*, was made for the Canadian Department of Agriculture, for use in the control of this moth in Canada, where it is now a serious pest.

Larch in one area in south Wales was defoliated by the web-spinning sawfly *Cephalcia alpina*, a study of which has therefore begun.

Further studies of *Ips cembrae* in Scotland show that this bark beetle has extended its host range, and in 1972 it bred then not only in logs of larch (and of Norway spruce, as it did also in 1971) but also of Douglas fir, Scots pine, Sitka spruce and Noble fir.

In trials with pre-planting insecticidal dips to protect young conifer plants against *Hylobius abietis* and *Hylastes* species, a lindane suspension proved as effective as DDT, and could be used on nursery plants stored in polythene bags if the plants were dried before bagging. As an alternative to dipping, the granular systemic insecticide phorate was used with promising results to control the same pests on Sitka spruce plants raised in Japanese paper pots.

Work on entomological aspects of Dutch elm disease was continued. It was found that adults of *Scolytus scolytus* emerged in greater numbers about the end of June, while those of *S. multistriatus*, the other vector of the disease in this country, emerged mainly in late July. In general, emergence and maturation feeding were delayed and flight was suppressed by the cold summer. Parasites infesting the vector beetle population proved to be greater in number than in 1971.

Methoxychlor, an organochlorine insecticide less persistent than DDT and less toxic to mammals, emerged from screening tests as the most promising of the

chemicals examined for use against the vector beetles of Dutch elm disease. It was included in large-scale field trials together with dursban and tetrachlorvinphos, using high volume ground sprayers, mistblowers and ultra-low-volume sprayers from a hydraulic platform, and aerial spraying from a helicopter. Generally, mistblowers gave the best results, though ultra-low-volume spraying was also very effective. For large-scale spraying, aerial application is likely to be most appropriate, however.

Among other work on pests of broadleaved trees, a study is being made of the beech scale, *Cryptococcus fagi* (Plate 12), which is associated with the Beech bark disease (p. 98), which affects many beech plantings in southern England.

Wildlife

Damage caused by grey squirrels was less than in 1971. In connection with legislation (now introduced) to authorise the use of warfarin to control this pest in England and Wales, work was done to minimise hazards to wildlife other than grey squirrels when the poison is used. A study of reproduction of the animal was also begun, in the hope that it may ultimately be possible to develop a reproductive inhibitor to control squirrel populations.

Red squirrels increased somewhat in north-east England and in Scotland, but again decreased in numbers in Wales. In connection with conservation of the red squirrel, a study of the animal and its food supply was continued.

Further work was done on age determination, reproduction, calf marking, and condition of red deer.

Damage surveys in nurseries, associated with others made by the Seed Section, showed that losses of seed, often associated with predation by birds, especially greenfinches and chaffinches, were commonly high. Damage in woodlands by grey squirrels appeared to be severe mainly in areas in which little or no systematic effort was made at the right time to control the animal.

Several new chemical repellents marketed to prevent browsing by animals were again tested. None proved as generally useful, either against deer or rabbits as AAprotect, the best material to emerge from earlier tests.

The use of nest boxes to increase kestrel populations is being examined with a view to improving the biological control of field voles by predatory birds.

Statistics and Computing

The staff of the Statistics Section again spent much time planning experiments and surveys for other sections, and in assisting other Divisions of the Commission's headquarters with statistical aspects of their work. Work done included the planning of a large survey of reserves of unplanted land, revision of the design of the Dutch elm disease survey of 1971 for use in a second survey made in 1972, and the planning of a survey designed to estimate losses through butt rot of Sitka spruce caused by *Fomes annosus*.

Engineering Services

Much of the time of the Engineering Services Section has been spent in the development of pressure systems for the injection of tree trunks (and more

recently of soil) in work on the control of Dutch elm disease. Work has also been done on the production of a camera mount for use in aerial survey work, of a programmed controller for use in glasshouses and environment chambers, and of a temperature gradient plate for use in seed research.

Photography

The Photographic Section was again short-staffed and the service provided was therefore less than sufficient. Demands for a service in aerial photography for various management and research purposes continued to increase, and to assist in this work, in collaboration with the Engineering Services Section, a camera mount was designed to be interchangeable with the baggage doors of a range of Cessna aircraft.

Publications

Fifteen new priced publications were issued through Her Majesty's Stationery Office and a further eight were revised and reprinted. One new unpriced publication was produced for general issue and seventeen others were revised and reprinted, while nine Research and Development Papers (unpriced papers mainly for internal use) were also printed.

Research Information

The Research Information Section organised two very successful Open Days at Alice Holt for schools and for the public. A new edition of the Section's Keyword Index to Forestry Commission Publications was processed by computer.

MANAGEMENT SERVICES DIVISION

Planning and Economics

The Planning and Economics Branch has worked mainly on the analyses and calculations required for the financial reconstruction of the forestry enterprise. The work has provided a firm basis for the improved forecasts of wood production, the valuation of the existing estate, and for forecast of cash flows associated with new planting and restocking.

Surveys of recreational use of forests by day visitors were made at Savernake Forest, south west England, and, jointly with the Countryside Commission at the Cwmcarn Scenic Forest Drive, Ebbw Forest, South Wales.

Field Surveys

About half the time of the Field Surveys Branch was spent on topographical and crop assessment work. In addition, in collaboration with the Pathology and Statistics Sections, a further survey was made to examine the incidence and distribution of Dutch elm disease.

An analysis of spacing experiments was made, and yield models based on the results have been produced.

A major site survey of the Commission's plantable reserves of land confirmed that much of the available land is in poor, exposed upland areas, where fertiliser treatment and the control of heather, *Calluna vulgaris*, are required, and where plantations are liable to windthrow.

Work Study

In the field of forest management, work was done on the planting of tubed seedlings, on planting and weeding machines, step cutters and brush cutters and ploughing tractors, on drains and their maintenance, on the application of fertilisers and on the control of heather. An important limiting factor in many forest operations is the lack of a suitably versatile tractor to carry drainage and mechanical weeding equipment and tree planting machines in the varied conditions encountered in forestry. One promising machine which may become commercially available is a hydrostatic crawler tractor now being studied.

Experiments on the control of heather are almost finished, and recommendations based on the results can now be made.

Work on harvesting systems again centred on the development of hydrostatic tractors and their associated timber handling equipment. Two 45 brake-horsepower machines have given very good results in long-term field trials, and a larger, 65 BHP machine is now being tested. Terminal loading time with these machines have been reduced by 25 per cent by the use of radio control of the winches.

Other work has been done on the modification and use of various other tractors, and on forwarders, delimbing machines, cable cranes, small mobile chipping machines, and chainsaws.

Follow-up studies on the vibration-induced "white finger" show that this problem has been greatly reduced now that anti-vibration saws have been developed and issued.

Organisation and Methods

The Systems Design Section of the Organisation and Methods Branch has taken part in the training of staff in the use of the Commission's new Financial Control System, the details of which it has modified for use within the Headquarters Division including the Research and Management Services Divisions.

HARVESTING AND MARKETING DIVISION

Utilisation Development

Further work undertaken on the development of horticultural uses for bark was focused on the assessment of the suitability of bark from the individual conifer species, with particular emphasis on the detection of phytotoxicity. Mushrooms, tomatoes and narcissi were used as the main test crops. Results with narcissi were good. When bark was used as a casing material for mushrooms, however, yields were again lower than those obtained with the peat controls. Of the barks used for casing, pine and larch gave better results than

Spruce and Douglas fir. Following earlier trials, commercial organisations have begun to market bark for horticultural use in considerable quantities.

The Warren Spring Laboratory of the Department of Trade and Industry has examined conifer bark with a view to its possible use in the absorption of marine oil slicks. The results show promise.

Other projects included the testing of a proprietary anti-desiccant used to reduce needle fall of Christmas trees. The material proved less effective than alginate.

The programme on home-grown timber carried out jointly with the Princes Risborough Laboratory of the Building Research Establishment, Department of the Environment, was continued.

Investigations on the advantages of machine stress grading of home-grown softwoods were begun in 1969, to include tests on four species. The tests on Scots pine, Sitka spruce and Douglas fir have been completed (the last in the present year) and those on Corsican pine now near completion. The results again showed that machine stress grading gave improved yields, particularly of higher grade material, as 13 per cent of the test pieces of Douglas fir were rated as M 75 grade by the machine compared with less than 4 per cent by visual inspection.

In research on the effects of fertilisers on growth and density of wood of Sitka spruce, wood samples were taken from experiments at Glasfynydd (South Wales) where plots had been treated in 1959 with fertilisers containing two or more of the nutrients N, P, K, Ca, and Mg. The results must be treated with caution as it appears that the effects of the fertilisers have been confounded by eccentric growth of trees on the site. Some change in the growth rate/density relationship was demonstrated, however, in the samples from plots treated with P + N, N and O.

A mathematical model has been used successfully in a preliminary investigation of sawmill conversion patterns for mature Sitka spruce logs.

An examination of the timber properties of four minor forest species, Grand fir, Western hemlock, Noble fir and Western red cedar, was completed. On the whole the results were not very encouraging, and did not suggest that any of these species should be planted on a wide scale, though in most respects the properties of the wood of Western red cedar appeared to be superior to those of the other three species.

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. H. A. Smith, of *Rothamsted Experimental Station*, Harpenden, Hertfordshire, comment briefly on determinations of N, P, K, Ca and Mg in whole-plant samples of healthy seedlings and transplants of Sitka and Norway spruce, Grand fir and Western hemlock. The analyses were made to find the content of these elements consistent with the production of green,

healthy trees, and eventually to give basic information needed for the formulation of manurial recommendations. Many of the figures agree well with the few available from other work, but more work still remains to be done.

Dr. H. G. Miller and Dr. B. L. Williams, of the *Macaulay Institute for Soil Research*, Aberdeen, discuss their continued work on forest soils and tree nutrition. The year was largely devoted to the initiation of a new investigation into nutrient cycling in Sitka spruce. To this end, the first two of a series of six experiments were laid out.

In work on diverse methods for sampling and analysis of rain water passing through Sitka spruce stands, it was found that Sitka spruce trees released into rain water not only significant quantities of K, Ca and Mg (as had been earlier found in studies on Corsican pine) but also large amounts of N and P.

In studies in pole-stage Corsican pine in Culbin, Laigh of Moray Forest, it was found possible to use levels of N in fresh needle litter to predict both the levels of this nutrient in top-whorl foliage and stem growth. These trees, growing in a forest on coastal sand dunes also provided evidence that sea spray may cause appreciable growth reduction even in the absence of visible needle scorch.

Studies of peat samples has suggested that the amount of mineral N released on incubation depends on total N content, which in turn is related to the botanical origin of the peat. This has prompted investigations into the chemical nature of the organic N and its distribution between size fractions for a range of peats.

Incubation experiments on Scots pine humus continue and are being extended to include organic layers formed under Sitka spruce.

Dr. W. Armstrong of the *Department of Botany, University of Hull*, and Dr. D. J. Read, of the *Department of Botany, University of Sheffield*, summarise their work comparing soil aeration and water potential with yield and stability of Sitka spruce growing on a peaty-gley at Kielder in Northumberland. It is generally considered that the poor rooting and consequent liability to windthrow on such sites results from poor aeration in all but the surface layers of the soil. Measurements of soil oxygen and of soil water potential were therefore made on a site on which trees were to be subsequently pulled by Forestry Commission research staff to study stability, root characteristics etc. The measurements were made in April, September and December, to represent conditions expected in the early and late growing season and the winter respectively. Similar conditions were found in April and December, and at these times there was a strong correlation between oxygen status and stability, stem weight, root weight, mid-height diameter and breast height diameter of the pulled trees. No such correlation could be established in the case of the summer oxygen status.

Dr. G. A. Salt, of *Rothamsted Experimental Station*, gives an account of his further investigations on the so-called "psychrophilic seed fungus", now given the name *Geniculodendron pyriforme*. The fungus, known here only on imported Sitka spruce seed, does not occur on all samples. It is therefore likely that seed quality could be improved by testing samples at the extractory and excluding those infested by *G. pyriforme* when bulking seed for general use.

In nursery beds, spread by the fungus to healthy seedlings can be prevented by dressing seed with 50 per cent thiram. Results with the treatment are erratic,

however, partly because all seed stocks are not infested, and partly because infection even in the presence of the fungus occurs only in cold conditions. Hence benefits from treatment are seldom striking, and indeed seedling emergence is sometimes reduced, and treatment is seldom applied.

Cold treatments to remove dormancy, either by early sowing or by "stratifying" in moist sand, favour the spread of *G. pyriforme*. In experiments it was found that losses were reduced by treating moist seed without sand in a cold store at 3°C. Results of further experiments with fungicides suggest that further protection may be obtained by adding thiram at 0·5 to 1 per cent to the initial water soak.

Dr. T. W. Tinsley, of the *Natural Environment Research Council's Unit of Invertebrate Virology* at the *Commonwealth Forestry Institute, University of Oxford*, contributes a brief note of work on viruses of birch, alder and poplar. Virus particles resembling those of tobacco rattle virus or tobacco mosaic virus were found in the sap from leaves of a plant of birch, *Betula pubescens*, showing chlorotic vein-banding symptoms associated with a seed-borne virus infection.

Mr. A. J. Deadman, of the *Department of Forestry, University of Aberdeen*, gives a short final report of his work on tit populations in the Culbin plantations of Laigh of Moray Forest, Morayshire. Work this season was concentrated on territorial behaviour. Results of the whole study will be published in greater detail elsewhere.

Miss Marjorie W. Adams, of the *Department of Zoology, University College, Cardiff*, provides a summary of work on the effects of forest management on songbird populations. The work was done in the winter and in the breeding season in coniferous and broadleaved woodland in the Forest of Dean and in Wales. In general, the numbers of songbirds were found in the two types of woodland. In winter there were rather more birds in coniferous than in broadleaved woodlands, but the populations were generally more diverse in broadleaved or mixed woods than in purely coniferous ones. In the conifer woodland one species was often strongly dominant, whereas the broadleaved woods usually contained smaller numbers each of several species.

The breeding surveys were all done in managed woods with no understorey, and in these the density of birds was less than in unmanaged broadleaved woods, in which it is to be expected that with time an understorey would develop and older trees would supply holes suitable for nesting sites.

Dr. D. C. Malcolm and Mr. C. F. Golding, of the *Department of Forestry and Natural Resources, the University of Edinburgh*, comment on work now resumed on effects of environment on shoot growth. Results so far tend to confirm those of earlier experiments on the effects of temperature on dormancy, shoot extension and needle morphology in Sitka spruce.

Mr. N. D. E. Custance and Mr. E. S. Owen Jones, of *Bedford College, University of London*, in collaboration with Dr. G. J. Mayhead, of the *Forestry Commission*, give a short note on preliminary work on the identification of forest areas affected by phosphate deficiency by photographic means.

Mr. Brian Goodall of the *Department of Geography, the University of Reading*, summarises work done on the recreational potential of Forestry Commission land. Data has been analysed to reveal characteristics of the forest landscape.

Requirements of various kinds of recreational uses have also been examined. The information obtained should help in formulating policy with regard to some recreational uses of forest areas.

Mr. B. S. Duffield and Mr. M. L. Owen, of the *Tourism and Recreation Research Unit*, the *Department of Geography*, *University of Edinburgh*, provide a note on a study on recreation demand in Scotland being made for the Scottish Tourist Board, the Countryside Commission for Scotland, the Highlands and Islands Development Board, and the Forestry Commission. The survey will seek information on day and weekend trips, and main and second holidays, and is intended to provide data of use in regional planning.

Mr. A. J. Veal of the *Centre of Urban and Regional Studies*, the *University of Birmingham*, comments briefly on a desk study sponsored by the Countryside Commission, the Sports Council, and the Forestry Commission, which will review techniques developed to examine the ways in which people perceive their recreation environment.

PART I

Work carried out by Forestry Commission Research and Development Staff

RESEARCH DIVISION

FOREST TREE SEED

The report is subdivided into Service and Research work of which the former has continued to absorb the greater part of the Section's staff resources.

SERVICE

Register of Seed Sources

The European Economic Community (EEC) Directives require a strict control of seed marketing for 13 forest tree species of which 11 are of forestry importance in this country i.e. Scots and Corsican pine, European and Japanese larch, Norway and Sitka spruce, Douglas fir, Beech, Sessile, Pedunculate and Red oak. Basically no seeds can be marketed unless they are proved to originate from officially approved seed sources. The scheme to control the marketing of forest seed (and of other forest reproductive material) comes into force on 1st July 1973, and will be operated by the Forestry Commission. To comply with the resulting new regulations for forest reproductive material the existing seed certification scheme is the subject of an extensive revision.

Seed Procurement (Table 1)

The decreasing trend in seed collection from home sources has continued and this year's crop was the lowest for the last five years. Altogether only 220 kg of conifer and 284 kg of broadleaved species were collected. The greater part of the conifer seed originated from registered sources.

The proportion of mature stands in Forestry Commission plantations is steadily increasing and therefore seed collection could be expected to increase at more or less the same rate. Unfortunately results are not coming up to expectation and therefore a special investigation is being organised in order to find out some means of increasing the seed collection from home sources.

As usual the shortages in home collections were made up from imports which amounted to 3,467 kg of conifer and 826 kg of broadleaved species. The main bulk consisted of Sitka spruce (1,751 kg), Japanese larch (1,106 kg), Norway spruce (440 kg), European larch (115 kg) and Red oak (788 kg). Crops abroad were insufficient and failed to produce the required amounts of Lodgepole pine from Alaska and of Sudeten larch from Czechoslovakia or Poland. Moreover a crop failure of Beechnuts and Sessile and Pedunculate oak all over Europe left the country without seed for the season under review. It should be mentioned also that *Nothofagus procera* seed was also in short supply due to failure of crops in Chile.

TABLE 1

SEED PROCUREMENT FROM 1.4.72 TO 31.3.73

Kilogrammes

Species	Imports			Home Collections					Grand Total
				Crop 1971*		Crop 1972		Total	
	General	Registered	Total	General	Registered	General	Registered		
Scots pine			—	4·1	44·6		18·2	66·9	66·9
Corsican pine			—				150·6	150·6	150·6
Lodgepole pine (Alaska)	4·8		4·8				0·4	0·4	5·2
" " (North Coastal)	2·4		2·4				—	—	2·4
" " (Skeena River)	40·3		40·3				10·5	10·5	50·8
" " (South Coastal USA)			—				1·3	1·3	1·3
Sitka spruce (Queen Charlotte Islands)	1,485·0		1,485·0			4·1	—	4·1	1,489·1
" " (Washington)	266·9		266·9			—	—	—	266·9
Norway spruce		440·0	440·0			—	—	—	440·0
European larch (Sudeten)		39·7	39·7			—	—	—	39·7
" " (Alpine)		75·3	75·3			—	—	—	75·3
Japanese larch	1,106·0		1,106·0			—	—	—	1,106·0
Hybrid larch			—		14·2	1·2	14·2	29·6	29·6
Douglas fir			—			—	2·1	2·1	2·1
Lawson cypress			—			5·5	—	5·5	5·5
Other conifers	6·9		6·9			14·1	0·3	14·4	21·3
Total Conifers	2,912·3	555·0	3,467·3	4·1	58·8	24·9	197·6	285·4	3,752·7
Red oak		788·4	788·4			—	—	—	788·4
Birch	1·0		1·0			4·5	—	4·5	5·5
Alder	6·1		6·1			9·8	—	9·8	15·9
Sycamore			—			176·5	—	176·5	176·5
Nothofagus			—			5·6	—	5·6	5·6
Other broadleaves	30·2		30·2			87·5	—	87·5	117·7
Total Broadleaves	37·3	788·4	825·7			283·9	—	283·9†	1,109·6
Grand Total	2,949·6	1,343·4	4,293·0	4·1	58·8	308·8	197·6	569·3	4,862·3

*Taken in charge after 31st March 1972.

†Including 183·09 kg collected by Conservancies for their own use, and not kept in the central seed store.

Seed Extraction

All collected cones were processed in the central seed extractory plant at Alice Holt; the season was not very busy due to very small crops as already mentioned. Altogether 276 hectolitres of cones were processed, consisting mainly of Corsican pine with 150 hectolitres and Scots pine with 76 hectolitres.

The poorer crops generally give lower seed yields per volume of cones but it has been observed for some time that Scots pine Seed Orchards produce relatively low yields irrespective of the size of the crop. Moreover some difficulties are being experienced with the proper opening of cones during seed extraction.

As the Seed Orchards are the main source for our Scots pine seed the above problem is being investigated under an intersectional research project in co-operation with Genetics and Physiology.

Seed Storage

Due to lower seed dispatches and higher imports as compared with the previous year the seed stock in hand increased by about 1,500 kg and has risen to the level of about 9,500 kg. With an average yearly requirement of about 2,500 kg the stock now covers almost four years requirement. Of course this varies from species to species and some provenances are covered better than others. Hybrid larch, Alaskan Lodgepole pine, Sudeten larch and *Nothofagus procera* are the species for which procurement continues to be difficult.

About 20 per cent of seed stock is from home sources. The remainder is imported, and at present originates mainly from unregistered sources.

Seed Testing (Table 2)

The decreasing trend in the number of tests performed has continued and is due to the reduction in the number of seed lots in stock and to the fact that some individual tests (purity, seed size, moisture content) do not require annual repetition for stocks retained for several years. However, the testing work for research projects has increased.

TABLE 2
TESTS PERFORMED ON SEED

Kind of test	Service	Research	Total	Total of previous year
Purity	303	—	303	518
Seed size	303	20	323	627
Germination	714	688	1,402	1,593
Tetrazolium	18	6	24	61
X-Ray	—	8	8	12
Cutting	11	—	11	5
Moisture content	266	53	319	481
Cone test	—	—	—	9
TOTAL	1,615	775	2,390	3,306

TABLE 3

SEED SUPPLIED FROM CENTRAL SEED STORE 1.4.72 TO 31.3.73

Kilogrammes

Species	Forestry Commission				Private Forestry				Export Research Gifts	Grand Total		
	General	Registered	Total		General	Registered	Total					
Scots pine	6·6	11·1	17·7		123·4	64·2	187·6		88·8	294·1		
Corsican pine	39·1	—	39·1		85·9	10·0	95·9		2·2	137·2		
Lodgepole pine (AL)	0·2	0·4	0·6		—	—	—		—	0·6		
,, ,, (NC)	1·3	—	1·3		—	—	—		0·4	1·7		
,, ,, (SC)	23·8	0·9	24·7	65·2	20·8	—	20·8	69·1	2·8	48·3	137·8	
,, ,, (SK)	21·6	—	21·6		30·8	—	30·8		0·1	52·5		
,, ,, (CI)	—	—	—		11·0	—	11·0		—	11·0		
,, ,, (SI)	17·0	—	17·0		6·5	—	6·5		0·2	23·7		
Sitka spruce (QCI)	263·6	—	263·6	298·9	355·3	—	355·3	388·6	9·2	628·1	697·5	
,, ,, (Wash)	31·9	3·4	35·3		30·0	3·3	33·3		0·8	69·4		
Norway spruce	9·8	6·6	16·4		73·1	55·5	128·6		1·4	146·4		
European larch (Alpine)	4·5	0·5	5·0	16·2	—	49·0	49·0	64·7	1·2	55·2	82·3	
,, ,, (Sudeten)	—	11·2	11·2		—	15·7	15·7		0·2	27·1		
Japanese larch	47·5	2·4	49·9		239·7	—	239·7		1·7	291·3		
Hybrid larch	11·2	12·1	23·3		40·2	29·6	69·8		3·8	96·9		
Douglas fir	19·1	18·4	37·5		39·9	89·7	129·6		1·5	168·6		
Western hemlock	8·3	—	8·3		50·1	—	50·1		1·2	59·6		
Western red cedar	2·5	1·5	4·0		40·1	9·7	49·8		0·7	54·5		
Grand fir	46·6	—	46·6		144·5	—	144·5		5·0	196·1		
Noble fir	53·7	3·0	56·7		53·5	—	53·5		3·8	114·0		
Lawson cypress	—	1·0	1·0		—	10·5	10·5		0·3	11·8		
Other conifers	20·1	2·9	23·0		3·6	—	3·6		1·2	27·8		
Total Conifers	628·4	75·4	703·8		1,348·4	337·2	1,685·6		126·5	2,515·9		
Oak	482·7	712·4	1,195·1		—	10·5	10·5		10·1	1,215·7		
Beech	46·0	—	46·0		—	—	—		—	46·0		
Sycamore	34·8	—	34·8		5·5	—	5·5		0·7	41·0		
Nothofagus	2·1	—	2·1		12·0	—	12·0		0·9	15·0		
Other broadleaves	32·5	—	32·5		6·6	—	6·6		1·1	40·2		
Total Broadleaves	598·1	712·4	1,310·5		24·1	10·5	34·6		12·8	1,357·9		
Grand Total	1,226·5	787·8	2,014·3		1,372·5	347·7	1,720·2		139·3	3,873·8		

Altogether for statutory quality declaration 557 samples were received relating to Forestry Commission seed, and an additional 30 came from private forestry and 59 from the stock held for the Commonwealth Forestry Institute, Oxford, which consist mainly of sub-tropical species.

On 1st July 1973 the seed testing laboratory will become the Official Seed Testing Station for forest seed for the whole country, and appropriate preparatory steps are being taken in order to fulfil this increased responsibility.

Seed Supply (Table 3)

The decreasing trend in seed usage has continued and during this year has reached the lowest level ever recorded i.e. 704 kg and 1,686 kg of conifer species for the Forestry Commission and private sector respectively. It is worth mentioning that during this sowing season the Forestry Commission has used only 10 per cent of the amount sown in 1957 (6,672 kg). During the same period the planting programme has been more or less at the same level.

This very dramatic decrease has been achieved by constant improvements in seed quality and nursery techniques which have widespread economical effects elsewhere i.e. lesser areas of both seed sources and of nurseries are required.

The decrease in seed usage in the private sector has been less spectacular and has amounted to 25 per cent. Both sectors have a similar planting programme but private forestry requires more than double the amount of seed than that used by the Forestry Commission (1,686 kg versus 704 kg). These comments refer only to conifer seed, which is mainly supplied by the Forestry Commission. In the case of broadleaved trees, private foresters normally collect their own seed or buy it independently of the Forestry Commission.

RESEARCH

Cone Collection and Seed Dormancy

In the absence of any home crop of Sitka spruce cones in 1972, attention was shifted to Douglas fir, where an adequate but only moderate crop of cones was located at Eggesford Forest, South west England. Four trees, each bearing about 1,000 cones were selected for examination. About 100 cones were collected by climbing on 10 regular occasions at 2 weekly intervals from 31st July to 4th December. Seeds from each tree and collection were hand extracted on four occasions (i) within two days of collection and (ii) five weeks, (iii) ten weeks and (iv) fifteen weeks after first collecting. The following observations have been made. The four trees varied markedly in the germination characteristics of their seeds, and in the percentage of full seed in each cone. Seeds from Tree I began to germinate on 28th August, and exceeded 90 per cent germination of full seed on 6th November. Other figures were Tree II: 14th August and 11th September, Tree III: 14th August and 25th September and Tree IV: 14th August and 9th October respectively. Prechilling of the seed had only a limited effect, generally speeding up by only about two weeks the date that germination exceeded 90 per

cent. By the normal period of cone collection for Douglas fir, (September-October) seeds from all four trees showed little if any reaction to prechilling. Storage of the cones for five weeks improved the germination of seeds from all trees very markedly both in the absence and presence of prechilling. Further cone storage, up to ten and fifteen weeks from collection, failed to change the germination at all. Seeds from the various collections and extractions will be sown in the nursery in 1973 and the influence of these variables on nursery establishment studied.

Scots Pine Seed Extraction

In recent years problems have been experienced during routine extractions of cones from Scots pine Seed Orchards. Not only have the yields per hectolitre been very poor, but difficulty has been experienced in getting the seed out of the cones by normal methods, and also the seed has germinated at times in an abnormal way. To study the problem cones were collected at four monthly intervals from November to February from all available trees of the same clone in four of the Scots pine seed orchards at Ledmore, East Scotland. The clones were chosen from those giving a reasonable yield of cones and to give a range of cone sizes. Half of the cones were extracted immediately after collection and half at the end of March 1973. It was at once obvious that there was a consistent clonal difference in the ease with which the cones from the four clones opened, but that this was not correlated with germination quality which stayed fairly constant for each clone from one collection to another. Storage of cones on pallets for from two–four months invariably speeded up the opening of the cones during extraction. This seed is also being grown in the nursery in 1973 to study the effect of collection, extraction and clonal variables on seedling yield.

Bulk Pre-treatment of Seed to dissipate Dormancy

The experiments under this heading were carried out with the co-operation of Silviculture (South) section and are reported in the section on Production and use of Planting Stock (see p. 32).

Post-Sowing Seed Losses

Experiments were laid out at four Conservancy nurseries and at Headley Research Nursery, Hampshire in order to try to explain the fate of the non-productive seed in Commission nurseries and in particular to explain the discrepancy of 25 per cent observed last year between expected and actual losses (*Report* for 1972, p. 26). A known number of seed of Sitka spruce, Lodgepole pine and Grand fir calculated to give the recommended sowing densities, were sown carefully in 10 cm strips, accurately marked out by string across the seed beds. Replicated strips, including grit, seed and soil were removed at regular intervals during the season and the seeds and seedlings counted. Seeds were removed from the soil and grit by a sieving and flotation technique previously shown to be accurate to within five per cent. It was found that highly significant losses of seed occurred at all nurseries for all species, but that the species and nurseries differed in the way that the losses occurred. The seed of both small-seeded species (Sitka spruce and Lodgepole pine) lost significant amounts of

seed between sowing and the first sampling date, which varied from ten days to four weeks from sowings. However, the larger seed of Grand fir was lost more or less regularly throughout the season up to a maximum of about 55 per cent of the seed sown. Significant linear relationships ($P > 0{\cdot}1$ per cent) were established at all five nurseries. For Sitka spruce and Lodgepole pine seed, in nurseries where birds had been observed to be active, the loss of seed amounted to not less than 30 per cent of the seed sown, but in nurseries where no birds had been observed the losses amounted to less than 20 per cent. This seed loss occurred at Headley nursery where the beds had been covered immediately after sowing. The fate of this and other seed where no bird or rodent action was noted could not be identified, but the loss might well explain the discrepancy mentioned above.

Seed Storage and Improvement of Test methods

In a small but comprehensive experiment to determine the best method of storing seed of Sycamore (*Acer pseudoplatanus*) it has been found that removal of any more than the surface moisture from the seed is harmful to germination quality. Only storage of the surface dried seed (moisture content 42 per cent) in polythene bags either at 3–5°C or at outside ambient temperatures maintained the quality of the seed almost to that at time of collection for at least six months. Forestry Commission Leaflet 33 (1960) recommends that seed of *Acer* should be dried "for a few days and then stored in sacks". This procedure reduces the moisture content to approximately 30 per cent which has been found to cause considerable loss of germination quality within three months. A series of excision tests have been carried out in order to find a rapidly performed "germination" test which could replace the "chemical" tetrazolium test which is difficult to interpret consistently for Acer.

Cold Fungus on Sitka spruce seed

All Sitka spruce seed lots in store and all new lots arriving have been tested for the presence of cold fungus (see *Report* for 1970, p. 174) which has now been given the name *Geniculodendron pyriforme* (see p.151). It has been found only on imported lots, originating in both Washington, USA, and Queen Charlotte Islands, Canada. It would seem that the contamination takes place prior to extraction since different lots from the same extraction plant and season showed both complete absence and varying amounts of the fungus. Seed from only one of four suppliers failed to reveal cold fungus.

In nursery experiments the effect of the cold fungus on prechilling treatments to remove dormancy was studied. It was found that sand pretreatment was more detrimental to seed viability than "naked" pretreatment. The effect increased with length of treatment, to the extent that at the end of seven weeks, seedling yield from a seed lot with less than one per cent infected was reduced to 30 per cent of the expected maximum.

International Seed Testing Association

G. M. Buszewicz has been leading the germination group of the Forest Tree Seed Committee, which has undertaken a very extensive revision of the existing rules for the germination testing of forest tree seed. The contrasting opinions

and recommendations from 24 of the 29 co-operators from 15 countries have proved very difficult to reconcile. The accepted revisions will be proposed for incorporation into the rules at the next International Seed Testing Association Conference in Poland in 1974.

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REFERENCE

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PRODUCTION AND USE OF PLANTING STOCK

Conventional Planting Stock

Investigations continued on methods of pre-chilling coniferous seed, and screening of seedbed herbicides. A preliminary study was made of the use of plastic tunnel cloches on nursery seedbeds.

Pre-chilling of Coniferous Seed

Additional information on the effects of various pre-chilling treatments for reducing germination resistance and improving speed of germination of Sitka spruce was obtained from experiments at Alice Holt (Hampshire), Wareham (Dorset) and Bush (Midlothian). In conjunction with results from earlier trials (see *Report* for 1972, p. 25) they indicate that early sowing is not a reliable method of pre-chilling seed, particularly where the seed is infected with the "cold fungus", *Geniculodendron pyriforme*. Refrigerator moist pre-chilling without the addition of sand has emerged as the most reliable technique for Sitka spruce seed of both high and low germination resistance, and in practice a three week period appears adequate, although in some trials some extra benefit occurred from periods of pre-chilling up to seven weeks. Pre-chilling in mixture with sand is undesirable both on convenience grounds and because it may lead to a reduction in germination of seed lots infected with the cold fungus. Irrigation of seed beds after sowing has not improved results with pre-chilled seed, despite the apparent risk of the already moist seed being adversely affected by dry conditions developing in the seedbed.

It was found to be possible to dry slowly pre-treated seed for up to four days after the moist pre-chilling period, without losing the effect of pre-treatment and without reduction in end of season height or numbers. Dry seed facilitates machine sowing; this result indicates a considerable safety margin for the very much shorter periods of careful drying necessary to achieve the correct condition (as little as half an hour for thinly spread conifer seed).

Screening of Seedbed Herbicides

Screening of new herbicides for use in conifer seedbeds (see *Report* for 1972, p. 27) continued in 1972 with experiments at Alice Holt and Wareham. Of the 11 herbicides which passed the 1971 screening tests, only propham, linuron, monolinuron, desmetryne, chlorthal-dimethyl and diphenamid were found to be sufficiently selective on Sitka spruce seedbeds to warrant further critical examination during 1973.

Seedbed Cloches

Plastic materials ranging from clear polythene sheeting to open-meshed plastic netting were tested as tunnel cloches on seedbeds of Sitka spruce at Alice Holt and Newton (Moray) nurseries during 1972. Materials which gave the greatest protection and "greenhouse" effect (e.g. polythene sheeting) produced the largest growth responses compared with control plots, which were covered

with "Netlon" protection netting. Experiments will continue, to evaluate response, and on a wider range of species.

Special Types of Planting Stock

Tubed Seedlings

Results from the many forest experiments established over the past five years continue to support the conclusion that tubed seedlings are suitable for planting on upland peat, provided weedy sites and sites subject to serious animal browsing can be avoided. In the older trials on exposed sites there is still little sign of serious wind loosening of south coastal Lodgepole pine; the trees are generally much more stable than would have been expected for trees of equivalent vigour originating as transplants.

A new trial at Selm Muir, Clydesdale Forest, (Midlothian) confirmed the effectiveness of dalapon for the control of grass growth during the second season in tubed seedling plantations. When applied by knapsack sprayer or mist-blower immediately before flushing of the tree crop, the chemical gave excellent control of *Molinia coerulea* and *Deschampsia flexuosa* with no obvious damage to the young trees. Delay in application until after flushing had taken place resulted in severe crop damage. The large-scale user trial of tubed seedlings mentioned in the 1972 *Report* continued in North Scotland Conservancy, and over 380,000 seedlings were produced and planted during 1972. As in the previous year, most of the seedlings were Lodgepole pine of Alaskan or South Interior British Columbian provenance. Some minor improvements were made in greenhouse handling techniques, but major changes are unlikely until a substantial increase in scale of production justifies the investment necessary for partial automation. In the 1971 plantations, survival after the 1971–72 winter was satisfactory but data are not yet available on growth during 1972.

Preparation of the Forest Record, on production and use of tubed seedlings mentioned in the 1972 *Report* has been delayed; it should be completed during 1973.

Japanese Paperpot Seedlings

Three topics were investigated at Alice Holt during the year: (*a*) Control of rooting to prevent roots extending below pot bases in the nursery, (*b*) "Hardening off", (*c*) The effects of pot size and planting date on early establishment.

(*a*) Too much root development below pots in the nursery is undesirable, and appears to be a particular problem with Corsican pine. Regular undercutting, barriers of polythene sheet or a very fine polythene mesh, both with and without a layer of copper paint, were tested during the raising of 16-week-old Sitka spruce and 20-week-old Corsican pine seedlings in a polythene house. The shoot growth of Sitka spruce was only slightly affected by treatment, but undercutting and unpainted polythene sheet treatments did not effectively prevent roots leaving the pot bases. The impression was however, that root retention treatment was not really necessary with Sitka spruce up to this age. Corsican pine shoot growth was reduced by any treatment which reduced root extension into the underlying sand (all treatments except unpainted polythene mesh), and many seedlings became chlorotic, especially in the treatments which

included copper paint. This may have been due to copper toxicity, but copper paint treatments were also the most effective at preventing roots growing beyond the pot bases.

Seedling experiments were extended to forest sites, some from each treatment being planted in a sandy soil at Alice Holt and root regeneration was examined at weekly intervals after planting. Details of the treatment effects will be published in due course.

(*b*) Observations during the early establishment phases of forest experiments have suggested that Paperpot seedlings suffer from exposure during the first year after planting out, especially on mineral soils. An experiment to test the effects of reducing watering in the last four weeks of the nursery phase and of fertiliser regimes with high potassium content on the development of hardening (as measured by morphological characteristics), produced no visible differences.

(*c*) 16-week-old F308 and F408 Sitka spruce Paperpot seedlings and 20-week-old F408 and F508 Corsican pine Paperpot seedlings were planted in various forests in the south of England and Wales at various dates during 1972 and in the spring of 1973. Initial survival in all treatments is excellent. Recent assessments of similar experiments established in 1971 and in the winter of 1971–72 are also showing that the Paperpot seedlings have survived very well and that the height of the best treatment at the end of the first full growing season (1972) was satisfactory, except on an upland site with mineral soil at Tywi Forest, Cardiganshire (see Table 4).

TABLE 4

MEAN HEIGHTS, AUTUMN 1972, OF F408 PAPERPOT SEEDLINGS AND OF TRANSPLANTS PLANTED ON THE DATES INDICATED

centimetres

Species	Forest	Soil Type	Paperpot Seedlings Planted July '71	Paperpot Seedlings Planted Spring '72	Transplants Planted Spring '72
Sitka spruce	Tywi (Cardiganshire)	Deep peat	29·6	32·5	42·1
		Mineral soil	22·7	28·9	41·5
Corsican pine	Rockingham (Northamptonshire)	Clay	12·9	17·6	16·5
	Thetford (Norfolk)	Sand	10·0	14·0	14·6

Note: Figures are from the best F408 Paperpot seedling treatments from experiments testing various ratios of peat and sand as a growing medium in the Paperpots; transplants are the comparable controls.

It should be remembered that Paperpot seedlings are much smaller than bare-rooted transplants at planting; however any failure to match or reduce this differential in the first one or two seasons will be a serious disadvantage only on very weedy sites.

Good survival and early growth have been obtained in a trial of Sitka spruce Paperpot seedlings planted in July 1971 on a peaty-gley regeneration site at Kielder (Northumberland). Turf planting gave somewhat better results than planting direct into the undisturbed ground surface, but it is not yet clear

whether the advantage gained would justify the cost of some form of superficial cultivation on such a site.

Roll Transplants

Corsican pine roll transplants were raised at Alice Holt and planted in Thetford (Norfolk and Suffolk) and Rockingham (Northamptonshire) Forests at various dates from June to August. This was the fourth successive year in which Corsican pine has been planted out in this way and recent assessments in the older experiments show that the roll transplants normally grow faster and survive better than bare-rooted transplants over the first three years after planting, with the exception of June/July planted roll stock.

No Sitka spruce roll transplants were planted out during 1972, but assessments of experiments planted between 1969 and 1971 show that, for this species, roll plants appear to have no growth or survival advantages over bare-rooted transplants in upland areas. Advantage lies, therefore, only in the flexibility provided to management by the extension of the planting season.

Roll transplants of Douglas fir, Norway spruce and Western hemlock were planted out at Exeter Forest during 1972 to provide information on the performance of roll transplants of other species.

It is now felt that there are sufficient forest experiments on the ground to provide evidence of the potential of roll transplants in uplands and lowlands, and it is not proposed to plant any new experiments unless forest managers begin to use this type of planting stock.

Other Types of Container Stock

Kopparfors Multipots and F620 Finnpots (for description see Low and Brown, 1972) were compared with F308 and F408 Paperpots for raising 16 and 20-week-old Sitka spruce seedlings at Alice Holt. At the end of the nursery phase, there were only small differences in seedling heights and out-turn between the various containers. Similar results were obtained for raising 12-week-old seedlings of Lodgepole pine at Inchnacardoch (Inverness-shire) and Sitka spruce at Tulliallan, Devilla Forest, (Fife). Seedlings from all three nurseries were planted on forest sites (both peat and mineral soils) during the 1972 growing season, and tubed seedlings were included in the northern experiments to provide a link with earlier trials.

During handling of the different containers some important differences became apparent. Sitka spruce seedlings raised in Kopparfors Multipots at Alice Holt were difficult to extract from the pots for planting without root breakage or stripping, while with those produced at Tulliallan, the root ball tended to disintegrate when seedlings were pulled from the pots. In both cases it was felt that seedlings were insufficiently developed for their roots to have created a satisfactory root-ball. On the other hand, no such problems were encountered with Lodgepole pine raised in Multipots at Inchnacardoch. At all three nurseries, Finnpots were so weak after the nursery phase that they were difficult to handle for transport between the nursery and the forest, and they were difficult to plant quickly.

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Vegetative propagation

Poplar

The recommendations that Grey poplar, *Populus canescens*, might be used as a species to replace elm in rural areas (Mitchell, 1973) led to propagation trials being conducted on this tree, which is difficult to raise.

Grey poplar has cultural peculiarities like those of some British elms; it is seldom if ever reproduced from seed; natural regeneration is from prolific sucker growth, and it is difficult and often impossible to propagate vegetatively in the nursery except by layering, budding or grafting. However, the year's work threw fresh light on both the hardwood and softwood cutting techniques in heated beds; sufficient progress was made to suggest that, if the demand for Grey poplar greatly increased, stocks might be built up rapidly.

Two results were encouraging. First, softwood cuttings collected in mid-August and inserted under mist in a peat-sand rooting medium maintained at about 20°C rooted as quickly and in the same number, and survived on bedding out as well as cuttings inserted earlier in the season. This result helps to dispel doubts about the behaviour of cuttings taken after the normal June to July insertion period, and tends to confirm that three batches of cuttings can be rooted in the summer. Second, hardwood cuttings inserted in mid to late winter in a heated bed maintained at 20°C were found after only four weeks to have developed roots sufficiently to permit their removal to pots. Grey poplar has not previously been propagated by this method (Howard, 1972); further trials are required before the method can be recommended for this species. The technique is becoming increasingly well known in horticulture and where it has already been successfully practised it should be preferred to attempts at plant production in the open nursery.

The work was conducted on 12 clones which had previously proved difficult to root outdoors.

Elm

Attempts to raise Commelin elm from hardwood cuttings were again unsuccessful. The experiment was designed to compare the effects of applications of different formulations of the synthetic auxin indolyl-3 butyric acid (IBA) on cuttings prepared and inserted at one-month intervals from November to January, and the effects on cutting behaviour of short periods of cold storage at +3°C. None of the treatments produced roots.

As in previous years, plants of selected clones were raised for use in trials on Dutch elm disease from softwood cuttings in mist. Trials started last year on cutting survival and vigour in plastic horticultural trays were continued, but two electrical power failures in mid-summer caused the death of all rooted and unrooted cuttings then under automatic mist and no conclusions could be reached. Observations made in late winter on more than a dozen full trays of cuttings rooted towards the end of the summer helped to confirm however, that because the plants can be easily transported in the trays and none of the plants need be individually handled prior to lining-out, many fewer failures occur than when insertion is made direct into the rooting medium on the bench.

Preliminary trials were started in late winter to assess the merits of elm propagation by means of shoots cut from callused roots (Tchernoff, 1963).

The roots of English, Dutch and Commelin elm were collected in February and cut into segments about 7 cm long; these were then inserted vertically into a rooting medium of 25 per cent sand—75 per cent peat and maintained at about 18°C. After two weeks shoots began to appear from the root segment and by the end of March some were nearly 4 cm long. On reaching this size the shoots were detached from the segment and rooted in the same way as softwood cuttings taken in June and July. So far the results accord with the success achieved in the Netherlands where the technique was developed for elm propagation.

Nothofagus

Plant shortages due to difficulties over seed procurement led to propagation trials being conducted during the summer on softwood cuttings of *N. procera* and *N. obliqua*, the two best known species in this country, and *N. dombeyii*, an evergreen species. The same techniques were used as those for softwood cuttings of elm and Grey poplar.

The first batch of cuttings was inserted in mid-June, the optimum time for rooting many deciduous species in mist. Unfortunately all the cuttings were lost in mid summer due to a breakdown in automatic misting caused by electrical power failure. However, a batch of cuttings inserted in mid August rooted sufficiently well in spite of the late date to suggest that, with proper timing, at least *N. obliqua* and *No. dombeyii* could be easily raised vegetatively. Nearly 80 per cent of the cuttings of *N. dombeyii* rooted. Regrettably, few cuttings of *N. procera* rooted.

J. JOBLING

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PLANTING

Spacing of Conifers at Planting

Available information on the influence of spacing at planting on establishment, early growth and crop stability in conifer plantations in Britain was reviewed as part of a more general study of spacing effects. There was a shortage of direct information on the subject, but the following tentative conclusions were reached:

For spacings up to 2·4 m there is little evidence of any biological advantage in using closer rather than wider spacings except on exposed upland areas. On more sheltered ground, therefore, the choice of plant spacing could be primarily on practical and economic grounds, at least as far as the establishment phase is concerned. Most establishment costs will be reduced by increasing spacing. However, on sites where slight to moderate losses are expected, beating-up might well be necessary for 2·4 m but not for closer spacings; the total cost of planting and beating-up is then likely to be lower for 2·1 m than for wider or closer spacings.

On the more exposed upland areas (where much afforestation takes place) the position is different because of the probable benefit to tree growth from early development of mutual shelter within the crop. Since wide spacing will delay this development, it appears unwise to widen spacing from the currently accepted 1·8 × 1·8 m on climatically severe sites where wind exposure is an important factor.

No evidence was found of a relationship between initial spacing and crop stability in strong winds. Within the spacing range studied, it seems likely that stability will be much more affected by thinning practice than by initial spacing.

The influence, after the establishment phase, of spacing on growth and yield, and particularly on timber properties, is under examination. The suspicion that wide spacing (2·4 × 2·4 m or above) may have adverse effects should, one way or the other, receive factual resolution from this study. Until this is resolved, it seems unwise to consider planting at spacings exceeding 2·1 × 2·1 m or equivalent rectangular spacing, except perhaps on very fertile sites; and in the case of pines which tend to have heavy branching, spacings wider than 1·8 × 1·8 m appear undesirable.

In the near future it is hoped to publish a report on the complete spacing study.

A. J. Low

CHOICE OF SPECIES

Tsuga mertensiana

Commonly known as Mountain hemlock, this species grows down to sea level in Alaska but below a latitude of 49°N it occurs only as a tree of the mountains, usually above 1,500 m. Its ability to grow well on exposed sites facing the Pacific at Prince Rupert and in S.E. Alaska suggested that it ought to be tested under plantation conditions in Britain, as existing plots are rare. Small trials were planted in 1960 at Tarenig, Cardiganshire in which an Oregon provenance of this species was compared with a Vancouver Island provenance of Western hemlock, and in 1962 an Alaskan provenance (Juneau) of Mountain hemlock was compared with provenances of Western hemlock from Juneau and from Avondale, Eire. The latter is believed to have originated in Oregon. The 1962 trials consisted of unreplicated plots at four sites: Achnashellach, Wester Ross; Braes of Angus; Elibank, Peeblesshire; and the Watermeetings section of Greskine Forest, Lanarkshire. A plot of Mountain hemlock was also included within a Western hemlock provenance experiment at Naver, Sutherland.

Early survival was good at all five Scottish sites, which were chosen because they were moderately fertile though at high elevation and with moderate or severe exposure. On these upland sites the trees were mostly protected by snow cover during the bitter 1962/63 winter, which did so much damage to the Western hemlock experiments planted in the same year. Survival continued at a satisfactory level except at the severely exposed Greskine site, where the more tender Avondale provenance of Western hemlock had heavy losses and only fifty per cent of the hardier provenances of the two species from Juneau had survived by six years of age when the experiment was written off. Height growth was slow at all sites, with the Mountain hemlock still less than 20 cm tall after six years at Greskine and less than 50 cm tall at all the other sites. At 10 years the best plot of this species was 1·3 m tall at Achnashellach on a site with some shelter from the original birch scrub. On the same site the Juneau provenance of Western hemlock was 3·1 m tall. Mountain hemlock was less than 0·8 m at all the other sites, including the relatively low elevation one at Naver. At Tarenig in Ystwyth Forest Mountain hemlock was 0·84 m and Western hemlock 1·8 m tall at eleven years.

It can be concluded that these trials confirm the pattern of slow early growth noted by Mitchell (1972) and that, if diversity of species is required on high elevation and exposed sites, Mountain hemlock is an unsuitable choice. It appears to have no advantage over an Alaskan provenance of Western hemlock in resisting cold blasting winds and is equally susceptible to *Calluna*-induced check (remedied by spraying with 2,4-D in these trials). According to Hosie (1969) it makes its best growth in Canada on deep moist soils on the sides of ravines with a northern aspect. The site at Achnashellach comes nearest to this description, but it is also less than 330 m in elevation whereas the other sites are up to 425 m. This is a species with distinctive foliage and form; however, its slow rate of growth may limit its role as an amenity tree to those sites where it can grow vigorously as a specimen tree without being crowded by stronger competitors.

R. LINES
A. F. MITCHELL

Tatter flags

Interest continues in the tatter-flag method for rough estimation of wind exposure and many enquiries were dealt with. These flags have now been used for such diverse purposes as testing the relative exposure at base camps on the lower slopes of Annapurna in the Himalayas and locating the best sites for fish tanks on a Scottish loch. Unfortunately the Annapurna flags were stolen, perhaps for future use as Buddhist prayer flags. The next step with the tatter flag technique is to see whether it can be superseded by wind tunnel trials of a topographic scale model.

R. LINES

Broadleaved Trees

The review of broadleaved silviculture, first referred to in the 1972 *Report*, continued during the year. Special attention was paid to the free-growth method of improving rates of radial increment of selected dominant trees in young to semi-mature crops by continued heavy thinning of the surrounding matrix, and a good deal of time was spent in the collection and computation of data for the production of supporting management tables. Sufficient progress was made with oak due to the availability of data from forest experiments started in 1950 to enable a report to be prepared on the subject. The absence of similar experiments on beech, ash and sycamore has prevented similar work on these species advancing at the same rate. Work in the south has also included a review of all the experiments on broadleaved trees conducted in Breckland forests at Thetford Chase in East Anglia and in the Forest of Dean and nearby forests in the west since the 1930s. An appraisal of scrub woodland in south-east England was also started during the year, and attempts to quantify coppice productivity, notably of the faster growing species, were continued.

With greater current interest in amenity planting, the results of northern experiments were re-appraised, particularly in relation to beech. The performance of progeny from outstanding parent sources such as Arundel and Cirencester Park has been disappointing, especially in regard to stem and crown form. In an attempt to find broadleaved species which will help to diversify the predominantly coniferous forests on the poor quality peatlands of the north of Scotland, Oregon alder was planted with some early success followed by extensive damage from autumn frosts in 1971 and to a lesser extent in 1972. Further trials include Grey alder and the Alaskan alder, *Alnus sinuata*.

J. JOBLING
R. LINES

Trials of Species on Other Soils

Industrial Waste Sites

Experiments planted during the year at Bramshill Forest (Hampshire and Berkshire) are expected to provide early guidance on the methods required to ensure the successful afforestation of recently restored open-cast sand and gravel workings. In the first planted experiment, seven species are being tested, including Scots pine, the predominant tree on sand and gravel sites prior to quarrying, and Corsican pine, the most common replacement species in woodlands in the southern half of England. Two fast growing broadleaved species,

Nothofagus procera and sycamore, have also been planted because of the amenity considerations pre-eminent in many land restoration schemes.

In the first year virtually all surviving trees regardless of species had a healthy appearance. Scots pine, sycamore, Grand fir and Corsican pine suffered fewer than 5 per cent losses. Survival of Western hemlock was less satisfactory (37 per cent losses). Leyland cypress and *Nothofagus procera* proved to be the most vigorous species, and Grand fir the least vigorous. Placement of the trees in soil cultivated immediately before planting, and application of a phosphate fertiliser shortly after planting led to only minor improvements in survival and vigour.

A second experiment was started in the autumn and continued in late winter to compare the behaviour of Corsican pine raised in the greenhouse in Japanese paper pots with normal bare rooted stock of this species. Three sizes of pot and the effects of an application of a phosphate fertiliser are being examined. It was recorded that the soil was so compacted at each time of planting that the special planting tool designed for Japanese paper pots could not be used.

J. JOBLING

Species on limiting sites

Advice was given on the choice of species and necessary silvicultural treatment on a wide range of sites from very exposed areas in the Orkney Islands, to coal tips in central Scotland and in Northumberland, and in areas believed to be subject to air pollution in the Pennines.

R. LINES

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PROVENANCE

Sitka spruce

IUFRO Collection

Seed collections of Sitka spruce organised by the International Union of Forest Research Organisations were made in 1968, 1969 and in 1970, covering in all a total of 73 provenances; 18 others were available, some from commercial sources. As it would be difficult in practice to carry such a large number through to the forest stage in large plot, medium-term experiments, 30 provenances were selected to represent the whole range. An additional 42 provenances were selected to consolidate this range (particularly in Queen Charlotte and Vancouver Islands) for inclusion in short-term forest experiments. These 72 provenances were sown in 1972 at Bush, Midlothian, and Fleet, Kirkcudbrightshire, nurseries while at Wareham, Dorset, 27 provenances were sown.

In most cases more than the expected numbers of plants, based on germination tests, were produced. Provenances with poor seed-bed germination included those from the north of the Alaskan area and three lots from the Skeena River in British Columbia. The latter gave poor germination in laboratory tests and may have carried a seed-borne fungus as other lots from this area germinated normally.

A cold spring gave low soil temperature; at the coolest site (Bush) the tallest provenances had grown only 3 cm by 3rd August. A week later the tallest provenance at Fleet was about 4 cm high and it is noteworthy that this came from Skagway, Alaska. Height assessments were made in August and November at the Scottish sites and the growth during this period expressed as a percentage of the height in November. The Alaskan provenances made between 34–50 per cent of their total growth in the late summer and autumn, when the group from southern Oregon and California made 59–64 per cent.

More surprisingly, the proportion of late growth made by the provenances from Queen Charlotte Islands covered a similar range to that of the Washington group, while the Vancouver Island provenances showed a wider variation than either of these groups. This suggests that it is impractical to separate one year old seedlings of unknown provenances by their proportion of late growth, except for those at the extremes of the range.

There was a highly significant clinal relationship between end of season heights and latitude of origin; this was evident from regressions calculated for each nursery experiment. Figure 1 shows the comparison at Fleet together with the mean height and range within each provenance group; it demonstrates within the given range of latitudes, the straight line relationship between latitude and height.

Statistical analysis (of end of season heights) separated the provenance groups into four classes, significantly distinguished from each other but with little or no

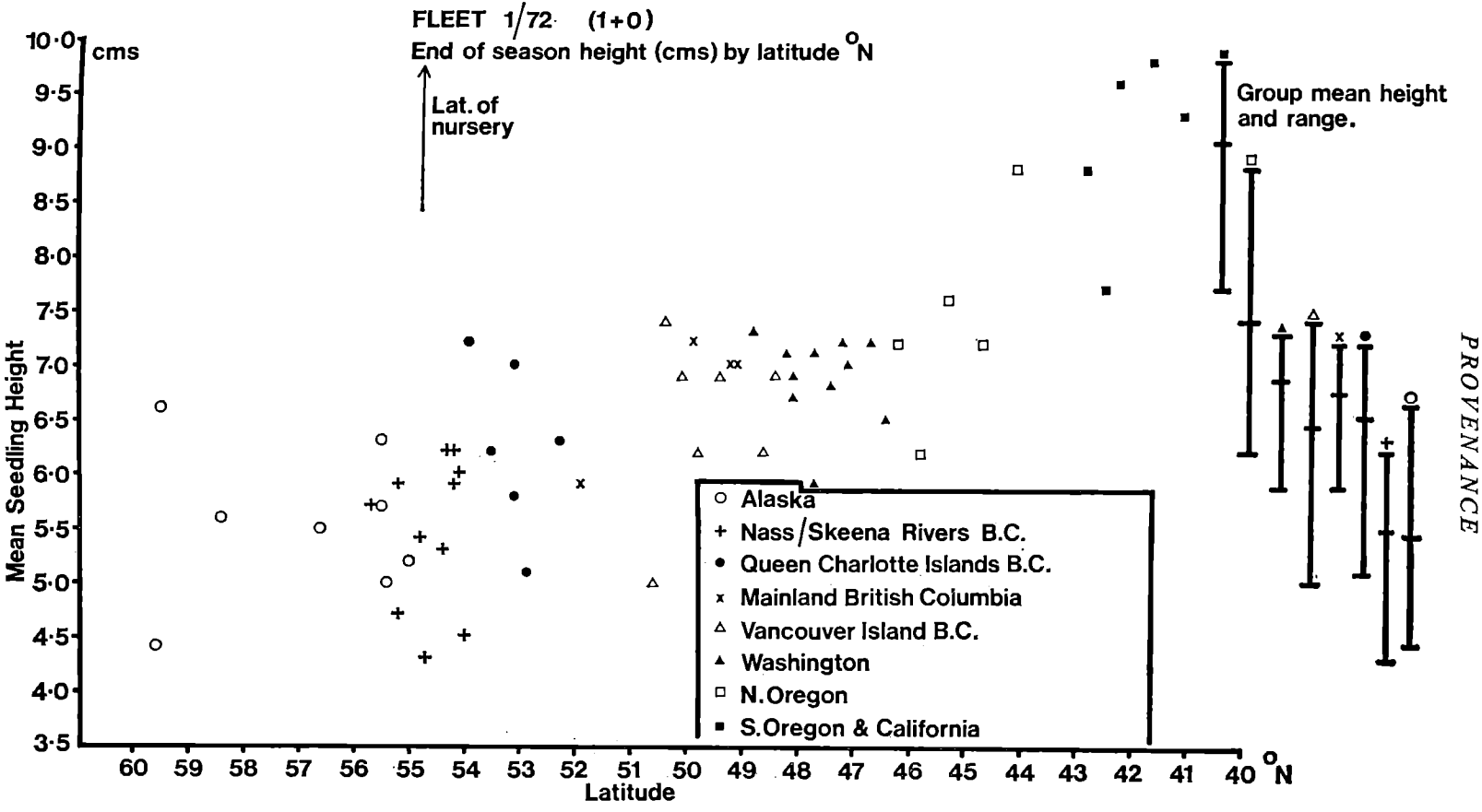

Figure 1: Relation between end of season height (cms) of one-year-old seedlings of Sitka spruce and latitude of seed origin (at Fleet Nursery, Kirkcudbrightshire).

significant difference between groups within the class. In ascending order of height performance were:

Class	*Groups*	*Performance*
1	Alaskan and Skeena/Nass	poor
2	Queen Charlotte Islands, mainland British Columbia, Vancouver Island and Washington	intermediate
3	North Coast of Oregon	tall
4	South Coast of Oregon and Northern California	outstanding

Similar growth patterns were shown by the experiments at Bush and Wareham, despite overall growth differences (poorer at Bush, much taller at Wareham), related probably, to differences in accumulated temperature. Comparing growth at Fleet and Wareham, all provenances south of Skeena and Nass rivers grew better at Wareham, but Skeena, Nass river and Alaskan provenances grew less well at Wareham than at Fleet.

There was wide and significant variation between the provenances within the two southerly groups and also in the Skeena/Nass group. The Queen Charlotte Island group also contained much variation between individual provenances while, somewhat surprisingly, the Washington group (of 11 provenances) did not show significant variation at either Bush or Fleet. Individual provenances were sometimes outstanding—e.g. the tallest Alaskan one (Skagway) was bigger than the poorest provenance in the north Oregon group, while only the tallest Washington seedlot (Bellingham) was ahead of the tallest Queen Charlotte Island provenance (Masset).

At Fleet nursery an attack by *Botrytis cinerea*, despite prompt fungicidal spraying, caused some loss of plants, particularly in the unreplicated section. At the two Scottish sites the seed beds were covered with screens to protect against autumn frost damage; at Wareham they were not covered. Frosts occurred in September but no damage was noted until the severe frost in late October (October 21st at Fleet). Damage occurred at all three nurseries and was restricted to the six most southerly provenances, no injury being suffered by provenances north of latitude 44° 30′. The percentage of plants frosted increased with decreasing latitude of origin. Typically the top of the plant has been killed back; the lower part has dormant buds which will form a new shoot. More detailed examination of the results is in progress and a fuller report will be published.

Abies grandis

Knowledge of provenance variation of *Abies grandis* in Britain is very slight, the only experimental evidence coming from a single series of five provenances planted in 1967/68. To extend this knowledge, 24 provenances were sown at Newton, Morayshire in 1972. They ranged from Vancouver Island, the coastal lowlands and Cascade Mountains of Washington to the Coast and Cascade Mountain of Oregon. Height of the seedlings varied from 6·8 cm (Matlock, Washington) to 3·2 cm (Blewett Pass, Washington). Differences between groups of provenances and between individual provenances within all of the groups were highly significant. There was some indication that within the coastal

sources those with higher seed weight gave the tallest seedlings, but within the Cascade Mountains seed sources this relationship did not hold true. The experiment has demonstrated that there are differences of practical importance between provenances of this species; and it may be noted that certain sources, widely-used in the past, produced small seedlings.

Results from three provenance experiments with this species in Denmark, Belgium and France were thought to be a further source of information, albeit with reservations about its applicability in Britain. Accordingly the overall mean height at each experiment was taken as 100 per cent; then the height of each individual provenance was expressed as a percentage of this. Results were combined with those from the Newton experiment to give a total of 66 provenances. They were grouped geographically into twelve North American Seed Regions (delineated by the Forestry Commission), and an analysis of variance between and within groups showed that there were highly significant differences between the groups. The tallest was the (7972) region of Washington, followed by the (7952) and (7951) regions of Oregon, while the shortest were from Idaho (796) and interior Oregon (7955) and (7956). When individual provenances were plotted on a map they formed a coherent pattern, with most of the coastal sources above 100 per cent and most of the interior sources (especially those east of the Cascade ridge) below 100 per cent. A multiple regression of latitude, longitude, and elevation of source on percentage height showed that elevation was the best single factor explaining height differences (34 per cent and highly significant). Longitudinal effects are synonymous with distance from the coast for provenances below a latitude of about 46° north. A separate multiple regression for these 30 provenances explained 54 per cent of the variation in height (38 per cent for longitude alone and 49 per cent for elevation alone). The main benefit from this analysis of the four experiments is that it will guide a IUFRO team under the direction of Dr. A. M. Fletcher in choosing areas in 1973 for further collections of *Abies grandis*.

R. LINES
M. L. PEARCE
A. F. MITCHELL

ARBORICULTURE

Arboreta

At Westonbirt Arboretum, Gloucestershire, planting has been completed in Palmer Glade and the area north to the Waste. A shelter has been erected at each end of the Glade as a donation from a benefactor. The extension to the oak collection west of Broad Ride has been completed and a number of oak species have been acquired and are being grown on. The siting of a visitor centre has been decided upon and work on it will proceed.

At Bedgebury new vistas have been cleared from high ground to Marshall Lake and a number of unsatisfactory broadleaved trees have been removed. A triangular area by the northeastern boundary of the Pinetum, which was planted in 1930 with groups of fairly rare conifers, has been cleaned and is being labelled.

The collection of dwarf conifers has been extended, as well as that of species cypresses and cypress cultivars.

Tree Records

Additions to and remeasurements of records totalled nearly 800, concentrating largely on increasing the representation of rare broadleaved trees.

Landscaping Projects

Two large schemes were prepared, one in detail for a large Ministry of Defence site in Wiltshire and one for the extensive grounds of a hospital in Surrey. Smaller projects include an arboretum in Farnham Park and minor plantings in connection with Tree Year.

A. F. MITCHELL

FOREST WEED CONTROL

CHEMICAL CONTROL OF SPECIFIC WEED POPULATIONS

I. GRASS AND HERBACEOUS WEED CONTROL

Atrazine

Forest user trials were run during 1972 to demonstrate, and gain confidence in, the degree of control of mainly grass weed populations provided by atrazine, both as a wettable powder and as a granular formulation. Experiments in 1970 suggested that control from granular formulations may be inadequate, but it was felt to be worth while using these trials to retest these findings because of the general interest in granular herbicides for forestry.

TABLE 5

SUMMARY OF WEED CONTROL SCORES IN 1972 USER TRIALS

Site	Alice Holt		Bere (Queen Elizabeth Forest)		Hursley		Salisbury	
Initial % live cover of fine/soft grasses	80		80		60		80	
Date of assessment	July	Aug/Sept	July	Aug/Sept	July	Aug/Sept	July	Aug/Sept
Treatment								
No spray	1·0	1·0	1·0	1·0	1·0	1·0	1·0	1·0
W.p. @ 4·5 kg/ha	4·5	4·2	4·7	4·8	4·6	4·5	4·6	4·0
Granules @ 3·8–5·5 kg/ha	4·7	4·7	4·9	4·8	—	—	4·0	3·6
Granules @ 5·7–7·7 kg/ha	4·4	4·6	4·8	4·7	4·4	4·5	4·9	4·9
Granules @ 9·6–10·0 kg/ha	—	—	—	—	4·9	5·0	4·9	5·0

Note: Score of weed control achieved: 1 = none, 2 = poor, 3 = marginally acceptable, 4 = good, 5 = excellent.

W.p. = wettable powder.

Table 5 shows that all treatments give good to excellent control, and that the control provided by the granular formulation was similar to that provided by the wettable powder. Previous experiments and information from other sources have suggested that granular formulations will rarely give as good weed control as wettable powder formulation; but these results show that granular atrazine *can* provide satisfactory control of grass species which are susceptible to atrazine.

Results from experiments in 1967 to 1972 inclusive have now been reported in two papers at the British Weed Control Conference (Brown, 1970 and 1972).

II. BRACKEN

Asulam

Following the preliminary test of conifer tolerance to asulam in 1971 (see *Report* for 1972, p. 44), a more sensitive experiment was laid down at Headley Nursery, Alice Holt in 1972 to examine the effect of overall applications of 1½, 3, 4½ and 6 kg active ingredient per ha at the beginning of July and September on Corsican pine, Sitka spruce, Norway spruce, Douglas fir, Western hemlock and Japanese larch.

A full assessment of any effect will not be possible until the end of 1973, but preliminary results are confirming that Western hemlock is rather sensitive to asulam, and are also suggesting that Douglas fir may not satisfactorily tolerate applications of 3 kg active ingredient per ha and above. All other species exhibited only minor symptoms of spray damage at 3 and 4½ kg active ingredient per ha. It is important to realise that in forest situations bracken fronds will prevent much of the spray reaching the trees, and the results from this experiment represent the maximum risk to the crop.

Meanwhile, the results of other workers continue to confirm that asulam provides excellent control of bracken (Soper, 1972; Martin *et al.*, 1972, Scragg *et al.*, 1972).

III. WOODY WEED CONTROL

Control of Heather (Calluna vulgaris)

Further trials were carried out through the dormant season with ultra low volume (ULV) spraying equipment in an attempt to extend the effective spraying period by increasing the amount of herbicide applied. Only in April did consistently satisfactory results occur at three sites using both ULV and mistblower, and then only when 8 kg active ingredient/ha (double the standard rate) were applied. There is greater risk of crop damage using this rate, when applied just before flushing.

To minimise possible crop damage from ULV spraying during the main (summer) spraying season, the "Hulva" applicator was tried at four sites. This has a slower disc speed producing larger droplets and thus has the potential for reducing damage. Damage was reduced but so also was heather kill, and therefore the Hulva applicator cannot be recommended.

Knapsack applicators used with low volumes of water (110–225 litres/ha) could be a practical way of extending the spraying season, and indeed could replace the mistblower at this rate of diluent. These low rates have been successfully used in field practice with the appropriate nozzle size, and their effectiveness has been confirmed in one research experiment. Further trials are planned for 1973 to investigate the effects on crop and heather with application in May/June, when the crop is most susceptible to damage.

Results and implications of the heather spraying trials which have been carried out over the past four years will be published as a Forest Record, due in 1973.

R. M. BROWN
J. M. MACKENZIE

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NUTRITION OF FOREST CROPS

Foliar Sampling Surveys

Research foresters have again assisted foresters in Southern England and in Wales to collect foliar samples for analysis and subsequent advice on fertiliser treatment. After stratifying the crops, samples were taken at randomly selected spots. Site and crop data at each sampling point were recorded to help in interpreting analysis results. Since last year's *Report* the following surveys have been completed:

Forest	*Area Sampled (ha)*	*Number of Samples*	*Nutrient*	*Number of Samples Deficient and, in Brackets, Moderately Deficient*
Clocaenog (Denbighshire)	1,550	59	N P PK	7(18) 4(4) 3(3)
Crynant (Glamorganshire)	1,650	95	P	27(13)
Dyfnant (Montgomeryshire)	600	20	N P K	—(11) 3(1) 4(5)
Hafren (Montgomeryshire)	1,300	152	N P K	4(30) 49(22) 4(16)
Halwill (Devon)	380	20	P	2(4)
Margam (Glamorganshire)	570	20	None	
Ringwood (Dorset)	780	49	N P	3(10) 15(6)

The results obtained in these surveys reinforce the findings in fertiliser experiments which, together with recommendations for the use of fertilisers in southern Britain, are soon to be published as a Forest Record.

Foliar Nutrient Concentrations and Tree Growth

Work has continued on determining the relationships between tree growth and foliar nutrient concentrations for various species and sites. Multiple regression analysis is currently used to determine which pair of the three nutrients, i.e. NP, NK, and PK account for most variation in tree height. The equation obtained is then used to plot a response surface of the type shown in Figure 2. This equation relates tree height and foliar N and K concentrations in six-year-old Sitka spruce on a peaty gley in North Wales.

Phosphatic Fertilisers in South-west England

The recommended rate of phosphatic fertiliser when planting heathland soils in south-west England is 75 kg P/ha (equivalent to 600 kg/ha of unground Gafsa

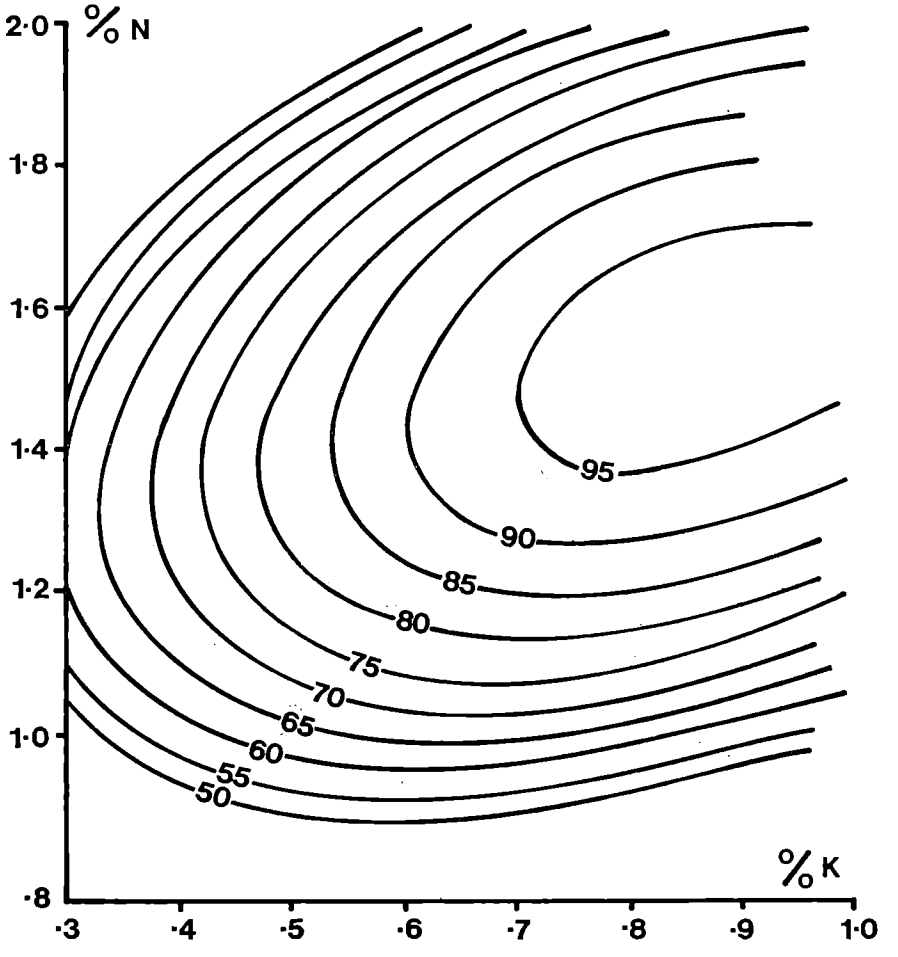

Figure 2: (Foliar nutrient concentrations and tree growth). The relationship between mean height and the foliar concentration of N and K in Sitka spruce at 6 years of age (Clocaenog Forest, Experiment 52, Denbighshire).

Plot mean height is expressed on a relative scale, the tallest plot being 100.

The equation:

Relative Height $= 174 + 316N - 131N^2 + 65K - 131K^2 + 105NK$ accounts for 81 % of the variation in measured plot mean height and is significant at 0·1 % level.

phosphate rock). Evidence from four experiments illustrated in Figure 3 shows that, even with this rate, Sitka spruce is likely to be deficient by about the fifth or sixth year.

The way in which P deficient Sitka spruce crops in south-west England respond to top-dressing is illustrated in Figure 4.

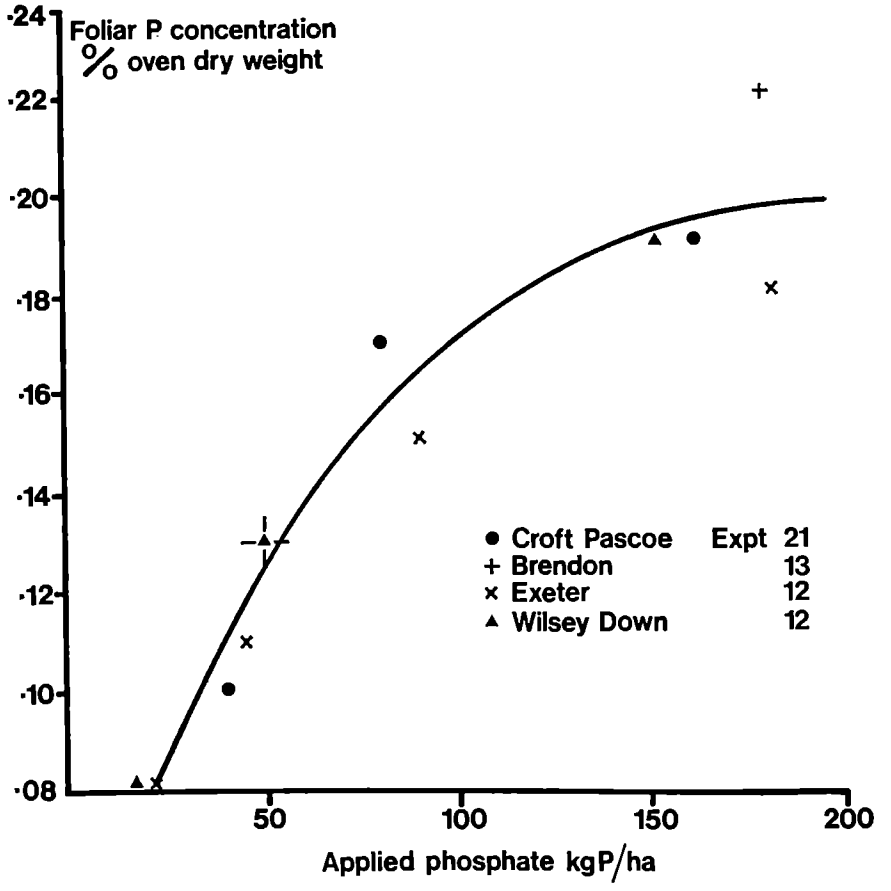

Figure 3: (Phosphatic fertilisers in south-west England). The relationship between the rate of applied phosphate and foliar P concentrations five years later, in Sitka spruce. Croft Pascoe and Wilsey Down are sections of Kernow Forest in Cornwall; Brendon Forest is in Somerset, and Exeter Forest is in Devon.

Phosphate on Northern Hill Peat

Two experiments planted in 1969 on deep hill peat at Shin Forest (Sutherland) both indicate, after 3 or 4 years, that phosphate applied after ploughing has given better P uptake in Sitka spruce than when applied just before ploughing. This refutes the suggestion, often made, that a double dose of phosphate in the "sandwich" layer from pre-ploughing applications might be beneficial. The rates were heavy (627 kg and 1,254 kg per hectare unground phosphate rock); there are no growth differences so far and all foliar P levels are satisfactory. Lodgepole pine has not shown any appreciable difference in P uptake between treatments.

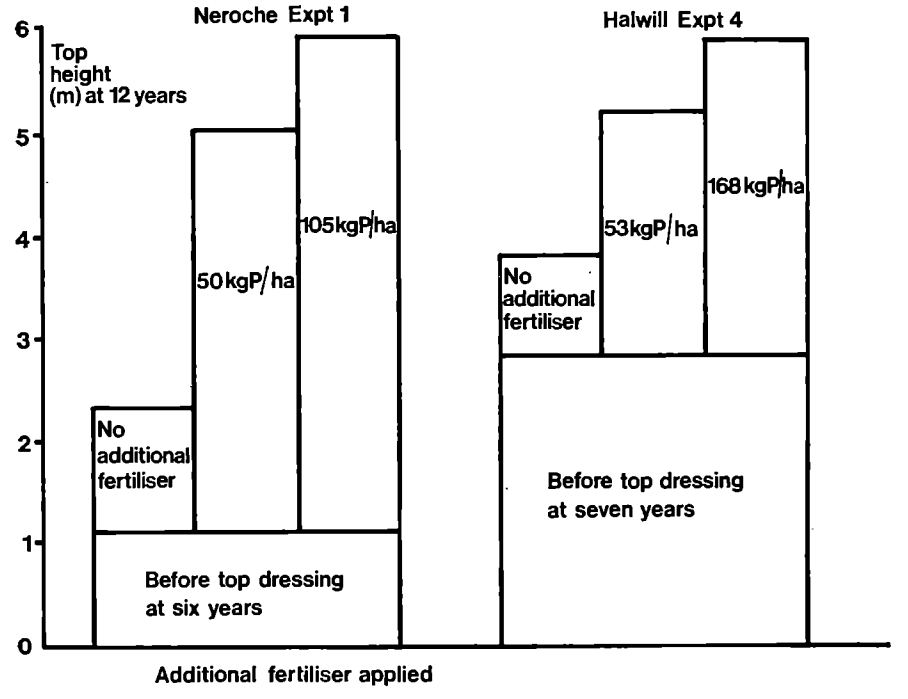

Figure 4: (Phosphatic fertilisers in south-west England). The effect of top dressing at different rates on the height growth of P deficient Sitka spruce in south-west England.

The effect of delayed application of phosphate at planting on South coastal Lodgepole pine is dramatic. Figure 5 indicates that even a delay of 3 years is unlikely to be made up; this stresses the importance of correct timing of application. There may be more flexibility with top-dressing, however, as Lodgepole pine height growth appears not to be immediately affected by deficiency levels. For the treatment with 42·5 g phosphate at planting shown in Figure 5, the P levels in the foliage were satisfactory at Year 3 (0·140 per cent); they reached deficiency levels by Year 5 (0·104 per cent), but no fall-off in growth appeared until Year 8; the response to top-dressing at Year 12 is shown, and the P level reached 0·167 per cent by Year 15. The fall-off in growth is more marked at the low rate, but less so for the plot which was top-dressed at 3 years.

The effect of earlier top-dressing, to avoid loss of increment, may be shown by an experiment at Shin Forest (Sutherland) where coastal Lodgepole pine was deficient by 6 years and uptake of phosphorus from top-dressing at this age has been considerably improved. Growth figures are not yet available.

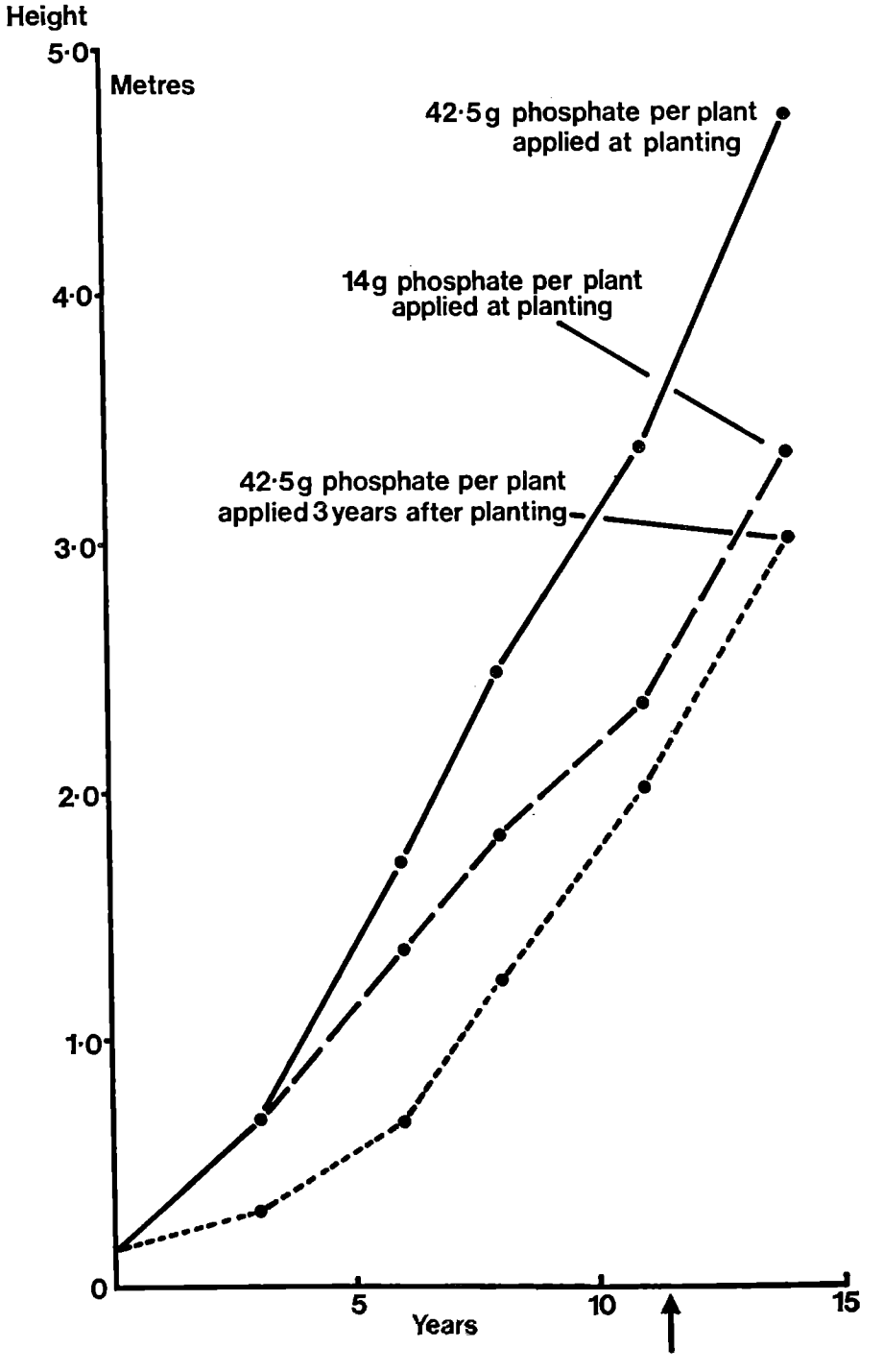

Figure 5: (Phosphate on northern hill peat). Mean height growth of south coastal Lodgepole pine at Naver Forest, Sutherland. (Experiment 3 P. 58.) The arrow indicates overall application of 375 kg/ha unground phosphate rock.

Phosphate Requirement on Estuarine Peaty Gleys in Yorkshire

Eight-year-old inland Lodgepole pine shows significant height increase 3 years after applying phosphate; needle weights and P contents are also much improved. Rates higher than the standard 50 kg P per hectare have not produced better growth, nor has potash application had a significant effect. Herbicide has increased needle weights, indicating improved vigour, but this has not yet been reflected in growth. Sitka spruce shows some improvement with herbicide and with phosphate alone, and a dramatic improvement when both are used, as shown in Plate 3. Application of potash has again had no effect. As with Lodgepole pine, more than 50 kg P per hectare has not yet improved Sitka spruce height increment; needle weights are no greater, but the 50 kg rate has produced significantly lower P uptake than the higher rates. Foliar nitrogen concentrations have not been affected by applied phosphate, but, 3 years after treatment, the herbicide treated plots still show an appreciably higher level (1·35 per cent) than untreated plots (1·08 per cent).

The Scots pine picture is less clear. In an experiment using different rates of phosphate with and without nitrogen, 100 kg P per hectare has given the greatest mean height increment after 3 years. Nitrogen has not affected mean height. There is a small but not significant difference in dominant height increment, favouring the 50 kg treatment. However, diameter increment of the same dominants gives a significant response to both applied phosphate and nitrogen, with no additional improvement in increasing the rate of applied P at about 50 kg. Foliar analysis indicates some improvement in N and P levels from fertiliser, but not as great as with Sitka spruce and Lodgepole pine.

Nitrogen on Unflushed Deep Peat

In the experiment on Sitka spruce at Strathy, Naver Forest, Sutherland (see *Report* for 1972, p. 51) the no-nitrogen treatment continues to maintain low N levels following herbicide treatment, in the presence of good P and K levels. The uptake of recently applied N has been good and growth differences from the various nitrogen regimes can be expected by the next assessment. In the same series, another experiment at Mabie Forest, Dumfries-shire, also has produced deficient N levels after 6 years in the no-nitrogen treatment, following heather control in the third year. It appears probable that for Sitka spruce a nitrogen input may be required before 10 years after planting, at least on the raised bog type, in order to maintain fast early growth. This is earlier than was previously expected. However, the limits of maximum and minimum growth patterns according to input have still to be determined and therefore it will be some years before early effects of nitrogen regimes can be estimated.

Ironpan Soils in East Scotland

At Teindland, Laigh of Moray Forest, Morayshire, different fertiliser treatments have not given any significant growth responses after 4 years on two provenances of Lodgepole pine, 5 years old at application, on complete cultivation. Foliage analysis after application had shown uptake of N and K, but not of P. Nutrient levels had not indicated deficiencies before application.

In an experiment at Rosarie, Speymouth Forest, Banffshire, though foliage analysis does not show any difference in nutrient uptake, there are significant

differences in mean height growth after 3 years. This follows application of P and NPK fertilisers at planting on Scots pine, inland Lodgepole pine, coastal Lodgepole pine and Sitka spruce planted on an ironpan soil following complete cultivation. The greatest response was from the two last species, with Sitka spruce benefiting most from the NPK treatment. How this improved start will affect future growth will be of interest.

In a nitrogen experiment at Drumtochty, Mearns Forest, Kincardineshire, with Sitka spruce on an ironpan soil derived from Old Red Sandstone, overall phosphate deficiency has occurred after only six years. Nitrogen deficiency has occurred on plots where heather growth was not controlled. The phosphate deficiency occurred where phosphate had been applied at planting and the heather had been mechanically "swiped" before ploughing. Study of the early growth behaviour of crops in experiments on different soil types should enable us to predict deficiencies before growth is seriously affected. New experiments are being established on mineral soils derived from different geological origins.

Times of Application of Potash Fertiliser

In four experiments on deep peat sites in Scotland, on which Sitka spruce is prone to show early potash deficiency, potash fertiliser has been applied at different times throughout the year. Foliage analyses at the end of the first year (Table 6) indicate that while uptake has occurred in the winter months, particularly at Carron Valley and Castle O'er, the best uptake is in May and July.

TABLE 6

FOLIAGE POTASSIUM LEVELS IN YOUNG SITKA SPRUCE RESULTING FROM POTASH FERTILISER APPLIED AT DIFFERENT TIMES THROUGH THE YEAR

K as Percent of oven dry weight of foliage

Site	Time of Application							5% LSD
	Control	Nov.	Jan.	Mar.	May	July	Sept.	
Minard, Argyll	0·31	0·56	0·65	0·65	0·83	0·91	0·88	0·06
Carron Valley	0·54	0·80	0·83	0·86	0·93	0·93	0·82	0·06
Castle O'er	0·58	0·86	0·87	0·89	0·96	0·99	1·03	not to hand
Kershope	0·26	0·65	0·71	0·75	0·84	0·84	0·41	0·09

It is interesting to note that at three sites uptake has been recorded from September applications. This indicates the rapid mobility of potassium, as foliage samples were collected four to eight weeks after the September application (3 weeks in the case of the Kershope site). The effects of this uptake pattern on growth must be determined before any new recommendations can be made on the timing of potash application.

Nutrition in High Exposure

The 6 year mean height assessments shown in Table 7 indicate that Sitka spruce had made a better start than south coastal Lodgepole pine on an exposed deep peat site at 305 metres elevation (mean daily flag tatter rate of 8·0 cm^2) at

Shin Forest, Easter Ross. The treatments as indicated in the Table show that PK at planting has given slightly better growth than P alone. This effect can be regarded more as a response to site deficiency in K, than to increased resistance to exposure. NPK inputs even at heavy rates have not increased height growth to date.

TABLE 7

MEAN HEIGHTS (cm) AT 6 YEARS; BALBLAIR, SHIN FOREST, EASTER ROSS

Species	Treatment* and Nutrients applied (kg/ha)					5% LSD
	S 49 P	PK 49 P 94 K	NPK 113 N 49 P 94 K	2NPK 226 N 98 P 188 K	NPK (Biennial) 339 N 147 P 282 K	
Lodgepole pine (south coastal)	74	90	83	71	83	25·1
Sitka spruce	95	105	90	109	103	25·1
Mean	85	98	87	90	93	17·7

*All treatments applied once, at planting in 1967, except NPK (Biennial), in which 113N, 49P and 94K were each applied at planting and then again at 2-yearly intervals, in 1969 and 1971.

It appears that no early height growth benefit is achieved by "luxury" nutritional input, in fact in the extreme biennial treatment the resultant softer growth led to Sitka spruce suffering more physical breakage on this exposed site.

Broadleaved Trees

Past fertiliser experiments have dealt almost exclusively with coniferous species. There is therefore little information on the relationship between height growth, foliar nutrient concentrations and applied fertilisers in broadleaved trees. An NPKCa factorial experiment has therefore been established at Ringwood Forest (Dorset), using oak and beech, with subsidiary plots of birch, Red oak and *Nothofagus procera*. By siting the experiment on a very poor soil it is hoped that unfertilised plots will quickly show deficiencies in the trees.

Maximum Site Amelioration

Growth of a forest is often measured, not by Management Table figures, but by the "norm" for the forest or region; if a limiting factor is unrecognised, or insufficiently modified, the norm might be low and there might be little incentive to improve. A project on Maximum Site Amelioration was therefore conceived as one way of lifting the sights of forest managers by identifying those limiting factors which might be modified at any site; the approach was described on page 77 of the 1970 *Report*. The major trial at Wareham is now 3 years old, and Plates 4 and 5 show the early growth of some of the species.

In addition to limitations imposed by site, foresters may be restricting production by their choice of species. Only a potentially high-yielding species is likely to respond well to our efforts to improve the site, so experiments should

includes species which are potentially more productive than those which have been chosen for use with past technology. In the drier half of the South, at moderate elevations, Corsican pine has been the best conifer, giving way to hemlock as second rotation species and to Douglas fir on more fertile and sheltered sites. Further west Sitka spruce is the preferred species. However, Corsican pine seems to reach its limit at about GYC 20 (Fourt *et al.*, 1971). Two other pines grow faster in the South and West. They might respond more favourably than the commonly grown species if factors (other than climatic) which limit growth are improved. These are *Pinus radiata*, of which there are many successful stands, and *Pinus muricata*, which, in its blue northern form, grows at similar rates with height increments of 1 m from the third or fourth year after planting in good conditions.

Preliminary work to evaluate these species proceeds, with emphasis on cultural methods, seed supply and dormancy treatments, winter hardiness, vegetative propagation, and tolerance of and effect on soil conditions. Plate 4 shows a stand of the blue form of *Pinus muricata* at the Bere block of Queen Elizabeth Forest (Hants), planted in 1960. The best trees were 13 m at the end of 1972. The seed came from an avenue at Muckross Abbey, County Kerry, Eire, as did that for Plot 130 of the Bedgebury Forest Plots (Mitchell, 1972).

Analysis of Foliage

Programme of Work

The number of samples sent in for analysis again rose, to 5,575. The increase over the years is shown in Figure 6. A new and increasing demand is for analysis of broadleaved foliage. The improved facilities mentioned below were made just in time.

Methods of Analysis

Problems have arisen from the increasing demand for analyses (*Report* for 1972). Consequently, we have been interested in new equipment and techniques to increase speed and efficiency of work. As in many other laboratories, there is not sufficient work to make full use of continuous-flow automated equipment at present. Nevertheless we have been able to make effective changes. We now use a single digestion for N, P and K, followed by colorimetry for N as well as P. The reagents and samples are handled by automatic electric diluters which have proved to be more accurate than careful manual workers and entirely reliable during the season. The chemical processes are ideal for further automation either on a continuous flow basis or by fully automatic handling of tubes which may well be easier to control.

The samples (300 mg whole spruce or broken pine needles) are treated with sulphuric acid (6 ml) followed by hydrogen peroxide (2 ml 30 per cent). This is digested for 60 minutes and after a second addition of hydrogen peroxide is heated for a further 30 minutes. McKenzie (1954) showed that similar procedures only yield 85–98 per cent recovery of nitrogen from certain amino acids which are difficult to break down, but we find that our pine or spruce needle samples yield results by this method identical with those from a much more drastic and prolonged digestion of comparable samples using both catalysts and salts. The

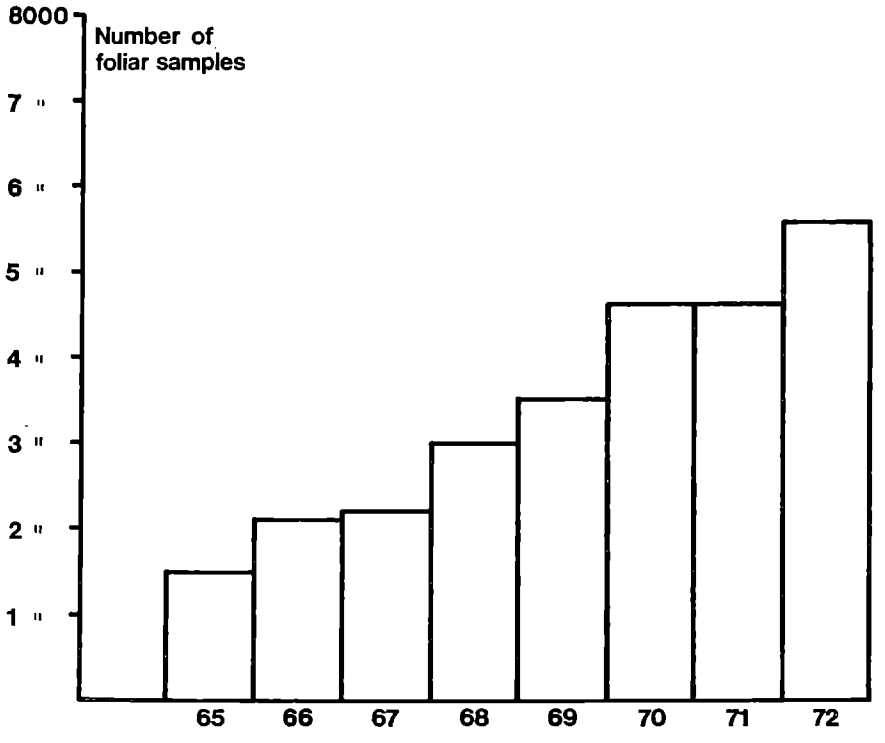

Figure 6: (Analysis of foliage). Numbers of tree foliage and vegetation samples for analysis received at Alice Holt, 1965 to 1972.

omission of mercury or selenium avoids risks of complications in the colorimetry and reduces toxicity hazards in the residues.

The samples are made up to a standard volume (80 ml) in the digestion flasks, shaken and dispensed into 25 mm specimen tubes in blocks of 10. Each block has a place for a blank and a combined standard tube containing N, P and K. The coloured solutions are developed in similar blocks by transfer of the sample and dilution with reagents effected by the automatic diluters. Nitrogen analysis is based on Chaney's (1962) indophenol blue method (currently a second reagent is added manually in this case). A single solution based on Murphy and Riley's (1962) method is used for phosphorus (molybdate reduced by ascorbic acid in the presence of potassium antimonyl tartrate). The blocks of untreated samples go to the flame photometer for K and are fed manually with a long flexible capillary tube. Finally, the tubes are packed in expanded aluminium baskets, emptied, rinsed and dried in units of 50.

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SOIL STUDIES

Studies on Chalk Soils

When Forestry Commission Bulletin No. 34 on *Chalk Downland Afforestation* was written (Wood and Nimmo, 1962) little was known about the effect of herbicides and fertilisers on establishment and early growth of trees. Rather like heathlands, chalk grasslands are typically nitrogen deficient, but application of nitrogenous fertiliser results in lush weed growth with little benefit to the planted trees. To control weeds, herbicides are being combined with fertilisers in an experiment to see if early growth of a planted tree crop can be speeded up.

As mentioned in Bulletin No. 34, soil inversion by ploughing markedly accentuates chlorosis, so a deep ripper has been used, spaced at planting distances, to loosen the soil without bringing up chalk. The work is being carried out on chalk downland on Salisbury Plain in collaboration with the Department of the Environment.

Different types of planting stock have been compared, and assessments of survival of Corsican pine are shown in Table 8.

TABLE 8

PER CENT SURVIVAL OF CORSICAN PINE PLANTED IN 1972 ON CHALK DOWNLAND

Type of stock	Age	Date assessed	
		10.10.72	20.2.73
Bare rooted	1+1	91	60
Nisula	1+1	99	99
Japanese Paperpots	1+0	99	99

Clearly the Nisula and Japanese Paperpot plants took very well and were strong enough to survive the winter on this exposed site. The bare-rooted stock did well to survive the dry growing season, but many died between the two winter assessments. The Nisula plants were somewhat yellower than the rest at the last assessment.

Bare-rooted Corsican pine and beech were also compared. Paraquat was sprayed and a little superphosphate was applied along the ripper lines before planting. Some figures of survival are given in Table 9.

TABLE 9

PER CENT SURVIVAL OF CORSICAN PINE AND BEECH BARE-ROOTED TRANSPLANTS WITH VARIOUS TREATMENTS

Species	Age	Treatment				Date assessed
		Control	Herbicide	Fertiliser	Herbicide and Fertiliser	
Corsican pine	1+1	93	86	88	89	20.2.73
Beech	1+1	98	97	97	97	10.10.72

These stocks were cold stored before planting, and a comparison with Table 8 where the Corsican pine plants were similar but lifted and planted directly suggests that cold storage was beneficial. It also seems possible that the shelter of the tall grass was more benefit than decreased competition following its control with herbicide. The small phosphate application might also have reduced survival slightly.

Tissue analysis of pine growing nearby has shown low levels of nitrogen and potash, and another analysis for these elements will be made in 1973.

Moisture conditions under the grass vegetation and under plots kept clear of weeds with herbicides are being studied, to see whether there are differences due to these treatments.

D. F. FOURT

Physical and Mechanical Properties of Soil Types

Soils on Indurated Material

Field testing and sampling of soils developed in indurated material has been completed. Analysis of samples in the laboratory will be completed soon and the work will be written up in 1973. A summary of the results will be presented in the next *Report*.

The Effects of Drainage Treatments and Tree Crops on Soil Physical Properties

A major new study of the aeration, moisture and temperature regimes of upland soils is planned for 1973/74; preliminary studies of moisture content and bulk density have been made in peaty gleys of Border forests on Carboniferous rocks.

The large drainage experiment on a peaty gley at Kershope Forest (Cumberland) (see *Report* for 1967 p. 45) was assessed for several years by measuring water levels in boreholes, but no significant treatment effects were observed. The experiment was however still considered worthy of further study to look for drainage effects, so an assessment of moisture content by soil cores was made in August 1972.

Cores of soil 6·5 cm in diameter and about 45 cm in length were taken from midway between drains in each of six drain depth × spacing treatments, and

also at different distances from drains. The cores were divided longitudinally according to the soil horizons, and values of moisture content and dry bulk density were determined for each horizon. Where the peat layer exceeded 15 cm thickness it was divided into sections approximately 10 cm long. Variability of the soil profile within the experiment necessitated special treatment of the data before statistical analysis was possible. The soil was mainly a peaty gley, but the thickness of the peat varied from 0 to over 45 cm, hence cores had different horizon compositions. It was assumed initially that comparisons between cores could only be drawn within particular horizons, and that the depth of occurrence of the horizon did not matter. Each 10 cm layer of peat was classified as a separate horizon.

Statistical treatment of the data continues, but it is already clear that increasing drainage intensity has had no effect in lowering the moisture content or in changing the bulk density, in any horizon. Indeed, as Table 10 shows, the plots with drains 90 cm deep have wetter peat than plots with drains 60 cm deep.

TABLE 10

MEAN MOISTURE CONTENT OF TOP LAYER OF PEAT, PER CENT OVENDRY WEIGHT

Drain Spacing	Drain Depth		
	60 cm	90 cm	Means
10 m	271	348	325
20 m	216	285	258
40 m	296	318	308
Means	263	322	

Differences between means for depth treatments are significant at 1 per cent, differences between spacings are significant at 5 per cent probability.

The shallow drain plots have thinner peat than the deep drain plots, and a possible relationship between moisture content of the peat and peat thickness could be involved in the results. Covariance analysis of moisture content on peat thickness enables this effect to be removed, and produces the adjusted values of Table 11.

TABLE 11

ADJUSTED MEAN MOISTURE CONTENT OF TOP LAYER OF PEAT, PER CENT OVENDRY WEIGHT

Drain Spacing	Drain Depth	
	60 cm	90 cm
10 m	281	309
20 m	250	307
40 m	287	337
Means	274	315

The relationship between moisture content of the top layer of peat and the total thickness of the peat is significant. The effect of the adjustments is to render the difference between the means for spacings not significant, and to reduce the significance of differences between means for depths to 5 per cent.

The reason for the deeply drained plots having wetter peat than the shallow drained plots in this experiment remains uncertain.

A further preliminary study of peaty gleys in Border forests has been made by measuring moisture content and bulk density in soil pits under tree crops and in adjacent unplanted rides. The techniques of assessment using a gamma-ray densitometer have been described on page 56 of last year's *Report*. The object was to determine the degree of desaturation of the soil under the older plantations, and to judge how far any improvement in the soil moisture regime is "permanent" or seasonal.

The main results are shown in Figure 7 (a to c). All three comparisons have given similar results. Significant decreases of moisture content have taken place in the peat (0h horizon) and subsoil horizons. Lack of significant effects in the Ag and Eg horizons is partly due to their variable physical composition. The C(g)2 horizon has not yet been affected. The great depth to which the drying out has occurred is interesting because tree rooting is limited to 20–30 cm at all

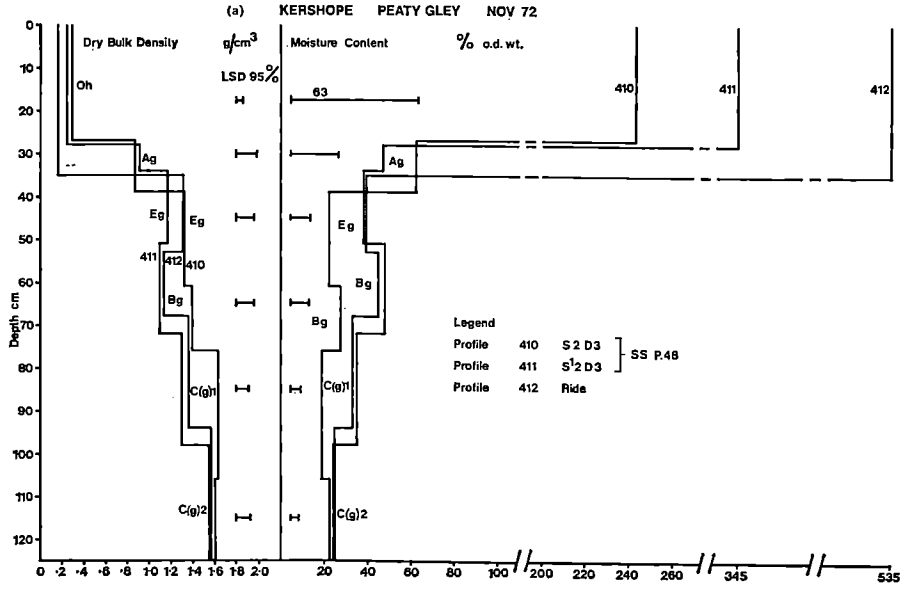
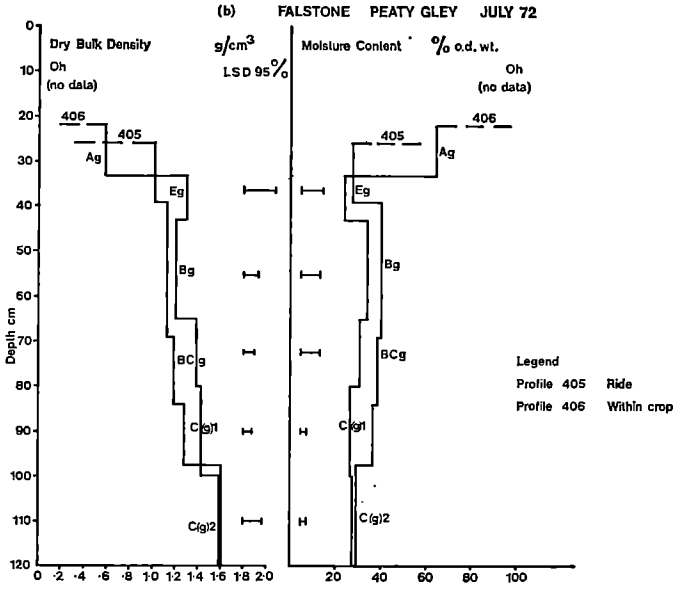
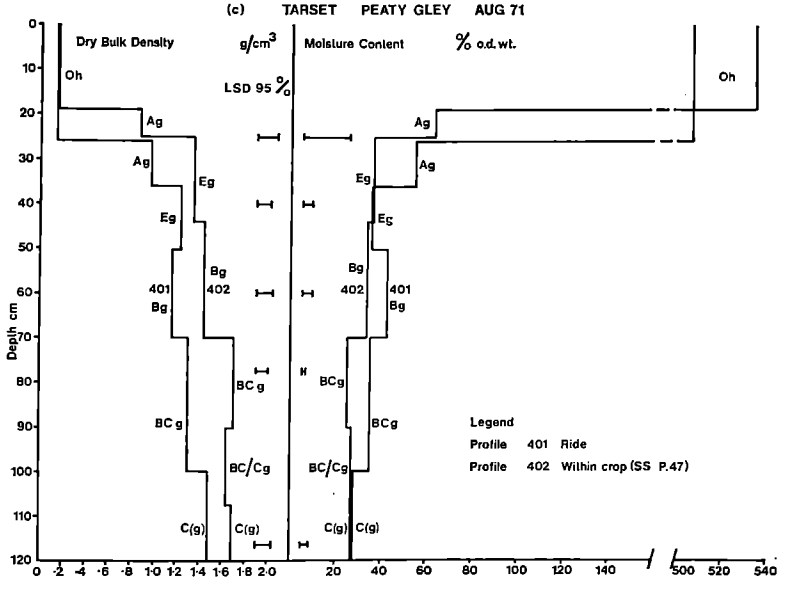


Figure 7: (a to c). Bulk density and moisture content of 3 pairs of profiles, each pair comparing the soil under a tree crop with that in an adjacent unplanted ride. The 3 soils are peaty gleys derived from similar clayey parent material.


(b) FALSTONE PEATY GLEY JULY 72
Dry Bulk Density g/cm3
LSD 95%
Moisture Content % o.d. wt.
Oh
(no data)
406
405
Ag
Eg
Bg
BCg
C(g)1
C(g)2
Depth cm
Legend
Profile 405 Ride
Profile 406 Within crop


(c) TARSET PEATY GLEY AUG 71
Dry Bulk Density g/cm3
LSD 95 %
Moisture Content % o.d.wt.
Oh
Ag
Eg
Bg
401
402
BCg
BC/Cg
C(g)
Depth cm
Legend
Profile 401 Ride
Profile 402 Within crop (SS P.47)

sites. The seasonal effect is evident in the results for October 1972 which followed four months of exceptionally dry weather (rainfall 44 per cent of normal for the period). The peat layer was particularly dry. The July 1972 comparison was made following four months with rainfall 129 per cent of the normal for that period, and the general similarity of the results suggests that the drying effect in the subsoil is carried over from year to year. (See also p. 73, soil moisture in tree pulling at Tarset, Northumberland.)

Dry bulk density of the soil has increased with the removal of water, and this means that the soil has settled or subsided, because the bulk density values would include any shrinkage cracks; indeed, shrinkage cracks have not been observed except in the peat and Ag horizons. The soil is noticeably firmer in consistence under the crop than in the ride, and this has been confirmed by penetrometer and vane shear tests. Clearly the altered conditions of the subsoil are not yet sufficiently improved to promote root extension there. The reasons for this will be the subject of more detailed investigations involving measurements of moisture, aeration and temperature throughout the year.

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DRAINAGE

Drainage of Peat

In the spring of 1958 four experiments were established at Naver Forest (Sutherland), Inchnacardoch Forest (Inverness-shire), Forest of Ae (Dumfries-shire) and the Kielder Forest District of Northumberland, to examine the degree to which peat shrinks after drainage by ploughing. The treatments consisted of single furrow ploughing and planting with Lodgepole pine on two plots and ploughing alone on two plots. Each plot was 10 m × 10 m. Twelve pairs of iron rods were inserted deep into the sub-soil in such a way that a bar placed across each pair acted as a datum from which the height of ground surface across the ploughing could be monitored. Measurements were initially made every three months.

In subsequent years five more experiments were begun at Forest of Ae (Dumfries-shire), Newcastleton Forest (Roxburghshire) and Wark Forest (Northumberland) which included plots planted with Sitka spruce.

By 1972 the results of the experiments indicate that there is little difference in vertical shrinkage of peat between planted and unplanted plots. (Horizontal shrinkage is assumed to be negligible.) Greatest shrinkage occurs during the first three summers in the turf ridge. The original surface remains at a fairly constant level while the furrow bottom tends either to silt up or develop a covering of moss which slightly decreases its depth.

Drainage of Soils with Clay Sub-soil

Previous reports have referred to the lack of effect on tree growth observed on many sites after various drainage treatments. The object in experiments has been to improve rooting depth by lowering the water table. However, two areas of doubt have arisen; first the extent to which gravity water can be rapidly removed from clay by draining alone, and second the nature of change brought about in the clay when water is removed from it.

Drains dug 60 cm–90 cm deep at intervals between 10 m and 40 m appear to have only slight effect on lowering the water table as measured by boreholes at Lennox, Mannan Forest (Stirlingshire), Kershope Forest (Cumberland) and Rosedale, Dalby Forest (Yorkshire). Further south at Kesteven Forest (Lincolnshire) and Bernwood Forest (Oxfordshire) significant lowering of the water table was achieved. This to some extent coincides with agricultural experience in the draining of clay soils, which has been shown to increase in effectiveness the more south and east the land.

There is evidence that under conifer crops which have closed canopy the influence of trees in removing soil water can be considerable. A. G. Rutter (in Kozlowski *et al.*, 1968) quotes various sources estimating evaporation loss from forests to be between 200 and 800 mm per year for sites with negligible water deficit. Interception may account for another 300 mm loss per year; so that it is possible that a large proportion of the annual rainfall (of between 900 and 1,800 mm) might be removed by the crop. Soil studies have indicated that, at the Kielder forests, clay subsoil is to some degree dried by Sitka spruce crops. Unfortunately any benefits suggested by this may be outweighed by a tendency

in these clays to shrink and become more dense as they dry. In shrinking, clay subsoils from different regions show different structural changes; whereas clay from Rosedale will form large cracks when it shrinks, clays from the Kielder forests form very few cracks if any. These differences may be attributed to the different lithologies from which the clay originates.

To summarise, it has proved inordinately difficult to drain clay subsoils in the north; any drying which has occurred is more probably engendered by the presence of a tree crop; only some clay subsoils develop a structure on drying, others, notably those of Carboniferous origin in the Borders, do not. The conclusion drawn from this work is that intensive deep draining into clay subsoils using present methods, is not recommended in these areas. However, it is possible and may be essential to remove surface water from soil horizons above the clay subsoil. To identify the most effective drainage treatment to achieve this object an experiment was begun at Kielder. Treatment involves saturating the soil artificially, measuring changes in borehole levels and measuring the outflow into drains of different depths.

As large scale empirical drainage experiments have not yielded clear and positive results efforts have been made during the year to study soil and tree responses to drainage at a more fundamental level. To this end co-operative work has been initiated with Messrs R. Boggie and A. H. Knight of the Macaulay Institute to monitor, by means of radioactive tracers, water movement in deep peat and peaty gley. Dr. R. M. M. Crawford of St. Andrews University has been involved in assessing root responses in anoxia; and the Forestry Commission Soils Section is developing expertise in the assessment of oxygen diffusion in association with Drs. D. J. Read and W. Armstrong respectively, of Sheffield and Hull Universities.

S. A. NEUSTEIN
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CULTIVATION

Cultivation of Ironpan Soils

Last year's *Report* mentioned a decrease of height and basal area increment twenty years after planting, in complete 33 cm deep ploughing treatments in a cultivation experiment at Teindland Forest (Morayshire). The decline related both to earlier results in this treatment and to current growth in spaced ploughing in the same experiment. The cultivation was relatively shallow, and to date has still given a gain in total volume; nevertheless, the decline merited detailed investigation, as it cast doubt on previous conclusions on the merit of complete cultivation on this soil type. Investigations to examine a variety of hypotheses continue. One hypothesis that faster earlier growth led to earlier exhaustion of mineral nutrients—receives some support from foliage analysis at 17 years which showed that the tallest trees, mainly those on deep complete ploughing, had lower concentrations of phosphorus and potassium. An application of P and K in the twentieth year has led to increased growth in 1972. However, the cause and significance of the effect are not yet positively determined.

An earlier experiment begun in 1948 at the same forest involves six cultivation treatments using Sitka spruce nursed by four other species. The cultivations were:

(1) Turves from furrows 4·5 m apart.
(2) Single furrows 40 cm, deep, 1·5 m spacing.
(3) Single furrows 27 cm, shallow, 1·5 m spacing with subsoiling at 1·5 m.
(4) Complete ploughing 40 cm, deep.
(5) Complete ploughing 20 cm, shallow.
(6) Complete ploughing 20 cm, shallow with subsoiling at 1·5 m.

Sitka spruce was planted in mixture with Scots pine, Lodgepole pine, Mountain pine and Hybrid larch. Half of each plot was tended to remove trees which competed with the spruce.

Early growth was very satisfactory and differences between cultivations became apparent. But between 6 and 10 years almost complete *Calluna* invasion of the plots induced growth check in Sitka spruce. Results were further confounded by the attentions of a large flock of gulls which nested in the experiment, damaging leaders and depositing guano. The guano affected growth in parts of each plot. Between 15 and 20 years gulls disappeared, heather became suppressed and growth rates improved.

At 20 years deep complete cultivation produced the best height growth, with the deep single furrow treatment in second place. The relative intensity of soil disturbance in terms of number of plough passes per plot was 12·5:8·5, and the gain in growth of Sitka spruce was equivalent to 0·4 cu m/ha. A fuller analysis of yield to date is in hand.

It has been decided to convert half the experiment to pure Sitka spruce where this is possible. This required an assessment to determine the ability of the spruce, in each plot, to withstand exposure when the nurse is removed. The assessment results clearly show that the deep complete ploughing, at this 25

year stage, has been the most successful treatment for the Sitka spruce, both as regards growth and in its emergence from the nurse species. Some other rather general conclusions can also be drawn on the establishment of Sitka spruce on this site. If heather growth is controlled (e.g. by 2,4-D) the spruce could be established without the use of nurses. Where the use of herbicide is prohibited, a combination of complete ploughing and a Scots pine nurse in a well balanced mixture will give successful establishment and best growth with a minimum of tending. Mountain pine on complete ploughing will also give effective establishment of the spruce, without the need to tend the nurse species; but the growth of the spruce is less at 25 years. On deep spaced ploughing Hybrid larch with its good early growth and needlefall was the most successful nurse, but required careful tending to prevent the spruce from being suppressed. Lodgepole pine of South coastal origin was not an acceptable nurse for Sitka spruce on this site, in any of the treatments used.

Examination of roots in various experiments has shown that in cultivating ironpan soils not only is it important to break up the ironpan and any induration but to distribute humus throughout the changed profile. (See *Report* for 1972, Soil Studies.) A new experiment has been established at Helmsdale Forest (Sutherland) wherein an attempt was made to cultivate an indurated peaty ironpan soil with peat 40 cm thick. Treatments include spaced and complete ploughing with deep tine plough to 80 cm depth and completely dug plots to 80 cm and 130 cm depth using a JCB 5C digger, with various fertiliser regimes. It is intended to measure response to the various degrees of soil mixing which have been achieved. In order to establish climatic and other environmental limits to early growth, various treatments involving weed control, shelter and protection have been included in an adjacent experiment. Root development is to be examined in both experiments by destructively removing trees and cores and through three "windows" which have been inserted in the soil (Plate 11). Through these windows direct measurements of root extension rates can be made.

Fragiogleys

An experiment at Black Isle Forest (Ross & Cromarty) in which the Lokomo plough was used at spacings of 4 m, 5 m, 10 m, 20 m, and 40 m was established in 1970. After three growing seasons there is a significant, positive correlation with cultivation intensity on the heights of Western hemlock but not on heights of Lodgepole pine or Sitka spruce.

Plough Development

Most effort in the south has gone into the development of ploughing machinery and techniques for:

(a) Restocking areas.

(b) The afforestation of peaty soils.

(c) The use of disc ploughs.

Restocking

An experiment using the mounted deep tine plough has been established at Margam Forest (Glamorganshire) to determine the benefit of ploughing after

windthrow and clear-felling. The crop was forty year old Sitka spruce and the soil a peaty gley over a compacted stony sub-soil. A good standard of ploughing was achieved, as can be seen in Plate 15. It was however necessary to use a Caterpillar D6 tractor in tandem with the Challenger 33 on which the plough was mounted.

The standard of ploughing achieved led to a recommendation to conservancy staff to use the Parkgate Humpy plough with two standard ploughing tractors for ploughing on wet stumpy sites. The results are encouraging.

Afforestation of Peaty Soils

As mentioned in last year's *Report*, a range of plough mouldboards has been developed for use with the Parkgate Humpy plough. Over the past two years the deep double mouldboard draining body has been used to produce planting turves at a number of forests throughout the country. Now a deep tine double mouldboard has been built at Parkgate and successfully tested (see Plate 14). These two mouldboards, together with the deep draining single mouldboard make the Humpy plough a very flexible outfit for ploughing wet peaty soils.

Use of Disc Ploughs on Heathland Sites

Trials have begun in southern England, on the use of disc ploughs to cultivate stumpy sites, and to control inter-row vegetation. Disc ploughs and harrows are used widely in other countries, particularly on heathland soils. The aim is to cultivate the soil, without leaving the ground surface too irregular to use wheeled tractors in subsequent operations.

Rotary Mouldboard Plough

During the coming year, in co-operation with the Scottish Station of the National Institute of Agricultural Engineering (NIAE), a rotary mouldboard plough will be developed for experimental use on forest sites. The NIAE has already developed an agricultural-scale prototype using this principle. With this plough it is hoped to increase the development of roots by providing a well mixed freely draining medium.

S. A. NEUSTEIN
J. EVERARD
D. A. THOMPSON

CROP STABILITY

Thinning

Monitoring of windthrow has continued in a series of experiments in which some plots are unthinned, and others subjected to various kinds of thinning (*Report* for 1972, p. 64). The trees in the Welsh and southern English experiments are not blowing over as quickly as the more northern series. However "pumping" (i.e. soil puddling and root loosening) is now starting on many sites, and some trees have been thrown. Line thinned plots are being thrown before unthinned plots.

The number of windthrown trees has increased during the year in the northern experiments, extending gaps already created. Snow damage in January 1973 followed the same pattern as the previous wind damage. The accumulated damage in the older experiments in the series is now averaging eight trees per ha "No thinning" 45 trees per ha "Normal thinning", 204 trees per ha "line thinning". All these experiments will be thinned this year and two new experiments laid down incorporating a different pattern of line thinning.

T. C. BOOTH
G. J. MAYHEAD

Tree Pulling

To elucidate the factors influencing tree stability on the Carboniferous gleys of the Border Forests a concentrated study was carried out at Tarset (Northumberland). At three chosen times during the year, comparisons were made with Sitka spruce on close-spaced Cuthbertson ploughing and hand prepared turves to obtain differing soil moisture contents, the extremely dry summer and early autumn giving ideal conditions for the study. Pulling was carried out in May (very wet), October (very dry), and December (re-wetting). Comparison of the forces required to overthrow the tree were made by the regression of turning moment on stem weight.

Dr. W. Armstrong (University of Hull) and Dr. D. J. Read (University of Sheffield) measured oxygen diffusion rates round a sample of the trees before winching over was carried out (see p. 148).

General Conclusions

The combined data for the three dates showed that a significantly greater pull was required (at the 1 per cent level) for trees on hand prepared turves at the full range of stem weights tested. The greater rooting depth, root weight and drier soil conditions on the ploughed ground did not compensate for the reduced root spread. This supports the conclusion reached in the 1972 *Report*, page 66, that the lateral spread of the root plate of Sitka spruce is an important factor in promoting tree stability. See Table 12.

While the different dates of pulling were a successful choice in that differences in soil moisture were obtained, no statistically significant differences were obtained on turning moment. This was in part due to the small range in tree

TABLE 12

COMPRISON OF MEAN TREE DIMENSIONS: SITKA SPRUCE: 25 YEARS OF AGE

Characteristic	*Turf*	*Ploughed*
Root weight (kg)	52·4	58·5
Root depth (cm)	34·3	59·7
Root area (m^2)	1·86	1·77
Root/Shoot ratio	0·36	0·31
Angle of maximum pull (degrees)	10·0	6·0
Height (m)	11·4	12·7

sizes available and the small size of sample (eight trees). However, useful pointers were obtained for future study. Despite the lack of significance the ranking of the tree pulling regressions agreed closely with the soil moisture content of the Eg horizon (see Table 15) in that for hand prepared turves, October and December were nearly coincident and May was very much lower. On ploughed ground May and December were co-incident while October was higher and virtually parallel. In general the higher the moisture content of the Eg horizon the lower the turning moment.

The moisture content has a far greater effect on the turfed area than on the ploughed area where the restriction in root plate width was the over-riding factor.

Soil Moisture Study—Details and Results

Soil moisture was assessed by taking a core of soil 6·5 cm in diameter and about 45 cm in length from two opposite sides of each tree approximately 1 m from the stem. The cores were divided longitudinally according to the soil horizons, and values of moisture content determined for each horizon by oven-drying. Where the peat layer exceeded about 15 cm it was divided into sections approximately 10 cm long. Mean values for each treatment were calculated for each horizon and section of peat.

Significant differences between turfed and ploughed treatments and between dates of pulling were found in the peat layer but differences in the underlying mineral soil were not significant. Unfortunately, in December the peat layer was not sub-divided, hence a comparison between all three dates could only be made for the whole peat layer (Table 13).

TABLE 13

MEAN MOISTURE CONTENT PER CENT OVEN-DRY WEIGHT FOR TREATMENTS AND DATES: WHOLE PEAT LAYER

Treatment	*May*	*Oct.*	*Dec.*
Turfed	465	346	447
Ploughed	365	269	394

(5 per cent least significant differences between treatments 35, between dates 29.)

Differences between treatments were significant at each date. May and December were not significantly different from each other but were significantly different from October for each treatment.

Comparisons were possible between May and October for two separate sections of the peat layer. Results were similar to those for the whole peat layer (Table 14).

TABLE 14

MEAN MOISTURE CONTENT PER CENT OVEN-DRY WEIGHT FOR TREATMENTS AND DATES: PEAT LAYER SUBDIVIDED

Section	*Treatment*	*May*	*Oct.*
Section 1 (Upper)	Turfed	522	371
	Ploughed	409	290
Section 2 (Lower)	Turfed	397	326
	Ploughed	322	241

All comparisons between methods within dates and between dates within methods are significant.

Table 15 gives the results for the eluvial Eg horizon which is usually the uppermost mineral layer.

TABLE 15

MEAN MOISTURE CONTENT PER CENT OVEN-DRY WEIGHT FOR TREATMENTS AND DATES: EG HORIZON

Treatment	*May*	*Oct.*	*Dec.*
Turfed	39·2	33·2	31·1
Ploughed	35·5	31·5	35·9

Although these differences do not reach significance, the moisture contents follow similar trends to those in the peat, with some interesting differences. Thus in the turfed treatment December is more comparable with October than March, whereas in the ploughed treatment December is similar to May.

There were insufficient data for comparisons in other horizons.

D. G. PYATT
T. C. BOOTH

Wind Tunnel Studies of Topographic Models

Topographic models have been used to prepare relative wind speed maps, using wind tunnel facilities kindly lent to us by the Department of Civil Engineering, University of Edinburgh. The objective was to produce the maps more quickly and with greater accuracy than by current field methods. An area of Wauchope Forest (Roxburgh) on which several field methods of testing exposure had been carried out was used as the first model. A standard horizontal scale of 6 in to 1 mile (1:10,560) was used and vertical scales of 3×, 6× and 12× were tested as also was the length of "fetch" around the test site.

Three-year-mean tatter flag results were tested against the wind tunnel results with the following principal conclusions:

(1) A vertical scale of 6× the horizontal scale, besides giving the most practical working conditions, gave a significantly higher correlation, significant at one per cent with a coefficient of linear correlation of 0·4526 with readings from tatter flags.

(2) It was not necessary to include in the model large areas of land to surround the test site.

(3) The correlation with the three-year-mean of tatter was sufficiently good to suggest strongly that further studies are worthwhile.

(4) The reduction in time taken (in comparison with that needed for a field study), from three years to three weeks and the saving in cost make this an extremely promising method.

A further study using extended facilities at the Department of Aeronautics, University of Bristol is now in process, testing models of part of Wauchope Forest and of South Kintyre (Argyll).

Distribution of Windthrow

An attempt to use the above system of mapping on the study area at Kershope (see *Report* for 1972, p. 64), improved the explanation of wind damage by only 4 per cent, i.e. 14 per cent instead of 10 per cent. The unravelling of the complexities of windthrow and topography in this situation has therefore not yet been helped by relative wind speed maps.

Crop Dynamics

In the last year there has been a change of emphasis in basic windthrow research. There are now two approaches to this work, one concerned with individual trees under static conditions (investigated by tree pulling) and one concerned with the examination of the dynamics of tree movement. Analysis of airflow data with its changes in energy spectra over a forest-grassland interface at Redesdale (Northumberland) has been completed by A. J. G. Papesch, of the University of Christchurch, New Zealand, who spent six months with the Silviculture (South) Section at Alice Holt. Mr. Papesch has prepared an internal report on the work, an account of which will be published in due course. A formula has been developed that will describe tree sway period (Mayhead, 1973), and work on tree damping reveals differences between trees of different sizes and similar sized trees on stable and unstable soils.

T. C. BOOTH
G. J. MAYHEAD

REFERENCE

MAYHEAD, G. J. (1973). Sway Periods of Forest Trees. *Scott. For.* **27**(1), 19–23.

REGENERATION

ARTIFICIAL REGENERATION

Gley Soils

Survival of all species was good in the first year in an experiment planted in 1972 at Halwill Forest (Devon) to compare the early behaviour of alternative successor species to Sitka spruce on recently felled surface water gley sites. Early observations also indicate few differences in health and vigour between species, though Grand fir looks at this stage the healthiest of all, Lodgepole pine, Red cedar and Leyland cypress look the least healthy and exhibit browning of foliage. Standards of Red alder, planted in pure plots and in mixture with Sitka spruce not only survived well but showed little of the expected dieback.

The unfavourable conditions of surface water gley soils, after felling and extraction of timber, appear well suited to test the stability of vegetatively propagated trees of species prone to socketing and early windthrow. In an experiment started in 1972 to test the behaviour of rooted cuttings of Leyland cypress in Japanese Paperpots no differences in survival and vigour due to pot size and type were noted in the first year.

The replanting of Sitka spruce on twelve sites at Kielder (Northumberland) which were specially chosen to illustrate bad site conditions gave an average survival of 94 per cent and a range of 90 to 97 per cent. Normal bare-rooted stock were notched directly into the slightly raised position adjacent to the old stumps. The result again emphasises that the site conditions, although not as amenable as freshly ploughed ground, are not lethal to good, well handled plants.

At the Forest of Deer (Aberdeenshire) on surface water gley, where Sitka spruce has been planted to follow a crop of Scots pine of Yield Class 6, slash burning and chemical weeding prior to planting have not increased survival and height at six years to a sufficient extent to cover the extra cost entailed.

Freely Drained Soils

At Thetford Chase (Norfolk and Suffolk) the main experiments, planted in 1964 and 1967, have been maintained and assessed. Measurements on the deep-acid soil type confirmed a correlation between density of Scots pine overwood and reduction in rate of height increment of the Corsican pine under-planting. In consequence, the overwood was removed. Volume assessments of the felled pine confirmed earlier findings of improved annual volume increment associated with initial heavy thinning carried out at the time of under-planting. This and other regeneration experiments at Thetford are discussed in detail in a recently completed draft report.

An experiment designed to examine alternative species to Douglas fir has been planted on a steep valley slope at Bodmin, Kernow Forest (Cornwall) from which the previous crop of Douglas fir had recently been removed. Information is required on rates of growth and volume production of species not hitherto widely planted on this site type in South-west England.

Scottish Woodland Owners' Association Questionnaire

A survey was made of regeneration programmes to be carried out over the next ten years in private forests in the area covered by the Scottish Woodland Owners' Association. An enquiry into expected resulting problems was also made, and the whole was summarised for discussion at a meeting held with representatives of the Association. In the main, the problems agreed with those forecast for Forestry Commission areas and are already covered by the present research programme. The difference in size of the areas being worked and in the economics of working small areas created a slightly different emphasis. Secondary objects of management connected with sporting and other amenities tend to exaggerate these differences since these increase the costs of regeneration for the main object of growing wood commercially.

J. JOBLING
T. C. BOOTH
R. M. URE

SITE STUDIES

Tree Growth in Forests of the South Wales Coalfield

In the last year work has concentrated on yield class comparisons in five main forest blocks of the coalfield: Margam, Bryn (Glamorgan); Margam, Cynon (Glamorgan); Ebbw (Monmouth); Rheola (Glamorgan); and St. Gwynno (Glamorgan). The relative growth rates of Sitka and Norway spruces, Scots and Corsican pines and Japanese larch were compared by means of paired plots on the free-drained upland brown earth and intergrade soils.

In the course of yield class determinations, it was found that many supposed crop ages derived from stock maps were not the same as actual ages derived from Pressler borings or whorl counts. In the 0·01 ha plots studied, there were deviations of up to six or seven years from recorded ages, the actual age of crops normally being less than the records suggested. South Wales forests have always suffered much fire damage and other establishment problems, and the age discrepancies may have resulted from this. British forestry relies strongly on the concept of yield in relation to known crop ages and these differences could have important implications for yield control.

A lichen-based pollution map of five zones is being prepared for the area (modified from the well-known 11-zone scheme of Hawkesworth and Rose 1970). The results show that the forests do not appear to be as polluted as had had been supposed. Margam (Bryn), and Ebbw were the worst areas, corresponding to Hawkesworth and Rose's zones 4 and 5 (i.e. 60–70 mg/m^3 SO_2).

The species/yield comparisons confirmed the excellent and consistent growth of Corsican pine in both polluted and unpolluted areas (as indicated by the lichen flora). Both Norway and Sitka spruces were confirmed to grow less well in the polluted areas. Estimates of the average local Yield Classes found on upland brown earths and intergrades in this study are shown in Table 16.

TABLE 16

SOUTH WALES COALFIELD FORESTS
SUMMARY OF LOCAL YIELD CLASS AVERAGES ON UPLAND BROWN EARTHS AND INTERGRADES (m^3/ha)

Forest	Scots pine	Corsican pine	Sitka spruce	Norway spruce	Japanese larch
Margam (Bryn)	11	14	12	12	10
Margam (Cynon)	12	14	14	15	11
Ebbw	12	14	13	11	11
Rheola	12	14	17	16	11
St. Gwynno	12	14	15	17	10

The above figures, suggest a definite pollution trend, but, of course, should be treated with caution, when comparing one block with another in terms of relative productivity. The proportions of the various soil types, degrees of exposure and

other factors influencing overall production will vary from forest to forest and strongly influence the results derived from individual plots, however comparable.

K. BROAD
G. J. MAYHEAD

REFERENCE

HAWKESWORTH, D. L., and ROSE, F. (1970). "Qualitative scale for estimating sulphur dioxide air pollution in England and Wales using epiphytic lichens". *Nature, Lond.*, **227**(5254), 145–8.

FOREST GENETICS

Seed Crops

Scots pine again produced moderately heavy crops in all the older seed orchards throughout the country; in seed stands the crops were light. Corsican pine crops were light as a whole but at Thetford Forest there were localised heavy crops on some of the old seed stands and particularly on rideside trees. Eight and seven-year-old Lodgepole pine seedling seed plantations of "Inland" origins in north-east England, East Anglia and south-west England produced their first commercial crops of cones, and five-year-old seedling seed plantations based on Alaskan origins at Wareham, Dorset also cropped well. Seed yields from these young plantations were generally low, possibly as a consequence of very early ripening during the prolonged dry late summer, which resulted in cones releasing their seeds 2–3 weeks before the normal period. In addition, the low seed-set on the young plantations could be accounted for by the relatively light pollen cloud generated from trees which were only four-years-old at the time of pollination.

Although old Douglas fir in certain limited areas in south-west England produced heavy male flowering and modest crops of female flowers, the resulting cone crops were light. Crops of all other coniferous and broadleaved species were light throughout the whole of Britain.

Register of Seed Sources

The survey of seed sources referred to in the 1972 *Report* (p. 76) was completed in the autumn. This was a major undertaking for the Section during the late spring and summer; to accommodate it, work on other projects had to be deferred. In response to a questionnaire the Genetics Section was notified by Conservators of phenotypically high-quality Forestry Commission stands which met the requirements defined in EEC Directive 66/404. The stands were inspected and classified as acceptable or not. Site details were recorded for those stands which were accepted for registration and maps were prepared to show access routes and the proximity of stands of similar species. Sitka spruce and Norway spruce were excluded from the survey because most of the stands which might otherwise be acceptable will be susceptible to windthrow following heavy thinnings which are essential in seed stand management. Furthermore, Sitka spruce in the required size-class has, in most regions, been derived from a small geographic area in the Queen Charlotte Islands and is, therefore, genetically relatively uniform. For these reasons, future home collections of seed will be obtained by felling trees which bear seed crops in stands which meet the EEC requirements; details of these stands will be registered retrospectively.

In contrast to the first survey of seed sources which was described by Faulkner (1962), this second survey made no attempt to classify the stands as Plus, Almost Plus, or Normal, according to the proportion of dominant trees acceptable as seed trees on the basis of their phenotypes. Instead, all stands which, on inspection, were found to be acceptable for registration were recorded as "selected". Summarised details of the "selected" sources, which also include a number of stands registered under previous schemes are presented in Table 17.

TABLE 17

AREAS OF SELECTED SEED SOURCES BY SPECIES AND CONSERVANCIES AS AT MARCH 31ST 1973

hectares

Species	Conservancy											Total
	Scotland				England					Wales		
	N(S)	E(S)	W(S)	S(S)	NE(E)	NW(E)	E(E)	SE(E)	SW(E)	N(W)	S(W)	
European silver fir*	—	—	—	—	—	—	—	—	—	—	—	Nil
Grand fir	—	17·6	—	3·5	—	—	—	3·5	—	6·3	—	30·9
Noble fir	1·2	2·0	0·8	—	—	2·5	—	—	—	4·0	1·0	11·5
Sycamore	—	—	—	—	6·0	—	—	—	—	—	—	6·0
Birch	—	7·5	—	—	—	—	—	—	—	—	—	7·5
Beech*	—	—	—	1·0	1·0	—	—	19·8	17·8	—	—	39·6
Ash	—	—	—	—	—	—	—	—	1·2	—	—	1·2
European larch*	11·3	3·1	—	—	—	1·6	—	—	—	—	—	16·0
Japanese larch*	13·3	24·1	—	8·0	—	—	—	—	7·0	6·0	2·5	60·8
Hybrid larch	1·6	10·1	—	2·5	—	—	—	—	—	—	—	14·2
Nothofagus obliqua	—	—	—	0·5	—	—	—	1·3	—	—	—	1·8
Norway spruce*	—	—	—	—	—	—	—	—	—	—	—	Nil
Serbian spruce	—	—	—	—	—	—	0·6	—	—	—	—	0·6
Sitka spruce*	—	—	—	—	—	—	—	—	—	—	—	Nil
Lodgepole pine	36·7	26·3	4·5	4·5	36·1	7·0	6·7	—	25·2	7·0	2·0	156·0
Corsican pine*	—	—	—	—	6·0	33·6	82·1	13·4	—	—	—	135·1
Scots pine (var *scotica*)*	142·0	200·0	—	—	—	—	—	—	—	—	—	342·0
Scots pine*	—	—	—	—	—	—	2·0	—	—	—	—	2·0
Douglas fir*	20·0	10·0	3·6	—	—	9·8	—	3·0	10·0	9·0	—	65·4
Red oak*	—	—	—	—	—	—	—	—	—	—	—	Nil
Sessile oak*	4·0	—	—	4·0	—	—	—	1·0	22·0	—	—	31·0
Pedunculate oak*	—	—	—	13·7	—	—	—	1·5	12·1	—	—	27·3
Western red cedar	1·4	—	—	—	—	—	—	—	—	1·0	1·0	3·4
Western hemlock	—	—	—	2·5	2·0	—	—	—	—	1·5	—	6·0
Totals	231·4	300·7	8·9	40·2	51·1	54·5	91·4	43·5	95·3	34·8	6·5	958·3

Note:
*Species covered by EEC forestry directives on forest reproductive material.

These include some older stands which are unsuitable for regular collection because of their size but which should provide useful seed crops if fellings are arranged to coincide with cone ripening in good crop years. The EEC rules only apply to those species marked with an asterisk in the table, but other species of importance in Britain have also been included in the National Register of Seed Sources. This Register will be published during 1973.

Seed Plantations

Thirty-five hectares of Douglas fir seed plantations were established in the Forest of Dean, Monmouthshire. Each plantation is composed of groups of six identifiable lines of plants derived from seed collected at six locations in each of eight regions in north-west America under the aegis of IUFRO. This was a co-operative Research and Forest Management Division exercise in which plants were raised by Conservancy staff at Rogate nursery in south-east England and were planted according to plans prepared by the Genetics Section by the local Forest of Dean staff under Genetics Section supervision. Inferior sources will be removed from these plantations using evidence from provenance experiments designed to compare similar material under forest conditions; the remaining crops will then be managed for seed production.

Vegetative Propagation

The propagation facilities at the Northern Research Station have been used for two grafting seasons, and most of the initial problems of plant-raising techniques and management have now been resolved. The main problems were related to the development of suitable watering regimes and to the forcing of root-stocks into early growth; further complications arose from the change-over from round to square pots for root-stocks; 127 mm square polypropylene pots are now in regular use. The 1972 programme was increased from 7,000 to 10,000 grafts. Additional space in an unheated plastic tunnel-house was used for grafting Scots pine, larch, and Douglas fir. The tunnel-house is of Finnish design and occupies an area of 15 m $\times$ 10 m; it is clad with ethyl vinyl acetate sheeting which has a life of approximately three years; the support arches are constructed of laminated wood.

4,000 Sitka spruce plants were grafted to provide material for tree banks. As in 1971 the initial success was slightly over 50 per cent. The grafted plants were graded before lining-out since previous experience has clearly shown that it is uneconomic to use poorly developed grafts for field planting. Additional seedlings were grown to provide suitable root-stocks for further trials of mini-grafting—a technique which showed some promise in previous trials at Grizedale (*Report* for 1969, p. 102).

Seed Orchards

The programme of "first phase" seed orchards, composed of untested clones, has now been completed for many species and the general position of both seed orchards and tree banks is currently under review. The total area of Forestry Commission-owned clonal seed orchards is 38·7 ha. To date the earliest planted Scots pine and larch orchards have made the largest contributions of seed, but, due to big changes in the demand for seed of certain species during the past

decade, certain orchards, mainly of Scots pine, which were surplus to requirements, have been felled.

The composition of the "first phase" seed orchards was based on several untested clones from defined regions, or on mixtures of untested clones from several regions. They were designed without information on clonal variation in dates, periodicity and amounts of flowering by sex. Data on flowering behaviour and from progeny tests, which are now becoming available, suggest that only about twenty-five per cent of the Scots pine clones have real breeding value. The first "second phase" Scots pine orchard whose design takes this data into account was established in 1968; further orchards of this kind will be established as the older orchards are phased out during the next ten years. Existing orchards are thinned by removing those clones which have a poor genotype and/or produce relatively small numbers of cones; this practice improves the average genotype of the orchard and increases the average yield of seed from each tree. To achieve the best combination of superior genotypes in "second phase" seed orchards a major re-grafting programme will be required to include those clones with compatible flowering times and which regularly produce worthwhile crops of both male and female flowers.

Orchard production of hybrid larch seed has been particularly low as a consequence of the often widely separated flowering times of the European and Japanese larch components. Three orchards, each of six hectares, are planned to meet the forecast higher demand for hybrid larch seed; clones with compatible flowering times have been located. The demand for Lodgepole pine seed is currently falling and no additional clonal seed orchards are planned until questions of choice of parent origin and intra-specific hybrids have been resolved on the basis of experimental evidence. Two small experimental Sitka spruce seed orchards have been established by on-site grafting. The main planting programme will begin in 1976 using glasshouse-grafted material. This programme has been deferred so that the choice of clones can be based on those parents which show distinct promise in progeny tests; information on flowering and behaviour will also be taken into account.

Controlled Pollinations

In 1972 controlled pollinations of Lodgepole pine were made in the tree bank at Newton. The programme was in 3 parts: repeat polycrosses to augment those made in 1971, some of which failed to produce sufficient seed for forest testing, one "Inland" and fourteen "Coastal" clones were used as female parents; new polycrosses were made on thirty-six previously untested "Coastal" and ten "Inland" clones; intra-specific crosses were made amongst seven "Coastal" and eight "Inland" clones selected on the basis of good general combining ability in open-pollinated progeny tests.

Early-Tests

During 1972, a detailed experiment was designed to determine the best of several early-test techniques, the main aim being to obtain data from which constants could be calculated. The treatments under test were: seven Sitka spruce progenies; two potting regimes; three seed size-classes; two pre-sowing seed treatments. The plants were measured at intervals over a period of 9 months.

There were very highly significant ($p = 0{\cdot}001$) height differences among all the treatments during the first few months, but towards the end of the experiment, when the plants were about 400 mm tall the only differences which were highly significant ($p = 0{\cdot}01$) were those due to progeny effects.

The 1972 *Report* (p. 79) referred to an experiment designed to test the repeatability of early-test results. The final data showed that Sitka spruce plants derived from the same seed source and grown for one year under similar glasshouse conditions provided the following correlation co-efficients between the two years 1969 and 1971:

Character	*Correlation co-efficients*
Height	0·846**
Deviation of the stem from vertical ...	0·835**
Number of branches	0·986***
Branch length	0·967***
Dry Weight	0·931***

** = significant at 1 per cent level; *** = significant at 0·1 per cent level.

The use of artificially extended day-length has become an increasingly important technique for some species. Without the aid of extended day-length it is impossible to produce Sitka spruce plants in one growing-season which are large enough for the satisfactory assessment of vigour and form. Currently an 18-hour day is used. This is the natural mid-summer day-length in the Edinburgh area. To test the suitability of an 18-hour day a number of Sitka spruce families from controlled crosses were grown in growth-rooms in which temperature and humidity were kept constant and the day-length was reduced by one hour every four weeks. Although each family was shown to have different relative growth-rates, the growth pattern of each was the same; that is, the growth-rate was at its maximum during the 18-hour day, and was reduced as the day-length was reduced. Growth ceased with a 15-hour day for some of the progenies and a 14-hour day for others. It was of interest that some progenies ceased growth abruptly whereas for others, the cessation was grandual. Up to the present time supplementary lighting used for early-test procedures has been provided by one 400 watt MBFR/u mercury fluorescent internal reflector lamp per 2 sq m. These lamps have been satisfactory when the head-room in the glasshouse allowed the lamps to be suspended at a distance greater than 1·1 m above the top of the plants. Smaller distances produced shadows resulting in a wavy pattern of growth across the glasshouse—plants receiving less light in the shadows being smaller than those directly under the light source. The use of larger numbers of lamps not only raises capital and running costs, but also creates excess heat problems. Fluorescent tubes also have the problem of high heat emission and are equally expensive to operate. A new type of lamp (180 watt low pressure sodium tube (SOX)) offered a possible solution to the problem. Each tube irradiates an area of 2 sq m and as the heat emission is very low, there is no danger of overheating the plants. Also, since the light source is from a tube and not a point source the problem of shadows is resolved; running costs are less than half those of mercury vapour lamps. Results from comparative trials of SOX and mercury vapour lamps showed that under the SOX tubes Sitka spruce, Douglas fir and larch plants were very similar in height and

appearance to those produced under mercury lamps. SOX lamps give a light which is almost monochromatic; even so it seems that in mid-winter, when the lights were compared, there is sufficient natural light to correct the inherent imbalance of the SOX emission. As a supplementary lighting system the SOX tubes offer an excellent possibility of providing acceptably uniform light; the lamp is cool and relatively inexpensive.

Sitka Spruce Population Study

The 1970 *Report* (p. 110) gave general details of the basis of this study which was undertaken in a 37 year-old Sitka spruce stand in South Strome Forest, Ross-shire. During 1972 a major effort was made to collect data from selected trees scattered throughout the population.

The study is in four parts: parent trees; progeny tests; early-tests; and wood investigations.

Parent Trees

The basis of much of the study depends on obtaining good estimates of the genetic variance for each character of importance in the parental population. This would normally involve measuring a number of selected characters in the parent stand over a period of time, and relating the information to similar measurements made on the progenies. However, because the parent stand was scheduled for early felling, it was necessary to collect as much detailed information as possible over a very short period of time. Advance felling of the selected parent trees enabled measurements of the various selected stem and crown characters to be made easily. The selected part of the population was subjectively classified into: 6 plus trees; 48 dominant trees; 61 co-dominant trees; and 35 sub-dominant trees. Twenty-one characters were measured on each tree and two were calculated. Correlation co-efficients were calculated among all the characters for all the 150 trees in the study, and among the trees in the four classes. Significant correlations were obtained among the diameters taken at various points along the stem and between the lengths of branches taken from the same whorl. There were also significant correlations between the total stem length and the diameter of stem; between the live-crown length, stem length, and diameter of stem; and among the inter-node lengths measured over a number of years. The parent trees will be vegetatively propagated to provide future breeding material.

Progeny Tests

Open-pollinated seeds were collected in 1969 from all the parent trees. These were sown and in 1972 were planted out in a series of progeny tests on sites in Tywi Forest, Cardigan, Garcrogo Forest, Kirkcudbright and Wark Forest, Northumberland. The objects of the trials are to estimate the magnitude of the genetic variance of several characters of the population, and to obtain, for several characters, estimates of genotype-environmental interaction variances; estimates of heritability values; parent-progeny correlations; and juvenile-adult correlations. Controlled pollinations will be carried out when the material in the tree bank starts to flower, and the progeny data will be used to give further and more detailed information on the heritability patterns of the selected characters.

Early-Tests

The open-pollinated seed was sown under glass in spring 1972 and the resulting plants were raised in pots. Due to limited facilities it was impossible to increase the growth-rate of these plants during the first year and accordingly they will be grown-on in 1973 before assessment. It has already been noted during the first year that there are considerable family differences in responses to the length of the growing-season.

Wood Investigations

Sample discs were removed from each parent tree at ground level, breast-height and mid- and three-quarter-points of the stem. The discs will be used to obtain information on certain wood characteristics including fibre length and specific gravity. Wood samples will be taken later from the progeny trials to provide data on the inheritance of wood properties.

Pollen Viability and Storage

An attempt is being made to induce male sterility in larch by application of ethrel (2-chloroethylphosphonic acid). This compound has been used successfully for this purpose in several crop plants, and acts by interfering with the normal course of pollen development. Branchlets bearing flower-buds of five clones each of Japanese and European larch were painted with aqueous ethrel solutions of a wide range of concentrations some weeks before flowering. In addition, branchlets of one clone were treated at various times prior to flowering to determine the optimal time of application. Pollen was collected from each treated branchlet, and will be assessed for its capacity to germinate.

Pollen is also being collected from Japanese and European larch for experiments on viability testing and on optimal long-term storage conditions.

Biochemical Variation

A description of the variation of polyphenols within Sitka spruce trees (1972 *Report*, p. 80–82) had shown that two-year-old lateral stems taken from the upper branches constituted a reliable sampling point. As a further step in the study of biochemical variation, the variation within and between provenances, and the effects of different sites on this variation, was studied. Four provenances were sampled at each of four widely separated sites, from the series of provenance trials planted in 1960–61 (see 1971 *Report*, p. 42–4). The provenances sampled were Cordova or Lawing, Alaska; Skidegate, Queen Charlotte Islands; Sooke, British Columbia; and North Bend, Oregon. The sites were at Ratagan, Rossshire; Deer, Aberdeenshire; Tarenig, Ystwyth Forest, Montgomery; and Wilsey Down, Kernow Forest, Cornwall. The stem extracts were assayed for different groups of polyphenols, and each extract was also fractionated into constituent polyphenols or groups of polyphenols by gel-filtration chromatography on Sephadex columns, and the concentrations of the fractions were measured. Variation of polyphenol concentrations between trees was high, but there were highly significant differences between provenances and between sites. The outstanding feature of provenance variation was that most components were very

significantly more concentrated in stems of the Alaskan provenance than in those of the other provenances. Site variation was less clearly defined, but the most consistent feature was that the highest concentrations occurred at Tarenig, with Ratagan occupying second place. In each case the most significantly varying parameters included the leucoanthocyanins and the glucosylated stilbenes *iso*-rhapontin and astringin. Of the parameters measured, only two showed an interaction between site and provenance. The concentration data were transformed to total component weight data for the years' lateral stem growth, using the fresh weights of the stem samples. An analysis of variance of these total weight data showed that there were no significant differences between provenances for any parameter. Site variation contrasted with that for the concentration data in that Ratagan, rather than Tarenig, was the site showing highly significantly greater weights of most components in the stems, as a consequence of the relatively vigorous growth there.

Both the concentrations and the total amounts of many of the pairs of parameters, taken over all samples, were highly correlated. In particular, the two non-glucosylated stilbenes were very highly correlated, as were the two glucosylated stilbenes; while the leucoanthocyanins were highly correlated with astringenin, and total *o*-hydroxphenols with the two *o*-dihydroxylated stilbenes. The sample fresh weights were highly correlated with data for mean tree height, and were therefore good estimates of vigour. Of the identified compounds, it was the leucoanthocyanin total weight which showed the highest correlation with vigour; this is of interest since these compounds are believed to be the precursors of bark and heartwood tannins in many woody species, possibly copolymerizing with stilbenes in the spruces; and it is the tannins which have been implicated in previous work associating vigour with phenolic content. The high correlations with vigour were responsible for much of the phenolic variation within provenances, for variation in mean vigour due to site was of the same order as that due to provenance. It is therefore likely that attempts to separate provenances by phenolic characteristics will be confounded by variation due to intra-provenance vigour variation.

The highest polyphenol levels occurred in the most northerly provenance and at the least favourable site for growth, while the highest total weights occurred at the most favourable site and there were no provenance differences. This latter effect implies that provenance variation was a consequence of the different final stem volume attained by the different provenances, the higher levels in stems of Alaskan provenance being due to constriction of the same quantity of phenolics in a smaller volume. The early cessation of growth of trees of northerly provenance may mean that photosynthetic products synthesized after that time will be converted to, and accumulated as, polyphenols, instead of being used, as in southerly provenances, for further cellular extension growth.

The site differences may have had a similar cause, with restricted cell expansion at the unfavourable sites leading to increased concentrations, but the mechanism here would have been environmental rather than genotypic. Also, Tarenig was a much less fertile site than Ratagan, and in the cool peat soil only a limited amount of nitrogen may become available during the growing season; when this was used up, extension growth would cease, although photosynthesis would continue to supply polyphenol precursors.

Gene-pools

Douglas fir gene-pools, totalling seventeen hectares, were established at the Forest of Dean, Eggesford Forest, Devon and Dunkeld Forest, Perthshire. Seed from 96 widely separated origins was used to provide the parent material and all the lots were mixed together prior to planting. Each of the three sites was chosen to provide a variety of soil types and aspects in order to create opportunities for different components of the mixed population to succeed.

R. FAULKNER
A. M. FLETCHER
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REFERENCE

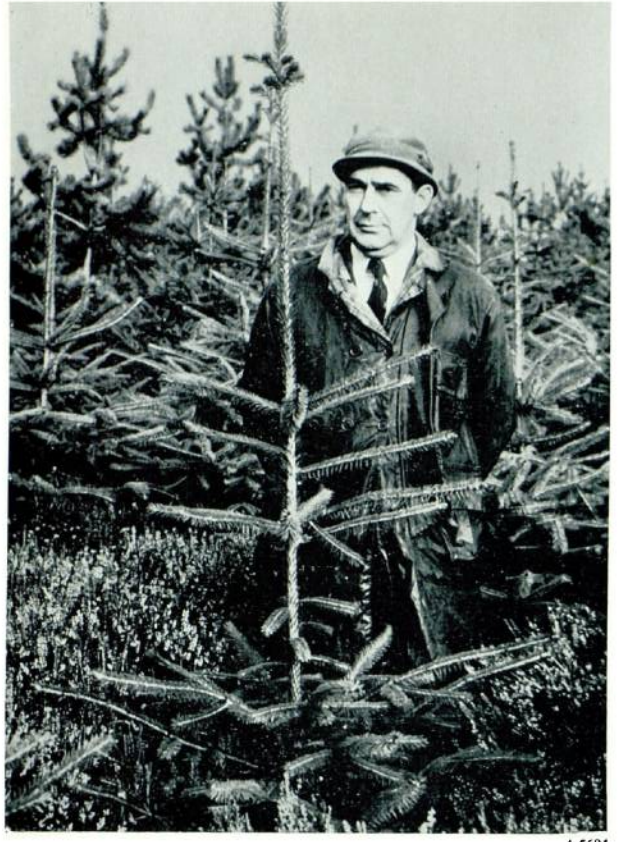
FAULKNER, R. (1962). Seed stands and their management. *Q. Jl For.* **56**(1), 8–22.

A 5678

PLATE 1. Photography (p. 119).
35 mm vertical aerial photography. Modified baggage door on Cessna 172 aircraft.

A 5683

PLATE 2. Photography (p. 119).
35 mm vertical aerial photography. Windthrow in Kershope Forest (Cumberland). Photograph taken using Canon F.I. system in mounting shown above.



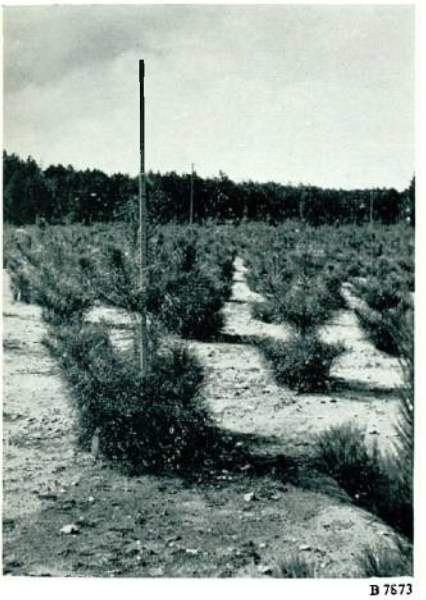
A 5684

PLATE 3. (*Left*) Nutrition of Forest Crops (p. 55).

Eleven-year old Sitka spruce on a peaty gley site in Yorkshire showing a dramatic growth response to phosphate (50 kg P/ha) and 2,4-D spraying three years previously (Langdale 117/70). Heather is now re-invading.

B 7877

PLATE 4. (*Above*) Nutrition of Forest Crops (p. 58).
A plot of *Pinus muricata* (Bishop pine), of the blue northern form, growing in Queen Elizabeth Forest (Hampshire). The top height is about 13 m at 13 years.



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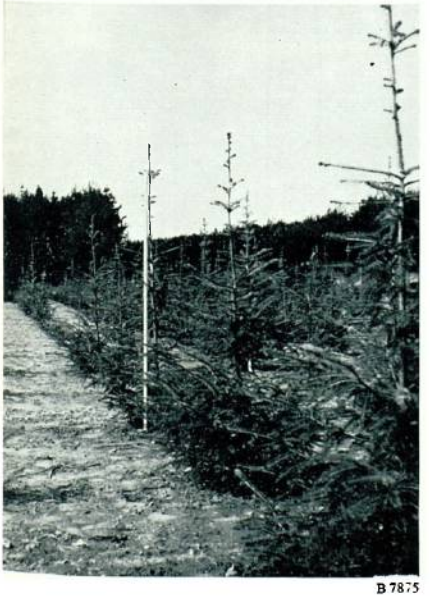

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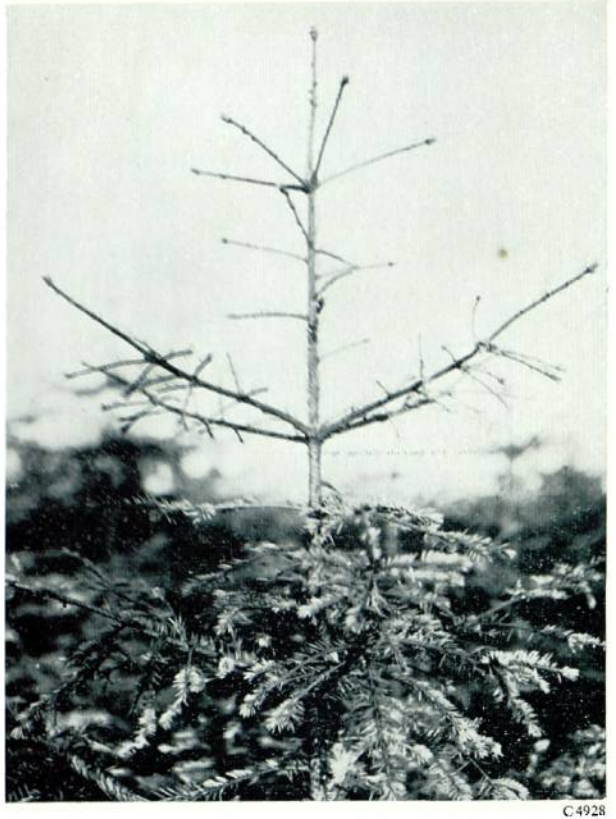
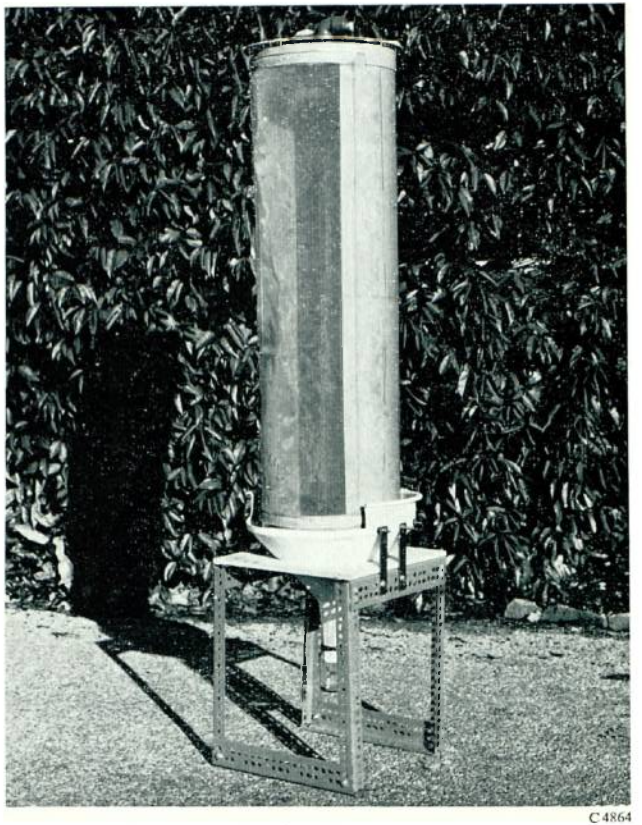
B 787(

PLATE 5. Nutrition of Forest Crops (p. 57).
Plots of four species after growing for three years without weeds and with high nutrition on a cultivated humus-iron podzol. (Wareham 156/70.) The measuring staff is 2 m tall and the figures given below are top heights. *Top left:* Corsican pine (1·3 m). *Top right:* Monterey pine (*Pinus radiata*) (2·2 m). *Lower left:* Sitka spruce (2·0 m). *Lower right:* Western hemlock (2·3 m).



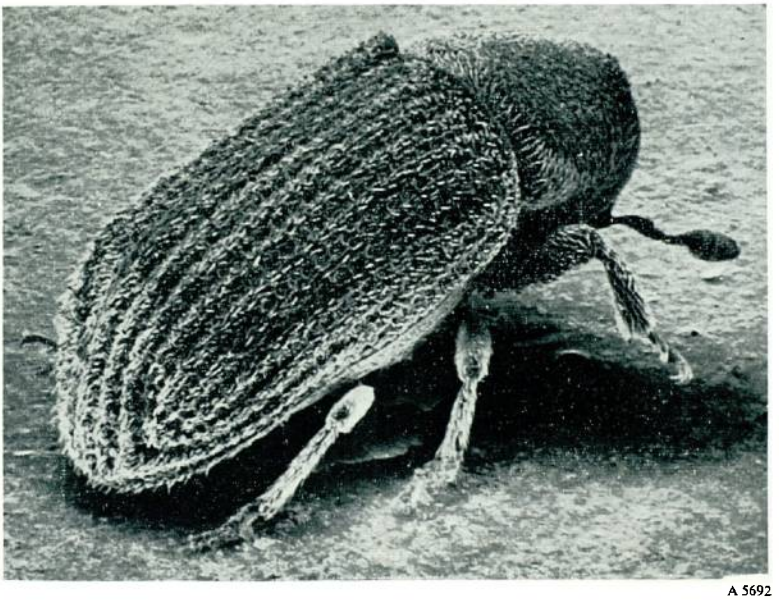
C 4928

PLATE 6. Forest Entomology (p. 104).
Gilpinia hercyniae—defoliation by the Spruce sawfly of 14-year-old Sitka spruce, at Hafren Forest, Montgomeryshire.



C 4864

PLATE 7. Forest Entomology (p. 109).
Trapping cage used for studying emergence of elm bark beetles and their associated parasitic and predatory insects.

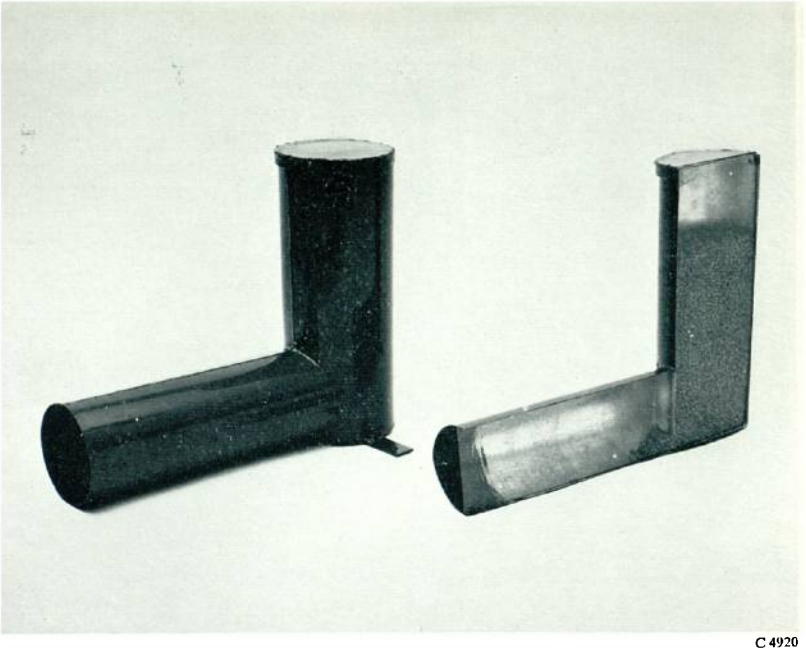


A 5692

PLATE 8. Forest Entomology (p. 109).
The American elm bark beetle, *Hylurgopinus rufipes*, found in imported Rock elm at Southampton in January 1973 (×16).

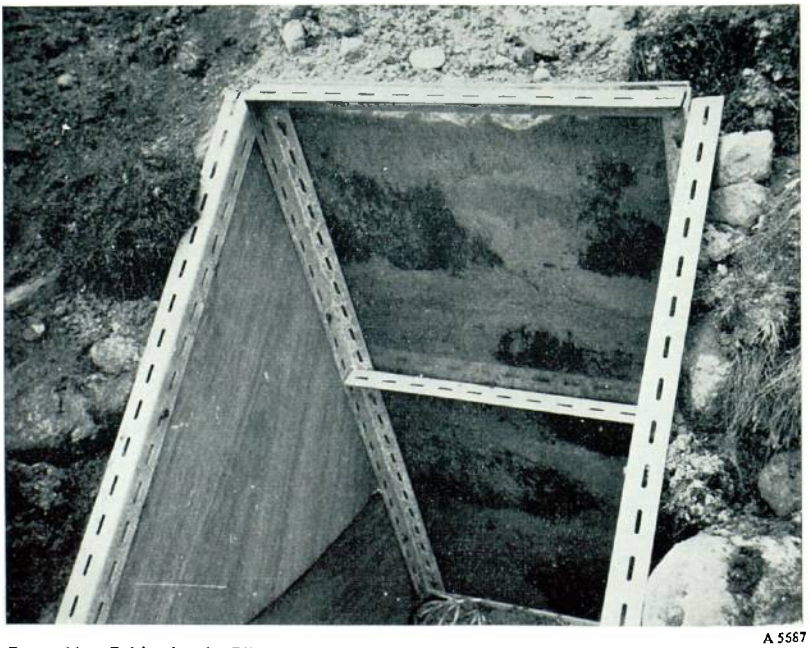
C 4929

PLATE 9. Forest Entomology (p. 109).
Rock elm bark showing breeding galleries of *H. rufipes*.



C 4920

PLATE 10. Wildlife (p. 112).
Left: A hopper suitable for use when laying warfarin-treated bait for grey squirrel control.
Right: The hopper sectioned to show bait and the aperture through which it trickles into the end of the access tunnel. (×¼)



A 5587

PLATE 11. Cultivation (p. 70).
Cultivation "windows" in the soil at Helmsdale Forest, Sutherland, through which root growth will be observed in a deep dug plot.

PLATE 12. Forest Pathology (p. 99). B 7872
Beech bark disease: infestation of the Beech scale insect *Cryptococcus fagi*.

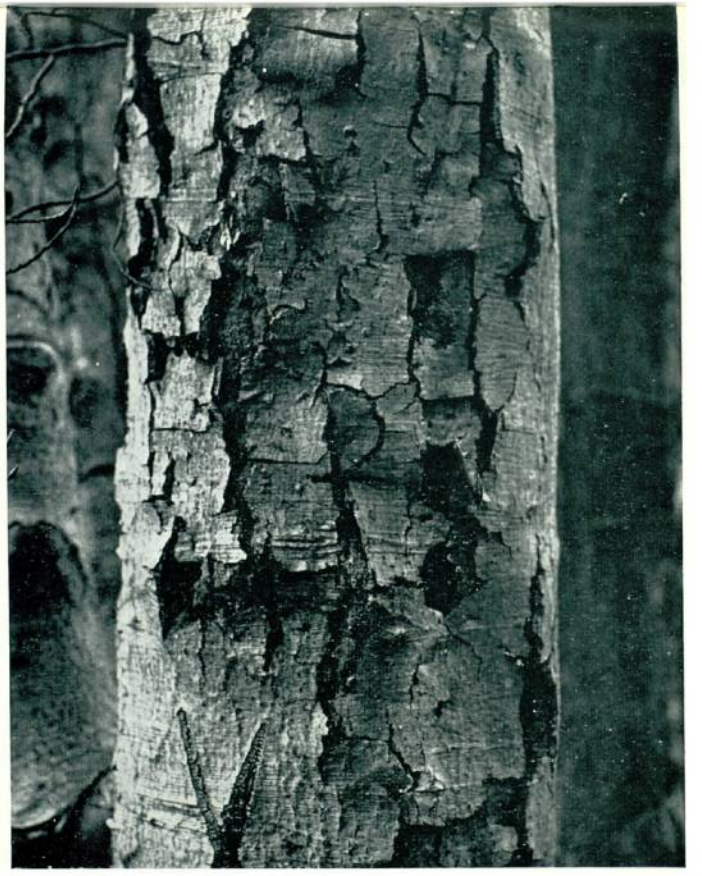


PLATE 13. Forest Pathology (p. 99). DH?
Beech bark disease: necrotic bark following attack by the fungus *Nectria coccinea*.

PLATE 14. Cultivation (p. 71). Plough development—Afforestation of peaty soils. The Parkgate Humpy with the deep tine double mouldboard, ploughing for planting. Coed y Rhaiadr Forest (Breconshire). (FT

PLATE 15. Cultivation (p. 71). Plough development—Restocking. Plough furrows on a peaty gley following windblow and clear felling. Margam Forest (Glamorganshire), experiment 5. (FT

TREE PHYSIOLOGY

Flowering and Seed Production

The background to this work has been given in the 1970 *Report* (p. 109). The Section has already achieved considerable success in inducing flowering and seed formation in several forest species using the technique of complete branch ringing (1972 *Report* p. 84–86). During the past year these investigations have been broadened to include a preliminary study of the effects of the growth hormone gibberellic acid on flower initiation.

Trees of two clones of *Thuja plicata* 4 m in height were used. Aqueous solutions of gibberellic acid were placed in funnels and allowed to run into the main stem by means of tubes inserted 1 m above ground level. A first application was made in early May and a second in late June. The number of flowers induced was measured in September of the same year. The results of the treatments are summarised in Figure 8.

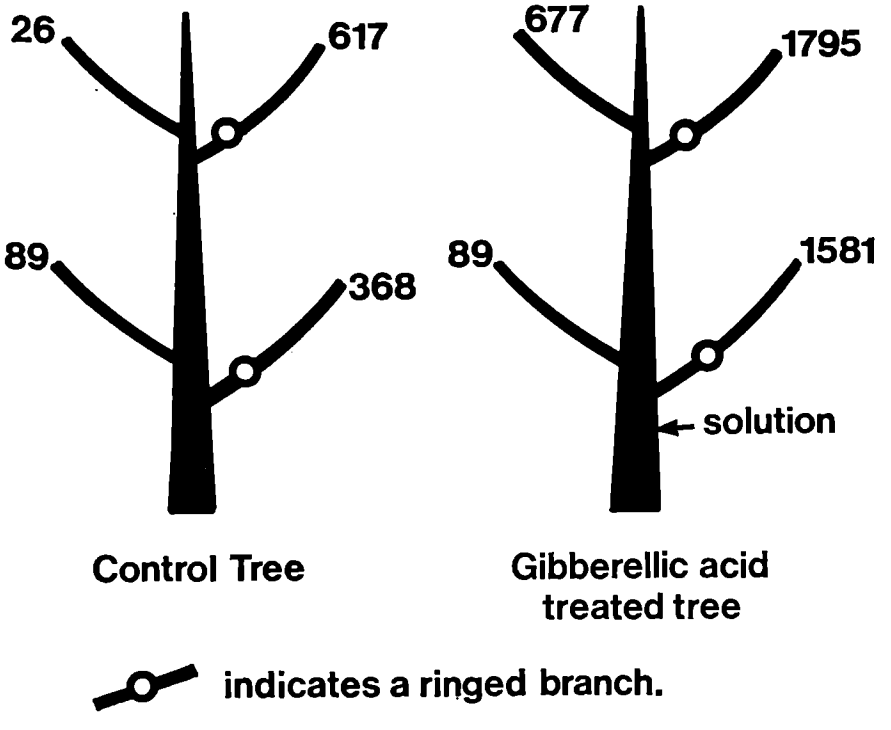


Figure 8: Effects of 2 × 100 ml gibberellic acid applied at a concentration of 500 ppm, on female flower induction in *Thuja plicata*.

Gibberellic acid applied at a concentration of 500 ppm has increased the mean number of female flowers initiated on upper, unringed branches from 26 to 667 (2,600 per cent), while the increase on ringed branches is from 617 to 1,795

(270 per cent). The number of shoots bearing 10 or more male flowers also showed a dramatic increase; 375 per cent for unringed branches and 220 per cent for ringed branches.

These results are most encouraging and future studies are planned, using tree injection equipment and other species, particularly Lodgepole pine and Sitka spruce.

Vegetative Multiplication

Work on the rooting of Sitka spruce and Lodgepole pine cuttings has progressed satisfactorily. Following the discovery that two different types of root could be produced depending upon auxin levels, detailed investigations have been made on the effect of varying concentrations of indole-butyric and naphthalene-acetic acids upon root number, type and time of initiation (Figs. 9 and 10).

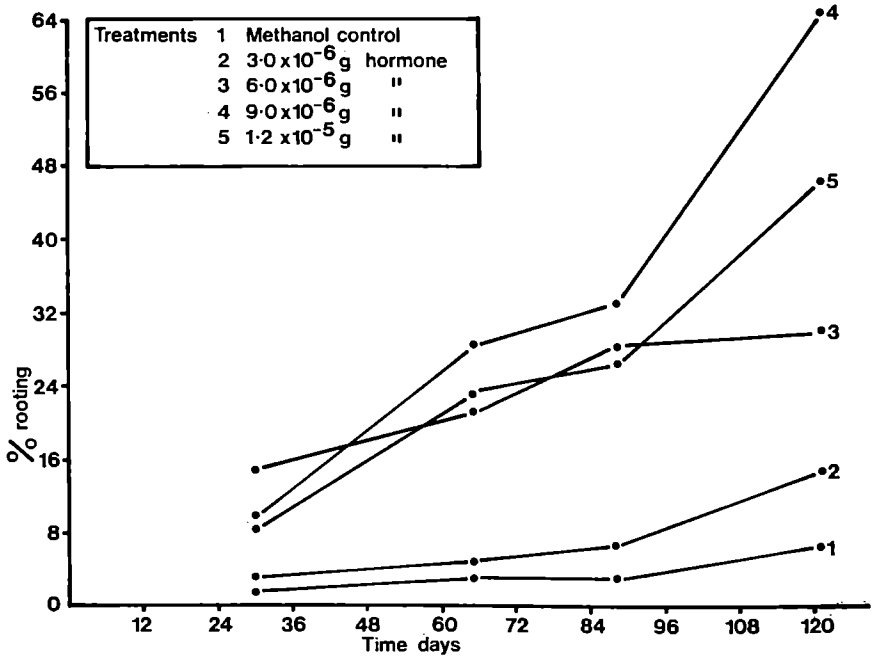


Figure 9: Effect of different weights of an equal mixture of indole butyric and naplthalene acetic acids on the rooting ability of cuttings from two clones of Lodgepole pine.

All the hormone treatments were more effective than the untreated control (7 per cent rooted after 120 days). The percentage of cuttings which rooted improved at each sampling interval with increasing weight of hormone applied, to a maximum of $9{\cdot}0 \times 10{\cdot}0^{-6}$ g per cutting (65 per cent rooting) while a further increase in weight of hormone decreased rooting ability (47 per cent).

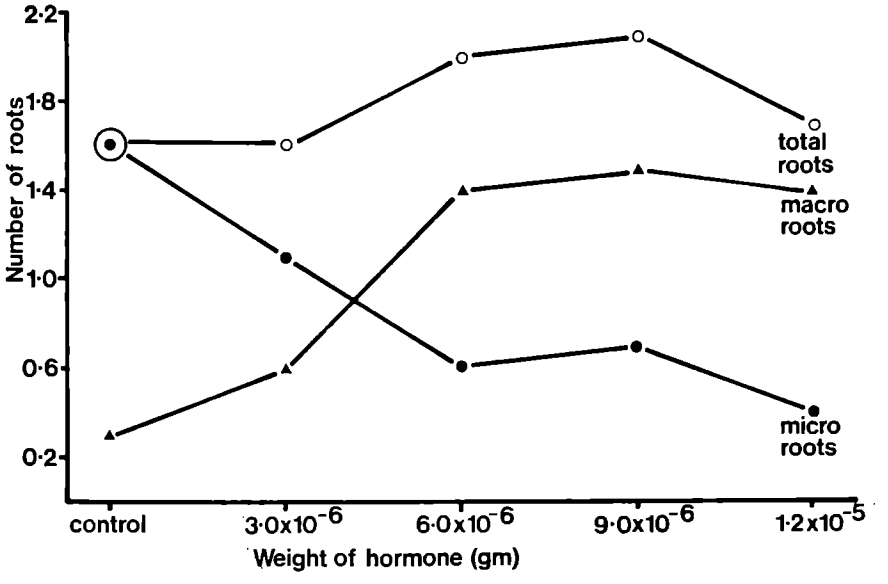


Figure 10: Effect of different weights of hormone on the number of roots on cuttings from two clones of Lodgepole pine.

Besides being the most effective treatment in inducing root formation, applications of $9{\cdot}0 \times 10{\cdot}0^{-6}$ g hormone also gave rise to the greatest number of roots per cutting (2·1) and roots were longer (36·2 mm) than those of other treatments e.g. 19·7 mm at a concentration of $6{\cdot}0 \times 10{\cdot}0^{-6}$ g. The effects of hormone concentration on root type are also clearly shown in Figure 10, the number of thin "micro" roots decreased with increasing hormone concentration while the number of thick "macro" roots increased.

Investigations have been started on the difficult problems of rooting cuttings of mature trees, using a wide range of hormone concentrations applied alone or in combination with other rooting co-factors. Preliminary results are moderately encouraging; it was found that epicormic shoots formed on the main trunk of mature Sitka spruce rooted more easily than cuttings taken from the crown. We are currently putting a considerable effort into following up this promising line of research and to the problem of inducing outgrowth of epicormic buds.

In consultation with Genetics Section a start has been made in the selection of suitable Sitka spruce and Lodgepole pine stock plants that may be expected to form the basis of future work, especially of clonal trials. The selection involves candidate plus-trees, plus-tree progeny and trees such as those which are frost or disease resistant or which have been shown to flower readily. Efforts will be made to propagate these selected trees and to build up quickly a supply of vigorous stock plants.

Physiology of Tree Roots

A programme has been developed to investigate the influence of internal and environmental factors on growth of Lodgepole pine and Sitka spruce roots. The emphasis is mainly on secondary growth; the programme is designed to provide a much needed insight into the development of the perennial, structural root system of the tree, with its implications for growth and stability. It has been observed that tree roots are better able to survive adverse soil conditions, such as water-logging and dessication, after secondary thickening has taken place.

Six sets of apparatus have been built and installed in the controlled environment rooms whereby soil temperature can be controlled independently of air temperature; preliminary results of an experiment with potted one-year-old Sitka spruce seedlings grown under short days at an air temperature of 14°C showed a considerable increase in root growth (dry weight basis) with soil temperature from 6° to 18°C, with little change at the higher temperatures used (Figure 11). Secondary growth of roots occurred, although very slowly, at temperatures as low as 6°C.

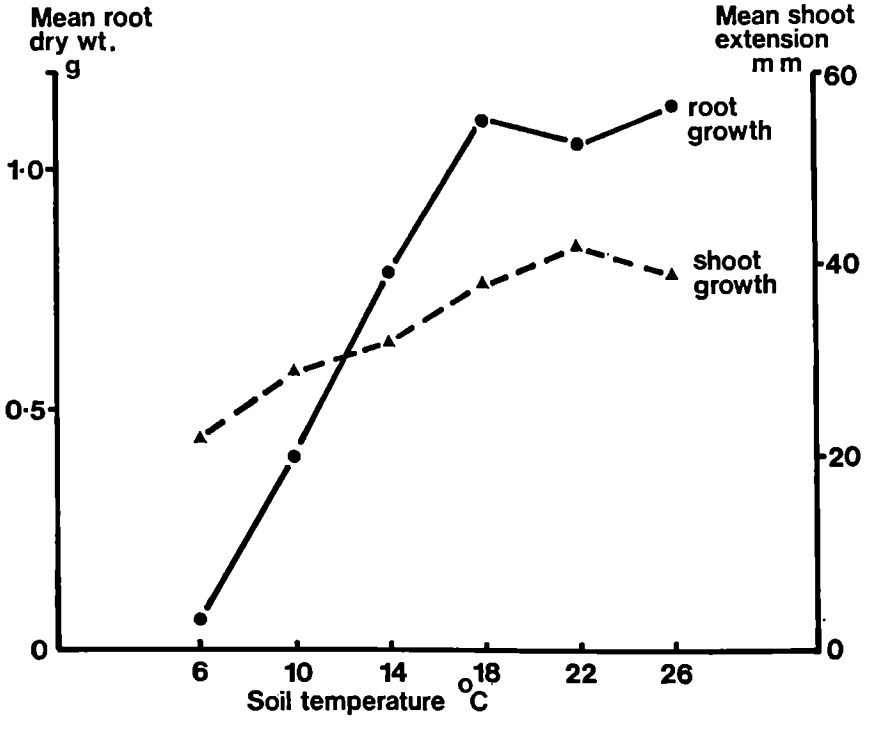


Figure 11: Growth of Sitka spruce in two months at different soil temperatures.

Effects on shoot growth were also apparent. Soil temperature had no effect on the duration of shoot extension under short days but the rate of extension growth increased with soil temperature up to 22°C, and diameter growth

followed a similar trend although much smaller relative differences were observed. These effects on the shoot, however, may relate to soil temperature in an indirect manner since they could be a function of the size of the root system rather than of the temperature at which it is grown. Further experiments are planned to clarify this aspect.

Other environmental factors believed to affect radial growth of roots, and which are currently being investigated, include soil aeration, mineral nutrition and mechanical stress due to wind sway. A combined field and laboratory approach is being adopted. For example, an experiment is in progress in which potted trees are being swayed mechanically in the glasshouse in order to study the distribution of photosynthate between the stem and various parts of the root system under conditions of mechanical stress while, at the same time, a field experiment is being established in which wind sway is reduced by guying and staking.

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FOREST PATHOLOGY

Death and Decay Caused by Fomes annosus

Deaths on Alkaline Sites

Although killing of trees by the fungus *Fomes annosus* is normally associated with pines, most other species can be killed if the conditions for the fungus are favourable. On the alkaline soils in Thetford Chase (Norfolk and Suffolk), high mortality of a wide range of species caused by *F. annosus* has occurred in underplanting trials. In one trial 18 species were planted beneath a 34-year-old Scots pine plantation thinned to 500 stems per ha. After 8 years highest mortality occurred in Leyland cypress (51·5 per cent), Douglas fir (45·7 per cent), *Nothofagus obliqua* (38·3 per cent), Scots pine (28·1 per cent), Red oak (25·1 per cent) and Hybrid larch (23·5 per cent). As indicated in the *Report* for 1967, variation in growth rates between species may contribute to the differences in mortality. The situation may be stabilising in the plots with the greatest losses, but more trees will undoubtedly die and the surviving trees will be subject to root attack which may lead to wind-throw or butt-rot. In these trials there is a strong correlation between pH and mortality with the greatest losses occurring in the more alkaline plots. In an identical trial on an acid soil elsewhere in Thetford, mortality is very low, but butt-rot and wind-throw may also occur in the future on such acid sites.

Butt-rot

A considerable volume of data has been collected during the year as part of a new project to evaluate the losses caused by butt-rot in Sitka spruce. Twenty-three infected compartments have been examined in crops (mainly second rotation) from 23 to 50 years of age and including a wide range of yield classes.

The incidence of infected trees was determined by marking out a hundred-tree plot within the compartment and by assessing each tree for the presence of butt-rot by means of pressler borings. The mean incidence of infected trees in the 23 plots was 28 per cent with a maximum of 68 per cent in one unthinned, 28-year-old crop which had succeeded a plantation of Scots pine. In many of the crops where severe infection was found pine was an important constituent of the previous crop.

Infected trees were felled, measured and then cross-cut at 0·5 m intervals. Three categories of butt-rot were recognised, stain, incipient decay and advanced decay, and measurements of the extent of each category were taken on the face of the 0·5 m section. These data will be analysed by computer and the information obtained will be used to help solve problems associated with the management of infected crops.

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Dutch Elm Disease (see also Forest Entomology, p. 109)

The Disease Situation

The 1971 Dutch elm disease survey (Gibbs and Howell, 1972) was followed by a further survey in 1972. This survey covered 677 10-km squares, 20 per cent

more than in 1971, the main additions being extensions further to the north in England, westwards into South Wales and additional parts of Devon and Cornwall. The results, summarised in Table 18 showed that of the estimated 23 million elms in the survey area, about 1·4 million were dying or recently dead, and that 1·6 million had slight to moderate disease. In addition it was estimated there were 0·5 million long-dead elms carried over from previous years.

TABLE 18

1972 SURVEY RESULTS (Elms in thousands)

Location	Total number of elms	Number of slightly infected	Number dying and recently dead	Number long dead
Non Rural	2,577	225	280	34
Rural	11,607	878	923	305
Woodland	9,146	542	197	146
All	23,330	1,645	1,400	485

TABLE 19

COMPARISON OF PERCENTAGE DISEASE IN 1971 AND 1972

Location	Slightly infected		Dying and Recently dead		Long dead	
	1971	1972	1971	1972	1971	1972
Non Rural	11·3	9·0	5·8	11·4	0·5	1·3
Rural	9·8	7·5	4·4	8·3	1·1	2·2
Woodland	9·1	6·0	1·1	1·2	0·5	1·6
All	9·1	7·1	3·2	5·7	0·8	1·8

Comparison of percentage infection for the area covered in both 1971 and 1972 (566 10-km squares) are contained in Table 19. These show that the proportions of dying, recently dead and long-dead trees markedly increased. When account is taken of trees felled because of disease, the cumulative losses are estimated at 8 per cent. In contrast to this the proportion of trees with slight to moderate infection showed a slight decrease. In some counties with relatively low levels of infection in 1971 (such as Bedfordshire, Berkshire, Buckinghamshire, Cambridgeshire, Hertfordshire and Surrey) there was a great increase in the proportion of dying and recently dead trees in 1972 ranging from four to tenfold. The greatest increase in numbers of infected trees however, occurred in areas where the disease was most severe in 1971. The numbers of dying and dead trees (including long-dead trees) in the worst affected counties are estimated as Gloucester, 277,000; Essex, 228,000; Worcester, 159,000; Hampshire, 115,000; Kent 107,000; Somerset, 90,000; Greater London Council area, 85,000; Berkshire, 73,000; E. Suffolk, 70,000; W. Sussex, 59,000; Surrey, 55,000; Hereford, 53,000. The detailed results of the survey are being prepared for publication.

The Aggressive Strain of Ceratocystis ulmi

Research conducted during the year has shown that the aggressive strain of *Ceratocystis ulmi* found in the areas worst affected by the disease (Gibbs, Heybroek and Holmes, 1972) possesses certain cultural characteristics which enable it to be readily distinguished from the non-aggressive strain (Gibbs and Brasier, 1973). Moreover, the aggressive strain shows a great similarity to forms of the fungus present in north America. Towards the end of the year, evidence was presented that the aggressive strain was introduced into Britain in logs of Rock elm imported from Canada (Brasier and Gibbs, 1973). Further research on the population dynamics of *C. ulmi* and the genetic control of pathogenicity is in progress.

In addition, data were published indicating that the aggressive strain has a much greater ability than the non-aggressive strain to spread from one annual ring to the next, and thus bring about a recurrence of the disease in the year following that in which infection first occurred (Burdekin and Gibbs, 1972).

The Beetle as Vector of the Fungus

A limited amount of work, now completed, was conducted in 1971 and 1972 on the role of the two elm bark beetles (*Scolytus scolytus* and *S. multistriatus*) as vectors of *C. ulmi*. In 1971 beetles emerging from elm logs from 4 sites were macerated and plated out on elm sapwood agar and streptomycin. Sixty-five of 124 (52 per cent) *S. scolytus* beetles were found to be carrying *C. ulmi*, while only 12 of 104 (12 per cent) *S. multistriatus* beetles were contaminated. In 1972 work by Neil Richards, a student from Brunel University who spent some time at Alice Holt, produced similar results. Three hundred and eighty-two out of 699 (55 per cent) of *S. scolytus* beetles and 42 out of 209 (20 per cent) of *S. multistriatus* beetles carried *C. ulmi*. Further it was found in both years that the number of spores of the fungus per contaminated beetle were very much greater on *S. scolytus* than *S. multistriatus*. Moreover, *S. scolytus* emerges earlier than *S. multistriatus* and is likely to be at its most active during the peak period of host susceptibility in June and early July. These facts taken alone suggest that *S. scolytus* is the more important of the two vectors. It must be realised however that many more beetles of *S. multistriatus* than *S. scolytus* may emerge from one diseased tree.

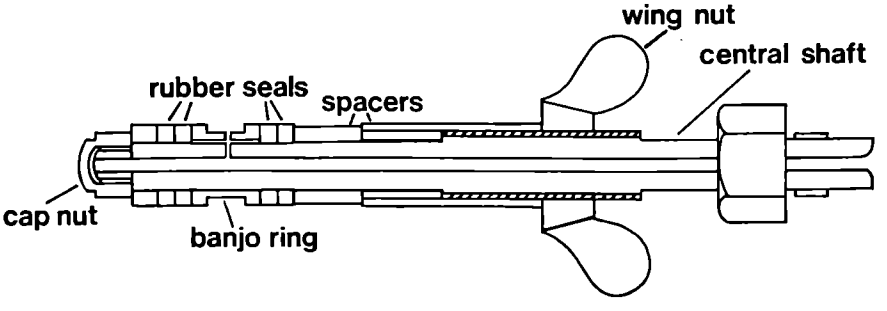

Figure 12: Lance for the injection of fungicides for Dutch elm disease control. The wing nut is tightened on a thread and acts through two spacers to cause the rubber seals to expand, thus securing the lance in the tree. The liquid passing under pressure along the central shaft emerges through the banjo ring between the two sets of seals.

Fungicides for Dutch Elm Disease

During 1972 a number of injection techniques were examined. These included non-pressure systems involving cones attached to the trunks of trees (Phelps, Kuntz and Ross, 1966) and pressure systems based on the equipment described by Jones and Gregory (1971). A satisfactory method used a pressure system operating at 50 pounds per square inch connected to a number of injector lances, based on a prototype developed by Cooper Pegler Ltd. The lance is so constructed (Figure 12) that when *in situ*, the fungicide gains access only to the outer xylem rings, being confined by two expanding rubber seals which also act to secure the head in the tree.

The fungicide so far used has been a solution of benomyl in lactic acid (McWain and Gregory, 1971).

J. N. GIBBS
C. M. BRASIER
D. A. BURDEKIN

Advice on Dutch Elm Disease Control

A large number of enquiries, both telephoned and postal, were received during the year from a variety of sources including members of the general public, local authorities and the news media. A new Forestry Commission publication, *The Control of Dutch Elm Disease* (Leaflet 54, HMSO 6p) and a number of more informal leaflets provided a useful means of communication.

Advice on the control of the disease was strongly influenced by the revocation of the Dutch Elm Disease (Local Authorities) Order 1971 in January 1973. At that time, the Minister of Agriculture decided that the large-scale sanitation felling programme should cease. This decision led to attention being focused on other possible means of control. The most promising of these is the fungicide injection treatment. Although still in the early stages of development, the treatment has aroused considerable public interest.

The Forestry Commission is planning large scale trials this year to further evaluate the technique and also conducting training courses where the limitations of the treatment are pointed out.

Several members of the Pathology section appeared on television and radio particularly in connection with the fungicide injection treatment.

D. A. BURDEKIN

Phytophthora Diseases

The survey of the distribution and frequency of *Phytophthora* fungus damage to trees has continued (see also *Report* for 1971 and 1972). A recurrent problem is that many probable cases of *Phytophthora* root damage are not reported until foliar symptoms become evident, often a year or more after initial attack and when the pathogen is in decline or has been replaced by other organisms. As currently active lesions are necessary for successful isolation, many cases of suspected *Phytophthora* damage referred to us cannot be confirmed. However, between January and December 1972, several new and interesting records of

association between *Phytophthora* and root damage to hardwood species were obtained:

Nothofagus. In June *P. citricola* was isolated from soil around dead roots of 6–8 m *N. obliqua* with crown dieback on a clay site at Rockingham, Northamptonshire and in December *P. cinnamoni* was obtained from soil around dead roots of 2-year-old *N. obliqua* at the Crown Estate Nursery at Ascot, Berkshire.

Populus. In November we examined a stand of 124 seven-year-old *P. robusta* in which 17 per cent had died after the 1971 growing season. Although this was a somewhat unexpected host for *Phytophthora*, the symptoms and pattern of damage were consistent with *Phytophthora* attack. Many trees, including apparently healthy ones, had numerous dead roots, basal stem lesions, and stem and branch cankers. Isolation from dead roots was unsuccessful, but *P. megasperma* var *megasperma* was isolated from soil around these roots. As similar damage to Poplar has been previously observed but the cause not diagnosed, the role of *Phytophthora* in this case is being examined.

Prunus. In July an unidentified species of *Phytophthora* was isolated from necrotic areas on large roots of streetside Kanzan Cherry in Cheltenham, Gloucestershire. This seems to be the first record of *Phytophthora* on *Prunus* in Britain.

Prunus, Salix, Berberis and *Viburnum.* In August we investigated the sudden death of about 20–30 trees and shrubs in public gardens at Bexleyheath, Kent. Isolation from dying roots yielded *P. cryptogea* from *Prunus* sp., and from *Viburnum bodnantense*; *P. citricola* from a large *Salix chrysocoma*, and from *Berberis stenophylla*; and an unidentified *Phytophthora* sp. from *Salix matsudana* "tortuosa". These seem to be the first records of *Phytophthora* on *Salix, Berberis* and *Viburnum* in Britain.

Tilia. In June 1972, we isolated *P. citricola* from extensive collar lesions on a 70-year-old lime (*Tilia* sp.) in an avenue at Elton, Northants. The tree had severe crown dieback, thin foliage and abnormally small leaves. Two other specimens with collar lesions had died, and several others were affected. This is the first record of *Phytophthora* sp. on lime in Britain although we have obtained *P. citricola* from soil around dead roots of *Tilia* sp. with similar symptoms on several occasions.

Our recent records of *Phytophthora* on new host species (see also *Report* for 1971 and 1972) emphasise the need for clarification of the role of the fungus in these diseases by experiment, and also suggest an explanation for some long unexplained diseases (e.g. "The Death" of *Prunus* species, Wormald 1955). Many *Phytophthora* diseases must have been overlooked in the past because of the difficulties involved in isolation, culturing and identification of the pathogen.

C. M. BRASIER
R. G. STROUTS

Beech Bark Disease

The Disease Situation

An annual survey of all pole stage beech plantations in the South-east England Conservancy is now undertaken to monitor the development of the disease.

There are indications that infestations of the Beech scale *Cryptococcus fagi* in southern England are increasing (Plate 12). The increased number of enquiries about Beech bark disease which have been received reflect a growing awareness of the potential loss in timber and amenity values (Plate 13).

Inoculation Experiments

Glasshouse experiments with 3-year-old potted beech confirmed that inoculations with isolates of the Beech bark disease fungus (thought to be *Nectria coccinea*) onto the main stem were successful during the dormant season. The inoculum of *Nectria* mycelium was grown on 1 per cent malt agar. A vertical scalpel slit provided the wound entry point in the bark. All plants inoculated produced spindle-shaped lesions of necrotic bark, from the edges of which the fungus could be re-isolated. All control wounds reacted with vigorous callus formation.

Drought conditions have sometimes been implicated as a precursor to the disease. Potted plants were therefore subjected to adequate and restricted watering regimes, using sunflowers as indicators of incipient wilting. So far no evidence has been obtained to support the hypothesis that beech are more susceptible to invasion by *Nectria*, and that the fungus develops faster in plants subjected to moisture stress.

E. J. PARKER

Dieback of London Plane

The experimental rapid and slow thawing of twigs (*Report* for 1971, pp. 93–4) was repeated in the winter of 1971/72 with an additional treatment in which twigs were left unfrozen. The earlier experiment gave results apparently in accord with the theory of a causal relationship between dieback and the over-rapid thawing of twigs and small branches in cold sunny winters, but conflicting results (Table 20) were obtained from the second experiment, in which only one previously tested clone (the resistant M15) and five untested clones were used.

TABLE 20

PERCENTAGE OF BUDS OF LONDON PLANE CLONES WITH LIVE GROWTH SIX WEEKS AFTER SUBJECTION TO RAPID, SLOW AND NO THAWS

(1) Clone	(2) No thaw	(3) Slow	(4) Rapid
M15(r)	26	44	47
VN(r)	27	28	27
V67(r)	29	10	3
GU6(r)	46	5	8
GU7(s)	35	9	11
M19(s)	15	0	0

Note: Col. (1): (r) = apparently resistant; (s) = susceptible.

The results suggest wide variation in London Plane clones in their response to freezing (—5°C), the resistant M15 seemingly benefited where the susceptible M19 was killed; they do not, however, indicate any direct causal relationship between dieback and rate of thawing.

C. W. T. YOUNG

Sirococcus strobilinus

In 1971 (see 1972 *Report*) dieback of two-year-old Lodgepole pine seedlings in a nursery in north Scotland was found to be associated with *Sirococcus strobilinus*. Generally only current year growth had been killed and the stage of development of many dead shoots suggested that infection had probably occurred in June/July. Disease distribution also suggested that Washington Coast (7972) Lodgepole pine might be more resistant than that from southern interior British Columbia (7118).

At the beginning of August 1972 an isolate of *S. strobilinus* from this outbreak was inoculated into both wounded and unwounded extending shoots of three-year-old Sitka spruce, Norway spruce and three provenances of Lodgepole pine [southern interior (7118) and central interior (7113) British Columbia and north coastal Oregon (7951)]. Mycelium from an agar culture was used as inoculum. Sitka spruce was included because it suffers a dieback disease (generally in September) which is usually ascribed to *Ascochyta piniperda*, a fungus very similar to *S. strobilinus*. Indeed, at least two authors (Roll-Hansen, 1967; Funk, 1972) consider them synonymous. Norway spruce has also been reported as a host for *A. piniperda*.

Lesions formed on all 12 wound inoculated plants of both Norway and Sitka spruce; four of the Sitka spruce leaders died back. Five out of six wounded southern interior British Columbia Lodgepole pine developed lesions but wound inoculations on six plants of both the other provenances were unsuccessful. Pycnidia of *S. strobilinus* formed in the dead bark of all lesions on both spruces and on two of the Lodgepole pine lesions. Inoculations without wounds were unsuccessful on all species. Wounds on control plants remained healthy and healed normally.

This experiment broadly confirmed results of inoculations carried out earlier in the season on Lodgepole pine and Sitka spruce except that the Lodgepole pine was apparently less susceptible than it had been earlier. At that time six out of twelve wound inoculated shoots of the central interior British Columbia provenance died back and sunken lesions formed on five out of twelve plants of north coastal Oregon provenance. All twelve wound-inoculated Sitka spruce shoots died back.

Spore inoculations on wounded and unwounded Sitka spruce shoots were entirely unsuccessful. They also failed on unwounded southern interior British Columbia Lodgepole pine. However necrotic lesions did form at the point of inoculation on seven out of 16 wounded pine and pycnidia of *S. strobilinus* formed on one of them. All controls remained healthy.

Further work on spore infection is clearly necessary. It is also intended to inoculate Sitka spruce and Lodgepole pine with an isolate derived from a

natural outbreak of Sitka spruce dieback as soon as one becomes available. However the results do suggest that southern interior Lodgepole pine may be more susceptible than Lodgepole pine from the northern Oregon coast.

D. B. REDFERN

Advisory Service (Alice Holt)

A record number of 538 enquiries was received. Of these, 99 concerned disorders in woodlands and plantations, 43 in nurseries and 342 in parks and other ornamental plantings. There were 70 enquiries concerning Forestry Commission trees. One hundred and four visits were made in the course of investigations. In 54 cases of damage the cause was not determined on investigation and in 62 cases the specimens and information supplied were inadequate for diagnosis. A further 37 are still under investigation. Damage was attributed to parasites in 233 cases and to non-living agencies in 41.

Discounting numerous enquiries on Dutch elm disease, the most frequently recorded diseases were those caused by *Armillaria mellea* (53 cases), *Marssonina salicicola* (34 cases, a great increase after the few cases recorded in the last three years), *Phytophthora* spp (17 cases), *Gnomonia veneta* (15 cases), and Beech bark disease (11 cases).

Damage attributed to non-living agencies was due most often to cultural malpractice (frequently misuse of herbicides), nutrient deficiencies (notably lime-induced chlorosis in young larch plantations) and, apparently, wind. Much browning of many species, notably beech in the south and west of Britain, was reported after south-westerly gales in May. However, the abundance of *Gloeosporium fagicolum, G. quercinum* and aphids on affected leaves suggested that, although the orientation of much of the damage was westerly, it may not have been due solely to wind.

Notable cases

Unusual coloration of leaves, seemingly associated with cold early summer conditions, was observed in several places. Some Horse chestnuts that had not previously been seen to do so produced near-white and variegated leaves amongst their normal foliage, and pale yellow leaves were seen on epicormics of *Acer negundo*. Large numbers of Red oak failed to turn green after flushing and retained their initial pale yellow colour throughout the summer.

A remarkable outbreak of *Gnomonia veneta* caused widespread defoliation of London plane throughout the south. Trees in Central London, however, were little affected.

In March 1973, a man's skeleton was found in woodland near Woking, Surrey. There was evidence that he had lived rough in the wood for a short while before his death, and we were asked to help in determining how long ago he had died. From a scar on a pine, and from birch seemingly cut to provide a shelter, it appeared that he went there at some time between the summer of 1969 and spring 1970. Roots from the pine had been growing in the remains of the man's coat for the last two years, and the tree's radial increments for this time showed a remarkable increase, possibly in response to a gruesome fertiliser.

C. W. T. YOUNG
R. G. STROUTS

Advisory Service (Northern Research Station)

One hundred and thirty-eight enquiries were received during the year, of which 47 were from Forestry Commission staff. Sixty-five concerned disorders occurring in woods and plantations, 18 concerned disorders in nurseries and 44 disorders in parks, roadside trees and other ornamental plantings. Visits were made in the course of 30 investigations. Fourteen enquiries remain unsolved and 11 are still under investigation. Damage was attributed to parasites in 60 cases and to non-living agencies in 39.

The most frequently recorded diseases were those caused by *Armillaria mellea*, *Marssonina salicicola*, *Lophodermella sulcigena* and *Fomes annosus*. Damage due to non-living agencies was mainly caused by early frosts and by misuse of herbicides.

Severe dieback of aspen caused by *Pollaccia radiosa* (the conidial stage of *Venturia tremulae*) was recorded in July at two sites in Inverness-shire and one site in Perthshire. *V. tremulae* occurs over most of Europe but it has only been recorded in Scotland once previously (Foister, 1961).

Spots caused by *Phleospora aceris* were recorded twice on the green portions of sycamore leaves also showing severe marginal necrosis, which itself might have been climatic in origin.

The period July–September 1972 was very dry in many parts of Scotland and northern England and several cases of premature needle fall in Scots and Lodgepole pine, branchlet yellowing in *Sequoiadendron giganteum* and premature leaf fall in beech may have been caused by drought. In parts of east Scotland a few areas received only 20–30 per cent of their normal rainfall for that period.

Other interesting occurrences were single cases of *Gnomonia veneta* on London plane shoots and *Melanconium betulinum* on birch leaves.

The unusual type of early frost damage on current year Sitka spruce needles which occurred in October 1971 and was referred to in the 1972 *Report* again occurred widely in central, south and east Scotland following several unusually severe frosts early in September. The lowest air temperature for the month, −5·9°C on the 3rd, was reported near Aviemore while Grantown-on-Spey recorded the lowest grass minimum of −11·2°C on the morning of the 9th. Five instances of identical damage to other species (*Abies procera*, Scots pine, Lodgepole pine and Douglas fir) were also observed. Damage to succulent shoot tips was much more common than in 1971 and was particularly evident on Japanese larch and Sitka spruce.

One case of Dutch Elm Disease was confirmed near Newcastle. In contrast to the two cases reported north of the Humber–Mersey line last year, the aggressive strain of *Ceratocystis ulmi* was involved in this outbreak.

D. B. REDFERN
S. C. GREGORY
J. D. LOW

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FOREST ENTOMOLOGY

The Spruce Sawfly, Gilpinia hercyniae

Work continues on the infestation of this Spruce sawfly affecting Norway and Sitka spruce plantations in North Wales. The areas being affected by high populations of *Gilpinia hercyniae* now exceed 1,600 ha and in addition to the damage obvious at Hafren and Ystwyth Forests (Plate 6), it can be seen in many of the nearby small privately-owned blocks of spruces to the west and south-west of Plynlimon Mountain. Damage can now also be seen in parts of Rheidol (Rheidol and Taliesin) Forest and in a southern outlier of Dyfi Corris Forest. Crops planted in 1964 at 1,850 ft above sea level, at Hafren and in 1931 at 1,500 ft at Ystwyth (Tarenig) suffered severe damage during 1972. All known areas of defoliation lie within a radius of nine miles (14 km) of Plynlimon.

Staff of the Unit of Invertebrate Virology, Oxford continued to investigate the epizootiology of the nuclear polyhedrosis virus of *G. hercyniae* and are studying the incidence and rate of spread of this naturally occurring fatal disease. This virus is now widely spread through Hafren Forest and has been introduced by transfer of infected caterpillars into heavily infested areas of Ystwyth Forest (Myherin and Tarenig).

No controlling parasites have been found in the population of sawflies causing the present epidemic and studies have commenced with the intention of obtaining suitable parasites from European populations of *G. hercyniae* for rearing and releasing into our infested areas.

Predation of cocoons by small mammals (mice and shrews) is everywhere obvious, but in spite of the destruction of up to half the population through this means, the effect of these animals upon the intensity of defoliation appears to be negligible at high densities of the sawfly. A considerable variety of birds have also been noted actively searching crowns and feeding upon the larvae which are present from May to October.

An aerial photographic survey of some of the defoliated areas of Hafren and Ystwyth (Myherin and Tarenig) Forests was undertaken by the Forestry Commission's Photographic Section in March 1973, and has provided a good basis for the mapping of the outbreak.

RONALD M. BROWN

Green Spruce Aphid, Elatobium abietinum

The winter months of 1971/72 were again favourable for this aphid to cause damage although the severity of attack was generally not so great as in spring 1971. Investigations into the occurrence of spring attacks and into the ability of the aphid to withstand low temperatures has shown that *E. abietinum* can become acclimatised by exposure to cool temperatures and can then withstand temperatures well below freezing; but if the insect has been reared under mild conditions it cannot tolerate frost so well. It follows therefore that a few sudden air frosts of about −11°C during an otherwise mild winter could be as devastating to the aphid as a generally cold winter (Carter 1972).

In the southern counties of England, there were notable numbers of the Cantharid beetle *Rhagonycha lignosa* preying on the aphid colonies. It may be relevant that the Sitka spruce infested by the aphid were growing in mixed woodland including hardwoods where this beetle is usually found.

In January 1973 a visit was made to the Republic of Ireland, where winter damage by the aphid was reported on an hitherto unprecedented scale.

C. I. CARTER

Pineapple Galls caused by Adelges abietis

Damage by this Adelgid continues to be a source of concern among Christmas tree growers and nurserymen. The early development of the insect in 1972 has followed closely that of the previous two years so that early April insecticidal treatment has failed to prevent galling and distortion of the new shoots.

Studies of the biology, dispersal and infestation patterns have been made. These show that within the five year period between planting and harvesting, insect numbers may rise from a small early nucleus to a level at which a high proportion of the crop can be rendered unsaleable. Experimental trials of various insecticides, including new selective compounds, are now being assessed. Late autumn applications of contact insecticides show promise.

C. I. CARTER

The Pine Looper Moth, Bupalus piniarius

Pupal Survey

The same 51 forest units as in previous years have been sampled this winter, and the results present a general picture of increasing populations, though no *Bupalus* pupae were found in ten of them. Last year Wykeham Forest had a *highest compartment count* of 1·6 pupae per m^2. This has now risen to 5·2 per m^2, and this forest is therefore in sixth place from the highest out of all the sample areas.

Sherwood (Clipstone) Forest shows a significant reduction in numbers of pupae from those found in 1972, when the *forest average* was 11·47 per m^2, and is now 3·75 per m^2. Also the *highest compartment count* this year is 9·6 per m^2 as compared with 49·2 per m^2 last year. The main species attacked was Corsican pine, and in parts of the forest browning of foliage was quite severe.

Culbin Forest has the second highest pupal count in the country. The increase is eight-fold bringing the *forest average* from 0·53 per m^2 to 4·25 per m^2 this winter, and the *highest compartment count* of 13·2. Such figures have not been reached since the epidemic of 1954.

In 1963 aerial control was carried out at Cannock Forest when the *forest average* was 19·47 per m^2. This year pupal numbers there are very similar, the overall count being 16·40 per m^2. However, two factors may help to avert the necessity of control measures in 1973. The main species now is Corsican pine, which may tolerate higher populations of *Bupalus piniarius* larvae than Scots pine. In addition the clear felling programme could be adjusted to include seriously defoliated areas. This was one of the control methods used at Wykeham Forest in 1970.

RONALD M. BROWN

The European Pine Shoot Moth, Rhyacionia buoliana

During the spring of 1972 severe damage by *Rhyacionia buoliana* (Schiff.) was observed on Lodgepole pine, *Pinus contorta* at several localities in England. The opportunity was taken at a seed orchard in Wiltshire to investigate possible insecticidal treatment against this insect. A number of insecticides were tested and preliminary results indicate that satisfactory control was obtained with fenitrothion applied at the start of larval activity in the spring.

T. M. SCOTT
T. G. WINTER

Pine Shoot Beetle, Tomicus piniperda

Past work has established that effective control of *Tomicus piniperda* can be obtained by spraying infested logs with 0·5 per cent BHC at the rate of 4·91 litres per 10 m^2 of bark surface area. It was later found that using half the dosage provided a variable and unreliable degree of control.

In 1972 an experiment was designed not only to test these two rates again but also to find alternative insecticides less persistent than the organochlorine BHC. This was carried out at Ringwood Forest (Hampshire and Dorset). Scots pine billets were allowed to become heavily infested with broods of the Pine shoot beetle. The plots were then sprayed using BHC, and the low-persistence organophosphorous compounds dursban and bromophos. Each insecticide was applied in three concentrations, 0·25, 0·5 and 0·75 per cent, in each case both at the standard dosage of 4·91 litres per 10 m^2 bark surface, and at one half of this rate.

Results showed that BHC gave good control at all three concentrations at the higher rate of application, with the best results at 0·75 per cent. Dursban at 0·75 per cent and at the higher rate gave good control, comparable to that given by 0·25 per cent and 0·5 per cent BHC. Bromophos was nowhere near as effective as the other two insecticides. The half rate of application did not compare favourably with the full rate of any insecticide or concentration.

It was planned to assess the survival rate of adults emerging from logs treated at the half dosage. There was some indication that beetles from treated material did not live as long as those from untreated logs. This suggests that they received harmful dosages of insecticide from the outer bark. However, more work needs to be done before drawing any conclusions.

J. M. DAVIES
C. J. KING

Larch Casebearer, Coleophora laricella

The Canadian Department of Agriculture is seeking living specimens of the parasite *Diadegma nana* to assist in the control of the Larch casebearer, a European moth, now a serious pest in Canada. Thorpe (1929) found this parasite in many of the specimens of the moth which he collected during a study in the Forest of Dean. At the request of the Commonwealth Institute of Biological Control, and on behalf of the Canadian Department of Agriculture, over 6,000 living casebearer larvae were therefore collected this year in three areas of European larch in the Cinderford District of the Forest of Dean, at Edgehills,

Staple Edge and Crabtree Hill. These three areas were moderately infested by *C. laricella*, and parasitised larvae of the moth were found. The highest percentage of parasitised larvae was recorded at Staple Edge. In this instance the parasite proved to be the chalcid *Dicladocerus westwoodi*, which Thorpe (1929) had found affecting only 2·9 per cent of the larvae collected for his study. In the collections made in 1972, *Diadegma nana* was found in only very small numbers affecting less than one per cent of the moth larvae. After collection and examination, the material was sent to Canada.

C. I. CARTER

The Web-Spinning Larch Sawfly, Cephalcia alpina

During July and August 1972 it was found that the Web-spinning larch sawfly *Cephalcia alpina* had caused severe defoliation in 27 hectares of Japanese larch planted in 1939 in the Cwm Afan block of Margam Forest, South Wales, and slight damage in a further 46 hectares. It was earlier suspected that the damage had been caused by the Large larch sawfly *Pristiphora erichsonii*, which proved, however, to be present only in very small numbers.

This European sawfly *C. alpina* was first found in Britain in 1953 at Alice Holt Forest, Hants (Styles 1959). Two adults were taken by Gurdon 1954 at Wytham Wood, Berks. It has now also been reported from Clwyd Forest, Denbighshire and Hafren Forest, Montgomeryshire.

Styles (1959) gave an account of the life cycle and descriptions of the various stages. The adults fly from late May to mid-June. The solitary larvae feed on the needles encased in a "silken tube". In autumn the larvae drop to the ground but do not spin a cocoon. They overwinter in the mineral soil to a depth of 2–8 inches (5–15 cm) as yellow-orange larvae. Sampling during this period in the infested area of Margam gave numbers in excess of 1,000 larvae per m^2. Surveys of nearby susceptible areas, however, showed either absence or extremely low populations.

Larval collections are being reared in the laboratory to watch development, and for the presence of diseases and parasites. The effect and extent of defoliation will be studied in 1973.

RONALD M. BROWN
D. BILLANY

Ips cembrae

This bark beetle was first found in Britain in 1955 on larch in the Moray Firth area of Scotland. It has become common in the East Highlands, breeding in larch logs and occasionally attacking and killing standing trees. Adults also bore into shoots for their maturation feeding, causing crown-pruning. Recently the beetle has been found to have extended its host range. In 1971 Norway spruce logs were attacked at Dunkeld (Perthshire). During 1972 *Ips cembrae* bred successfully in Douglas fir and Scots pine logs at Dunkeld and the Moray Firth area, and also in the latter region in logs of Sitka spruce and Noble fir. The beetle has not so far been found attacking standing trees of these species but there is an obvious risk and an investigation of its biology and pest potential has been started.

J. T. STOAKLEY

Control of Hylobius abietis and Hylastes species

Dipping Treatments

Results of the experiment laid down at Kielder in 1969 comparing "Gammacol" (a water-based fine suspension of lindane) with DDT were recorded in the *Report on Forest Research 1971.* In the third year after treatment both these insecticides gave significant control, although DDT was not as effective as "Gammacol" in controlling *Hylastes cunicularius.*

Following some adverse reports on the protection provided by 1·6 per cent "Gammacol" a further series of trials testing this material was established in 1970 in West Scotland and South West England on eight sites with high rainfall. Results over two years showed "Gammacol" to be as effective as DDT although neither insecticide gave adequate protection where populations of weevils were very high.

Storage of Dipped Plants in Polythene Bags

A number of experiments to test the effects of storing plants dipped in "Gammacol" and placed in sealed polythene bags for four weeks were concluded in 1972. The results although initially unsatisfactory because the plants were bagged while still wet were nevertheless encouraging. Plants treated and then stored in polythene were as well protected from *Hylobius abietis* and *Hylastes* spp as plants first stored and dipped just prior to planting. It was concluded that the aerial parts of the plants must be thoroughly dried before bagging. Residue analysis revealed that little change in depositions of insecticide had taken place during storage.

Application of Granular Systemic Insecticides at time of planting

During 1970 and 1971 a range of organo-phosphorous insecticides known to translocate in agricultural crops were tested against *Hylobius abietis.* The results of the 1970 trials were reported in the *Report on Forest Research 1971.* The experiment was repeated in 1971 and results again were negative. The work has now been discontinued.

Application of Granular Systemic Insecticides to plants in Japanese paper pots

The only method of protecting potted plants against *Hylobius abietis* and *Hylastes* spp at present is to spray or drench with "Gammacol" immediately prior to planting. This is not very satisfactory as retreatment of the small but rapidly growing plants is necessary after a short period. In Norway it has been shown that when the organophosphorous systemic insecticide phorate is applied as granules to the soil surface of potted spruce plants and watered in it gives protection for up to three years. In 1971 an experiment was laid down to test different methods of application with phorate to Sitka spruce.

In one treatment phorate at different rates was mixed in the potting compost prior to sowing. In another it was applied to the soil surface after germination just prior to removal of the plants from the greenhouse for hardening-off. The first year of assessment showed the latter method to be most promising. This work will continue for the next two years. More experiments are planned for 1973 using Corsican pine.

T. M. Scott
C. J. King

Beetles associated with Dutch Elm Disease
(See also p. 94, under Forest Pathology)

Biology

Studies on the biology of the Elm bark beetles that act as vectors of Dutch elm disease, and of their parasites and predators continued throughout 1972. In order to collect the insects a new type of emergence trap was developed with the help of the staff in the Research Workshop (Plate 7). Seventy-five traps were made, and each one could take a log up to 1 m in length and 25 cm in diameter.

Logs were obtained from four sites around the Gloucestershire outbreak area, and from one place at Basildon, Essex. At two and three day intervals collections were made from the traps, and insects counted and identified.

It was found that the greatest number of *Scolytus scolytus* adults emerged towards the end of June, whereas the peak for *S. multistriatus* occurred in late July. Logs with bark up to 6 mm thick tended to produce mainly *S. multistriatus*, while in bark of greater thickness *S. scolytus* was dominant.

Parasite emergence was much higher than that found during 1971, when it was around 6 per cent. The mean for the four western sites was 29·5 per cent and for Basildon 9·6 per cent. The species of parasites were the same as last year. Only 11 per cent were braconids, and the most common was the Eulophid *Entedon ergias* which accounted for 79 per cent of the total parasites found. The number of predatory insects was not great, but quantification and identification is not yet complete.

Three window traps were set up in an infected area near Great Malvern. Unfortunately no *Scolytus* spp were collected. This may have been due to siting, or to the low summer temperatures depressing flight activity.

In the field, general observations showed that the cold summer delayed emergence and suppressed flight and maturation feeding. In Essex this feeding was observed in mid June, but little was seen in the west until late July. Most of the breeding was also late, little being noted until the end of July and early August. However, when it did take place the larvae grew quickly and overwintering populations of fully fed larvae are now high.

In January 1973, a consignment of Rock elm logs with bark attached, imported into Southampton from Canada, was found to be infested with *Hylurgopinus rufipes* (Plates 8 and 9). This, the American elm bark beetle, is one of the vectors of Dutch elm disease. The beetle larvae were accompanied by the aggressive strain of the disease (Walker, in press).

C. WALKER

Control—Prophylactic treatment

Screening trials of candidate insecticides were carried out during the late winter and early spring. Test branches of elm were dipped and allowed to weather in a nursery for one and two months before caging with 10–15 *Scolytus scolytus* beetles. The number of feeding scars and percentage mortality was assessed. Results indicated methoxychlor to be as effective as DDT and markedly

superior to the other materials tested. Methoxychlor is an organochlorine and though close chemically to DDT is not so persistent and very much less toxic to mammals. It was selected for field trials along with two other possible organophosphorous insecticides, dursban and tetrachlorvinphos.

A number of spraying techniques and a lot of equipment was tested prior to selection for the field trials. In the main field trial at Madresfield Estate near Malvern three insecticides were tested at two concentrations applied by four methods. The methods included ground spraying with high volume hydraulic pumps, spraying with mistblowers and ultra-low volume fan-assisted sprayers from a hydraulic platform lift, and aerial spraying from a helicopter. At Basildon in Essex, and at Eton College a modified tractor-mounted mistblower was used. The modification consisted basically of an extension tube three metres in length fitted to a fan housing with a ring of 12 nozzles mounted at the top of the tube. At Basildon and at Hillyfields Park, Lewisham, the fan-assisted ULV sprayer was tested further.

Assessments were based mainly on bioassays of sample twigs because disease incidence was found to be an unreliable indicator owing to the high percentage of recurrent damage symptoms. Results confirmed the superiority of methoxychlor although the higher concentration of dursban also gave good control.

Generally mistblowers were superior to other sprayers although ultra low volume spraying was surprisingly successful. Clearly for large scale application aerial spraying would be most appropriate although further work on dosages is required.

T. M. SCOTT

Beech Scale, Cryptococcus fagi

For the past two years the life history of the Beech scale *Cryptococcus fagi* has been followed in an infested area of Queen Elizabeth Forest.

The immature parthenogenetic females overwinter under the protection of their woolly secretion, and there they reach maturity and lay eggs during the summer. A study of the movements of the crawlers hatching from the eggs has been made by using a number of sticky plates within beech stands. So far it appears that their dispersal by wind currents occurs from late summer until the winter; and that they readily drift into uninfested stands.

C. I. CARTER

Enquiries

During the year 75 written enquiries were sent to Alice Holt from Forestry Commission staff and 27 at Northern Research Station. One hundred and fifty private enquiries were received at Alice Holt and 27 at Northern Research Station.

D. BEVAN
J. M. DAVIES

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STYLES, J. H. (1959). Notes on the Collection of the Adults and the Web-spinning larvae of *Cephalcia alpina* Klug., *Entomologist's mon. Mag.* **95**(1142), 152–153.

THORPE, W. D. (1929). Notes on the Natural Control of *Coleophora laricella*, the Larch case-bearer. *Bull. ent. Res.* **24**, 271–291.

WALKER, C. (1973). The North American Native elm bark beetle (*Hylurgopinus rufipes* (Richh.)) imported from Canada into Britain in Rock elm (*Ulmus thomasii* Sarg.) logs. *Pl. Path.* (In press).

WILDLIFE

Grey Squirrels (*See cover picture and caption, inside front cover*)

Investigations of the rate of break-down of warfarin on the whole grain wheat bait used in research on the control of grey squirrels were carried out (in collaboration with the Biochemistry Section of the Pest Infestation Control Laboratory at the Ministry of Agriculture) since the grey squirrel's habit of burying small quantities of food might present a hazard to other animals. Results so far suggest that degradation is relatively rapid even on sterilised wheat once the grains are exposed to wind and weather. Unsterilised wheat (such as would usually be used in squirrel control) germinated within a few weeks of exposure; the warfarin concentration was then less than 0·005 per cent on fragmented seed coats and in the surrounding soil.

An illustration of the hopper approved for use when laying down warfarin-treated bait to control grey squirrels appears as Plate 10.

The annual Squirrel Questionnaire showed that damage reports had decreased in numbers and severity compared with 1971. The grey squirrel is extending its range in north-east Scotland. In Wales, damage continues to be more extensively reported as the animal consolidates the extension in range seen in the last few years.

A fundamental study of the factors affecting reproduction in the grey squirrel in relation to its forest environment and of the possibility of developing reproductive inhibitors as a method of control has begun in conjunction with the University of Reading.

Red Squirrel

Studies of the silvicultural and biological problems involved in managing pine woodlands for red squirrel conservation have continued at Thetford Chase, Suffolk. An investigation of Corsican pine cone and seed production and use by red squirrels and birds showed that some 28 per cent of the current cone crop had been removed by January. It did not prove possible to separate cone removal by crossbills and woodpeckers from that due to red squirrels.

Reports of the occurrence of various body and tail colours of adults in summer pelage are being collected throughout the range of the red squirrel. These observations in conjunction with the study of skull characters being carried out by the Nature Conservancy will provide a basis for assessing the sub-specific status of the red squirrel in Britain.

The annual Squirrel Questionnaire suggested that numbers of red squirrels had increased slightly in parts of north-east England and in Scotland. Reports of damage, to Scots and Lodgepole pine, had also slightly increased. In Wales, the general trend to fewer red squirrel observations continues.

Deer

Material from known-aged red deer of the Galloway area (animals marked as calves) has been used in constructing an age determination guide based on tooth eruption and wear as described by Lowe (1967). This is being used to assess the

reproductive performance of hinds of different ages and the proportions of different year classes represented in the annual cull of both sexes. Calf-marking has continued and is providing interesting data on changes in the behaviour of individual animals as the home range alters from open hill to woodland.

Work on three different methods of assessing the proportion of fat in bone marrow showed that, at both low and high fat levels, this could be reliably estimated using the oven-dried and fresh weights to obtain a percentage fat content. This was as accurate as a more complicated procedure using 1,1,1-trichloroethane for organic solvent extraction; both methods were more satisfactory than a simple compression measurement. In extreme cases of lost condition, the texture and colour of the marrow alters.

Roe deer accepted cut ivy and sugar beet pulp presented both separately and together despite the mild winter. Consumption was slow and irregular at first but increased in January and February. It is possible that this is a useful technique for increasing the chance of observing animals in a particular area during these months.

Damage

A survey of eight tree species sown in twelve different nurseries showed that, on average, 20 per cent of the seed had disappeared prior to germination. The sources of this loss could not be accurately identified. More extensive losses of seed and seedlings are almost invariably associated with bird predation, greenfinches and chaffinches being the chief culprits.

Grey squirrel damage is being surveyed in those forests from which reports of damage were most severe in 1972. These appear to be mainly in areas in which little or no systematic control at the right time of year has been carried out. Most of the more extensive damage is in beech aged between 10 and 40 years and consists of bark-stripping from the butt and base of the stem. In most cases this affects the stem base to a height of not more than one metre. Damage beyond this height has so far not been found in more than five per cent of the trees in any of the crops examined.

In this connection, a survey of 17 sawmills in the Chilterns beech woods area suggested that grey squirrel damage was at present of little concern to sawmillers. Much of the beech so far being milled is of relatively low grade and its value is little affected by squirrel attack. The value of beech of high quality is more seriously affected, but as yet there is little squirrel-damaged beech of otherwise good quality on the market. This is in part because large home-produced beech is too big to be susceptible to attack by the squirrels.

Fencing

After three years, the first signs of deterioration have been observed in fence components in longevity trials. Rusting has appeared in ring-lock woven field fencing at Hope Forest, Derbyshire, where there is an above-average level of industrial pollution. At Newborough Forest, Anglesey where salt and wind are the main factors, Gordian fasteners have abraded the PVC covering of line-wires and the exposed metal has rusted away. No deterioration has been observed on any of the components at Alice Holt Forest, Hampshire.

Alternative strainers (Bobbejaan) for erecting spring steel line-wires were tested. These were unsatisfactory as they marked and severely damaged the wires.

Protection of Individual Trees and Small Groups

Methods of preventing mammal and bird damage to individual trees or small amenity plantings are being reviewed.

Chemical Repellants

Three new chemical repellants, Cervacol, Fegol and Fowikal, were tested against fallow deer browsing during the 1972/73 season. Cervacol and Fegol, which are smeared on to the tree, reduced fallow deer browsing for a time. However, AAprotect is still the "best buy" since spraying is less laborious than smearing. Fowikal, which is sprayed on to the tree, has a short effective life of about two months. It might be suitable for protecting roses and garden shrubs from roe deer browsing (a common problem in southern Britain) as it is colourless and not phytotoxic.

Dendracol 17 was given a second trial; it appears to be as effective as Monacol, which it replaces, but, despite taking the manufacturer's advice, serious problems arose in de-contaminating clogged-up spraying equipment.

FCH 60 1 was compared with AAprotect as a rabbit repellant. AAprotect proved considerably more effective in preventing winter rabbit browsing; the trees treated with FCH 60 1 were as severely browsed as were the untreated controls.

Field Vole

Surveys are being made of damage by the field vole (*Microtus agrestis*) associated with different establishment regimes in young plantations. Voles can increase to high numbers in areas where afforestation of extensive *Molinietum* provides suitable conditions. The possibility of increasing avian predation is being investigated. A limiting factor for kestrels may be lack of suitable nest sites and nestboxes of the type found successful in Holland and Switzerland have been erected in three areas of Tywi Forest, Cardiganshire.

Dissemination of Information

Approximately 70 written and 30 telephone enquiries were dealt with during the year. Over half the enquiries concerned grey squirrel control and the effectiveness of chemical repellants but information on fencing and on the problem of roe deer browsing roses was also frequently sought.

JUDITH J. ROWE

REFERENCE

LOWE, V. P. W. (1967). Teeth as indicators of age, with special reference to Red deer (*Cervus elephas*) of known age from Rhum. *J. Zool.* **152**, 137–153.

STATISTICS AND COMPUTING

Statistics

The main advisory work of the Section has continued to be in designing experiments for Research Division, time studies for Work Study Branch and various special surveys.

Advice on analysis and interpretation of results from data obtained over many years has featured prominently this year. Such work has included the "yield class/site factor" studies and the 1959/1967 "date of sowing" experiments for Silviculture (South).

During the year there was a large survey of reserves of unplanted Forestry Commission land, reported principally in terms of nine soil groups, three altitude classes and the presence and absence of heather. It was planned that each of seven conservancies would provide up to 1,000 sample plots, stratified in the larger conservancies by size of sampled area. The 1,000 plots were collected in up to four geographically representative groups, one of 400 and three of 200. The scheme was sequential to the extent that results for 400 plots were first distributed in the 54-cell table and estimates of within-cell variance obtained. The other groups of 200 were added one at a time and if the variance estimates from the total distribution were not, in general, significantly different from those of the former distribution no further groups were surveyed.

Double sampling schemes were designed for the Audit and Data Processing Branches to monitor the proportion of payment vouchers with errors which would not be detected by computer. Other schemes to sample wages and absences due to injury were designed for Industrial Establishments Branch.

For the 1971 Dutch Elm Disease survey a post-survey check was made to assess observer errors. The design of the 1971 survey was modified for use in 1972 in the light of the first year's experience. Additionally, five 1-sq km permanent observation plots were established and surveyed in the spring and autumn of 1972, the intention being to continue to record the development of the disease by individual trees in these areas.

C. J. A. Samuel contributed to a joint paper analysing a diallel cross in Sitka spruce (Samuel, Johnstone and Fletcher, 1972).

JEAN BIRCHALL
I. D. MOBBS
R. BOSWELL
R. S. HOWELL

Programming

The programming group bears the main responsibility for writing major programs for Research Division projects and for Management Services Division but not those required in establishing the Commission's computerised accounting system. This subsection also advises "occasional" programmers and conducts programming courses as required. One such course, lasting two days, was given this year.

At Alice Holt, programs were developed for Management Services Division to forecast production, analyse recreation surveys and transcribe Census data to magnetic tape. Major jobs for Research Division have been the analysis of the data from an aerodynamic study made at Redesdale Forest (mentioned above under Crop Stability, p. 75) and the surveys of Dutch elm disease and of *Fomes annosus* in Sitka spruce (mentioned above under Forest Pathology, p. 94).

At the Northern Research Station J. Baird and R. Kerray developed to a pilot testing stage an information retrieval system for maintaining the Genetics Section's Register of Plus Trees in the Edinburgh Regional Computing Centre's IBM 370/155 computer. There are now nine species files on disk store, together with programs to write and update them, and to search and retrieve in response to user queries.

Throughout the year increasing use has been made of the link between the IBM 1130 computer at Alice Holt and the Univac 1108 computer at the University Computing Company's centre in London (UCC), and for the Redesdale data the BMD Spectral Analysis program at UCC proved invaluable. Special programs were written to gain familiarity with new facilities as they became available through the Edinburgh Regional Computing Centre which is accessible by teletype from both the Northern Research Station and the Forest Research Station, Alice Holt.

Late in the year the Principal Statistician was asked to provide general information and advice on the supply of calculating machines to other sections of Research Division. The programming group has the delegated responsibility for providing this service. Experience this year has shown that coding common statistical algorithms for a programmable calculating machine is easy and small quantities of data are rapidly analysed by such means.

D. H. STEWART
G. J. HALL

Data Analysis and Computing

Members of these groups share responsibility for developing and maintaining a consistently quick turn-round of data analyses. The main function of the data analysts is to help research workers who need assistance in organising their data for efficient punching and computing and in interpreting computer output.

Use of Computers

This year has seen steadily increasing use of the new facilities provided. Average "switched-on" time of the IBM 1130 is now 10 hours per day and metered "run-time" is now more than six hours per day. With the present configuration the link between the IBM 1130 and the Univac 1108 operates at 2400 Baud. Use of the Teletype to interrogate and edit files loaded onto the 1108 via the 1130 has increased as has use of the linked 1108 itself. A trial of the CALL 360 system as an alternative is in progress.

Equipment Changes

Only minor changes in the equipment of the section have taken place this year. The two Sirius computers have been transferred to the Communications Branch

of the Commission's Engineering Division. The hired IBM 029 A22 card punch has been exchanged for a C22 to allow a higher rate of card interpretation than that possible with the ICL punches.

A Canola 167P programmable calculating machine was bought for the Northern Research Station.

C. A. THORNE
M. H. M. WEBB

Data Capture

At Alice Holt C. J. A. Samuel developed operating plans for testing the automatic recording caliper designed by René Badan* and obtained reading and decoding routines for processing tapes from that machine in the IBM 1130. The prototype of this tape-encoding portable caliper was developed by M. Badan in 1960/61, and is now manufactured in Switzerland in several advanced forms under the name of Swissperfo by Transdata S.A.

R. Boswell developed new standard forms for recording experimental data. He also analysed the errors obtained when each of the research stations used ASR 33 Teletypes and Datel 200 terminals to transmit to and receive from the computers of two particular bureaux and he studied the cost-effectiveness of such links.

In the north J. Baird reported on costs of "OCR trial results June 1972" and T. C. Booth on the "Use of optical character reading (OCR) in data capture and processing for silvicultural research". These reports suggest that OCR might be suitable for large batches of standard forms, possibly for field survey work or for computing the Forestry Commission's accounts, payments and similar business returns but for small batches of research assessments, often written under adverse conditions, it is still too expensive.

D. H. STEWART

Students

The section was helped during the year by two students for periods of six months. In the north R. Kerray worked mainly on the Plus Tree Register (see above). In the south R. Hall worked mainly on the reprogramming required by the revision of the Working Time Survey for the division.

D. H. STEWART
R. S. HOWELL

REFERENCE

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*Now at the Département de l'Agriculture, de l'Industrie et du Commerce, 2me Service, Forêts, Chasse et Pêche, Lausanne, Switzerland.

ENGINEERING SERVICES

Work for the Pathology section, mainly on equipment for use against Dutch elm disease, has occupied a large part of the workshop effort this year. Three different types of injection head, for use in the injection of tree trunks at low pressure (50 pounds per square inch) have been made and tested, the most promising for general use being one based on a modified commercial injector. Several complete pressure systems, some incorporating flow gauges, have been made for this section's use. This injection system may have applications for purposes other than Dutch elm disease control, and one complete pressure system has been supplied to the physiology section. A commercial manufacturer is now marketing a pressure system for general use. To aid in the injection of soil (also for work on Dutch elm disease) a probe has been made and will be tested shortly.

The safe mounting of cameras for aerial work can be time-consuming and expensive. A camera mount has been designed and made, in conjunction with the photographic section, which can be fitted to a specified aircraft within 15 minutes or so (Photography p.119). This has been tested and issued with an air worthiness certificate. Details of this and other photographic aids will be published later.

The programming of temperature conditions, particularly in greenhouses and environment chambers, can be a problem as these areas are often kept hot and damp, an atmosphere not conducive to electrical safety. A low voltage programmed controller was designed and built for such applications and has been tried by the Seed section. Further development will include an indicated controller (based on a commercially available model) for general purpose use in incubators and greenhouses. A temperature gradient plate for germination and seedling growth studies, is being built that will operate between $-5°C$ and $+40°C$ using these indicated controllers.

A Bruce compaction unit has been built to enable tests to be carried out on soil samples.

Work on the production of engraved labels has dropped to an acceptable level of approximately 3,000 per annum. This has enabled experimental work to be carried out on the engraving of maps, diagrams and sign templates, and also resulted in a quicker service to the research sections. Encapsulated maps and diagrams have been obtained that complement the standard wooden signs and engraved labels. For large signs or intricate detail these encapsulations are cheaper and more durable than those in engraved plastic.

R. E. STICKLAND

PHOTOGRAPHY

General

Once again the Section was unable to meet many of the requests made for its services. With increased demand and the present level of staffing this was inevitable.

Demands now seem to fall into two main categories. This has been apparent as a trend over the past two or three years, but demands now seem to be for two methods—one type required by the territorial Conservancies and the Research Division (including the Publications Section), and the other by the Headquarters Information Section and those Headquarters Divisions concerned with amenity and recreation. Photographically there is no problem, as the two types of material are not mutually exclusive, but the increased demand for publicity material limits time available for work of the other type, which is often by its nature more demanding and time-consuming.

Photographic Collection

Extensive use continues to be made of the Collection by external agencies as well as by Forestry Commission staff.

Though key-wording is now virtually complete little or no progress has been made with secondary classification of the collection nor have all the file prints which have "strayed" over the years yet been replaced.

Printing was still one of the major bottle-necks and though the use of stabilisation processes and the putting of some work to the trade has helped, the possibility of using a fully-automated system to produce prints of a standard size will have to be considered. Wherever possible, prints for exhibition and display where quality is of prime importance were produced in the Section.

Aerial Photography

Most of the work on aerial photography has been concerned with the design, construction and testing of a camera mount for a 35 mm vertical camera system (Plates 1 and 2). This has been done in collaboration with the Engineering Services Section who built the mount.

The idea behind the design was that its application should be as universal as possible, i.e. it should not be restricted to use in a single modified aircraft. There were limits as to how far this could be taken in practice and it was decided to make a mount that would fit any individual aircraft of a particular type. On the basis of suitability and, just as important, availability—to avoid long and expensive positioning flights—we chose the Cessna 172 range, a type which can be hired fairly easily at most airfields, and designed a mount based on the 172 baggage door. This requires no modification to the aircraft so that any 172, anywhere, can be used. In practice it takes about ten minutes to remove the standard door from its hinges and put our modified door in its place. As the camera mount is integral with the door "pre-flight" delays are minimal, aircraft stand-by time is reduced and advantage can be taken of the often sudden changes in our weather. Small enough to be carried in the back seat of a car,

the door is easily transported. The door has been test flown and a Civil Aviation Authority Modification Certificate issued. As the modified door has no effect on the flight characteristics of the aircraft it can be left in place for all normal flying between photographic sorties. There is no need to remove the door after every flight.

The camera system used is the Canon F.1 with E.E. finder, motor drive, 250 exposure magazine and remote control. Early tests have been satisfactory and it is hoped that, sometime in 1973, we will be able to offer a service for 35 mm vertical photography.

I. A. ANDERSON

PUBLICATIONS

The following fifteen 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 Her Majesty's Stationery Office, and also in *Forestry Commission Catalogue of Publications*, available from the Publications Section, 25 Savile Row, London W1X 2AY.

Of particular significance in view of the growing public interest in amenity trees and the designation of 1973 as Plant a Tree Year are Booklets No. 33 and 38 and Leaflet No. 57.

Reports

Fifty-Second Annual Report of the Forestry Commissioners, 1971/72 (HC 521, Session 1972/73) (75p).

Report on Forest Research for the year ended March 1972 (£1·60).

(Report on) Forestry Policy, June 1972 (18p).

Bulletins

No. 43. Nursery Practice, by J. R. Aldhous (£1·50).

No. 46. Forest of Dean Day Visitor Survey, by R. J. Colenutt and R. M. Sidaway (60p).

Forest Records

No. 82. Dutch Elm Disease Survey, 1971, by J. N. Gibbs and R. S. Howell (25p).

No. 83. The Pine Shoot Moth and Related Species, by T. M. Scott (14p).

No. 84. Winter Temperatures and Survival of the Green Spruce Aphid, by C. I. Carter (7p).

No. 85. The Coal Tit, by A. J. Deadman (14p).

Booklets

No. 33. Conifers in the British Isles, by A. F. Mitchell (£2·25).

No. 36. Timber Measurement for Standing Sales using tariff tables, by G. J. Hamilton (14p).

No. 38. Common Trees, by A. F. Mitchell and J. Williams (8p).

Leaflets

No. 54. The Control of Dutch Elm Disease, by D. A. Burdekin, J. N. Gibbs and A. F. Mitchell (6p).

No. 57. Replacement of Elm in the Countryside, by A. F. Mitchell (4p).

Guide

East Anglian Forests, edited by H. L. Edlin (50p).

In addition, eight priced publications sold by Her Majesty's Stationery Office were reprinted after varying degrees of revision.

6574 I

A Guide Map to Your Forests, priced at 30p, was produced by the Conservation and Recreation Branch of Forest Management Division and published in conjunction with John Bartholomew and Sons Ltd., of Edinburgh.

One new unpriced publication for the general public, *Trees and People*, produced especially for Plant a Tree Year was issued, and seventeen others were revised and reprinted. These include *See Your Forests*, which, on revision, was issued in four regional pamphlets instead of the one comprehensive booklet. The pamphlets cover *Northern England*, *Southern England*, *Scotland* and *Wales*.

Research and Development Papers

Nine of these unpriced papers were produced, mainly for internal use. Their titles are:

No. 86. Census of Harvesting Equipment and Methods, 1969, by A. A. Rowan and T. R. Sawyer.

No. 87. Production and Use of Ball-Rooted Planting Stock in Sweden and Finland, by A. J. Low and R. M. Brown.

No. 88. Dissemination and Application of Research Information in the Field, by O. N. Blatchford.

No. 89. Formulation and Implementation of Forest Policy, by D. R. Johnston.

No. 90. Planning and Development of Markets for Man-Made Forests, by F. C. Hummel and J. L. Davidson.

No. 91. Silviculture and Good Landscapes in British Forestry: The Improvement of Planning and Practice, by M. H. Orrom and A. F. Mitchell.

No. 92. The Special Contribution of Forests and Woodlands to Recreation in an Industrial Society, by J. A. Spencer and R. M. Sidaway.

No. 93. Valuation of Non-Wood Benefits, by A. J. Grayson.

No. 95. Some Aspects of Recreation Planning in the Forestry Commission, by A. J. Grayson, R. M. Sidaway and F. P. Thompson.

Single copies of all unpriced publications listed are available on request from the Forestry Commission, 25 Savile Row, London W1X 2AY.

H. L. EDLIN

RESEARCH INFORMATION

Visitors

Two local Open Days were held in the Autumn to cater for local schools and the general public. Over 800 schoolchildren came on the first day, and on the public day—a gloriously sunny Sunday—a capacity crowd of over 3,500 people visited the Station. No major arrangements for a scientific presentation of our work was undertaken, but merely the opening of the Research Station's doors to outsiders to let them "see us as we are".

In addition a further 598 visitors came to the Station at other times, including visitors from 25 countries.

Information Services

A Keyword Index to Forestry Commission Publications was entirely processed on the computer, and issued to 450 FC staff. Eleven Current Information Notes were written and each distributed to 573 people, and there have been 24 issues of the Current Awareness Bulletin "CABER" (with 82 recipients). The card alerting "DISCUS" service has continued to serve 118 people. Each week we have sent out 130 copies of a selected list of articles appearing in the "Periodicals on Display" in the Library, and each quarter we have sent out 294 copies of the selections from the UK Forestry Journals as "Assistance With General Reading".

The number of written enquiries involving information searches etc. increased to 521.

Library

One hundred and ninety-seven new books were acquired; a further 8 new periodicals were taken and 26 translations commissioned. The number of loans directly from the library amounted to 3,193 with a further 854 items borrowed from outside libraries. To reduce the workload and provide a better service we have, wherever possible, made photocopies in preference to lending items, and approximately 720 copies have been sent in response to loan requests.

A modest monitoring exercise provided some impressive statistics of library services not normally recorded. On each working day approximately 15 members of staff visit the library, 8 people require assistance in finding particular items of information and 4 ask for help in using library facilities. Each day 4 telephone enquiries require time to investigate and answer. On average 1 non-FC visitor makes use of our library facilities and such callers often require considerable assistance to search through our literature.

Miscellaneous

For the first time in over ten years no courses were held for Field District Officers at either Research Station. Displays of research work mounted in the hall have been changed approximately every 6 weeks through the year. A programme of staff seminars was once again arranged for the winter period.

O. N. BLATCHFORD

MANAGEMENT SERVICES DIVISION

Reports on the research and development aspects of the work of the Management Services Division are given for each of the following branches:

(1) Planning and Economics.

(2) Field Surveys.

(3) Work Study.

There is, in addition, a report on the work of the Systems Design Section of the Organisation and Methods Branch.

D. R. JOHNSTON

PLANNING AND ECONOMICS

Financial Reconstruction of the State Forestry Enterprise

Most of the resources of the Branch have been devoted to the analyses and computations needed for the financial reconstruction of the forestry enterprise. This work has required the provision of material from three sources. In the first place certain general assumptions, usually of a long-term nature, have been agreed following discussion with other divisions of Headquarters. Secondly, Field Surveys Branch has provided revised data on the composition of the growing stock and has also assessed the distribution of site types within the plantable reserve. Thirdly, conservancy staff, with whom close collaboration has been maintained throughout, provided decisions and assumptions on such points as the definition of cutting regimes by type of stand and the specification of silvicultural and road operations, their timing and costs.

The resulting cash flows have thus provided a firm basis for the valuation of the existing estate and for the assessment of the net discounted revenues per hectare of new planting and restocking on the different site types which have been recognised. These valuations have provided a stimulus to Forestry Commission planning both at the corporate level and at the tactical planning level of the conservancy. Thus the newly formulated forecasts of wood production are more realistic than any prepared in the past. The overall long-term forecasts of expenditure are also more soundly based than earlier ones and provide a reliable basis for assessing future resource requirements.

A. J. GRAYSON
J. F. MORGAN
R. J. N. BUSBY

Recreation

Day Visitor Survey, Savernake Forest

At the request of Conservator of Forests, South West England, an observation survey of day visitor use of the main block of Savernake Forest in Wiltshire was made in the summer season of June/October 1972. Counts of parked cars, traffic counter readings at two main entrances and observations of

vehicle movements at these entrances were used to make estimates of the total use of the forest in visitor hours, car arrivals and visits at the two entrances and peak parking in the forest through the season. Total use of the forest was estimated at 180,000 ± 40,000 visitor hours for June to October 1972. Sunday afternoons were the busiest time of the week when peak parking was rarely below 100 cars. Calibration of traffic counters proved successful and could form a basis for estimating future use at Savernake. The dispersed nature of day visitor use through the forest suggests that charging for entry is unlikely to be practicable.

Cwmcarn Scenic Forest Drive, Ebbw Forest

An experimental project has been set up jointly with the Countryside Commission in Ebbw Forest, Monmouthshire South Wales Conservancy. The seven mile route over forest roads was opened to the public in May 1972 at a charge of 30p per car. Some 17,500 cars used the drive during its first season. A joint project to monitor public use at weekends has been carried out by the two Commissions. The Countryside Commission interviewed about 500 visitors leaving the drive. Observation surveys designed by the Forestry Commission were used to estimate length of stay of visitors to the drive. Counts of parked vehicles were also made and a similar survey programme will be continued during the summer of 1973.

Other Activities

Development work has continued in devising simple methods of estimating day visitor use. Advice on survey techniques was given to Conservancy Recreation Planning Officers in a seminar held by Forest Management Division. This material has now been formalised into simple written instructions.

R. M. SIDAWAY
R. Q. OAKES

FIELD SURVEYS

Topographic Surveys and Assessment Projects

Field checks on the accuracy of basic data and assistance to local staff in updating them were completed in the early part of the year in preparation for the financial reconstruction of the Forestry Commission.

Field work was completed on the pilot project set up to correlate crop growth with the Site Group classification (Table 22) developed as part of the financial reconstruction project and the data are currently being analysed.

A survey to examine the distribution of Dutch elm disease was carried out for the second year running and the area extended to cover all of England south of the Wash and an extension into South Wales.

A pilot survey to determine the distribution of size classes of woodland areas was completed for the South-East England Conservancy. To summarise the results for woodland size, 18 per cent of the total woodland area is composed of woods $\leqslant 5$ ha, 22 per cent > 5 ha but $\leqslant 25$ ha and 60 per cent > 25 ha.

About half the staff resources of the Branch was spent on routine topographic and crop assessment work. Completed surveys are summarised in Table 21.

TABLE 21
TOPOGRAPHIC SURVEYS AND CROP ASSESSMENTS

	New surveys		Revision surveys		Total	
	Total Area (ha)	Number of Forests	Total Area (ha)	Number of Forests	Total Area (ha)	Number of Forests
Scotland	19,800	7	16,700	5	36,500	12
England and Wales	10,200	9	8,100	6	18,300	15
Total Great Britain	30,000	16	24,800	11	54,800	27

L. M. SIMPSON

Site Survey

The major project in the year in connection with the Financial Reconstruction was the collection and analysis of site data from 4,087 systematic point samples taken within 53,000 ha of the plantable land reserves.

A summary of the site group structure and major vegetation classes is shown in Tables 22 and 23. These data confirm the dominance of upland site types in the reserve. At least a quarter of the area is likely to be subject to production limitations through moderately severe climatic constraints owing to high altitude, exposure and high susceptibility to windthrow. Some problems are likely to emerge in the control of *Calluna*, manurial requirements and windthrow in forests planted on these site types.

TABLE 22

PLANTABLE RESERVE SURVEY: PERCENTAGE DISTRIBUTION OF "SITE GROUPS"

Altitudinal zone	Percentage of plots by zone	Calluna vegetation group	Soil "Groups"															
			Brown earths		Intergrades to ironpan soil. Ironpan soil. Podzol.		Peaty ironpan soil. Peaty podzol.		Surface water gley. Flushed gley. Humic gley. Flushed basin peat.		Peaty gley		Molinia bogs		Hill peat. Unflushed bog. Raised bog.		Skeletal soils	
				Total		Total		Total		Total		Total		Total		Total		Total
Low	23	Dominant or frequent	0·3	3·0	1·0	1·4	1·4	1·6	0·4	2·7	3·3	6·4	0·8	3·2	3·6	3·8	0·6	0·9
		Occasional or absent	2·7		0·4		0·2		2·3		3·1		2·4		0·2		0·3	
Mid	48	Dominant or frequent	0·9	3·1	2·2	3·9	3·6	4·4	0·7	5·1	6·5	13·6	1·7	6·9	9·0	10·0	0·8	1·2
		Occasional or absent	2·2		1·7		0·8		4·4		7·1		5·2		1·0		0·4	
Upper	29	Dominant or frequent	0·3	1·1	1·0	1·8	2·3	3·0	0·3	2·3	3·5	7·0	0·7	3·4	7·4	9·0	0·8	1·2
		Occasional or absent	0·8		0·8		0·7		2·0		3·5		2·7		1·6		0·4	
	Total Soil "Group" %		7·2		7·1		9·0		10·1		27·0		13·5		22·8		3·3	

Notes: 1. Conservancies covered by samples: North Scotland, East Scotland, West Scotland, South Scotland, North-west England, North-east England, South Wales.

2. The Table represents the results from 4,087 plots in 53,500 ha.

3. Low Altitudinal Zone refers mainly to 0–225 m [0–180 m in West Scotland, North Scotland: 0–300 m in South Wales].
Mid Altitudinal Zone refers mainly to 225–365 m [180–275 m in West Scotland, North Scotland: 300–425/450 m in South Wales].
Upper Altitudinal Zone refers mainly to over 365 m [over 275 m in West Scotland, North Scotland: over 425/450 m in South Wales].

TABLE 23

PLANTABLE RESERVE SURVEY: PERCENTAGE DISTRIBUTION OF VEGETATION CLASSES

Calluna vulgaris		*Trichophorum caespitosum*		*Eriophorum vaginatum* 0 / *Molinia caerulea* 0	*Eriophorum vaginatum* 0 / *Molinia caerulea* 1	*Eriophorum vaginatum* 0 / *Molinia caerulea* 2/3	*Eriophorum vaginatum* 1 / *Molinia caerulea* 0	*Eriophorum vaginatum* 1 / *Molinia caerulea* 1	*Eriophorum vaginatum* 1 / *Molinia caerulea* 2/3	*Eriophorum vaginatum* 2/3 / *Molinia caerulea* 0	*Eriophorum vaginatum* 2/3 / *Molinia caerulea* 1	*Eriophorum vaginatum* 2/3 / *Molinia caerulea* 2/3
0	0	0		12·4	2·1	6·5	[illegible]	0·5	1·2	0·9	0·3	1·6
		1		0·3	[illegible]	0·8	[illegible]	[illegible]	0·9	[illegible]	[illegible]	1·3
		2/3		0·3	0·1	0·6	[illegible]	[illegible]	0·3	0·2*	[illegible]	0·3
	1	0		1·2	0·7	3·1	0·1	[illegible]	0·5	0·2	0·1	0·8
		1		[illegible]	0·2	0·9	[illegible]	[illegible]	1·6	0·1	0·5*	1·2
		2/3		[illegible]	[illegible]	0·7	0·1	[illegible]	0·4	0·3*	0·6*	0·6
	2/3	0		6·8	2·2	1·5	0·8*	0·5	0·5	3·4*	1·2	0·5
		1		1·5	1·7	1·4	1·4*	1·2*	1·3	3·3*	2·4*	1·5
		2/3		1·1*	3·0*	2·0	3·3*	3·5*	2·2	3·0*	2·8*	1·5

Notes: (*a*) Species frequency is scored—0 absent, 1 occasional, 2 frequent, 3 co-dominant/dominant.
(*b*) The two-way entry table represents data for all plots, mineral, organo-mineral and organic soils inclusive. An additional analysis is available for organic soils only and for mineral and organo-mineral soils only.
(*c*) *Denotes vegetation classes which have been associated with poor performance of Sitka spruce.
(*d*) Classes in the top left-hand side of table are favourable vegetation types such as moist grassland (*Holcus lanatus*, *Rubus* spp., herbs), or *Agrostis-fescue*, *Nardus* acid grasslands, or soft rush flushes; conversely those in the bottom right-hand side are unfavourable vegetation types such as unflushed *Sphagnum* bog and *Calluna/Trichophorum/Eriophorum* blanket bog (hill peat).

Soil surveys covering 13,125 ha were completed in four conservancies.

One course on site survey appreciation was held at Moffat for professional staff in the Scottish Woodland Owners Association.

D. B. PATERSON

Mensuration

An analysis of spacing experiments was completed during the year. These experiments were laid down in 1935/36 at spacings of 0·9 × 0·9 m, 1·4 × 1·4 m, 1·8 × 1·8 m and 2·4 × 2·4 m. The following factors were investigated:

(a) Survival.
(b) Height growth.
(c) Basal area production.
(d) Volume production.
(e) Diameter growth.
(f) Form and taper.
(g) Resulting assortments.

A comprehensive description of the analysis and the results will be published in due course (as Forestry Commission Bulletin No. 52, *Influence of Spacing on Crop Characteristics and Yield*).

Yield models based on the results of the spacing experiments have been produced by a computer program, which has already been reported but which has now been further developed. A report on the construction and application of these yield models will be published. (Since issued as Research and Development Paper No. 96, *Construction and Application of Stand Yield Models.*)

Another computer program is being developed which will be used to predict, from a few basic parameters, the size assortments which can be cut from a standing crop. It is expected that this program will be used to help optimise the product mix where markets for more than one size specification are available.

G. J. HAMILTON

WORK STUDY

FOREST MANAGEMENT STUDIES

General

Progress has been made in the development of ploughing equipment, granular applicators and weeding machines. One of the major difficulties has been to find a tractor suitable for a wide range of terrain to carry drain cleaning and mechanical weeding equipment. The only machine which may become available from commercial sources is a hydrostatic crawler tractor and the Research and Development team is carrying out feasibility studies on a 6 × 6 low ground pressure all-terrain vehicle. In order to reduce drawbar pull and to obtain a better mixture of soil horizons when ploughing the possibilities of developing a rotary mouldboard plough and a vibrating sock are being examined.

Tubed Seedlings

Work has continued on refining procedures for planting tubed seedlings in the field and on up-dating output guidance as the range of this work increases. Greenhouse methods continue under study.

Planting Machines

Appraisals of tree planting machines have confirmed the fact that the only system which might compete with hand planting on spaced ploughing would be one in which a single planter is mounted behind the plough. The performance of such a combination would still be severely limited by the capacity of those tractors currently available to cope with the ground conditions involved.

Step Cutters

The prototype step cutter tested last year is now in fairly wide use and is working satisfactorily except on some particular types of peat. A modified proboscis type of sock is currently under trial.

Ploughing Tractors

Comparative trials of 100 BHP crawler tractors with 70 BHP machines have shown the former to be capable of outputs which more than justify the additional expenditure as well as providing an improved ploughing specification.

New Drains: Afforestation Areas

Long term trials with an experimental DMB Parkgate deep draining plough are progressing satisfactorily. The objective is to test hydraulic control from the tractor cab of the disc coulters, the angle of the mouldboard and the angle of the mouldboard extensions. Alteration of the disc setting can change the direction of throw of the turf so that on cross slopes the greater part of the turf can be directed downhill. The main advantage of altering the angle of the mouldboard is to be found in areas of high bogging risk where the nose can be pointed upward to reduce the drawbar pull. The alteration of the mouldboard extension angle allows optimum placement of the turf for planting.

New Drains: Reafforestation Areas

Investigations continue on ploughing techniques to replace the use of back-acting diggers and excavators. A V-blade mounted on a TM55 crawler tractor did not spill the brash properly. Trials of a Rome KG blade on a D7 proved only partially satisfactory on the firmest sites but on peaty or surface water gleys the stumps had insufficient hold to provide shear resistance to the blade. Brash chopping may offer a solution but equipment so far tested has been damaged on the stumps and heavier machines will be tried out when they become available. Meanwhile studies are being carried out on strip felling systems where drains are ploughed along the cleared strip.

Drain Alignment in Thicket Stage Plantations

A simple periscope mounted on a pole has been designed for quick and accurate drain alignment prior to ploughing in thicket crops up to 6 metres in height.

Maintenance of Drains

In the mechanisation of the maintenance of drains the emphasis continues clearly towards the rotary principle and trials with the Oja Viska rotary ditcher were continued following the fitting of a reduction gearbox to the Roadless 115 tractor. This ditcher has a single rotor and cleans one side of the drain only but following the fitting of a forming plate on the non-cutting side satisfactory maintenance of drains in peat and peaty gleys was achieved on a single pass. The equipment has also operated successfully on clays in East England.

A Finnish Meri twin rotor will be evaluated this year but before the potential of such a machine can be fully realised a suitable tractor with reduction gearbox and low ground bearing pressure must be found.

Fertilising

A sampling procedure to determine the uniformity of aerial distribution of fertiliser has helped to pinpoint certain inadequacies in methods and can also be used to monitor future distribution patterns.

Granular Herbicide Application

A number of applicators are being tested and so far the Casereron G gravity feed applicator has been found suitable for band treatment.

Heather Control

A joint project with Research Division on heather control is now almost completed and recommendations are being made on medium, low and ultra low volume spraying techniques based on trials carried out over a wide range of sites. Results will be published soon.

Pedestrian Controlled Weeding Machines

Trials of the Wolseley HS Clearway machine have shown it to be one of the best pedestrian controlled weeding machines currently available. It can tackle a wide range of the lighter woody weeds as well as herbs and grasses and it compares well with other machines on handling and cost.

Portable Brushcutters

Trials of the Husqvarna clearing saw carried out with a series of different cutting heads showed that the "Maxi" type of circular blade is the best choice since it will cut all vegetation from grass to woody weeds and is cheaper than alternatives and easily maintained. Studies of alternative lighter machines continue.

HARVESTING STUDIES

General

The major effort of the Research and Development Workshop continued to be on the development of the hydrostatic tractors and their timber handling equipment. This development work is now nearing completion and future programmes include studies of felling, delimbing and cross-cutting equipment. A wide range of harvesting machinery has also been evaluated.

Hydrostatic Tractors

Two 45 BHP machines have been built and given long term field trials mainly in South Scotland. Outputs of from 4 to 5 cubic metres per hour in early line thinning have been sustained over an average extraction distance of 170 metres. Radio control of the winches has reduced terminal loading times by 25 per cent.

A third hydrostatic tractor now on field trial has a larger engine of 65 BHP giving the machine additional capacity for uphill extraction and providing more powerful winches. This machine incorporates a joystick control for both drive and steering.

Final prototypes now under construction will complete the development programme and arrangements for manufacture are in hand.

International 574

Hydrostatic front wheel drive has been added to this machine as well as underguarding, front mounted stacker, butt plate and hydraulic winch for trials on tree length extraction of small trees mainly on firmer sites with moderate slopes.

County 4000 × 4 Tractor

This machine has been modified and re-designed to incorporate an Igland Kompact winch, a moveable butt plate, and an improved log-rolling blade and field performance proved to be most encouraging.

Forwarders

Good outputs have been obtained in the South of England from the Volvos SM 868 and SM 462 and another SM 462 is to be evaluated under limiting conditions in the Border forests and Scotland. Trials of the Danish Gremo TT 12 forwarder have just commenced.

Delimbing

An extensive field trial of the Can Car Processor gave useful pointers as to the type of machine which would be required for conditions in the United Kingdom. A joint field study of the Norwegian Strip Delimber is now under way, Norwegian delimbing belts are being tested on a static rig and feasibility studies are in hand on a prototype machine.

Cable Cranes

Further modifications to capstans have only met with limited success despite the attractiveness of this control principle.

Two simple choker line pay-off systems using extra pulley blocks and wire loops were tried out but side haul power was greatly reduced in both cases. Trials with a carriage utilising spring motors to drive a separate hoist line drum have been very promising. An assessment of radio controlled long distance Vinje cable cranes in Norway suggested that these have only a very limited potential in this country. A comparative trial of the Smith winch and locking carriage with one and a half tonnes load at up to 500 metres range is being made with the Igland system.

Studies of load diversion methods have continued but although several of these are quite successful mechanically the time penalty incurred for diversion distances in excess of 10 metres is sufficient to limit the use of such methods to a very few situations.

Amongst the minor equipment the Fleming quick release hook was found to be useful for skyline extraction in that the winch man does not need to leave the controls to unchoker the load or climb on to the stacks. The Skogsmateriel Tongs also save chokering time when used for butt first extraction of heavy single poles over short extraction distances.

Line Thinnings

Studies have been made of extraction by ground skidding tractors of line thinnings including comparison of pole presentation in row and chevron thinning. With the larger 75 BHP tractors now being used indications are that a chevron system applied to a two row main rack is the most suitable.

Chokers

The use of polypropylene rope for chokers in conjunction with EIA spring chokers and quick release pin has become standard practice in many areas. The chokers are light, cheap and easily replaced.

Loading

This has continued under review in various parts of the country and a current study of alternatives for loading 1 metre pulpwood should prove a useful guide to the general problem of short specification loading a large proportion of which is still carried out by hand.

Chipping

Short trials have been conducted of small mobile chippers and further studies planned will look at supply, demand and technical possibilities for the disposal of forest residues.

Chainsaws

The review of new equipment is continuous. Base lines were set for future performance analysis, and for standardisation of bar, chain and sprocket for comparative testing.

OTHER WORK

Work Measurement

It was agreed during the year that there should be a change of emphasis from standard time tables to output guides, the former being retained for major production operations only.

Safety

Written evidence was submitted to Governmental Committees who reported this year on "Noise" and "Safety and Health". In association with the Department of Health and Social Security follow-up studies have been made of operators suffering from vibration-induced "White Finger" and it is clear that the issue of anti-vibration saws has considerably reduced the problem. Investigation of noise levels continues and the results of all these studies will be reflected in "Codes of Practice" which are in preparation.

Ergonomics

With the assistance of Birmingham University staff studies were made of heavy physical work to examine the relationships between work load, determined by physiological measurement of oxygen intake and heart rate, and work study rating and relaxation allowances.

I. A. D. GRANT

ORGANISATION AND METHODS

Systems Design

A modification of the Commission's Financial Control System was developed for use within Research Division. This system will become operational during the year 1973/74. The method of project cost control used within Research and Management Services Divisions is under study and the possibility of integrating project cost control with the system of budgetary control is being examined.

Maintenance work on the Financial Control System continued with the emphasis on training line managers in the use of the data. Training courses held for this purpose provided useful feedback on the operation of the system. One area identified as causing problems was the planning and control system for machinery and equipment. A small working group with some members drawn from conservancies has been formed to examine the problem and recommend necessary changes.

The introduction of the Financial Control System in 1971 brought with it changes in the responsibilities of the different levels of management. A review of non-financial information systems to align these with the new financial control procedures and responsibilities has been completed in conjunction with the appropriate Headquarters Divisions. Development work on the provision of local job control data continued during the year.

G. M. COWIE

HARVESTING AND MARKETING DIVISION

TIMBER UTILISATION

The Use of Bark in Horticulture

Most of the development work concerned the assessment of the suitability of bark from individual coniferous species for various horticultural purposes, with particular regard to the possible incidence of phytotoxicity. This involved experiments using bark for mushroom casing (i.e. the upper layer of the growth medium through which the sporophores penetrate), bulb forcing and the growing of pot-plants. Observations on the performance of bark as mushroom casing were undertaken both by the Commission and the Lee Valley Experimental Horticulture Station of the Agricultural Development and Advisory Service. The results, which are given in Table 24 below, were largely inconsistent, but a few conclusions could be drawn:

(a) Under the watering regimes adopted, the yields given by all species of bark were generally inferior to those from the peat controls.

(b) Corsican pine bark gave better results than other species.

(c) Yields of bark from pines and larches were usually superior to those from spruces and Douglas fir.

(d) Norway spruce bark invariably gave the worst results.

TABLE 24

CUMULATIVE YIELDS OF MUSHROOMS AFTER 6 WEEKS, IN KILOGRAMMES PER SQUARE METRE

Casing	*Lee Valley Experimental Horticulture Station*	*Forestry Commission*
Peat Control	6·03	8·52
Bark of Scots pine	3·36	1·36
„ „ Corsican pine	5·11	2·39
„ „ European larch	1·41	0·44
„ „ Japanese larch	1·51	2·14
„ „ Norway spruce	0·68	No yield
„ „ Sitka spruce	2·00	1·27
„ „ Douglas fir	0·73	0·82

Complementary experiments on the effect of volatile products emanating from fresh bark on the rate of mycelial growth in culture have been carried out by the Pathology Section. The results provide evidence that under some conditions the bark of spruces and Douglas fir can inhibit the development of the cultivated mushroom.

In the bulb forcing trials narcissi were grown in a medium of bark the pH of which had been raised to neutrality by the addition of lime. The results given in Table 25 indicate that bark of the larches gives better leaf growth than that of the other species, but this could perhaps be a function of the air/moisture ratio of the bark rather than of any biochemical effect. Sitka spruce was markedly inferior.

TABLE 25

MEAN HEIGHT OF LONGEST LEAF PER BULB 7.3.73

Bark of Scots pine	24·4 cm
„ „ Corsican pine	23·2 cm
„ „ European larch	26·8 cm
„ „ Japanese larch	27·2 cm
„ „ Norway spruce	25·9 cm
„ „ Sitka spruce	15·8 cm
„ „ Douglas fir	24·2 cm
Proprietary fortified bark compost	23·3 cm

In the pot plant trials tomato cuttings were placed in pure bark of the same seven species. All survived the winter but those in the bark of the spruces and Douglas fir grew less vigorously than the others, exhibiting slight symptoms of toxicity by the appearance of black areas around the veins of some of the leading leaflets. In practice toxicity of this type is no problem, because the suppliers of pulverised bark allow their product to heat up by bacterial activity to a temperature around 60°C, before delivery. This procedure ensures that any harmful voltatile products are driven off and the bark becomes quite innocuous to the most sensitive plants. Preliminary experiments at the Glasshouse Crops Research Institute, Littlehampton, and the Lee Valley Experimental Horticulture Station, Hoddesdon, have demonstrated that bark is likely to prove to be a good rooting medium for cucumbers; and at the John Innes Institute, Norwich, a bark-based potting mixture gave superior results when used as a medium for *Streptocarpus*. During the year two organisations were set up for the retailing of bark to the small grower, and overall sales for horticultural purposes are believed to have been in the region of 3,000 tonnes.

The use of bark for bulb forcing, for mushroom casing, and for footpaths was featured at the 1972 Chelsea Flower Show.

The Use of Bark for the Control of Oil Pollution

Assessments were made at the Warren Spring Laboratory of the Department of Trade and Industry of the capacity of various particle sizes and species of bark for absorbing oil, and hence of its possible value in the control of oil pollution. It was found that Sitka spruce bark can absorb 4·3 times and Scots pine 3·5 times its own weight of oil. Using the spruce bark in large particles appears to be more efficient than in a finely granulated form.

Fence Post Trials

The final assessments of these fifteen year old trials were made, and a report is being prepared. No new trends were observed.

In England and Wales most of the sites were passed to the Ministry of Agriculture, Fisheries and Food, who will continue to record the service given by the various species and preservative treatments. Those in Scotland have been abandoned.

The Reduction of Needle Fall in Christmas Trees

A small experiment was undertaken to see whether the treatment to reduce needle fall by dipping in alginate could be carried out on trees with their branches bound to the stem. The results given in Table 26 (mean of six replicates) indicate that this has no observable effect on the efficiency of the dip.

TABLE 26

NEEDLE FALL IN TREATED CHRISTMAS TREES: DRY WEIGHT OF NEEDLES SHED AFTER 28 DAYS

Loose Trees	*Bound Trees*
103·1 ± 40	106·9 gm ± 41

In another trial a proprietary anti-desiccant was tested. The cumulative weights of needles shed over a 31-day period (means of three replicates) expressed as a percentage of the total foliage are given in Table 27.

TABLE 27

ANTI-DESICCANTS FOR CHRISTMAS TREES: PERCENTAGE NEEDLES SHED

Days after treatment	15	22	25	28	31
Control	2·50	9·11	16·67	20·06	25·45
Alginate (½% solution)	0·66	3·06	6·36	8·11	15·00
Proprietary Anti-Desiccant	1·76	3·67	8·31	11·74	18·17

While the anti-desiccant is less effective than alginate in reducing needle fall, it is more resistant to being washed away by rain after treatment.

J. R. AARON

THE JOINT RESEARCH PROGRAMME ON HOME-GROWN TIMBER

PRINCES RISBOROUGH LABORATORY AND FORESTRY COMMISSION

The following is a brief account of the work carried out by the Princes Risborough Laboratory of the Building Research Establishment (Department of the Environment) and the Forestry Commission, under the Joint Programme of Work on Home-grown Timber.

Stress Grading of Home-grown Softwoods to Determine their Suitability for Building

Experience in the stress grading of imported European redwood and whitewood and Canadian western hemlock has shown that machine grading can provide a better assessment of the strength of timber than is possible by visual inspection. With the imported timber, machine selection to the 75 and 50 grades specified in CP 112: Part 2:1971 enables higher values of modulus of elasticity to be used and gives much better yields, especially of the higher grade material.

The investigation on home-grown softwoods was initiated in 1969 to explore the advantages of applying machine grading techniques to Scots pine, Sitka spruce, Douglas fir and Corsican pine, using the Computermatic stress-grading machine. The results for Scots pine were given in the 1971 *Report* and those for Sitka spruce in last year's *Report*. Tests on Douglas fir have been completed and those on Corsican pine are nearing completion.

The investigation showed that Douglas fir can be machine graded. Improved yields of the better grades were obtained, with some 13 per cent of the pieces that were rated by the machine as M75 grade compared with less than four per cent by visual inspection. The improvement was less, however, than that obtained with European redwood and whitewood and home-grown Scots pine and Sitka spruce, where approximately 70 per cent or more of the pieces have been rated by the machine as M75 grade.

The effectiveness of the machine selection was examined by comparing the value of ultimate bending strength of each piece obtained from a destructive test with the minimum value of ultimate strength required for the grade to which each piece was assigned. The machine selection for Douglas fir was less effective than for Scots pine and Sitka spruce, with about five per cent of the pieces being too weak for the grade to which they were assigned.

The Effect of Fertiliser Application on Growth Increments and Wood Density in Sitka spruce

Details of this project were given in the 1971 *Report*, page 119.

Material for the investigation was taken from the Commission's fertilising experiments in Sitka spruce at Glasfynydd (South Wales). The Glasfynydd experiment comprises 16 × 0·1 acre plots treated with fertiliser in 1959. Apart from one left untreated, the plots were given applications of two or more fertilisers from N, P, K, Ca and Mg. Subsequent assessments (1965 *Report*) showed that only P caused a significant increase in basal area increment with N having the effect of reducing growth.

At the time of sampling, 11 years after treatment, the plots had been marked for thinning and consideration was being given to further fertiliser applications. Two sampling procedures were adopted for each plot, as follows:

(1) Breast height boring samples were taken on a random basis from trees selected for retention on the plots after thinning. Three trees from each of three strata of equal basal area (representing the largest, medium-sized and smallest trees) were sampled making a total of nine trees per plot. Borings were taken at the internode nearest breast height in a north-south direction and penetrating the full diameter of the trees.

(2) Disc material was taken at proportional heights (at the internodal positions nearest to the 10, 30, 50, 70 and 90 per cent points in the stem measured from butt to a top diameter of 2½ inch over bark) from the trees removed in thinning, or, where more than three trees were removed, from the three largest trees.

For the purpose of comparison, four plot populations were recognised following the observation made in the field assessments that P stimulated radial growth whereas N tended to depress it. The four groups were as follows:

(1) Plots receiving P but no N, designated P,

(2) Plots receiving P and also N, designated P + N,

(3) Plots receiving N but no P, designated N,

(4) Plots receiving neither P nor N, designated O.

Each of the above groups comprises four treatment plots; it should also be noted that in some instances plots also received one or more of K, Ca and Mg. Only one plot received no application of any fertiliser.

The results of the study are being treated with some caution since it is believed that the effects of fertiliser application on wood growth and density have been confounded by an increasing tendency to eccentric growth in the trees on the site as a whole.

As a result, it has not been possible to demonstrate that the growth rate/density relationship for the wood of Sitka spruce is unaffected by the application of fertilisers. Some effect was observed in plots receiving P + N, N and O, but plots receiving P but no N, although giving the highest volume response, showed no apparent change in the density/growth rate relationship.

It has been shown, however, that although radial incremental widths following fertiliser application were clearly wider in crown formed wood compared with those in stem wood (at 10 per cent tree height level) when cross-section area increments at the two heights were compared, these were of the same order for the plots receiving N and O and only marginally higher in the crown formed wood receiving P.

Simulation of Softwood Sawlogs and Sawmilling Conversion Procedures

A mathematical model for the representation and conversion of true cylindrical logs has been programmed. This initial simulation model has been used successfully for a preliminary investigation to determine the approximate conversion patterns to be used for the conversion of mature Sitka spruce. (A major project on the assessment of 40–50 year-old Sitka spruce is being undertaken in 1973/74.)

The sawlog is represented in the computer by matrices which describe the cross-section of the log at various intervals along its length. Each matrix element represents a portion of the cross-section which measures 2·4 mm × 2·4 mm. The simulated circumference of the log is therefore of a step form and the model has been arranged so that the steps fall inside the true circumference. Thus, the simulated volume will be less than the true volume. Initial tests have shown that the difference is in the region of three per cent. The element size of 2·4 mm coincides conveniently with the kerf width of a conventional bandsaw, but other element sizes can be used depending on the material sizes to be sawn, the kerf width of the sawing machines being simulated and the accuracy required.

For the initial model the log conversion is carried out by a computer subroutine which is based on the usual cant conversion technique, which has been used in all the sawmilling trials to date. The simulation model has been designed to incorporate any feasible conversion technique programmed as a subroutine. The initial validity checks on the conversion routine were inconclusive owing to the difficulty in obtaining live conversion data on true cylindrical logs.

Conversion validity checks will not be meaningful until sweep, taper and ovality are incorporated into the simulated log. The method for achieving this has been planned and the modified model will be programmed in the near future.

Properties of the More Important Minor Softwood Species

Work has continued on the programme to examine the timber properties of Grand fir, Noble fir, Western red cedar and Western hemlock. The results of the sawmilling and machining trials on Grand fir were given in last year's *Report*. During the year, trials on the other three species have been completed.

Western hemlock

The results of the original investigation, on six consignments of Western hemlock, were disappointing and it was thought that the sample selected was probably below average quality for the species as it is now being grown in this country. A further three consignments from older stands were therefore included.

Some of the forests yielded generally poor quality sawlogs which contained a considerable amount of sweep and frequent knots that were often dead and large. A considerable proportion of the butt logs from some forests also showed evidence of bacterial wet wood or attack by *Fomes*. The quality of logs in the repeat consignments was markedly better than most of the original sample logs and this was reflected in the overall quality of the sawn timber. Degrade due to distortion which occurred during drying was often severe, particularly in the original sample.

The machining properties of the timber varied considerably. Material with a slow rate of growth and high density, and material with few knots which were not too large invariably machined satisfactorily. The low density and knotty material did not machine well and would be unsuitable for uses where machine finish and appearance were important unless great care was taken with its preparation.

Noble fir

The logs were of good form and quality with almost 50 per cent of them in Grade A* when staining and drought cracks were not taken into consideration. Unfortunately many of the logs, particularly from the Scottish forests, were heavily scarred and frequently stained at the butts.

Much of the sawn out-turn was down-graded due to the fast rate of growth and frequent occurrence of knots. Consequently very little timber was graded I Clear and I and the major proportion occurred in Grades III and IV according to the rules specified in BS 3819.

As with the Grand fir and Western hemlock, the better quality material of this species machined well but the lower grade material did not machine satisfactorily under normal machining conditions. Some improvement in the machinability of this lower grade material can be obtained by changes in the basic cutter geometry. For example, reduction of the standard 30° cutting angle can lead to improved surface finishes on irregular grained timber, but this modification results in a higher power consumption from the machine.

Western red cedar

A large proportion of the logs were graded A or B*, with none below grade, and butt rot did not occur frequently. Fluting on the butt logs made debarking and conversion a little difficult and appeared to be the cause of a conversion efficiency which was overall slightly lower than that for the other three species. Knots did not occur too frequently and apart from an occasional pocket of rot associated with a knot, the majority of knots were live and quite small. Growth rate was generally slower than for the other three species and the overall result of these features was a marked increase in the amount of sawn material which was Grade II and better. The general quality of the timber also resulted in very little degrade during drying.

When dried and planed, the timber had a very pleasing appearance. Grain disturbance around knots produced the expected machining defects but these were rarely severe and the timber generally machined satisfactorily.

Other Work in Progress

Work on several other projects has been completed or is nearing completion but the results have not yet been fully analysed. These include: breast height boring/whole tree density relationships for Sitka spruce; the splitting of timber on nailing, particularly larch and Douglas fir; sawmilling studies on Douglas fir from a well-documented pruning experiment.

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*As defined in *Grading of British Round Timber: Log Grades for Softwoods.* Forest Products Research Laboratory (now Princes Risborough Laboratory) 1964.

PART II

Research Undertaken for the Forestry Commission at Universities and Other Institutions

NUTRITION AND FOREST SOILS

NUTRIENT CONCENTRATIONS IN HEALTHY NURSERY-GROWN SEEDLINGS AND TRANSPLANTS OF CONIFERS

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Extract from *Rothamsted Report* for 1972, Part I

The approximate range of nutrient concentrations in plant tissues for conditions of deficiency can be defined more easily than for those of sufficiency. However, with such high-value crops as British nursery conifers, fertilisers constitute less than 5 per cent of the production cost and the main consideration in manuring them is to achieve good survival and growth after forest planting. To meet this need, reliable analytical values are required which are consistent with the production of green, healthy trees. There is, at present, little relevant published information of this kind, especially for Western American species, some of which are widely planted in Britain.

Concentrations of N, P, K, Mg, Ca and Mn were determined in whole-plant samples of healthy one-year seedlings and two-year (one-plus-one) transplants of Sitka spruce (*Picea sitchensis*), Norway spruce (*Picea abies*), Grand fir (*Abies grandis*) and Western hemlock (*Tsuga heterophylla*). The conifer crops were grown with inorganic fertiliser supplying N, P, K, Mg and Ca, using standard manuring methods developed during an extensive experimental programme. The samples were taken between 1967–69, at the end of the growing seasons, from nursery beds on four contrasted soils in south-east England. The soils ranged from a nutrient-poor very acid sandy podsol (Wareham) to a soil which, though well supplied with nutrients, had near-neutral pH, i.e. conditions where good plants of the species listed could be grown only if the soil had previously been acidified or treated with partial sterilants.

N, P and K concentrations (but not those of the other nutrients) were consistently smaller in transplants than in seedlings, and all nutrient concentrations tended to vary less in the older plants. With plants of both ages, Norway spruce had larger concentrations of N, P and Ca than Sitka spruce, but smaller concentrations of K. Most of these differences were well supported by our earlier experiments.

Manganese was the only nutrient which showed large differences in tissue concentrations between nurseries. The values of 20-80 ppm Mn at Wareham, unusually small for such an acid soil, are related to the exceptionally small Mn reserves in soil and parent material.

Many of the analytical values derived from this work agree remarkably well with the few published elsewhere for the same species grown in nurseries or in solution culture; where the values diverge, there is often a plausible explanation. However, there is a risk that what appear to be matching results are in fact fortuitous. Until more detailed compilations are published, with conditions of growth carefully described, these nutrient ranges may not be generally valid.

RESEARCH ON FOREST SOILS AND TREE NUTRITION

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Nutrition of Sitka Spruce

The year under review was largely devoted to initiating a series of investigations into the relationship between tree growth and nutrient movement in pole-stage Sitka spruce. Prepared in consultation with representatives of the Forestry Commission, the plan requires the establishment of six new experiments, two to be laid out in each of the years 1973, 1974 and 1975. Each experiment is to comprise three replicates of an untreated control and a complete fertiliser treatment (200 kg ha^{-1} N, 100 kg ha^{-1} P and 150 kg ha^{-1} K). In these six plots nutrient turnover will be monitored for a period of five years. To isolate the effects of individual nutrients in this comparison a concurrent fertiliser experiment will be laid out on a "central composite rotatable" design.

Methods of whole tree sampling in Sitka spruce have already been established and work has concentrated on devising effective means of sampling rainwater, throughfall, stemflow and litterfall. In collaboration with the Department of Spectrochemistry suitable methods of water analysis have been devised, using samples collected in a small stand of this species within the Institute grounds. From previous experience with Corsican pine (*Report* for 1969) it had been anticipated that rainwater would transport a significant proportion of the potassium, calcium and magnesium released by the trees. It was found, however, that in addition Sitka spruce releases large amounts of nitrogen and phosphorus into rainwater. For example, in relation to the original precipitation, throughfall collected in the trial plot contained twice as much nitrate and twenty times as much ammonium, and stemflow about seventeen times as much nitrate and sixty times as much ammonium—increases that more than compensate for interception loss (possibly about 40 per cent of incident rain).

Attention has also been given to possible means of assessing input in aerosols. Trials have been made with various possible techniques, including exposing glass-fibre filter discs in tubular wind vanes similar in construction to those devised by Edwards and Claxton (1964). Impacted aerosols can be removed for analysis by washing the exposed filter in acid. Sections of exposed filter have also been examined by light microscopy, by scanning electron microscopy and by an associated electron microprobe analyser. The latter technique enabled identification of crystals of both sodium chloride and calcium sulphate on these filters. There remain, however, many problems in obtaining a quantitative estimate of the input of nutrients to a forest from this source.

The search for possible sites for these new experiments was described in the previous report (*Report* for 1972). Those at Fetteresso, Mearns Forest (Kincardineshire) and Leanachan Forest (Inverness-shire) have been chosen for the first series. By the end of March 1973 these had been established and equipped and tree sampling was well advanced in preparation for fertiliser application in early May.

Glasshouse work has largely been concentrated on the establishment of a bank of Sitka spruce clones, as described in the previous report (*Report* for 1972).

Nutrition of Pines

A number of ten year old experiments in young pine have been closed but the pole-stage fertiliser experiments in Scots pine and Corsican pine at Culbin, Laigh of Moray (*Reports* for 1965 to 1972) have continued to be sampled and assessed, as have the experiments in mature Scots pine at Alltcailleach forest (*Reports* for 1966 and 1968).

Detailed examination of the results from the experiment in pole-stage Corsican pine at Culbin continues with analysis of the distribution and nutrient content of litterfall over a period of six years. Nitrogen levels in fresh needle litter were found to respond to the nitrogen fertiliser treatments; indeed, it proved possible to construct fairly precise models using the levels of nitrogen in October needle litter to predict both nitrogen levels in top whorl foliage at the end of the previous year and stem growth during the current year. The pattern of needlefall and seasonal variations in the levels of nutrients in fresh litter were both subjected to a series of abnormalities that could be associated with salt spray input during periods of high wind with fetch across the sea. Although typical salt scorch was never observed in the experiment, considerable circumstantial evidence suggests the frequent occurrence of a sub-clinical damage level that is likely to be associated with some loss of revenue.

In the trial of forms of nitrogen fertilisers on Scots pine at Culbin (*Reports* for 1970 and 1971) maximum response continues to be shown to ammonium nitrate four years after fertiliser application ceased. Foliage collected in October 1972 from treated trees gave nitrogen levels of 2·30 per cent for ammonium nitrate, 2·06 per cent for ammonium sulphate, 1·89 per cent for urea and 1·62 per cent for sodium nitrate as against a value of 1·19 per cent for unfertilised trees.

Nitrogen Mineralisation in Peat and Mor Humus

Studies on samples of peat taken from field experiments suggest that, in general, the amount of mineral nitrogen produced on incubation depends on the total nitrogen content of the sample; indeed, for peats with a nitrogen content in excess of 2·0 per cent, considerable quantities of nitrate appear about four to six weeks into the incubation period. This would seem to suggest that the botanical origin of the peat might be an important factor, for certainly it is frequently related to the total nitrogen content; accordingly, samples representing a range of botanical origins are now being intensively studied.

Two techniques are being employed, one being a detailed chemical fractionation of the nitrogen in hydrolysates prepared by refluxing a sample with 6 N HCl for six to nine hours, a treatment that takes more than 90 per cent of the organic nitrogen into solution. The nitrogen in this hydrolysate can then be identified as ammonium, hexosamine or α-amino nitrogen. For example, the hydrolysate of a sample of blanket peat with a total nitrogen of 2·0 per cent comprised approximately 12 per cent ammonium, 10 per cent hexosamine and 50 per cent α-amino nitrogen, the remaining 28 per cent being unidentified. The second approach has been to separate the peat into its component size fractions by

making a suspension in distilled water and washing this through a range of sieves varying in mesh size from 5 mm to 10μm. Chemical analyses of the size fractions show that, in agreement with published data (Powers, 1932), certain peats, notably those derived from *Sphagnum* mosses, show a progressive rise in nitrogen content of the fractions as particle size diminishes (0·32 and 1·36 per cent for fractions > 5 mm and > 10 μm, respectively). For peats having higher total nitrogen contents, however, especially those derived from woody species such as birch and heather, the nitrogen content shows less change across size fractions.

Incubation studies continue on samples of humus taken from the fertiliser experiment in pole-stage Scots pine at Culbin, Laigh of Moray (*Reports* for 1969 to 1970). Results of chemical and incubation studies on samples taken at intervals during the first three years have been published (Williams, 1972) and experience gained from these studies is now being applied to spruce-derived humus as part of the investigation into nutrient cycling in pole-stage Sitka spruce described above.

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A COMPARISON OF SOIL AERATION AND WATER POTENTIAL WITH YIELD AND STABILITY OF SITKA SPRUCE ON A PEATY-GLEY SITE IN THE KIELDER REGION OF NORTHUMBERLAND

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Instability leading subsequently to wind-throw before full rotation is the unfortunate but inevitable outcome of the shallow rooting pattern displayed by Sitka spruce on the peaty-gley soils of upland Britain. Winter waterlogging is a characteristic of these soils, and shallow rooting is generally believed to arise because of prolonged periods of inadequate aeration in all but the surface layers. What little exploitation there is of lower horizons results in the characteristic "shaving-brush" root effect, and indicates a recurring failure of fresh roots to cope with renewed soil anaerobiosis following more favourable growth periods. The success of the crop before the onset of instability appears to be the result of a more effective exploitation of the surface humus layers which are aerobic.

Whilst there has always been ample reason for believing peaty-gleys to be poorly aerated, little was known of their precise oxygen status owing to the lack of a suitable sampling technique. This deficiency is now rectified and the purpose of the present investigation has been to make a quantitative study of oxygen status and water potential in the peaty-gley soil under an established crop Measurements have been made in conjunction with seasonal tree-pulling studies carried out by staff of the Forestry Commission's Northern Research Station and thus it has been possible to make comparisons of yield and stability with the degree of aeration and the levels of water stress found in the soil.

Oxygen flux was measured by the platinum micro-electrode technique with equipment developed earlier for studies in North Yorkshire (Read, Armstrong, and Weatherall, 1973), and re-housed for this investigation in an enclosed trailer. This equipment enables the simultaneous assessment of oxygen in the soil profiles of five dispersed sites. Limiting potentials and flux equilibria are determined from recorder tracings, and as five replicates may be assessed at each site in little more than the time necessary to measure a single profile, this has considerably speeded the rate at which oxygen data may be collected. A paper giving details of this equipment is now being prepared (Armstrong and Wright).

Tensiometers (supplied by the Soil Moisture Equipment Co., Santa Barbara, California) were selected as the most suitable instruments for assessing the water potential.

The plot examined was turf-planted with Sitka spruce in 1947 at a 5 ft × 5 ft spacing.

Measurements of both oxygen and water potential were taken in close proximity to those trees scheduled for pulling, and sampling was carried out in April, September and December 1972. These times were selected to represent

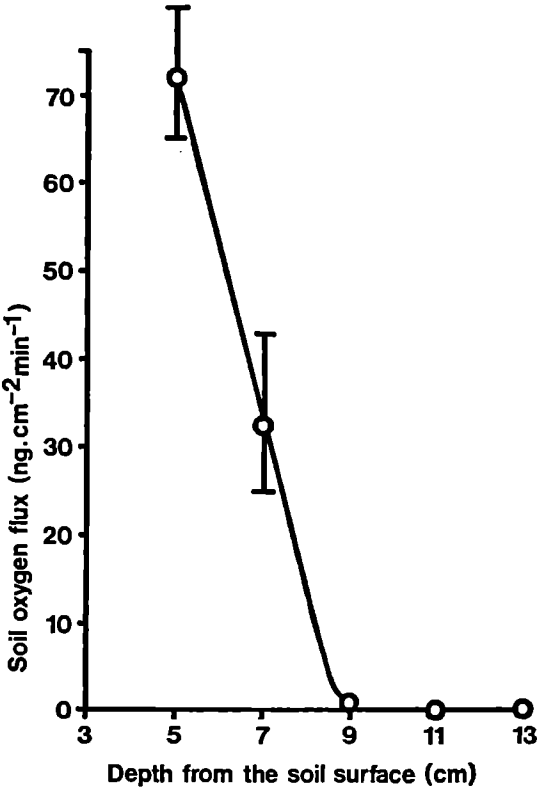

Figure 13: An oxygen profile typical of the winter and early growing season. (A mean of three replicates; vertical lines indicate the limits of variation about the mean.)

conditions expected in the early growing season, late growing season and winter respectively.

Similar conditions were found to prevail in both the early growing season and winter periods. Our instruments indicated free water at 15 cm, and oxygen never penetrated below 20 cm. A typical example of the oxygen status at these times is shown in Figure 13. A strong positive correlation was found between the oxygen status during these periods and such factors as stability, stem weight, root weight, mid height diameter, and breast height diameter of the pulled trees. No obvious correlation could be recognised between summer oxygen status and these parameters, and it is tempting to suggest that the small cross-site differences in aeration measured during the high water-table conditions may be the reason for the yield differences observed. However, it is extremely difficult to discriminate between cause and effect in such a situation and it might equally well be suggested that the larger trees are themselves responsible for the observed differences in aeration. Further experiments are being designed to clarify this position.

It was interesting to note that while healthy young "shaving-brush" roots were much in evidence during the late summer, few living examples were found during the December pull approximately ten days after the return to sub-surface waterlogging.

Full details of the results obtained during this study are being prepared for publication at a later date.

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FOREST PATHOLOGY

CONIFER SEEDLING PATHOLOGY

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Experiments in Wareham Nursery

Field experiments at Wareham Nursery in Dorset were continued and gave similar results to those in 1971 (Salt in *Report* for 1972 p. 150), except that the weather was less favourable to growth, seedlings were smaller, and responses to formalin soil treatment less. Conditions also seemed unfavourable for seedling pathogens, for seedling emergence was very good and no losses were recorded in counts between June and September. In one experiment (W.238) the number of living Sitka spruce seedlings per square metre in September averaged 1,370 for Washington provenance 70(7972)5 and 1,296 for Queen Charlotte Island provenance 66(7111)3. Under these conditions dressing seed with 50 per cent thiram failed to give any improvement in emergence or survival.

Geniculodendron pyriforme Salt, gen. et sp, nov.

A new fungal genus *Geniculodendron*, has been erected to accommodate the previously unnamed pathogen found in Sitka spruce seed imported from British Columbia and commonly called the "psychrophilic" or "endophytic seed fungus" (see Salt in *Report* for 1966, p. 105; 1967, p. 143; 1968, p. 156; 1969, p. 147; 1970, p. 174; and Buszewicz and Gordon in *Report* for 1972, p. 25). The generic name is derived from the related genus *Geniculosporium*, from which it differs in having colourless conidia and complex dendroid branching conidiophores. The single species *G. pyriforme* is named after its small pear or pip-shaped conidia (Salt, 1974).

We only know *G. pyriforme* as a parasite of imported Sitka spruce seed, which spreads to healthy seed in cold nursery seed-beds, and the rest of its life cycle is unknown. The fungus has not been recorded in home grown seed and we do not know when, how or from where it infects the seed we import. It may be significant that the related genus *Geniculosporium* is the conidial stage of the Ascomycete *Hypoxylon*, species of which are common on dead wood of deciduous trees.

Recently, seven samples of imported seed from different localities, which had been extracted at the same time and place, were found to contain from 0 to 60 per cent of infected seeds. This indicates strongly that infection occurred at source and not during extraction, and that the quality of seed sown in nurseries could be improved by testing the health of small local collections and excluding those with much disease before bulking for general use.

The Control of G. pyriforme in Nursery Seed-beds

Dressing seed with 50 per cent thiram (Salt and Brown in *Report* for 1969, p. 147) can prevent infection of healthy seedlings in nursery seed-beds. However,

Clearly, the cold treatment of infected seed requires careful control of temperature. Risk of damage is greatest in open stratification pits where temperature can rise above 5°C and increase the growth of the fungus. In cold stores the risk can be decreased by keeping temperature down to 3° or even 1°C and by treating for the minimum time necessary to break dormancy. Thiram at 0·5 to 1·0 per cent active ingredient in the initial water soak seems likely to give further protection, which might extend after sowing, but this still needs to be tested experimentally.

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VIRUS DISEASES OF TREES

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A seed-borne virus infection of *Betula pubescens* associated with a chlorotic vein-banding symptom on leaves was observed in one plant grown from seed in sterilised compost. When sap from the leaves of this plant was examined in the electron microscope, virus particles resembling those of tobacco rattle virus or tobacco mosaic virus were seen. Attempts to transmit virus from symptom-bearing leaves by rubbing sap onto leaves of a range of test plants in the glass-house failed and tests are in progress using a model system to find methods favouring manual transmission from similar material. Plants of *B. pendula* and *Alnus incana* were grown from seed in sterilised compost and leaf sap expressed from these plants was mixed with preparations of tobacco rattle virus. When the virus was mixed with sap from either species and rubbed onto leaves of *Chenopodium amaranticolor* the virus infectivity was eliminated. Very little of the infectivity of untreated virus persisted when either birch or alder sap was treated with 2-thioglycerol (10^{-2}M) or ethylenediaminetetracetic acid (10^{-2}M). However, approximately 60 per cent of the infectivity was retained if either the alder or the birch sap was treated with polvinylpyrallidone (PVP) at a final concentration of 1 per cent.

Poplars of clones susceptible to poplar mosaic virus but free of symptoms and detectable ions have been planted at sites in Bedfordshire and Lincolnshire in experiments to study the spread of the disease under field conditions.

FOREST ZOOLOGY

STUDIES ON TIT POPULATIONS AT CULBIN, LAIGH OF MORAY FOREST, MORAYSHIRE

By A. J. DEADMAN

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The field work for this study was completed in June 1972 and the results of the work will be published elsewhere at a later date.

During 1972 further work was carried out on winter flocking and the winter range of adult and first-winter birds. Individuals of both age groups in both species had definite wintering areas and the majority remained in the wintering area to breed.

Work was carried out on territorial establishment and it was shown that adult and first-winter birds became territorial at about the same time. There was no indication that adult birds tended to establish larger territories than first-winter birds or vice-versa.

Experimental removal of territory holders to determine whether territorial behaviour played some part in regulating breeding density failed to reveal a surplus of birds excluded from the area by territory holders. However, there was considerable evidence to indicate that some compression of territory size was operating, and that the population was tending to space itself out.

Data were also collected on the amount of the total territory which was utilised at different phases of the breeding cycle. It was shown that those individuals which had smaller territories utilised the whole of the territorial area throughout the season and often utilised areas outside the original boundaries. Those individuals with large initial territories rarely used the whole of these and during the brood-feeding phase only that part of the territory within 150 metres of the nest was used for food collection.

EFFECTS OF FOREST MANAGEMENT PRACTICES ON SONGBIRD POPULATIONS

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Between November 1970 and February 1973, studies were made on populations of small passerines in various types of woodland, particularly in conifer plantations approaching economic maturity. The bird populations in a number of broadleaved woods, both managed and unmanaged, were also studies for comparison. Studies were undertaken in woodland plots of 7, 12, or 20 hectares, in the Forest of Dean, and in various forests throughout Wales. Most of the coniferous woods were about 50 years old; most broadleaved plantations were about 80–90 years old.

Censuses were made during the winter season, and during the breeding season. In the winter, counts were made primarily of birds occurring in flocks, particularly in tit flocks. In the breeding season, all non-corvid passerines were studied. In general, similar numbers of birds were found in coniferous and broadleaved woodlands. Rather more birds were found in coniferous woods than broadleaved woods during the winter. In the winter of 1971/72, exceptionally high numbers of birds were found in tit flocks in a larch plantation. In the spring of 1972, exceptionally low numbers of birds were found in two half-grown plantations, one of 30-year-old oak and one of 25-year-old pine. The oak plantation contained only six pairs of birds in 12 hectares, while most other woods contained between 35 and 45 pairs within the same area. In the winter of 1972/73, studies were made of woods on moorland in mid and north Wales; previously, all work had been done on agricultural land in Tintern Forest and the Forest of Dean. Numbers of birds in tit flocks in woods on moorland were generally lower than in woods surrounded by agricultural land in the same winter. However, there was again little difference between broadleaved and coniferous woods in similar areas, the coniferous woods containing a slightly greater number of birds.

Far fewer species of birds were found in coniferous woods than broadleaved woods. In addition, proportional representation of the species was less uniform in the coniferous woods, one or two species comprising the bulk of the population. An "index of diversity" was calculated for the bird populations in each study plot; this index took into account both the number of birds present and the proportional representation of each species. With the exception of the half-grown oak plantation, the index of diversity in broadleaved or mixed woods was far greater than in coniferous woods. The coniferous woods tended to be dominated by goldcrests, or, where a sufficient field layer had developed, by wrens. The broadleaved woods, on the other hand, generally contained moderate numbers of several species: several species of tits, and also wrens, robins, and chaffinches, as well as small numbers of other species.

All breeding surveys to date have been done in managed woodlands. In every case, the density of breeding birds was well below the figures reported for various unmanaged broadleaved woods. The managed woods in the present survey

generally contained no understorey; the field layer was often of short grass rather than of taller vegetation. In addition, most of the trees in the managed wood were too young to have developed holes suitable for nesting birds. In an unmanaged wood, one would expect better development of the various vegetation layers; in addition, older trees would contain more holes, providing nesting sites for birds. This may account for the greater density of breeding birds usually recorded in unmanaged broadleaved woods.

ENVIRONMENT

ENVIRONMENTAL EFFECTS ON SHOOT GROWTH IN CONIFERS

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Work on this project (*Report* 1971) has been resumed after a lapse due to staffing difficulties.

The earlier growth-room experiments indicated that temperature regime had marked effects on dormancy, shoot extension and needle morphology in Sitka spruce grafts. This result is being tested by repeating the experiment using rooted cuttings of several clones and also field grown transplants of known parentage. As a contrast rooted cuttings of Lodgepole pine have been included. Environmental conditions are a fixed photo period of 17 hr, vapour pressure deficit of 2·0 mb and two relatively extreme temperature treatments of 20°C and 8°C constant with one of 20°C day/8°C night.

Although incomplete, results so far tend to support the earlier work with grafts. Considerable differences are appearing between clones and diallel progeny material in respect of flushing and shoot extension, particularly within the low temperature treatment, and of course, between treatments.

The opportunity of following development of the annual cycle in the same diallel crosses in the field is being taken by setting up a small meteorological station within the Genetics Section trial in Bush Nursery.

Further experiments being prepared include:

(1) A study of bud formation and maturation in different photoperiodic/thermoperiodic conditions utilising seedling material from the IUFRO provenance collection.

(2) An investigation of the minimum winter chilling required by Sitka spruce.

REMOTE SENSING

By N. D. E. CUSTANCE and E. S. OWEN JONES
Bedford College, University of London, and
G. J. MAYHEAD
Forestry Commission

Phosphate deficiency is an important and costly problem over large areas of Forestry Commission land, and to date the only effective method of detection has been by foliage analysis. Considerable sums of money could be saved if such phosphate deficiency could be detected by aerial survey. Initially, an inexpensive feasibility study has been conducted from the ground; "live" investigation from the air would be extremely costly, and could only be justified by promising early results.

Narrow band filters (in steps of 20 nm) were used over the visible and near infra red part of the spectrum with Kodak TRI-X black and white, and Kodak black and white infra red film in a standard 35 mm camera. Two separate Sitka spruce crops were photographed from the side at ground level throughout the growing season. One crop at Wareham (Dorset) was fast growing and had ample phosphate. The other at Headley Nursery (Hampshire) was of 1 + 1 transplants subjected to a range of levels of soil phosphate.

The side photographs were of limited use but a set of verticals of the transplants taken in bright overcast conditions in late autumn from a 13 m scaffolding tower revealed subtle tonal differences between different needle phosphate levels when filters of 588 and 625 nm were used. A filter of 762 nm also emphasised the plants as bright white against a dark background of bare moist sandy soil, although this is to be expected in the infra red range.

The experiment was not entirely successful because of lack of replication and trouble with the thick filters. The work continues but the results are not considered suitable for field use at present.

RECREATION

THE RECREATIONAL POTENTIAL OF FORESTRY COMMISSION HOLDINGS

By BRIAN GOODALL and JOHN B. WHITTOW

Department of Geography, University of Reading

This project was described in some detail in the *Report* for 1972, and the following notes provide an account of progress made leading to the final report of which an abstract should be available in the *Report* for 1974.

Objectives

These were:

(a) To define qualitatively the characteristics of various types of forests in relation to various recreational requirements.

(b) To assess the effect of accessibility within the forest on this relationship.

(c) To define a practical method of assessing forest recreation potential.

(d) To identify planning problems.

The study is confined to the supply side of the demand/supply equation.

Fieldwork

Data for each of the 99 sample areas, spread over 20 forests drawn from the 350 forest administrative units, has been coded for terrain and mantle characteristics and analysis provides a basis for describing forest landscape (Goodall 1973) and relating it to recreation. Three separate indices; for physical features, for mantle characteristics and for intra-forest accessibility are developed and this leads to a comprehensive descriptive index.

Recreational User Requirements

The requirements of recreational uses in terms of physical parameters (area, distance, slopes etc.) and preferred general environment had to be established. In the case of water-based recreational activities, consequent upon increasing demand in the face of scarcity of suitable water, requirements are well documented and it has been possible to present preferred conditions, constraints and environmental impacts in matrix form. This allows the recreational potential of water bodies which occur in forests to be evaluated. For example, there can be instances where the presence of forest around a water body is detrimental to certain recreational pursuits, as in the case of sailing.

Land-based recreation activities have not been subject to a similarly intensive study. Approaches have therefore been made to governing bodies of active outdoor recreational activities in order to establish their requirements and to ascertain the desirability of a forest environment for the activity in question. This information, together with that for passive or informal recreation, will also

be presented in matrix form, as well as complementarities and conflicts between these activities. These matrices which illustrate the tolerance range of conditions for each activity are then compared with the combinatorial forest index, which is also expressed as a range of recreational potential.

Future Planning Problems

These are likely to arise in the areas of conflict that can occur as a result of:

(1) demand by differing recreational users for the same preferred environment, and

(2) particular recreational activities in a forest environment.

REFERENCE

GOODALL, B. (1973). The composition of forest landscapes. *Landscape Research News* I, Summer, No. 5.

SCOTTISH TOURISM AND RECREATION DEMAND STUDY

By B. S. DUFFIELD and M. L. OWEN

Tourism and Recreation Research Unit
Department of Geography, University of Edinburgh

The study is being conducted by the Tourism and Recreation Research Unit of the Department of Geography, University of Edinburgh, for the Scottish Tourist Board, the Countryside Commission for Scotland, the Highlands and Islands Development Board and the Forestry Commission. The total cost of the survey over three years including preliminary analysis is £53,000 of which the Forestry Commission is contributing £5,000. The study will examine the nature, volume, distribution and incidence of existing and potential demand for tourism and recreation in Scotland at sufficient detail to be used in regional planning. The survey is in two parts, a Home Interview Survey of a random sample of the Scottish population and a Cordon Survey of holiday-makers leaving Scotland by road, rail, air and ferry.

The Home Interview Survey obtains details of day trips made from home, weekend trips, main and second holidays. The principal questions about each trip concern the frequency and length of trips, the place visited, transport used and numbers in the party. There are questions on participation in named activities, types of accommodation, total cost, reasons for choice of location, attitudes to tourism and demographic details of the respondent. There are specific questions on visits to woodlands, their location, prior knowledge and activities while in the woodland. The Cordon Survey pursues similar lines of inquiry about holidays spent in Scotland.

A pilot survey was conducted in the autumn of 1972 and the main survey will be taking place during the summer of 1973. A progress report on the pilot has been submitted to the sponsors and a final report will be submitted by 31 December 1974.

RECREATION PERCEPTION STUDY

By A. J. VEAL

Centre for Urban and Regional Studies
University of Birmingham

The Countryside Commission, the Sports Council and the Forestry Commission are sponsoring a desk study of research into the ways in which people perceive their recreation environment. The aim of the study is to review techniques developed in the field of perception research with a view to developing their use in recreation research and planning.

Topics under consideration include perceptual capacity of recreation areas, on-site activity, the attraction to the public of recreation areas and perception of landscape. The Centre are producing working papers on these topics during the course of the study. An annotated bibliography will be produced and the study will be completed at the end of September 1973.

APPENDIX I

Publications by Forestry Commission Staff

Priced publications issued by the Forestry Commission are available from Her Majesty's Stationery Office at addresses shown on the back cover

AARON, J. R. (1972). Pulverised pine bark. *Jl R. hort. Soc.* 97(5), 214–217.

Describes the use of bark as a mulch, a medium for pot plants, orchid growing, and bulb forcing; explains the difficulties in composting bark; and answers allegations of phytotoxicity.

AARON, J. R. (1972). Bark for the garden. *Newspap. Midland Garden Club* (2), p. 6.

Deals mainly with the advantages of mulching with bark, but also mentions plunging and digging-in.

AARON, J. R. (1973). Bark for your garden. *Amat. Gdng* 10th March, p. 34.

Gives the advantages of bark as an effective and ornamental mulch, mentions its use in potting work, bulb-forcing and orchid culture; refutes allegations of toxicity; and outlines the supply situation.

ALDHOUS, J. R. (1972). *Nursery practice.* Bull. For. Commn, Lond. **43.**

This Bulletin summarises results gained from the extensive programme of experiments and enquiries carried out by the Forestry Commission's Research Division, from its inception in 1919 until the year 1970, together with the practical experience obtained in the large-scale raising of planting stocks for the national afforestation programme. It contains chapters on Nursery Policy, Site Selection and Layout, Soils, Plant Nutrition, Seed Supply, Cultural Technique for Seed Beds and Transplant Lines, Weed Control, Protection against Pests and Vegetative Propagation.

ALDHOUS, J. R. (1972). Silvicultural techniques and problems with special reference to timber production. In *Lowland forestry and wildlife conservation.* Symposium No. 6 Monks Wood Experimental Station, 65–79.

Silvicultural techniques reflect current objectives of management. These, in lowland Britain, have changed radically in the last 200 years, reflecting the changes in utilisation of wood and wood products. Currently, conservation, recreation and amenity objectives are rated more highly than often in the past. However, for whatever blend of objectives woods are managed, the manager is inevitably under some pressure to get the best value for money. He is therefore subject to conflicting pressures on the one hand to increase the scale of work, in order to obtain economies of labour which could conflict with demands of conservation or amenity to ensure that any one clear felling area for example should be on a relatively small scale.

Current silvicultural practice is outlined and the growth rates of 11 broadleaf and seven conifer species is given for contrasting soil types representative of lowland Britain. Assuming current market prices, the revenue from some broadleaf and conifer species growing for timber production is given. The effect of standard economic discounting over the rotation age for various species reveals the relative profitability of different species by this criterion.

Alternative choices of species and silvicultural techniques are considered. Finally, the concept of the normal forest is discussed in relation to the proportion of the rotation spent by species in even-age plantation at different stages of growth.

BARSON, G., and CARTER, C. I. (1972). A species of Phylloxeridae, *Moritziella corticalis* (Kalt.) (Homoptera) new to Britain, and a key to the British oak-feeding Phylloxeridae. *Entomologist* 105, 130–134.

On 4th September 1970 specimens of oak twigs supporting dense colonies of phylloxerids were received from Bolnore Estate, Haywards Heath, Sussex. The insects were later

identified as *Moritziella corticalis* (Kalt.), a species new to Britain, and complied well with the original description by Kaltenbach (1867).

BINNS, W. O. (1972). Purpose, understanding and authority in statistical research: their bearing on statistical consultancy. *The Statistician* **21**(3), 211–213.

Experimenter and statistician both need to understand the programme and policy of the research as well as the purpose of the experiment. Consultancy should begin at the time the questions are formulated. Biologists must have some training in biometrics; in-post training can be valuable. Conversely statisticians should understand the environment of forestry research, which may necessitate field visits amid gorse in snowstorms; the great site variability must also be appreciated.

The statisticians advice should normally be taken on details of experimental design, but the biologist must stand firm on the strategy of experimentation; flexibility, with originality if appropriate, are the qualities needed in the consultant.

BLATCHFORD, O. N. (1972). *Dissemination and application of research information in the field.* Res. Dev. Pap. For. Commn, Lond. **88.**

In theory the forester in the field should be aware of the latest research findings, and be able to implement recommendations.

In practice he may not know that research has been or is being carried out in a particular field; if he does, his information may be out of date, or inaccurate; he may find that he is not permitted to effect new methods or techniques.

The difficulties in bridging the gap between Research and the Field are explored. The key obstacles are identified and recommendations made to overcome them.

The experience and present arrangements of the Forestry Commission of Great Britain are used to demonstrate the problem and suggest solutions.

BOWEN, M.R. *et al.* (1972). Auxin transport in roots, VIII. The distribution of radioactivity in the tissues of *Zea* root segments. *Planta* **105**, 273–292.

Experiments involving soluble-compound microautoradiography and girdling procedures were carried out in an attempt to identify the tissues responsible for the acropetally polarised transport of indole-3-acetic acid through segments of *Zea mays* roots. The results strongly suggest that acropetal movement of IAA takes place in both stele and cortex, but with a much greater efficiency in the former tissue than in the latter. Basipetal movement of IAA is much less than acropetal movement and appears to take place with equal efficiency in the cortex and stele.

BRASIER, C. M. (1972). Observations on the sexual mechanism in *Phytophthora palmivora* and related species. *Trans. Br. mycol. Soc.* **58**(2), 237–251.

Twelve out of twenty-three isolates of *Phytophthora palmivora* (Butl.) and related species formed oospores in single culture when freshly subcultured from paraffin oil stock culture, demonstrating their bisexual nature. This ability declined with further subculturing, and the isolates were apparently self-sterile under normal conditions. They fell into two compatibility groups in the classical manner on the basis of oospore formation in paired cultures. More oospores were formed in pairings between isolates from black pepper than in pairings between isolates from black pepper and isolates from other host plants. This situation is discussed. A relationship between ability to form sex organs in single culture and in paired cultures is suggested.

The possibility of chemical stimulation of sexual reproduction between compatible isolates of *P. palmivora* was investigated. No evidence of this was obtained from experiments involving liquid culture filtrates, but single isolates from both compatibility group were stimulated to form sex organs when separated by a cellophane membrane from an isolate of the homothallic species *Phytophthora heveae* Thompson in agar culture. An isolate of *Trichoderma viride* Pers. ex S. F. Gray stimulated sex organ formation in a single isolate of *P. palmivora.* These results are considered possible evidence of chemical stimulation of reproduction in *P. palmivora.*

Alternative mechanisms of sexuality in heterothallic *Phytophthora* species are discussed.

BRASIER, C. M., and SANSOME, EVA (1973). Diploidy and chromosomal structural hybridity in *Phytophthora infestans*. *Nature, Lond.* **241**(5388), 344–345.

In a cytological examination of gametangia formed on pairing A^1 and A^2 isolates, and of gametangia formed by single A^2 isolates in response to *Trichoderma viride* two nuclear divisions, including stages of meiotic prophase were observed. This indicates that *P. infestans* resembles higher organisms in being diploid in the vegetable state. The chromosome number of *P. infestans* is 16–20 ($2(9 \pm 1)$).

Chromosomal structural hybridity in the isolates examined is described, and its significance for sterility in Phytophthora is discussed.

BROWN, R. M. (1972). The use of container and ball-rooted planting stock systems in Sweden and Finland. *Scott. For.* **26**(4), 268–284.

This paper is a report following a visit to Sweden and Finland in June 1971, and is a short version of Research and Development Paper 87. Container and ball-rooted systems of producing forest planting stock being used or tested in Sweden and Finland are described and their possible application to British conditions discussed.

BURDEKIN, D. A. (1972). Bacterial canker of poplar. *Ann. appl. Biol.* **72**, 295–299.

Bacterial canker is a serious disease of poplar and it is important for commercial planting to select those clones of poplar which show resistance to the disease. In inoculation tests, natural bacterial slime and a pure bacterial suspension gave similar extent of invasion. A study of the life-cycle of the disease indicated the presence of inoculum and of potential infection courts throughout the growing season. It is suggested that the susceptibility of a poplar clone should be determined by assessment of both artificial inoculations and natural infection.

BURDEKIN, D. A. (1972). A study of losses in Scots pine caused by *Fomes annosus*. *Forestry* **45**(2), 189–196.

Data are presented from unreplicated Scots pine (*Pinus sylvestris* L.) sample plots in Thetford Forest which have been differentially attacked by the fungus *Fomes annosus* (Fr.) Cooke. Volume production of severely infested crops differs markedly from that forecast by management tables. The volume of dead trees may not represent the total loss of volume in these plots as there appears also to be reduction in the growth of the remaining live trees. These observations may have considerable significance in forecasting future volume production from stands attacked by *F. annosus* and also in deciding the optimum time for their replacement.

BURDEKIN, D. A., and GIBBS, J. N. (1972). Dutch elm disease—recurrence and recovery in Britain. *Nature, Lond.* **240**(5379), 306.

Native elms attacked by Dutch elm disease in earlier outbreaks in this country frequently recovered from the disease. Evidence is presented to show that elms infected by the aggressive strain of *Ceratocystis ulmi* can show recurrence of symptoms in years following initial infection as a result of movement of the fungus from one annual ring to the next.

BURDEKIN, D. A., GIBBS, J. N., and MITCHELL, A. F. (1972). *The control of Dutch elm disease.* Leafl. For. Commn, **54** (HMSO 6p).

A revision and expansion of Research and Development Paper No. 78 presented as a popular pamphlet.

BYRNE, R. C. (1972). Results of an investigation into fertiliser response in pole-stage Sitka spruce: Forest of Ae, Dumfriesshire. *Scott. For.* **26**(4), 292–295.

CARTER, C. I. (1972). *Winter temperature and survival of the Green spruce aphid.* Forest Rec., Lond. **84** (HMSO 7p).

The Green spruce aphid, *Elatobium abietinum*, can acquire a type of cold-hardiness. Those individuals reared in mild conditions cannot withstand frost as well as those reared under cool conditions. Some newly-born unfed aphids have withstood a temperature colder than −19°C. A sudden air frost of −11°C following an otherwise mild winter could check

a potential spring outbreak. In Spring 1971 severe damage by the Green spruce aphid was confined to regions where the air temperature did not fall to −8°C during the preceding winter. In other regions a brief icy spell in late December 1970 and early January 1971 appeared to have killed sufficient aphids to prevent severe damage.

CARTER, C. I., and BARSON, G. (1972). Flight activity of alate Adelgids (Homoptera, Aphidoidea) in Southern England. *Bull. ent. Res.* **62**(3), 507–516.

The flight periods of eight species of Adelgids were deduced from suction trap catches in a mixed woodland site at Alice Holt, Hampshire, from 1965 to 1970. Nine species from other natural forest areas in the northern hemisphere occurred on trees in the study area, but some immigration may have contributed to the numbers trapped. Large catches (often >200) individuals per day of three pest species, *Adelges laricis* Vall., *A. cooleyi* (Gill.) and *Pineus pini* (L.), occurred during late May and June. Only small catches (<110 individuals per day) were obtained during July–September. The sexuparae from the non-*Picea* hosts occurred mainly in May and June whereas the gallicolae from *Picea* hosts flew during certain periods from June to September. Analysis showed that the threshold temperature for flight was 16°C and that 64 per cent or more of the total monthly catch occurred in the afternoon (13.00—19.00 h). The variation in length of the early summer flight period by ± one week was related to air temperature maxima, but the fluctuation (± one week) in the mean date for flight of each species in the early summer period is probably connected with the phenological condition of the host-plant.

CHARD, J. S. R. (1972). Forestry and wildlife. *Q. Jl For.* **66**(2), 113–122.

Our new conifer forests provide a constantly changing series of habitats for wildlife and encourage a much richer flora and fauna than the hill sheep farms they are replacing.

CHRISTIE, J. M. (1972). The characterisation of the relationships between basic crop parameters in yield table construction. IUFRO 3rd Conference Advisory Group of Forest Statisticians. Jouy-en-Josas, France. 7–11 September 1970, 37–58.

One of the basic difficulties in calculating yield tables is the accurate characterisation of the complex relationships that exist between the various crop parameters. This has been overcome to some extent by the methods discussed in this paper which were developed specifically to produce new yield tables in metric units to replace those given in the Forest Management Tables. The method offers one possible solution to yield table construction for use in those situations where because of limitation of data a graphical approach would normally be used. It suggests a method of subsequently characterising the basic relationships so that the final yield tables may be computed, thus providing functions that can be used to construct models to help solve management problems. It is not intended that this should supersede the more sophisticated methods of yield table construction that have developed in recent years (see for example, Vuokila, 1969; Decourt 1965, 1967) or methods of simulating stand development (see for example, Newnham 1965, Mitchell 1969). The method establishes the normal level of total production and by varying thinning treatment or spacing the total production is "broken down" into its component parts of standing crop and thinnings.

The method has already been used to produce simple variations of the yield tables and the programmes are currently being revised to allow the calculation of more complex models. The programmes were originally written in Sirius Autocode for use with computers at the Forest Research Station, but the revised programme is being written in Fortran.

CLARKE, J. C. (1973). The advantages of bark as a growing medium. *Nurserym. Garden Centre*, 25th January, 127–129.

In a "Compost Special" issue the advantages of bark for use in potting mixtures, such as superior aeration, freedom from pests, and light-weight, are described. The use of bark for orchid culture and bulb forcing are also outlined. Mention is made of the Commission's experiments which refute allegations of toxicity.

DICKSON, J. A. (1972). Seventh World Forestry Congress. *For. homegr. Timb.* **1**(4), 7 and 10.

A report is given of the Seventh World Forestry Congress held in Buenos Aires from 4–18th October 1972.

DRUMMOND, J. A., ROWAN, A. A., and TROUP, L. C. (1972). The place of short distance cable cranes in British forestry. *Scott. For.* **26**(2), 123–140.

A paper presented to the symposium on forest operations in mountainous regions held at Krasnodar, USSR, describing the cable-crane systems used by the Forestry Commission, with details of their operation, performance and costs.

EDLIN, H. L. (Ed.) (1972). *East Anglian forests.* Guide For. Commn, Lond. (HMSO 50p).

A popular account for visitors, with contributions from G. W. Backhouse, formerly Conservator of Forests for East England, and Conservancy staff and leading local experts on plant life, animal life, topography, geology, soils, antiquities and history. Includes artistic line drawings, mostly by Noel Spencer, aerial photos by Dr. J. K. St. Joseph, and an exceptional set of animal and bird photos by the late John Markham. Describes Thetford Chase and all other Commission forests in Norfolk and Suffolk.

EDLIN, H. L. (1972). Woodland notebook: Tourism in French forests. *Q. Jl For.* **66**(4), 338–345.

In 1966 the French Government created a new agency for the administration of its national and communal woodland estates, entitled the Office National des Forêts. Besides its economic function of growing timber for national needs this organisation was required to promote forestry for "social reasons", implying the conservation of landscape and the provision of tourist amenities. The author describes a journey across the country, five years later, and notes the welcome provisions now made for visitors to state and communal forests, though seldom on private estates.

EDLIN, H. L. (1973). *Woodland crafts in Britain.* Newton Abbot: David and Charles, 192 pp. 160 photos. £3·95.

A reprint, with a new foreword, of the comprehensive and fully illustrated book published by Batsfords, London, in 1949, out of print since 1955.

ELGY, D. (1972). Starling roost dispersal in forests. *Q. Jl For.* **66**(3), 224–229.

Some success has been achieved in dispersing starling roosts in forests by using amplified distress calls in conjunction with bird-scaring cartridges. On five occasions roosts were dispersed for a season in four nights. Attempts to disperse starlings from two other sites failed mainly because size and access problems reduced mobility of men and equipment.

EVERARD, J. E. (1973). Foliar analysis—sampling methods, interpretation and application of the results. *Q. Jl For.* **67**(1), 51–66.

In the Forestry Commission recommended practice for the analysis of foliage of slow-growing coniferous crops under 6 metres in height is to stratify the population by species, soil type, vegetation and, if necessary, vigour. Samples collected in each stratum consist of one shoot of the terminal whorl, taken between early October and mid-November from six dominants in a 0·01 ha plot.

Mean needle weight, per cent N, per cent P and per cent K are determined in the laboratory. The standards used for interpretation based on relationships of growth and the needle nutrient concentrations, are given for the major species. "Deficiency" in Sitka spruce foliage, the species most commonly sampled, has been set at $N < 1{\cdot}0$ per cent, $P < 0{\cdot}14$ per cent, $K < 0{\cdot}5$ per cent. In a varied, unpredictable situation, foliar analysis gives the manager a link with the reponse curves from fertiliser experiments, and should lead to the judicious use of fertilisers applied as top-dressing.

EVERARD, J. E. (1972). Next generation of ploughs? *For. homegr. Timb.* **1**(4), 38–40.

Methods of site improvement and the associated machinery are discussed and illustrated. The mounted deep tine plough successfully copes with dry sites, but difficulties are posed by wet sites with stumps. The Parkgate Humpy with deep double mouldboard combines deep drainage with the provision of planting turves. The use of Riggs and furrs and raised beds is discussed in relation to research experiments rather than forest practice.

GIBBS, J. N. (1972). Tolerance of *Fomes annosus* isolates to pine oleoresins and pinosylvins. *Eur. J. For. Pathol.* **2**(3), 147–151.

Ten *Fomes annosus* fungus isolates from pine and ten from non-pine-hosts were subjected to the volatile components of pine oleroresin and to various concentrations of pinosylvin (PS) and pinosylvin monomethyl ether (PSM). Both the volatiles and the PS and PMS significantly reduced growth rate compared with controls. However, no detectable difference existed between the two groups of *F. annosus* isolates in their reactions to the substances tested.

GIBBS, J. N., and BRASIER, C. M. (1973). Correlation between cultural characters and pathogenicity in *Ceratocystis ulmi* from Britain, Europe and America. *Nature, Lond.* **241** (5389), 381–383.

Isolates of *C. ulmi*, the causative fungus of Dutch elm disease, from Britain fall into two groups on the basis of cultural characters. Pathogenicity experiments show one group to be aggressive and the other to be non-aggressive. Some North American isolates resemble the aggressive isolates, while isolates from Northern Europe are non-aggressive.

GORDON, A. G. (1973). The rate of germination. In *Seed ecology* (ed. W. Heydecker), pp. 391–409. Butterworths. Proceedings of 19th Easter School in Agricultural Science 1972, University of Nottingham.

The inability of a seed to germinate is described in terms of a variable characteristic—its resistance to germinate—rather than an absolute characteristic as is normally understood in the term dormancy. It is shown that the loss of germination resistance—initially equivalent to the increase in number of seeds germinating—does not stop once all seeds have germinated. Significant changes take place in the germination of seeds long after they have lost all dormancy in the old sense. In studies on cereals this germination resistance is shown to be a heritable characteristic and to be affected significantly by environmental conditions in which the crop is grown. It is also shown to be affected significantly by conditions at harvest and during long-term storage. In all these studies the total germination was unaltered. Measures of changes in the rate of germination are seen therefore as more critical indicators of seed quality than simple total germination counts. Uses of the concept of germination resistance are discussed.

GRAYSON, A. J. (1972). *Valuation of non-wood benefits.* Res. Dev. Pap. For. Commn, Lond. **93**.

Cost-benefit analysis is the field of economics concerned with the identification and evaluation of costs and benefits (whether markets exist for them or not) from the point of view of society as a whole. Good progress has been made in recent years with evaluation of certain non-market benefits such as arise in recreation and examples are quoted of evaluations of effects on water yield and of informal day-visitor recreation which were made in a recent cost-benefit study of forestry in Britain. General amenity, or landscape, as well as nature conservation benefits are more difficult to handle but some approaches to the problem can be stated. More data on the physical and social consequences of forestry are needed. Even if the effects cannot be evaluated in money terms, more informed discussion will be possible than where no measurements are available.

GRAYSON, A. J., SIDAWAY, R. M., and THOMPSON, F. P. (1973). *Some aspects of recreation planning in the Forestry Commission.* Res. Dev. Pap. For. Commn, Lond. **95**.

Concentrates on informal day visitor recreation and discusses the valuation of recreational benefits to such visitors. A simple method of forecasting use at any given site can be combined with estimates of benefit per visitor-hour and costs of facilities to yield measures of return on the capital invested in recreation. Data on use and benefits accruing can also be used to study economically desirable variations in forest management necessary to maintain a continuing flow of recreation benefits.

HAMILTON, G. J. (1973). *Timber measurement for standing sales using tariff tables.* Bookl. For. Commn, **36** (HMSO 14p).

Provides detailed measurement procedures to be used primarily in connection with the sale of standing timber. Supersedes Forest Record 31, by giving metric values.

HOLMES, G. D. (1972). Forestry research in the future. *Ned. Boschb. Tijdschr.* **44**(11), 241–6.

A forward look at the probable development of forestry in the Netherlands and the UK in a paper delivered on the occasion of the 50th Anniversary celebrations of the Netherlands Forestry Research Station "De Dorschkamp". An attempt is made to show the way in which forest research is likely to move in the next 10 years.

HOLMES, G. D. (1973). What's ahead in research. *For. homegr. Timb.* **2**(1), 39–41.

An abbreviated version of the author's paper above.

HUMMEL, F. C., and DAVIDSON, J. L. (1972). *Planning and development of markets for man-made forests.* Res. Dev. Pap. For. Commn, Lond. **90**.

This paper is concerned with the planning of the primary markets for wood such as sawmills, pulpmills and particle board mills. It is written from the viewpoint of the forest owner and is based mainly on experience in Britain where the state and private growers embarked on a major afforestation programme after the 1914–1918 war. The forests and the industries based upon them are regarded as interdependent sectors of a single industrial complex with common interests. Four aspects of market development are regarded as being of particular importance: the assessment of wood supplies available for new developments; the formulation of a comprehensive industrial development strategy; the establishment of an institutional framework which ensures co-ordination of effort between growers and industrialists at national level; and, finally, commercial arrangements which ensure similar co-ordination at project level.

INGOLDBY, M. J. R. (1972). Tackling collection—a report on Forestry Commission work. *Fm Contractor*, June/July, p. 35.

Extraction using a light agricultural tractor—such attachments as the Alice Holt drawbar, Thetford tongs, Hydratongs and front mounted stackers are described.

JOHNSTON, D. R. (1972). *Formulation and implementation of forest policy.* Res. Dev. Pap. For. Commn, Lond. **89**.

Forest policy is formulated by governments on political grounds. Policy is interpreted and converted into strategy in the corporate plan of a forest enterprise. Regional tactical plans are prepared in the framework of the corporate plan. Operational planning is a matter of balancing work and resources within a timetable. Forest planning today is less concerned with ensuring a sustained yield of wood for local consumption than with the implementation of a variety of political objectives on a regional or national scale. Governments need to be aware of the functions which forestry can perform while foresters require an awareness of political aims. Forest policy has to be integrated with other sections of the economy. It cannot be stable for long periods, and it must respond to the economic, political and technological developments of the modern world. Investment in environmental forestry should not depend upon the returns from wood production. The discount rate used in making an appraisal of the social value of forestry to a country is too high for merely financial calculations. The planning functions of the various levels of management need precise definition. Flexibility is an important characteristic of planning. Financing and accounting must be compatible with the political objectives.

KEIGHLEY, G. D. (1973). Vibration and noise-risk of injury to chainsaw operators. *For. homegr. Timb.* **2**(1), 29–31.

Vibration induced white fingers (VWF) and the problems of hearing conservation are discussed together with the measures taken by the Forestry Commission to reduce their effects on chain saw operators.

LAX, J. (1972). Signs in the Forestry Commission. *Recreation News Suppl.* (7) August, 13–14.

Following a review of signs in 1970 it was decided to introduce a standard system of signing throughout the Commission. A unit system was devised which enabled the signs to be changed or removed at will. Machine routed lettering of two sizes was agreed upon and

the wood chosen was iroko, an African hardwood. The signs were painted in green and the lettering in white. The end product is a house style fully identified with the Forestry Commission.

LINES, R., and BOOTH, T. C. (1972). Investigation of basal sweep of Lodgepole and Shore pines in Great Britain. *Forestry* **45**(1), 59–66.

This paper comments on an earlier one by Moss (Forestry **44**(1), 43–69) and discusses in more detail some of the genetic and site factors affecting basal sweep. It highlights the reasons for choosing coastal provenances on many sites and gives data showing that they are not illustrating the slowing down in increment claimed by Moss.

LINES, R., and NEUSTEIN, S. A. (1970). Afforestation techniques for difficult sites: wetlands. Proc. VIth World Forestry Congr. Madrid, 1966 **2**, 1316–1326.

Defines wetlands and describes their classification and extent in North temperate Europe. Policy and site factors determine optimum treatment by ploughing, draining and manuring. Species and provenances suitable for wetlands are described and appropriate spacing and thinning treatments are suggested including a "no-thinning" policy.

LOW, A. J. (1973). The effective planting season in Scotland. *Scott. For.* **27**(1), 4–8.

The normal planting season in Scotland lasts for 10 to 14 weeks in late winter and spring, and most planting is completed during this period. Cold storage of plants allows large scale planting to continue until late summer. Planting of non-dormant stock in late summer is also used successfully. "Back-end" (autumn) planting is seldom used on any scale. Summer planting of container-grown seedlings may well expand in future, especially on peatland.

LOW, A. J., and BROWN, R. M. (1972). *Production and use of ball-rooted planting stock in Sweden and Finland.* Res. Dev. Pap. For. Commn, Lond. **87**.

Recent developments in the production and use of ball-rooted planting stock were studied during a tour of Sweden and Finland in 1971. Of the four main methods seen, three are concerned with seedlings grown in Japanese Paperpots, Kopparfors plastic pots and peat pots (Finnpots) respectively, while in the fourth, transplants are raised using the Nisula roll method. Each method is described, with assessments of the success achieved with it, and its relevance to British conditions. Information is also given on plastic houses which are widely used in Scandinavian forest nurseries for producing bare-rooted as well as a ball-rooted seedlings.

MACKENZIE, J. M. (1972). Early effects of different types, rates and methods of application of phosphate rock on peatland. *Proc. 4th Internat. Peat Congr.* **3**, 531–546.

A series of eight experiments was established recently in several areas of northern Britain on ploughed and drained acid peat. Either Lodgepole pine or Sitka spruce was planted at each site, according to local practice. Three types of finely ground phosphate rock from different sources were used—Kola, Nauru, Gagsa. These types were applied either as a spot application close to the plant, or as an overall broadcast application. Four initial rates were used.

Third year foliage analyses and height assessments were taken, and results of the series of experiments are given.

MAYHEAD, G. J. (1973). Sway periods of forest trees. *Scott. For.* **27**(1), 19–23.

The sway period of conifers in closed canopy is found to increase with increasing tree size. Trees may be considered to behave as would a uniform metal rod, firmly fixed at one end, of mass (M), length (L) and diameter (D) vibrating with a period of P, so that:

$$P = K \frac{L\sqrt{ML}}{D^2}$$

K is a constant.

Spacing and drainage intensity have no detectable effect on sway period.

MITCHELL, A. F. (1972). Biggest is not always best. *For. homegr. Timb.* **1**(4), 27 and 32.

A reasoned account of the numerous factors which hinder good survival, growth and appearance, of trees planted when they are large.

MITCHELL, A. F. (1973). Dutch elm disease and birds. *Bird Study* **20**(1), 84–7.

A resumé of the disease and its history in England, leading to some thoughts on the species of birds affected most adversely if the English elm were to diminish greatly in the countryside.

MITCHELL, A. F. (1973). Bedgebury Pinetum. *Amat. Gdng.* 3 February.

A popular account of the origins of Bedgebury and a brief summary of what it contains, illustrated by photographs.

MITCHELL, A. F., and WILLIAMS, J. (1973). *Common trees.* Bookl. For. Commn, **38** (HMSO 8p).

A popular booklet with drawings and brief descriptions of sixteen of the commonest broadleaved trees and sixteen of the commonest conifers.

MITCHELL, A. F. (1973). *Replacement of elm in the countryside.* Leafl. For. Commn, **57** (HMSO 4p).

A summary of the importance of elm in lowland scenery and how its loss cannot be fully replaced. The few species which share some of the attributes of English elm are specified and a table summarises the salient features of 20 species which may often be planted where there were elms.

MITCHELL, A. F. (1972). *Conifers in the British Isles.* Bookl. For. Commn, **33** (HMSO £2·25).

A summary of all that has been found about the growth of 270 species of conifers. Nearly all are fully described from original observations and all the main genera have full keys. Over 200 species and cultivars are illustrated by line drawings of foliage, and all the largest and best specimens known are tabulated.

NEUSTEIN, S. A., and WADDELL, J. (1972). Some investigations in the use of 35 mm aerial photography. *Scott. For.* **26**(3), 196–204.

Describes satisfactory trials by the UK Forestry Commission of a procedure for taking 35 mm aerial photos from a fixed-wing light aircraft without necessitating permanent modification of either aircraft or equipment. Black-and-white photos can be used for appraisal of stocking, assessment of windthrow damage and site classification of unplanted sites in terms of vegetation distribution; colour photos can be used for surveys of crops showing nutrient deficiency.

ORROM, M. H., and MITCHELL, A. F. (1972). *Silviculture and good landscapes in British forestry: the improvement of planning and practice.* Res. Dev. Pap. For. Commn, Lond. **91**.

The British forest landscape is seen as being largely man-made. The modern afforestation programmes after an early insensitivity now pay increasing regard to good landscape principles.

The cost of working to these principles is seen as involving some revenue foregone and requiring an input of landscape skills on two levels. The classification of landscape is discussed and it is recognised that with the growth of recreation in our forests, the forests open to visitors need the highest priority for the detailed landscape improvements to the woodland edge. Nevertheless this work needs to be based on a plan which recognises the intrinsic nature of the forest and is based on sound conservation principles.

The advantages of landscaping in forests are presented and discussed with a history of the three different forms of forestry practised in Britain. The differences among these kinds of forestry and their history have a profound effect on their impact with the landscape. Aesthetics are discussed, with an attempt to show that the basic requirements can usefully be stated, derived largely from the workings of the human eye.

Some aspects of forestry and forest landscaping are considered in the light of the basic aesthetics derived. It is stressed that a managed forest presents a rich pattern of habitats to the benefit of wildlife and of the variety of scenery. There should be little conflict between good forestry and good landscaping, and the areas of such conflict are discussed.

ROWAN, A. A. (1972). Harvesting systems, present and future. *Suppl. Forestry*, 13–36.

ROWAN, A. A. (1972). Perspective d'intéressement entre agriculture et forêt. *Bull. Soc. r. for. Belg.* **79**(6–6), 380–384.

The bulk of the forests owned by the Forestry Commission and forestry syndicates have been established on low quality farm land. Close integration of forestry and farming has rarely been possible, but this is the normal pattern on private estates. Only 4 per cent of estates in England and Wales have over 200 ha of forest, and only 11 per cent in Scotland. Tractors used in estate forestry are almost always farm tractors. Simple modifications such as winches, trailers, half-tracks, etc. allow enhanced production, but the very small scale of work, ignorance of technique and lack of marketing expertise are obstacles to higher productivity. Possible solutions are co-operative use of machinery by neighbouring estates, or hire from machine-hire companies, but the development of specialist firms of forestry contractors, employed by forest owners' associations, offers the best hope for full use of mechanisation.

ROWAN, A. A. (1972). Contraintes de mécanisation. *Bull. Soc. r. for. Belg.* **79**(6–7), 341–347. In French.

Mechanisation is the principal means of reducing the cost of forest operations, by reducing labour content; giving better working conditions; simplifying work; increasing the speed of the production process; by better quality of work; and by reducing waste. How far and how fast mechanisation should go depends on the relative costs of labour and machinery. High-production machines can only be used profitably on large forest management areas, and this presents difficulties in countries like Belgium and Great Britain where the majority of forest properties are small. We look for machines which are one-man operated, with low capital and depreciation costs; standardised components and work tools; flexibility and simplicity in use. Criteria for felling, extraction, processing and silvicultural machines are discussed.

SAMUEL, C. J. A., JOHNSTON, R. C. B., and FLETCHER, A. M. (1972). A diallel cross in Sitka spruce assessment of first year characters in an early glasshouse test. *Theor. appl. Genet.* **42**, 53–61.

The successful pollination of a complete diallel cross among six Sitka spruce (*Picea sitchensis* (Bong.) Carr.) trees is described, together with the assessment of a range of characters in the first growing-season of an early progeny-test in a glasshouse. Those characters chiefly concerned with tree form were found to be inherited in a predominantly additive fashion, whilst those characters reflecting various aspects of tree vigour were found to be under additive, dominance and maternal control. The results are discussed in the light of selection criteria and current techniques in Sitka spruce breeding.

SCOTT, T. M. (1973). *The pine shoot moth and related species.* Forest Rec., Lond. **83** (HMSO 14p).

The main features of the life cycle and the forest importance of nine species of moths previously classified in the single genus *Evetria* is described. All the moths are confined to pine trees mostly mining the buds and shoots, causing die-back and deformations. The most important species in England and Wales is *Rhyacionia buoliana*—the pine shoot moth, and in Scotland *Blastethia turionella*—the pine bud moth, although other species may become serious pests locally. Control measures recommended are mainly silvicultural although the use of insecticides may be justifiable in certain circumstances.

SIDAWAY, R. M. (1972). Assessing day visitor and camping use in the New Forest. In *The use of aerial photography in countryside research.* Report of a conference held in London on 29 March 1972, published by the Countryside Commission on behalf of the Countryside Recreation Research Advisory Group, pp. 4–7.

The paper assesses a trial of oblique aerial photography as a means of estimating day visitor and camper use in the New Forest. Flights were made on two occasions in 1971:

Bank Holiday Monday, 31 May, and Sunday, 2 August. The photographs were taken from a Cessna 172 flying at a height of between 1,000 and 1,300 feet. On three areas, ground counts were made simultaneously with the flights so that the counts made from aerial photographs could be checked. Panchromatic and colour cover were obtained on the first flight and colour cover only on the second. On the second flight it was found that most of the popular recreation areas in the New Forest could be covered in a period of two hours. Certain techniques to obtain overlapping coverage and a minimised masking by trees are given.

While the technique of oblique aerial photography looks promising for counting people and vehicles, it can only be used for open land in the forest. As more of the open areas in the New Forest become car-free zones, aerial photography will become less valuable. However, on suitable areas, aerial photographs provide a valuable permanent record and a source of further information for research.

(COLENUTT, R. J.*) and SIDAWAY, R. M. (1973). *Forest of dean day visitor survey.* Bull. For. Commn, Lond. **46** (HMSO 60p).

The first part of the report describes a survey of day visitors to the Forest of Dean which was carried out in the summer of 1968. The survey was designed to investigate the factors influencing day visitor demand and to predict future use of the forest. Among the problems that arise are the appropriate level of aggregation of the day visitor population and the independent effect of the relative location of the Dean. Models for predicting use of the forest are developed which forecast a considerable increase in numbers over the next decade. However, these forecasts must be qualified by limiting assumptions regarding underlying social changes and the interactions with use of other recreation areas.

In Part II the local and general significance of the survey results is considered. Certain of the survey findings give guidance to the management of individual sites in the Forest while the predictions for future use of the area have major implications for the management of the Forest Park. Possible strategies are suggested on the basis of the survey data and local knowledge. In the final section further research work and general policy considerations are discussed.

SIMPSON, L. M. (1972). The woodlands; their extent and location. In *Lowland forestry and wildlife conservation.* Symposium No. 6, Monks Wood Experimental Station, 3–24.

Data covering woodland changes, ownership, species, age, productivity and site classification are given.

SPENCER, J. A., and SIDAWAY, R. M. (1972). *The special contribution of forests and woodlands to recreation in an industrial society.* Res. Dev. Pap. For. Commn Lond. **92.**

Background trends in leisure and the countryside are given together with the Recreation Policy and the Role of the Forestry Commission. The Commission's achievements to date are listed and future plans are outlined.

STERN, R. C. (1972). Poplar growing at close spacing. *Timb. Grow.* May, (44) pp. 20–24, and *Q. Jl For.* **66**(3), 230–235.

The limitation of the future market for match splints coupled with the developments of new varieties of poplars and of other markets in recent years have indicated that a fresh approach to the method of growing poplars is worth examining. Making use of the results of the Commission's Research Division experiments on close spacing and on coppicing of poplar, and also making certain assumptions, based as far as possible on realistic appraisals, profitability assessments have been carried out on three different situations and at three different delivery costs. The indications are that growing at close spacing is reasonably profitable and coppicing possibly even more so, particularly if the markets (in particular pulp mills) are not too far.

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* Syracuse University, New York, USA.

STERN, R. C. (1973). Growing of hardwoods for pulpwood. *Scott. For.* **27**(1), 11–18.

There is a substantial area of utilisable scrub and of coppice in Britain, especially in the southern half of England. Much of this is suitable for pulpwood production. The silvicultural and economic aspects are examined and it is concluded that hardwood pulpwood crops can be an attractive commercial proposition if they arise from natural re-growth following fellings.

STERN, R. C. (1972). Marketing developments and timber needs. In *Lowland forestry and wildlife conservation.* Symposium No. 6, Monks Wood Experimental Station, 80–86.

Reviews the markets for the wood produced from lowland forests. Considers that markets for coniferous wood are both satisfactory and stable, but for hardwoods it is thought probable that supplies of the better grades of logs will become increasingly scarce. The implications for conservation and for methods of growing are discussed.

THOMPSON, D. A. (1972). Post-establishment treatment of Sitka spruce. *Scott. For.* **26**(4), 288–291.

Afforestation of hill ground in the South West with Sitka spruce is faced with two problems; the increasingly heather (*Calluna vulgaris*) dominant vegetation and low nutritional status soils. To attain high yields we cannot tolerate a slowing of growth rate, and a systematic approach to the management use of 2, 4-D and fertilisers depending on the development of the crop and ground vegetation is recommended.

WEBB, P. J. (1973). An alternative to chemical stump protection against *Fomes annosus* on pines in state and private forestry. *Scott. For.* **27**(1), 24–28.

The background to biological control of the fungus *Fomes annosus* using *Peniophora gigantea* is briefly outlined and the practical application of *Peniophora* stump treatment is described.

WHAYMAN, A. (1972). Extraction machinery. *Suppl. Forestry*, 64–72.

The factors influencing the choice of extraction machinery are discussed together with a broad classification of the types available.

WITTERING, W. O. (1973). Technical Note 5—Weed rollers. *For. homegr. Timb.* **2**(1), 44.

The control of such grasses as *Calamagrostis*, etc. by rolling is described together with indications of outputs and costs.

WITTERING, W. O. (1972). Machines offer economy in weed killing. *Fm. Contractor*, **1**(1), 54.

The place of the weeding machine in the forest armoury together with details of costs is discussed.

APPENDIX II

Staff Engaged in Research and Development

As at 31st March 1973

The main centres for research and development are:

FORESTRY COMMISSION RESEARCH STATION
Alice Holt Lodge
Wrecclesham
Farnham, Surrey. Tel. Bentley (Hants) 2255 (STD Code 042 04)

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 Princes Risborough Laboratory of the Department of the Environment's Building Research Establishment, 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	N. E. Stutter, A.M.I.P.M. (*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, pathology and entomology, and for seed supply, publications, photographic and engineering services).

SEED (*Alice Holt*)
G. M. Buszewicz, Mgr. Eng. (For.), Head of Section
A. G. Gordon, B.Sc. Agric., Ph.D.

Laboratory:	T. A. Waddell, D. C. Wakeman: Mrs. L. S. Billany, Mrs. E. M. Boswell: Miss R. E. Crumplin, Mrs. E. Hart-Dyke
Seed Store and Extractory:	M. D. Witts (Research Forester): L. Crumplin
Office:	Miss P. A. M. McCunnin: Mrs. M. Greenwood

6574 N

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. J. W. Greig: J. E. Pratt, R. G. Strouts, J. Dickinson, N.D.F.D.
Laboratory:	E. J. Parker, M.I.Biol.: Miss J. S. Cross, Miss P. M. Smith: M. Awdry, Miss A. Trusler
Office:	Miss S. R. Wilcox: Mrs. J. G. Anderson (Typist)

Northern Research Station

D. B. Redfern, B.Sc., Ph.D.
S. C. Gregory, M.A., Ph.D.

Research Forester:	J. D. Low
Laboratory:	Miss S. H. Harris

ENTOMOLOGY, WILDLIFE

D. Bevan, B.Sc., Head of Section

ENTOMOLOGY

Alice Holt

Miss J. M. Davies, B.Sc.
C. I. Carter, M.Sc., M.I.Biol.
T. M. Scott, B.Sc.

Research Foresters:	R. M. Brown, L.I.Biol.: D. J. Billany, C. J. King, C. Walker
Laboratory:	T. G. Winter: M. Jukes, L. J. O'Neill, Miss J. Slater
Office:	J. Ellison

Northern Research Station

J. T. Stoakley, M.A., M.Sc., D.I.C.

Laboratory:	D. A. Barbour

WILDLIFE (*Alice Holt*)

Miss J. J. Rowe, B.Sc., Dip.Cons., Head of Sub-Section

Research Foresters:	L. A. Tee: R. A. Baldwin (*Bourne*), H. W. Pepper, S. J. Petty
Laboratory:	B. A. C. Don: Miss M. M. P. Johnston

PHOTOGRAPHY (*Alice Holt*)

I. A. Anderson, F.I.I.P., Head of Section
Mrs. T. K. Evans, F.R.P.S.
Mrs. H. J. Geoffrey
J. Williams (Illustrator)
Miss M. Trusler

Office: J. G. Jackman

ENGINEERING SERVICES (*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. G. E. Copeman: Mrs. R. Mathias

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)

SILVICULTURE (NORTH) (*Northern Research Station*)

R. M. G. Semple, B.Sc., Head of Section
R. Lines, B.Sc.
A. J. Low, B.Sc., M.Sc.F., Ph.D.
S. A. Neustein, B.Sc.
T. C. Booth, B.Sc.
J. M. Mackenzie, B.Sc.
D. A. Thompson, B.Sc.

		Centre
Research Foresters:	N. P. Danby	Northern Research Station
	A. B. Lewis	Northern Research Station
North Scotland Region		
North Scotland Area	A. A. Green, M. K. Hollingsworth	Fort Augustus
North East Scotland Area	J. E. Kirby, N. MacKell	Lairg, Sutherland
East Scotland Area	E. R. Robson: A. L. Sharpe, A. W. F. Watson	Newton, Elgin
Central Scotland Region	J. H. Thomson	Northern Research Station
Central Scotland Area	W. G. Paterson A. McInnes: J. D. Lindsay, M. Rodgers	Kincardine-on-Forth Perth
South East Scotland Area	J. B. McNeill, A. H. Reid	Northern Research Station
West Scotland Area	A. R. Mair: E. A. Crofts	Kilmun, by Dunoon, Argyll
South West Scotland Area	E. Baldwin: J. D. McNeill	Mabie, Dumfriesshire
North England Region	G. Bartlett	Wykeham, Scarborough
North East England Area	K. A. S. Gabriel: J. E. J. White	Wykeham, Scarborough
Borders Area	G. S. Forbes: P. Priestley, D. L. Willmott	Kielder by Hexham, Northumberland

SILVICULTURE (SOUTH) (*Alice Holt*)

J. R. Aldhous, B.A., Head of Section
M. A. Anderson, B.Sc.
R. M. Brown, B.Sc.
J. E. Everard, B.Sc.
J. Jobling, B.Sc.
A. F. Mitchell, B.A., B.Agric. (For.), V.M.H.
G. J. Mayhead, B.Sc., Ph.D.

Office: P. H. Hamilton: F. R. W. Stevens (Research Forester): Mrs. A. Johnston: Mrs. S. A. M. Bridger

Research Foresters:		*Centre*
South East England Region	R. M. Ure	Alice Holt
South East England Area	P. W. W. Daborn, J. B. H. Gardiner, M. L. Pearce: D. W. H. Durrant, P. D. Howard, A. M. Jenkin, P. Marsh, F. S. Smith	Alice Holt
Wareham Area	L. A. Howe: G. F. Farrimond	Sugar Hill Nursery, Wareham Forest
Bedgebury Area	A. W. Westall: M. J. Scott	Bedgebury Pinetum
South West England Region	D. A. Cousins	Westonbirt
South West England Area	K. F. Baker: D. T. A. Hendrie	Exeter
Dean and South Wales Area	K. Broad, F. C. Thompson, T. J. Davies	Dean
	A. J. A. Graver, C. J. Large	Brecon
Westonbirt Area	E. Leyshon: P. J. Webb, 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: R. Dean	Knighton, Radnor
East England Region	I. H. Blackmore: P. A. Gregory, R. E. A. Lewis	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.: I. G. Carolan

Laboratory: R. Carnell: Mrs. S. A. Wright: Miss K. G. Corfield, Mrs. J. E. Parker, Mrs. D. Wild, Mrs. N. Johnson

Northern Research Station

D. G. Pyatt, B.Sc.

Research Forester: T. E. Radford

Laboratory: G. D. Bell, B.Sc., D. T. McLaren, B.Sc.

GENETICS (*Northern Research Station*)

R. Faulkner, B.Sc., Head of Section
A. M. Fletcher, B.Sc., Ph.D., A.I.W.Sc.
R. C. B. Johnstone, B.Sc., M.Sc.
G. I. Forrest, B.Sc., M.Sc., Ph.D.

Research Foresters:	C. McLean: R. B. Collins, I. J. M. Dawson (*Westonbirt, Glos.*), M. T. T. Phillips (*Newton, Elgin*): W. Brown, D. S. Coutts (*Inchnacardoch*), G. C. Webb (*Westonbirt*)
Laboratory:	Miss B. P. Branson, M.A., Mrs. N. Campbell

PHYSIOLOGY (*Northern Research Station*)

M. P. Coutts, B.Sc., Ph.D., Head of Section
M. R. Bowen, B.Sc., Ph.D.

Research Forester:	J. Howarth
Laboratory:	Miss C. M. H. Flint, B.Sc., Mrs. M. A. Willet, B.Sc.

STATISTICS

Alice Holt

R. S. Howell, Head of Section
C. J. A. Samuel, B.Sc., Ph.D.
I. D. Mobbs, M.I.S.
R. C. Boswell, B.Sc.
G. J. Hall, B.Sc.
Miss B. J. Smyth, B.Sc.
Miss C. A. Spence, B.Sc.

Research Foresters:	A. E. Coates, C. A. Thorne: M. H. M. Webb
Machine Operators:	Miss I. B. Timperley: Mrs. E. Butler, Mrs. S. M. Nicholls, Mrs. E. C. Wilson
Office:	Mrs. C. A. Yeomans: Mrs. A. M. Clements (Typist)

Northern Research Station

D. H. Stewart, B.Sc., M.I.Biol., F.I.S.
Mrs. J. Birchall
Miss A. C. Elmhirst, B.Sc.
Miss A. C. Roberts, B.Sc.

Machine Operator:	Mrs. M. Robertson

RESEARCH INFORMATION SECTION (*Alice Holt*)

O. N. Blatchford, B.Sc., A.I.Inf.Sc., Head of Section
Miss T. M. Crowley, B.Sc.
Mrs. J. A. Gower, F. C. Fraass, S. H. Sharpley: Mrs. M. Butt:
Mrs. L. D. Birchall (Typist)

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Alice Holt

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Establishment:	L. W. Thomas: Mrs. A. C. Vandeleur-Boorer, B. D. Higgins: Miss J. R. Lacey

Finance:	Miss N. Murphy: Mrs. M. Harvey, Miss G. B. Hayden, N. A. Trollope: Mrs. L. Land
General Services:	Miss S. B. Page: W. E. Powell: Mrs. K. S. Butcher
Typists:	Miss M. Hopkin (Superintendent): Mrs. E. L. Allen, Mrs. B. E. Dickinson, Mrs. F. E. Edwards, Mrs. J. Richardson, Mrs. E. A. Walters
Photoprinter:	F. H. Khawaja
Telephone Operators:	Mrs. E. A. R. Empson, Mrs. J. M. Plant
Messengers:	C. H. Beckett, Mrs. L. Gower
Gardens:	H. Farr
Workshop:	R. H. Butt, R. D. Butt: E. V. Tattam

Northern Research Station Office:	P. Hunter: J. F. Black: R. F. Fotheringham, Miss M. E. Grant, Mrs. E. M. Hiddleston: J. A. Ballantyne, Miss J. M. Black
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Telephone Operator:	Mrs. A. A. Martin
Messenger:	C. Stewart
Workshop:	J. Dixon: R. McLuckie

MANAGEMENT SERVICES DIVISION

(The main Organisation and Methods Branch, based in London, and the Central Drawing Office, based at Basingstoke, are not included here)

Director	D. R. Johnston, M.A. (*Alice Holt*)
Personal Assistant	Mrs. M. E. Douglas
Office:	J. Empson

PLANNING AND ECONOMICS BRANCH (*Alice Holt*)

A. J. Grayson, M.A., B.Litt., Head of Branch
R. J. N. Busby, B.Sc.
J. Dewar, B.Sc.
J. F. Morgan, B.Sc.
R. M. Sidaway, M.A.
*P. A. Wardle, B.Sc.
E. R. Adams, B.Sc., A.I.S.
R. Q. Oakes

Foresters: G. D. Spiller: K. Mills

FIELD SURVEYS BRANCH (*Alice Holt*)

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