REPORT ON

FOREST RESEARCH

1971

FORESTRY COMMISSION

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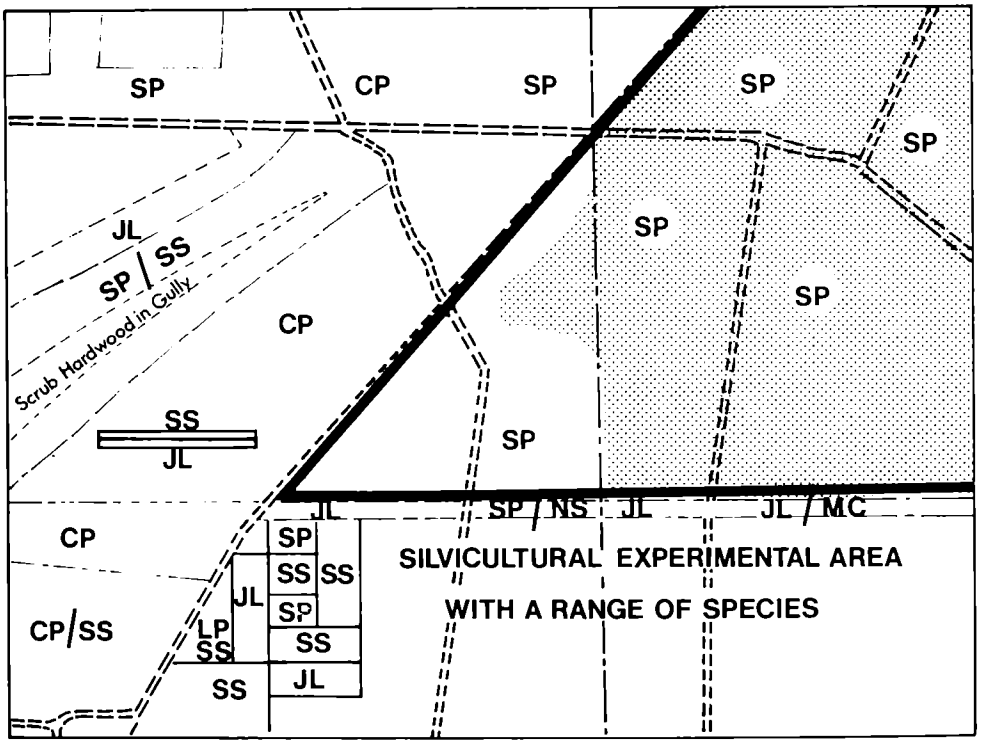

The plate on the cover is of an area photographed on 4 May 1970, in infra-red colour ('false colour') to indicate areas of Scots pine damaged by the Pine looper moth, Bupalus piniarius, *in Wykeham Forest, Yorkshire.* (*See Entomology, page 85*).

The above diagram explains the variously coloured areas in the photograph.

The top right-hand sector bounded by the solid line is of Scots pine with a few scattered Japanese larch, all planted in 1930. The pine defoliated by Pine looper appear blue in the photograph (stippled in the diagram), those relatively unaffected are a deep purplish red; the Japanese larch are pink.

The area covered by the photograph also includes other tree species planted both in the normal afforestation programme and in silvicultural experiments. Gaps in some of the silvicultural plots have been caused by mechanical uprooting of trees to compare the rooting patterns of tree species in connection with their susceptibility to windthrow.

Key to tree species: CP Corsican pine, JL Japanese larch, LP Lodgepole pine, MC Mixed conifers, NS Norway spruce, SP Scots pine, SS Sitka spruce.

FORESTRY COMMISSION

REPORT ON FOREST RESEARCH

for the year ended
March 1971

LONDON
HER MAJESTY'S STATIONERY OFFICE
1971

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885282 A 2

The abbreviated title of this Report is:
Rep. Forest Res., Lond. 1971

Corrigenda to Rep. Forest Res., Lond. 1970

Page 23, line 17. For ammonium nitrate, read ammonium sulphate.
Page 32, last line. For 20°C—30°C, read +20°C to −30°C.
Page 124, line 13. Delete *Evetria purdeyi* Durr.

CONTENTS

ACKNOWLEDGMENTS

The cover picture (described on inside front cover) is by Dr. J. K. S. St. Joseph, Director in Aerial Photography, University of Cambridge. Plate 12 is by the Department of Trade and Industry's National Engineering Laboratory, East Kilbride. All other photographs are from the Forestry Commission's Official Photographic Collection. The diagrams were supplied by the authors and prepared for publication by the Commission's Photographic Section.

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INTRODUCTION

By G. D. HOLMES

Director of Research

Advisory Committee on Forest Research

The Committee met at the Northern Research Station in Edinburgh in October 1970, when a major item for consideration was the report of the Visiting Group appointed by the Committee to examine the work and organisation of our Silviculture, Soils and Ecology Sections. The Group members were Professor J. D. Matthews, Department of Forestry, University of Aberdeen (Chairman); Dr. R. W. Gloyne, Meteorological Office, Edinburgh; Professor J. P. Hudson, Director, Long Ashton Research Station, Bristol; Dr. R. L. Mitchell, Director, Macaulay Institute for Soil Research, Aberdeen; Mr. R. G. Sangster, Secretary, Scottish Woodland Owners Association Ltd., Edinburgh; Professor W. J. Thomas, Department of Agricultural Economics, University of Manchester, and Professor E. K. Woodford, Director, Grassland Research Institute, Hurley. In terms of staff and resources the work of these three Sections represents some 60 per cent of the entire Division and the examination of their work and methods by the Group was a major and demanding task extending over five days from September 13th to 18th, 1970. Many valuable recommendations were made and we are most grateful to the Group, and to our Advisory Committee, for the effort and skills they put into this job. This is the third Visiting Group we have had, the first having been in 1966 concerned with Seed and Tree Improvement work, and the second in 1968 on Forest Protection. Like the earlier ones, the present examination was stimulating and useful, not least in the "stocktaking" involved in the preparations, and in the discussions with Group members. It was agreed that the next Visiting Group would be in 1972 on the work of our Physiology, Genetics, and Seeds Sections.

The Research Programme and Report

The *Report*, which has been deliberately shortened compared with recent years, describes progress with the main projects being tackled within the Research, Management Services and Harvesting and Marketing Divisions, and by research workers doing work for the Commission in other Institutions. The list of Contents, the Index, and the Review by Dr. Phillips and Mr. Holtam (pp. 7–21) will help the reader locate the topics that interest him.

Our research continues to be predominantly applied or "mission-oriented" in the sense that work is aimed at particular practical objectives, with the broad aim of improving the benefits of forests and devising more efficient means of achieving them. However, an element of more speculative research, particularly on biological phenomena, forms an important and vital part of the total programme. The scope of the programme is very wide and I will not attempt a detailed summary here, but I would draw attention to a few special features of the current work. There has been an increase in research on

diseases of hardwood species, including elm due to the recent resurgence of Elm disease; *Phytophthora* species causing root diseases in hardwoods; beech bark disease causing damage in parts of the South; and die-back of London plane. For control of major pests and diseases, efforts continue to find alternatives to DDT. In combating *Fomes annosus* a major step forward has been replacement of chemical treatment of pine by biological control using a competing fungus (*Peniophora gigantea*).

Weed control remains costly and difficult and the search continues for effective herbicides and methods which minimise hazards to man and wildlife.

Intensive production of plants in tubes and paper pots shows promise of work flexibility and reduced growth check on planting.

Two features of the joint Forest Products Research Laboratory/Forestry Commission programme are of particular importance, namely the start of a major programme of work on machine stress-grading of softwoods, and some revealing work on the effect of increased vigour of growth achieved in various ways, on wood properties.

A study of demand for recreation facilities in forests by day-visitors was completed to help pin-point development opportunities.

In the Work Study field, important progress was made in design and construction of hydrostatic frame-steering forest tractors and development of long-range " skyline " cable-crane systems.

Research Facilities

Edinburgh-based staff moved into our new Northern Research Station building on the Bush Estate of the Edinburgh Centre of Rural Economy in February 1970. The building was officially opened on 8th May 1970 by the Secretary of State for Scotland. This provides laboratories and modern facilities for staff, most of whom had been accommodated for some years in unsatisfactory offices. The new laboratories and equipment of the Station, which includes substantial controlled environment rooms and glasshouse facilities, complement the facilities at Alice Holt and should strengthen the support we are able to give to forestry, not only in the North but throughout Britain. About two-thirds of our professional, scientific and technical staff are now based at Alice Holt and one-third at the Northern Research Station.

The location of the " NRS " on a " campus " of research institutes on the Bush Estate is excellent, and we are very grateful to the staff of the Edinburgh Centre of Rural Economy and the Royal Botanic Garden, Edinburgh, for their help in developing the Station. We also acknowledge with gratitude the internal panelling and entrance gates, donated by the Home Timber Merchants Association of Scotland, and the Scottish Woodland Owners Association, Ltd.

Our new IBM 1130 Computer was installed at Alice Holt in March 1971 to replace the now obsolete Sirius machines, in order to give the necessary data-processing support to all staff engaged in research and development work.

January 1971 saw the final closure of Kennington Nursery, Oxford, after management as a research nursery since 1925. Much pioneer work on forest nursery techniques has been done at this centre over the years, and much that is now standard practice originated there. However, reduced programmes on conventional nursery systems required that the centre be closed.

Research Liaison and Communications

Close contacts were maintained with many research organisations at home and abroad. At home, this applies particularly to the Universities, Forest Products Research Laboratory, the Nature Conservancy, and to the members of staff of the newly formed Institute of Tree Biology of the Natural Environment Research Council, located in Edinburgh. With close liaison of the research staff concerned, the work of these organisations and our own can be made mutually complementary.

Advisory and extension work by research staff is of great importance and provides in effect a two-way flow of information with forest managers and supervisors. Several meetings and seminars were arranged to help communicate research information to managements, including a whole-day discussion with SWOA at the NRS on the needs of the private woodland owner, and meetings with Forestry Commission Assistant Conservators, and organisation of refresher courses for District Officers on technical developments.

Publications remain a major avenue of communication, and the design and treatment of our official publications has been amended to improve their appearance and impact.

Visitors

A total of 600 visitors were received at Alice Holt during the year. There were 22 visiting parties, including a Working Group of the International Union of Forest Research Organisations (IUFRO) on Operational Research, the International Poplar Commission, the Technical Sub-Committee of the Timber Growers Organisation, and a large party from the Royal Forestry Society. Aberdeen, Bangor and Oxford forestry students again visited us on two-day visits. A valuable opportunity to exchange information on agricultural research came with a visit of the Heads of Technical Services, at the Ministry of Agriculture, Fisheries and Food.

Conferences

G. D. Holmes, J. R. Aldhous, R. Faulkner, A. J. Grayson, Dr. W. O. Binns, D. A. Burdekin, and A. Whayman, and also M. H. Orrom of Forest Management Division, attended the 15th IUFRO Congress at Gainesville, Florida, in March 1971.

In connection with the Congress, G. D. Holmes made a tour of research centres in south-east USA ; J. R. Aldhous toured in Florida, Georgia and North Carolina, and discussed safety matters and the current use of herbicides ; R. Faulkner visited experimental work in tree breeding and tree nutrition in Florida, Georgia, Alabama, Mississippi and Louisiana ; A. J. Grayson toured Florida, Georgia and North Carolina, and saw the work of

the National Park Service and of Resources for the Future, Inc.; Dr. W. O. Binns saw hydrological and silvicultural research work in Georgia, North Carolina and Tennessee; D. A. Burdekin visited forest pathology laboratories in Georgia and North Carolina; A. Whayman made a tour of mechanised forestry operations in Georgia and Alabama; M. H. Orrom visited recreational sites across the country, and the headquarters of the National Parks and Forest Services.

Participation in other international meetings included: D. R. Johnston (United Kingdom delegate to the 15th European Forestry Commission, Rome); P. A. Wardle (Chairman of the IUFRO Working Group on Managerial Economics and Operational Research, at Alice Holt); D. A. Burdekin (7th International Congress of Plant Protection, Paris, and FAO Working Party on Diseases of the International Poplar Commission, Alice Holt); C. I. Carter (9th Commonwealth Entomological Conference, London); A. Whayman (IUFRO Working Group on Mechanisation of Timber Transport, Finland); R. Lines (International Meeting of the Association of Belgian Geneticists, Belgium); S. A. Neustein (7th International Symposium on Forest Fume Damage, Essen); J. M. Christie (3rd Conference of the IUFRO Advisory Group of Forest Statisticians, Paris). Attendance at nearly twenty Conferences at home included G. D. Holmes to the Tercentenary of the Royal Botanic Garden, Edinburgh, and with A. F. Mitchell and R. Lines to the Conifer Conference, London; D. H. Phillips and O. N. Blatchford to the Commonwealth Agricultural Bureaux Conference, London; A. J. Grayson and J. F. Morgan to the Annual Conference of the Institute of Management Science; R. M. Brown to the 10th British Weed Control Conference, Brighton, and several staff attended the Society of Foresters Symposium in Edinburgh in January.

Visits Abroad

Dr. A. M. Fletcher and N. P. Danby, on behalf of IUFRO, organised provenance collections of Sitka spruce cones from sample trees at each of 47 locations in British Columbia and Alaska. Dr. K. A. Longman visited the Federal Forest Research Institute, Nigeria, and the Forest Products Research Institute, Ghana, as consultant on tree improvement projects for the Overseas Development Administration. C. I. Carter visited Delemont, Switzerland, to discuss possible biological control methods of Adelgids. R. M. Sidaway took part in a tour of recreation areas in Holland, arranged by the Countryside Commission. W. O. Wittering and F. B. W. Platt visited Brunnsta, Sweden, to see a demonstration of forest machinery arranged by Volvo Ltd. C. W. T. Young visited the Forest Research Institute at Wageningen, Holland, to discuss top-dying of Norway spruce and die-back of Corsican pine.

Staff Changes

D. R. Johnston was promoted Director of Management Services, in succession to J. Q. Williamson who resigned from the Commission. The former Planning and Economics Branch of Management Services Division was divided into two, Planning and Economics Branch under A. J. Grayson, and Field Surveys Branch under L. M. Simpson.

Other transfers and promotions: A. R. Sutton (District Officer I, Work Study) left on five-year loan to the Civil Service Department on promotion to Assistant Conservator. G. M. L. Locke (District Officer I, Field Surveys) returned from Alice Holt to Edinburgh. R. T. Bradley (District Officer I), from Planning and Economics to West Scotland Conservancy. A. Ray (District Officer I), from North Scotland Conservancy to Work Study (Brockenhurst). J. T. Stoakley (District Officer I) returned to Research Division (Entomology N.) from North Scotland Conservancy. D. A. Cooper (District Officer II), from North Scotland Conservancy to Field Surveys Branch. D. H. Stewart (Senior Scientific Officer, Statistics), from Alice Holt to Northern Research Station. C. I. Carter (Entomology) and Dr. A. M. Fletcher (Genetics) were promoted to Senior Scientific Officer.

J. E. Everard (Silviculture S.), Dr. A. J. Low (Silviculture N.) and J. F. Morgan (Planning and Economics) were promoted to District Officer I. R. D. L. Toleman (District Officer II, East England Conservancy) moved to Field Surveys (Northern Research Station) and was promoted to District Officer I. T. C. Booth (Silviculture N.) was promoted from Forester to District Officer II. G. Bartlett and J. H. Thomson (Silviculture N.) were promoted to Chief Forester. P. A. Hills became Deputy Administration and Finance Officer on promotion to Higher Executive Officer from East England Conservancy, to succeed W. D. Wardrop who moved to Finance Division, Edinburgh.

Staff newly appointed during the year: Dr. A. G. Gordon (Senior Scientific Officer, Seed Section); Dr. G. I. Forrest (Scientific Officer, Genetics); G. J. Hall and Dr. C. J. A. Samuel (Scientific Officers, Statistics); J. Williams (Illustrator); Mrs. J. Birchall and Miss C. A. Spence (Assistant Experimental Officers in Statistics N. and S. respectively).

Departures from the Commission included the retirement of A. M. Mackenzie (District Officer I, Field Surveys) and the resignations of Dr. D. R. Causton (Senior Scientific Officer, Statistics N.), I. S. D. Hay (Illustrator) and Mrs. J. M. Boyd (Assistant Experimental Officer, Statistics).

Awards

H. L. Edlin, Publications Officer, was awarded the MBE; A. F. Mitchell (Silviculture S.) was awarded the Victoria Medal of Honour of the Royal Horticultural Society; Ph.D. degrees were conferred on Dr. A. I. Fraser, at Edinburgh University, and Dr. C. J. A. Samuel at University College of Wales, Aberystwyth; J. M. W. Black, Scientific Assistant in Soils Section (North), gained admission to Aberdeen University in the Science faculty as from October 1971.

Obituary

We sadly record the deaths of two colleagues. J. M. Littler, Clerical Officer in Finance Section at Alice Holt, died suddenly in February 1971. R. C. Kirkland, Head Forester in Entomology Section at the Northern Research Station, died in November 1970. He had been a member of the Section since 1950, and his long experience will be greatly missed.

REVIEW OF THE YEAR'S WORK

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

PART I

RESEARCH DIVISION

Forest Tree Seed

Home seed crops this year were in general relatively poor. Nevertheless, the home collection of Hybrid larch seed (in which demand usually greatly exceeds supply) was one of the largest for some time, and will meet requirements for the next two years. Among the hardwoods, seed of *Nothofagus* species has always been difficult to import, but this year useful quantities of seed of *N. procera* and *N. obliqua* were collected from home stands.

Fairly large quantities of seed (particularly of Sitka spruce from Queen Charlotte Islands, British Columbia) were imported to build up stocks.

Research was carried out to compare the effects of constant with those of alternating temperatures on germination of seeds of Sitka spruce and Lodgepole pine. Sitka spruce germinated best at a constant temperature of 25°C, but Lodgepole pine germinated best when the temperature was alternated between 20 and 30°C.

Work was carried out in collaboration with the Commonwealth Forestry Institute, Oxford, to find the best stage at which to collect cones of *Pinus merkusii*, samples of which were sent for this purpose from the Philippine Islands.

New work is being developed on dormancy of conifer seeds, and on the fate of non-productive seeds in the nursery.

Production and Use of Planting Stock

Research on methods of raising conventional planting stock was further reduced. Most results from experiments on slow-release fertilisers, late top-dressing, use of simazine and precision sowing were similar to those in previous seasons. In Scottish trials, soil sterilisation with dazomet emerged as a possible treatment for seedbed weed control. Trials at Wareham showed that dipping plant roots in sodium alginate solution was no substitute for enclosure in polythene bags or boxes during storage. However, where short-term box storage is used, root dipping prior to boxing may give improved results.

Results from a large greenhouse experimental programme led to some changes being made to the "standard" procedure for producing tubed seedling stock. Using Lodgepole pine and Sitka spruce seed of high viability it is possible to obtain a usable 8-week-old seedling yield of 65-75 per cent. Forest trial results continue to suggest that, in the absence of serious animal damage, tubed seedlings will be suitable for afforesting upland peat sites with an effective planting season from mid-April to late

August. During 1971 a large-scale user trial will take place in North Scotland Conservancy; almost 300,000 Lodgepole pine tube seedlings will be raised and planted. A special planting tool has been developed which enables a man to plant well over 3,000 tube seedlings per day.

Work continued on the development of the most appropriate techniques for producing transplants of Corsican pine, Sitka spruce and Grand fir rooted in polythene rolls. Preliminary trials of the Japanese paper pot system for seedling production gave promising results with Sitka spruce and Corsican pine.

In forest trials at Towy (Cardiganshire) and Thetford (Norfolk), early performance of transplants grown in polythene rolls compared well with that of normal transplant stock.

Choice of Species: High and Exposed Sites

Attempts are being made to correlate flag tatter with windthrow risk, to try to make it possible to include an appreciation of critical height in the earliest investment appraisals.

There is some evidence of improved tree growth in the smoke-polluted South Pennines and further work is proposed to establish cause and current prospects.

Provenance

Lodgepole Pine

First results of experiments with four Alaskan provenances show little difference among them, though all grew more slowly than others from more southerly latitudes. Further studies of the root/shoot ratios of different provenances show that the pattern found with transplants is similar to that found with seedlings; Alaskan provenances had the highest, and southern coastal provenances the lowest ratios. The new series of 14 experiments using up to 86 provenances was successfully established except at Glengarry (Inverness-shire), and one new experiment was planted at Rumster. R. Lines was appointed Co-ordinator for the new IUFRO series of experiments using up to 146 provenances and a plan was issued to co-operators. Part of this collection sown at Newton (Moray) showed rather variable germination due to poor climatic conditions.

Scots Pine

The patterns of height growth of 11 provenances from seed stands grown at three sites in East Scotland were similar at 15 years to those of earlier assessments, and statistical precision has improved. There was a significant correlation between needle length and tree height. The tallest provenance is from a stand believed to be of German origin while the only certain native one grew slowly.

Sitka Spruce

A small study of seed gathered from plantations of unknown origin showed that, when grown in comparison with known provenances, it was possible to separate most trees of unknown origin into northern or southern groups on the basis of needle colour and rate of autumn bud formation.

Large-scale plantings of Washington provenances in 1968/70 were sampled to check whether they suffered heavier losses than those from Queen Charlotte Islands, British Columbia. Such heavier losses occurred at a few forests but the main danger is at the nursery stage. The collection of 14 provenances planted at 14 sites was assessed at 10 years of age. The tallest provenances were from Jutland (ex Washington) and Sooke, Vancouver Island, B.C. The Oregon provenances were the tallest group followed by those from Washington, then came one from Queen Charlotte Islands. Alaskan provenances were markedly poorer, except on some extreme sites, and one from Terrace, B.C. was only marginally taller. Forking and lammas growth were also assessed.

Silver Firs

Current information from recent experiments shows the superiority of provenances of *Abies grandis* from Vancouver Island, B.C., and northern Washington. Further provenances of *Abies alba* from selected stands in Czechoslovakia were planted.

Nutrition of Forest Crops and the Use of Herbicides

There are indications that similar fertiliser inputs may be less effective in colder northern areas than in warmer zones. It is confirmed that on lowland raised bog, potash as well as phosphate at planting improves height growth of Lodgepole pine. If Sitka spruce is grown on lowland peats early control of heather is essential for maintaining initial fast growth. In treatment of checked crops it appears that on the poorest sites herbicide as well as fertilisers will provide the longest period of response.

Tests of the distribution of fertiliser from the air indicate that the systems of ground control being used ensure an acceptable degree of accuracy of distribution.

Further trials of chlorthiamid (" Prefix ") support current recommendations for its use as a forest herbicide. In the south, atrazine shows promise in controlling a range of fine and soft grasses for most of the growing season. Tree injection experiments show that for woody weed species injection of 2, 4, 5-T or 2, 4-D can give as good control as basal bark spraying.

It appears from heather spraying experiments in the north that the currently recommended spraying period of the latter half of August for treating checked Sitka spruce can be extended into July. Spraying can also be successfully carried out in May, before trees flush.

Ultra low volume spraying of herbicides shows promise; on species susceptible to 2, 4, 5-T, control is as good as with mistblower application. Trials are being extended to test heather control by this method.

Cultivation and Drainage

Recent results from drainage experiments on deep peat have shown an encouraging growth response to increasing intensities of drainage. On gleyed soils, however, the effect of drainage on tree growth has been slight despite a definite soil water response to increased drainage intensity. These results are disappointing, but the soil drainage effects may yet prove to be significant in their effect on crop stability.

Cultivation experiments on some gleyed soils on the other hand continue to give an encouraging growth response, which suggests that better rooting conditions have been created by the cultivation. Following upon this encouragement a field trial was conducted in Wykeham Forest (Yorkshire) to demonstrate the technical feasibility of producing riggs and furrs at reasonable cost. A large motor grader was employed for the trials (see Plates 2.. and 3..), with very satisfactory results, which confirm the forecast made on page 93 of last year's *Report*.

Crop Stability

Aerial photography, using 35 millimetre film, is being further investigated as a means of classifying and quantifying sporadic windthrow.

The earliest results from controlled comparisons indicate that line thinning induces more damage in crops susceptible to windthrow than selective thinning or " no thinning ".

Regeneration

Experiments have been established, and others are proposed, to examine the problems of replacing crops of Scots pine with higher yielding species on freely drained and on ironpan soils. On both site types Grand fir, though frost tender and slow growing to begin with, is potentially a valuable species and figures prominently in the work. Planting below an overwood and in felled strips to improve its survival and early growth are among the techniques being tested.

At Tentsmuir Forest (Fife), where Sitka spruce is being tried as a successor species as well as Grand fir, the treatments include stump removal to lessen the risk of *Fomes* infection. At Speymouth (Moray) and Wykeham (Yorkshire), where the experiments are located on ironpan soils, the effects of various establishment methods, including deep and intensive cultivation, are being examined in the felled strips.

On freely drained soils at Thetford further evidence of the overwood protection required for Grand fir was collected. This species, together with Corsican pine, the main replacement species in this forest, has been included in most of the recent regeneration experiments.

Ecology

Work continued on growth problems of Sitka spruce in the forests of the South Wales coalfield. There are now indications that topography is an important factor in determining the net effect of the interactions between climate and soil. Where slope helps to provide drainage, good rooting and growth may occur even on peaty gleys. On flat peaty summits and wet shelves in valley sides, growth is often poor, and the trees liable to windthrow, and drainage to improve the situation is often difficult. Deficiencies of P and sometimes of K also occur on some of these soils.

Studies of seedling trees grown for three seasons under artificial shade were brought to a close, and the results are being prepared for publication.

Forest Genetics

Prolific beech and oak seed crops occurred throughout most of Britain ; heavy crops of larch were restricted to the north-eastern region of Scotland. Good seed crops of other species were localised and relatively unimportant.

Seventy-eight additional Sitka spruce Plus trees were selected and registered, and sixteen selections amongst other species brought the total number of registered Plus trees to 3,949.

The main vegetative propagation centre at Grizedale Forest (Lancashire) was closed during July ; the work was transferred to new glasshouses at the Northern Research Station, where over 7,000 grafts can be handled annually.

Controlled pollination work concentrated on Lodgepole pine clones in the National Tree Bank at Newton (Moray) using pollen which had been shed two weeks earlier at Alice Holt. Further intraspecific hybrid crosses between " coastal " and " inland " Lodgepole pine provenances were made at Saltoun in Stenton Forest east of Edinburgh, and a 5 × 5 diallel crossing was made between Douglas fir clones at Newton.

Four " form " and four " vigour " characters were assessed on each of thirty-six families obtained from a 6 × 6 diallel cross on Sitka spruce and raised under glass at Alice Holt. The analysed data showed that much of the variation for form and vigour is accounted for by additive genetic differences between parents. Gene-interactions were complicated and probably due to the heterozygous nature of the parent trees.

In early 1971 work started on the qualitative and quantitative analyses of polyphenols in conifers using thin-layer chromotography as a possible aid in early selections for vigour.

Lodgepole and Scots pine gene-pools composed of a rich variety of genetic material obtained from a wide scatter and selection of both home-collected and imported seed material were established on several sites throughout Britain.

Tree Physiology

The New Section

The establishing of our new Physiology Section was referred to in the Introduction to last year's *Report*. The Section has experienced the usual difficulties encountered when new and complex equipment has to be made to work effectively and calibrated before research can begin. Four greenhouses and four large controlled-environment growth chambers, whose use is shared with Genetics Section, are now operating and fully used. Laboratory facilities are installed, and a new greenhouse is to be built close to the growth rooms to allow easy transport of experimental material.

The Section is not yet fully staffed ; a senior scientific officer and an experimental officer are to be recruited soon.

The Research Projects

The principal physiologist, Dr. K. A. Longman, began his programme of work more than a year ago while temporarily accommodated at the Department of Forestry and Natural Resources of Edinburgh University (see pp. 107–110 of the 1970 *Report*). Since moving into the new Northern Research

Station in May 1970 the programme has been developed to include groups of research projects on control of shoot growth and bud dormancy, and on root growth and production, in addition to those on vegetative multiplication and on flowering and seed production. With limited staff it has not been practicable to work on all project groups; the main effort has been devoted to studies of vegetative multiplication and investigations of the effect of single climatic factors upon the rate and duration of shoot growth.

Encouraging results have been obtained in the use of hormones and controlled bed temperatures to stimulate root initiation in cuttings of Sitka spruce and Lodgepole pine. In the growth rooms, large effects of day-length have been found, using clonal experimental plants, in Sitka spruce (formation of terminal resting buds), Scots pine (outgrowth of unchilled buds in late summer), and Western red cedar and Leyland cypress (rate of shoot elongation and production of both lateral branches and flowers). Day and night temperatures have been shown also to affect these processes markedly, and work has started on determining the optimum conditions. In field experiments it has been shown that the proportion of female flowers can be increased on the larches, by ringing and gravimorphic treatments.

The work will be more fully reported next year.

Forest Pathology

Fomes annosus continues to be the major research problem. The most significant step forward during the year was the recommendation given for the wider use of *Peniophora gigantea* as a stump treatment in all major pine forests. This is the first commercial use of a method of biological control of this kind in forest pathology. Research has recently concentrated on butt rot caused by *F. annosus* but results from many of these studies are not yet available.

After a long period of relative quiescence, Dutch elm disease has increased in importance in the past three years, and this year again caused considerable damage to English elms in south-east and south-west England. A much expanded research programme has now been planned, in part in collaboration with the Entomology Section, and work has started on a detailed study of the biology and control of this disease. A summary of several year's inoculation experiments has confirmed that the Huntingdon elm is rather more resistant than our other native elms and that the Dutch-bred Commelin elm is the most suitable resistant elm currently available.

Until recently little was known about *Phytophthora* diseases of trees in this country, except that *P. cinnamomi* and *P. cambivora* caused "ink disease" of Sweet chestnut and beech and that the former species damaged Lawson cypress. However, *Phytophthora* species have now been found in a number of different hosts causing either a root and collar necrosis or a stem canker. In one instance, *P. cambivora* was found attacking *Acer pennsylvannicum* ahead of the advancing mycelium of *Armillaria mellea* (Honey fungus). This observation suggests that *P. cambivora* may have been the primary pathogen in this case, though further experimentation is required to establish the true sequence of events.

More basic studies of *Phytophthora* species in culture have provided some interesting results. Little is known about the sexual stage (the oospore) of *Phytophthora* species in nature, though it is important for their identification in the laboratory. The presence of two mating or compatibility types was thought to be required for sexual reproduction. Both compatibility types of *P. cambivora* have been isolated during the year, indicating that mating of this species might occur in nature. Sexual reproduction in one compatibility type has been stimulated by the presence of the common saprophytic fungus *Trichoderma viride*. This observation has considerable implications for the identification, ecology and genetics of *Phytophthora* species.

Research has recently been started on Beech bark disease, a disorder causing considerable damage to a number of relatively young beech plantations in south-east England. A survey has indicated that the disease is less severe in unthinned crops than in thinned ones.

Dieback of Corsican pine associated with *Brunchorstia pinea,* after several years of virtual absence, has reappeared and is causing some concern in East England. Detailed observations of symptoms and dendrochronological assessments have been made during the year.

Fewer enquiries were received this year by the advisory service at Alice Holt although the staff continued to work under some pressure. About three-quarters of all queries still came to Alice Holt from Wales and southern England, however, with the remaining quarter going from Scotland and northern England to the Northern Research Station. The use of a successful isolation technique for *Phytophthora* species has markedly increased the number of positive identifications of diseases caused by these fungi. The isolation of a *Kabatina* species from cypress both in England and Scotland and its successful inoculation into Leyland cypress are noteworthy.

Forest Entomology

Pupal counts of the Pine looper moth, *Bupalus piniarius*, were generally low, but those at Wykeham Forest (Yorkshire) were so high that insecticidal control was necessary. An insecticide without the disadvantages of DDT was therefore sought, and after bioassays and a small field trial, tetrachlorvinphos was selected, and applied by helicopter on 18th and 19th August, 1970, with satisfactory results.

Earlier experiments have shown that infestations of log stacks by the Pine shoot beetle, *Tomicus piniperda,* can be controlled by spraying with gamma BHC in diesel oil at about 5 litres/10 m^2. This is too costly, however, but experiments this season using about half this rate gave poor results. Further trials on the chemical control of the Large pine weevil, *Hylobius abietis,* and bark beetles of the genus *Hylastes,* on planting stock have been made with BHC and DDT dips and with granulated systemic insecticides placed in the soil at planting time. These tests were done in part to find materials to replace DDT. A BHC dip gave good control, but results with the granulated systemics were disappointing, perhaps because the dry summer weather may have reduced uptake into the plants.

Experiments on the Green spruce aphid, *Elatobium abietinum*, which can survive very low temperatures when reared under cool constant temperatures, showed that it was much less hardy if raised in fluctuating temperature conditions.

For many years die-back of European larch has puzzled pathologists. Observations and experiments now indicate that the disorder may be due not to a fungal infection but to infestation by *Adelges laricis*.

Winter washes of DNOC/petroleum and tar oil have given promising control of adelgids in previous trials, and these materials were therefore sprayed on to a wide range of trees to test their possible phytotoxicity. Tar oil caused browning of European larch when applied from May to August, but caused no significant damage to any other species. At the rate used, DNOC caused severe damage to almost all.

In the survey of entomological damage to young crops in Scotland, in one small area of Sitka spruce, 20 per cent of the leading buds had been eaten by larvae of the moth *Clepsis serecionana*. Damage by various other moths was revealed in the same survey.

From other survey work concerned primarily with the effect of fertiliser applications, shade and drainage on insect populations, it appeared that the population of *Zeiraphera griseana* at Selm Muir Forest (Midlothian) offered a potential threat, and should be carefully watched. A mite was found killing many of the buds of Sitka spruce at Halwill Forest (Devon).

Severe defoliation of Sitka spruce by the sawfly *Gilpinia hercyniae* was found at Hafren Forest (Montgomeryshire), and damage to Norway as well as to Sitka spruce was also found in the adjacent forests of Tarenig and Myherin (Cardiganshire).

Mammals and Birds

In further Warfarin poisoning trials against Grey squirrels (which the annual questionnaire shows is spreading into new territory in both east England and east Scotland), whole grain wheat was taken more readily than cut wheat, and bait using a latex sticker was as readily taken as that with an oil sticker. No fully satisfactory cheap bait hopper specifically for squirrels is yet available, however.

More work was done on the catching and marking of roe deer. Associated licks and baits were also tested, both with roe and fallow deer. A glucose-based lick proved more palatable to both than did the usual salt-licks.

Of four chemical repellants tested for the prevention of browsing by fallow deer, Monacol (like Aaprotect, which was previously examined) protected dormant shoots for three months.

Statistics and Computing

Training courses in statistics were continued.

An IBM 1130 computer was delivered at the end of the year, and this will ultimately replace the two small Sirius machines previously in use.

Service support for Research and Management Services Divisions included statistical work on Sitka spruce crosses, blue-stain of pine, the clearing of windthrown areas, and the use of staff time.

Development work included the production of a draft revision of the Research Divison Code of Assessments, and further trials of audio methods of data capture.

Research Workshop

This year a workshop was opened at the Northern Research Station. Equipment designs will still be drawn up in the main workshop at Alice Holt, but items will now be built as appropriate either at Alice Holt or the Northern Research Station or by a commercial contractor.

Among the items designed and made in the Workshops this year were a one-man high seat for controlled deer shooting, equipment for fence erection, cold chambers for pathological work, and sample new-style beaters for fire control. A good deal of time was also spent in the design and manufacture of notice boards and signs. Now that suitable designs have been decided upon, further manufacture will take place at production centres, with advice from the workshop as required.

Photography

Reclassification of the photographic collection was continued, and the main sorting of the colour slides and monochrome prints has now been completed. Photographic tours were made during the year to cover the South-West England, East England, South Wales and South Scotland Conservancies.

Publications

Twelve new priced publications were issued through Her Majesty's Stationery Office, and eight others were revised and reprinted. Six new unpriced publications were issued, and sixteen others were revised and reprinted.

Research Information

Requests for loans from the library continued to increase. The revised library catalogue was sent to press (subsequently published in May 1971). A good deal of work was done on the organisation of library facilities at the Northern Research Station. Increasing use of computer techniques was made for library and information work.

Research Appreciation Courses for Conservancy District Officers were again held, this year at the Northern Research Station as well as at Alice Holt.

MANAGEMENT SERVICES DIVISION

Planning and Economics, Field Surveys, and Work Study Branches form parts of the Management Services Division, but for completeness and convenience accounts of their research and development work, and also of that of the Harvesting and Marketing Division, are included in this Report.

A new system of budgeting and budgetary control designed by a special project team has now been introduced, and has been in operation in all Conservancies for a development period of one year. The procedures are working satisfactorily but it is expected that a further year's experience will be necessary before the system becomes fully effective.

Planning and Economics

Work on the preparation of the Commission's Corporate Plan has been continued. A statement of objectives has been prepared, and economic criteria set against individual operations or activities. In addition, broad appreciations of various factors affecting prices are being prepared, and resources and cash flows associated with various programmes of operations are being studied.

A study of potential demand for day visitor recreation was undertaken to assist the Commission's Conservation and Recreation Branch. From an initial group of 210 forests within easy reach of urban centres or within major holiday areas, a short list of 22 was obtained. These 22 forests were free of legal constraints, and were judged to be both suitable for recreational development and to have a high potential recreational demand from day visitors. The greatest opportunities seem to lie in South-east England, South Wales, the Midlands, the Tyne/Tees area, and the Central Lowlands of Scotland. A further survey of actual day recreational use of forests was carried out in the summer of 1970 in 17 recreational areas widely scattered over the country.

In further work on fire protection, factors needed in determining the possibility of a fire outbreak over daily periods in the area studied included the time of year, the day of the week, weather conditions and condition of the local vegetation, and the average number of fires experienced over the previous five years. There seems to be room for financial saving on fire protection in "non-fiery" forests, which account for just over 50 per cent of annual expenditure but experience only about 20 per cent of the reported fire starts.

To enable rapid advice to be made available to forest managers, a computer programme has been written to define optimal felling age in a given situation and to indicate the opportunity cost of premature felling.

Field Surveys

The Field Survey Branch completed the metric revision and up-dating of area and yield class data begun at the end of 1968.

Also completed was an estimate of the scale of the occurrence of soil groups and soil types for Forestry Commission forest land. This was based on data from existing sample surveys and from Soil Survey maps. It is being used to define the scale and location of problems involving site type.

This year the Forestry Commission changed to metric units, and the more important of the necessary mensuration tables have now been published. Others are in the press or in active preparation.

Studies of the results of a line thinning experiment in Sitka spruce at Glen Trool Forest (Kirkcudbrightshire) indicate that appreciable growth responses are shown only in rows adjacent to those removed. The experiment has not yet been long enough established to make possible any useful comparison of the total production by area of the various degrees of thinning included in the trial.

Work Study

Work continued on equipment for the planting of tubed seedlings, and in short field trials 700 trees per hour were successfully planted. Trials with the now further modified Finn Forester tree planter have also given promising results.

In studies on outputs of ploughing outfits, it has proved possible to relate time taken to plough a given furrow length to an objective Index of Difficulty (incorporating ground and tractor characteristics), and to other ploughing work. These studies should lead to the production of an output guide.

Drainage trials mainly in indurated soils using a Lokomo plough and a BTD 20 tractor have also continued. Successful results, with costs of about £0·75 per 20 m, were achieved in cleared windthrown areas, though build-up of brash and lop-and-top sometimes hindered operations. The Parkgate deep draining plough with double mouldboard was modified and tested, and has possible uses in ploughing for cross drainage, and in ploughing for planting, for which it has been used with success on deep peat and on peaty gley.

Promising results were obtained in drain cleaning trials using the Oja-Viska rotary digger.

Because the double roller produced for control of grass weed growth in 1969 has given problems in use, a redesigned single roller with added transportation wheels has been made to overcome the difficulties.

The 75 BHP hydrostatic frame-steering forest tractor produced in 1970 has been improved, and a smaller, 45 BHP machine of the same type has now been built, and has given encouraging results in preliminary field trials.

The hydraulically operated timber tongs developed earlier to take a one-tonne load are now being made commercially, and a prototype two-tonne model is now under test.

Hydraulic stackers to be fitted to tractors to reduce the manual labour of stacking at conversion sites have been designed, and some have been made and tested.

Further work has been done on cable cranes, aimed mainly at the production of a skyline able to support 1·5 tonne loads over 300 m. Systems in which one tractor operates two skylines, alternating from one to the other, have also been studied in order to minimise stacking problems. Other ways of reducing stacking problems are also being examined.

HARVESTING AND MARKETING DIVISION

Timber Utilisation

Trials to test the suitability of Lodgepole pine for use as telegraph poles were begun jointly with the Post Office. A provisional approximate creosote preservative treatment schedule was worked out, and treated poles have been put into service. Strength tests showed the poles to be about as strong as those made from Corsican and Scots pine.

New assessments of trials of treated and untreated fence posts of various species again showed the superiority of creosote treatment, which was still giving outstanding protection to treated posts after up to 13 years.

Further experiments to find ways to prevent needle fall of Christmas trees, and also to reduce flammability of the trees, were undertaken in collaboration with the Ministry of Agriculture, Fisheries and Food at the latter's Efford Experimental Horticulture Station. Needle fall was again reduced by dipping in a sodium alginate solution (and in one of gelatine), and by keeping the freshly-cut tree butt in water. Some evidence was also obtained that the same treatments reduced flammability of the foliage.

In experiments on the use of bark in horticulture, pulverised bark again gave good results as a main constituent of potting composts, and as a cover for forced bulbs. It also gave promise as a medium for mushroom culture.

The Joint Programme on home grown timber being carried out with the Forest Products Research Laboratory, Princes Risborough, was continued.

Machine stress grading gives a better forecast of the bending strength of timber than does visual inspection. Trials showed that Scots pine could be satisfactorily stress graded, and that stress grading gave a considerably improved yield of the better grades. The information gained can be used to prepare programmed cards for the Computermatic machine to stress grade Scots pine for a range of thicknesses and widths in two grades. Similar work is being done on Sitka spruce, and is planned for Douglas fir and Corsican pine.

Fertiliser applications, particularly of phosphate, may greatly stimulate growth, but increased vigour may result in an increase in the proportion of early to late wood, and so reduce wood density. It may be too that applications of fertiliser cause the addition of more wood at the base of the crown than further down the stem, and so reduce taper. These possible effects of fertiliser treatment are therefore being examined in Sitka spruce.

Following work on the effect of spacing on wood density and wood yield already done on Sitka spruce, a similar study has been carried out on Norway spruce. Results were in contrast to those obtained with Sitka spruce, as Norway spruce grown at a very wide spacing at 2·5m produced a lower yield than it did at a close spacing. It seems likely that over-wide spacing in the case of Norway spruce may lead to the production of too high a proportion of vigorously grown wood of low density and reduced value as saw timber.

Trials with Sitka spruce showed that this could be used as a 3mm core with 1·5mm Scots pine faces to make a satisfactory construction-grade plywood.

Saw milling and machining properties of Western hemlock, Grand and Noble fir, and Western red cedar are also being investigated.

A review of the possibilities of whole-tree utilisation has also been initiated.

In further work on the control of blue stain, particularly good results were given by buffered sodium pentachlorophenate/lindane and pentachlorophenol/lindane mixtures in mineral oil.

PART II

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

Forestry Commission support for work at *Rothamsted Experimental Station,* Harpenden, Hertfordshire, on nursery nutrition of forest trees, has now ceased. Miss B. Benzian, however, here reports some outstanding results of experiments done in collaboration with other Rothamsted workers on tree seeds and on the slow-acting nitrogen fertiliser isobutylidene diurea (IBDU). Following work elsewhere, seed of Sitka spruce was soaked in dilute solutions of manganese and copper before sowing. The copper solutions did not affect germination or growth, but some concentrations of manganese increased growth and dry matter production, and this finding may be of use in the intensive production of conifer seedlings.

The IBDU was compared with formalised casein and "Nitro-Chalk" in seed-beds and transplant lines on loamy sand at Kennington, Oxfordshire, and acid heaths are Wareham, Dorset. It gave good results with transplants at both nurseries, and in seedbeds at Kennington. At Wareham, however, it became steadily less effective, for reasons as yet unknown.

Dr. H. G. Miller and Dr. B. L. Williams, of the Macaulay Institute for Soil Research, Aberdeen, describe work on tree nutrition and on nitrogen mineralisation in peat and humus. A Corsican pine crop on windblown sand at Culbin Forest (Moray) had grown rapidly in basal area and height to the age of 12 years (probably the time of canopy closure) but growth had then remained fairly constant until at 22 years a decrease in rate of growth took place, continuing to the present time, at age 42. Annually for three years ending in 1966, the crop was given nitrogen, and this gave an increase in growth rate until 1968. In a second experiment, comparing the effects of different forms of N on the growth of Scots pine, ammonium nitrate gave a greater increase in foliar nitrogen concentrations and in growth than did either ammonium sulphate, urea or sodium nitrate.

Greenhouse experiments indicated that Sitka spruce (like Corsican pine) shows a marked preference for ammonium sources of nitrogen.

Work on peat and humus again showed that the addition of nitrogen fertilisers increased the mineralisation of nitrogen present in these materials.

Dr. G. A. Salt, of the *Rothamsted Experimental Station* in Hertfordshire, reports the results of further work on conifer seedling pathology. Some of this work was on the effects of formaldehyde soil fumigation in the sandy loam at Kennington and the acid heath at Wareham. Before fumigation, the two soils were also treated to give a range of pHs. In general, the higher the pH of the soil, the greater the response to the formaldehyde treatment. The effect of fumigation on the soil fungi varied with both soil type and pH, and though fumigation decreased numbers of some species, there was no clear connection between the changes and the growth responses. Plant losses at a high pH at Kennington were probably due mainly to attack by *Pythium* species.

The systemic fungicide benomyl gave some increase in seedling numbers at both nurseries. The nematicide aldicarb was also tested, and killed many free-living and plant parasitic eelworms without affecting numbers or species of fungi. It had little effect on seedling growth.

Dr. C. S. Millar, of the *Department of Forestry, University of Aberdeen,* summarises the results of further work on the role of *Lophodermella sulcigena* in premature browning and death of needles of Corsican pine. Spores of *L. sulcigena* were trapped from the end of June to mid-August, with peaks in July. For infection of the foliage to occur, it seems that a period of sustained high humidity must follow spore deposition. Assessments showed that trees with moderate or severe leaf damage also showed considerable reduction in ring width, but height growth was little affected.

Dr. P. G. Biddle, of the *Commonwealth Forestry Institute, University of Oxford,* gives a short account of his studies on virus diseases of forest trees. Attempts to demonstrate that trees of Sitka and Norway spruce showing often marked virus-like symptoms are in fact affected by a virus have been continued, using grafting and aphid transmission techniques. Similar attempts are being made to transmit a virus-like bushy stunt of Scots pine. Investigations have also begun on a damaging stem fluting defect in poplars, which may result from a virus infection.

Dr. T. W. Tinsley and members of his staff in the *Insect Pathology Unit, Commonwealth Forestry Institute, University of Oxford,* refer briefly to the work of the unit, and list recent publications arising from it.

Mr. W. H. Parry, of the *Department of Forestry, University of Aberdeen,* gives an account of further work on the Green spruce aphid, *Elatobium abietinum.* Sap analyses showed that concentrations in Sitka spruce needles of total soluble nitrogen and of a range of amino acids fell to a minimum early in July, at about the time of the decrease in the population of infesting Green spruce aphids. Parallel analyses are proceeding to elucidate the amino acid requirements of *E. abietinum.* In studies on the effect of cold on this insect, it was found that *E. abietinum* can supercool without harm to temperatures as low as −12°C and sometimes even lower.

Dr. Myles Crooke, of the same *Department,* summarises his work on tit and Pine looper moth populations at Culbin Forest, Moray. The population of the Pine looper, *Bupalus piniarius,* was too low to give useful results, and studies were therefore concentrated on the population of tits. Much of the work was on individual ringed coal and crested tits, though some was done also on the movement of flocks of the birds.

Mr. J. S. Campbell, of the *Department of Forestry and Natural Resources, University of Edinburgh,* continued investigations on brown trout and sea trout in forest streams in Peebleshire. The effects of various environmental factors on the biomass of fish have been monitored, and the results are being prepared for publication.

Dr. D. C. Malcolm and Miss E. A. Caldwell, of the same *Department,* summarise the results of work (done jointly with the Research Division of the Forestry Commission) on the effects of various environmental factors on the shoot growth of conifers. Optimal day length for growth of Sitka spruce proved to be $16\frac{3}{4}$ hours, while that for Western red cedar was about 15 hours.

Other work has begun on the effect of differing day/night temperature regimes.

Dr. L. Leyton, Dr. E. R. C. Reynolds, and Mr. F. B. Thompson, of the *Department of Forestry, University of Oxford,* describe their work on forest hydrology. Various methods of determining net rainfall below tree canopies were tested, using stationary and roving rain gauges, and calculating the results in various ways. The results provided information on the reliability of the different methods, and will assist in the planning of future studies on environmental factors.

PART I

Work carried out by Forestry Commission Research and Development Staff

RESEARCH DIVISION

FOREST TREE SEED

SERVICE

As in previous years the service work on seed procurement, extraction, processing, storage, testing and distribution continued as the main function of the Seed Section. The research content of the Section's programme is slowly increasing but still is dependent on the weight of work involved in the service. The report on seed services is included here for practical reasons because it is not published elsewhere.

Register of Seed Sources

The main changes in the register were as follows :

	Number of Stands	*Hectares*
Areas gained	Nil	Nil
Areas lost—Total	9	37.6
Clear-felled	3	2.3
Reduced in area	3	32.4
Windblow	3	2.9
Stands thinned	8	125.7
Scots pine seed orchards deleted	8	5.4

As reported last year the register requires a thorough revision and the preparatory work towards this aim has been initiated.

Seed Procurement (Table 1)

In spite of great efforts and some recent successes with home collections the greater part of our seed requirements must still be imported. On the whole the 1970 home crops of cones and fruits were rather poor with, however, some moderately good crops of Scots pine, Sitka spruce and larches in pockets. Altogether 752 kg of conifer species were collected, of which the main bulk of about 70 per cent consisted of Hybrid larch, Scots pine (from seed orchards) and Sitka spruce (almost all of which originated from East Scotland). The Hybrid larch collection was one of the largest for some years and gave enough seed to cover the requirements of two or more years.

TABLE 1

TOTAL SEED PROCUREMENT FROM 1.4.70 TO 31.3.71

Kilogrammes

Species	Imports			Home Collections					Grand Total
				Crop 1969*		Crop 1970			
	General	Registered	Total	General	Registered	General	Registered	Total	
Scots pine				2·9	109·5	3·9	106·3	222·6	222·6
Corsican pine				50·3	0·6	6·2	4·6	61·7	61·7
Lodgepole pine (AL)†	24·9		24·9						24·9
,, ,, (NC)	2·2		2·2						2·2
,, ,, (SC)	22·2		22·2				0·3	0·3	22·5
,, ,, (SK)	66·3		66·3						66·3
Sitka spruce	2,555·6		2,555·6	521·0		196·3	9·7	727·0	3,282·6
Norway spruce		254·5	254·5			12·1		12·1	266·6
European larch						4·2	0·2	4·4	4·4
Japanese larch	272·5		272·5	15·9	1·6	10·6	21·7	49·8	322·3
Hybrid larch		1·0	1·0	55·2	9·7	105·2	130·5	300·6	301·6
Douglas fir						0·9	11·6	12·5	12·5
Western hemlock	96·4		96·4			0·1		0·1	96·5
Western red cedar	37·0		37·0				30·6	30·6	67·6
Grand fir	239·0		239·0	0·7		8·6		9·3	248·3
Noble fir	154·4		154·4			48·3	3·7	52·0	206·4
Lawson cypress						17·3	17·2	34·5	34·5
Other conifers	7·5		7·5			1·4		1·4	8·9
Total conifers	3,478·0	255·5	3,733·5	646·0	121·4	415·1	336·4	1,518·9	5,252·4
Oak	205·5		205·5			62·8	2,807·9	2,870·7	3,076·2
Ash							0·8	0·8	0·8
Sycamore	2·3		2·3			9·3		9·3	11·6
Other broadleaves	12·5		12·5			97·9	22·7	120·6	133·1
Total Broadleaves	220·3		220·3			170·0	2,831·4	3,001·4‡	3,221·7
Grand Total	3,698·3	255·5	3,953·8	646·0	121·4	585·1	3,167·8	4,520·3	8,474·1

* Taken in charge after 31st March 1970.
† AL—Alaska; NC—North Coastal; SC—South Coastal; SK—Skeena River BC.
‡ Including 1,155·4 kg collected for Conservancies' own use.

As regards hardwoods there was a good crop of Sessile oak in the registered stands in South West England. Finally one should mention the success obtained with the *Nothofagus* species which are so difficult to import from abroad. Thanks to the great efforts of the Research Foresters, 6 kg of *Nothofagus procera* and 64 kg of *Nothofagus obliqua* were collected.

Due to relatively poor crops abroad during the past few years, the stocks in hand of some species became rather dangerously low, and it was therefore necessary to try to import relatively larger amounts. The main bulk (about 70 per cent of the whole import) consisted of Sitka spruce from Queen Charlotte Island, British Columbia, which is the most popular provenance in this country. With some other species, however, the success was not so good, especially with Grand and Noble firs which unfortunately again did not produce sufficient crops in the areas of our interest. Unfortunately the traditional sources are slowly being felled and therefore one must look for supplementary sources for future procurement. A similar situation but on a relatively smaller scale exists with Western hemlock. Lodgepole pine from Alaska also continued to be difficult to obtain in sufficient amounts.

In 1970 British Columbia joined the OECD Seed Certification Scheme (Organisation for Economic Co-operation and Development). This is very advantageous for us for with their entry the whole coastal area of North America, except Alaska, is now covered by Seed Certification Schemes.

Seed Extraction

All seed extraction took place at the Alice Holt seed extraction plant and consisted of just over 70 m^3 (700 hectolitres) of cones. Scots pine, Sitka spruce and Hybrid larch formed the main bulk (see Table 1). The seed yields and qualities were up to the required standards. The work on the improved method of seed de-winging was continued. Dust from the extracted and processed seed is causing some problems and therefore action has started to improve the efficiency of the existing dust extraction system.

Seed Storage

The total seed stocks of conifer species held in our refrigerated store by the end of the reported period was 8,353 kg and it was over 1,500 kg larger than the previous year. With an average yearly requirement of about 3,500 kg this means that the total stock is still short by about 2,000 kgs, according to the current policy of holding at least three years' supply. The main gaps are in the stocks of Corsican pine, Japanese larch and Hybrid larch, Western hemlock and *Abies grandis* which species have not produced sufficient crops for several years past.

Storage services are also provided for private operators and the Commonwealth Forestry Institute at Oxford.

Seed Testing (Table 2)

Due to a relatively larger seed procurement and research programme the number of tests has rapidly increased, by 50 per cent, and reached the highest number ever recorded. The service tests were performed on 773

samples, including 45 from the private sector and 30 samples of tropical forest tree seed from the Commonwealth Forestry Institute at Oxford. On average, 3·9 tests were required per sample. Seed testing work for the research programme has increased by 30 per cent. In order to improve the facilities for this expansion four new incubators were installed.

TABLE 2

TESTS PERFORMED ON SEED

Kind of Test	Service	Research	Total	Total of previous year
Purity	563	—	563	408
Seed size determination	712	88	800	534
Germination	1,065	578	1,643	966
Tetrazolium	34	15	49	19
X-Ray	8	8	16	4
Cutting	22	5	27	155
Moisture content	551	263	814	431
Cone tests	2	5	7	57
Total	2,957	962	3,919	2,574

Seed Supply (Table 3)

The total requirement of conifer seed has increased slightly by about 200 kg, and as in previous years this was mainly due to the increased demand of the private sector. On the whole the private sector took about 600 kg more than the Forestry Commission, and this means that at the moment about 60 per cent of seed procured by the Commission is taken by the private sector. As regards the popularity of the individual species there are also some significant differences. If the Commission's demand is taken as 100 per cent then the private sector is using proportions as follows:

	per cent
Scots pine	405
Corsican pine	99
Lodgepole pine	91
Sitka spruce	82
Norway spruce	299
European larch	1,688
Japanese larch	787
Douglas fir	252
Western hemlock	211
Western red cedar	258
Grand fir	92
Noble fir	149

Almost the entire seed demand of the private sector is covered by the Commission, and therefore the figures above reflect the differences in species popularity between both sectors. The most striking differences are among the

TABLE 3

SEED SUPPLIED FROM CENTRAL SEED STORE FROM 1.4.70 TO 31.3.71

Kilogrammes

Species	Weight in kilos despatched from general and registered sources						Export, research and gifts	Grand total
	Forestry Commission			Private Forestry				
	General	Registered	Total	General	Registered	Total		
Scots pine	10·5	27·3	37·8	60·6	92·7	153·3	99·5	290·6
Corsican pine	78·0	46·9	124·9	116·1	7·3	123·4	1·2	249·5
Lodgepole pine (AL)	15·3		15·3					15·3
,, ,, (NC)	2·2		2·2	1·3		1·3		3·5
,, ,, (SC)	46·9		46·9	62·5		62·5		109·4
,, ,, (SK)	46·6		46·6 } 134·0	41·5		41·5 } 121·6	5·1	88·1 } 260·7
,, ,, (CI)	1·9		1·9	5·0		5·0		6·9
,, ,, (SI)	21·1		21·1	11·3		11·3		32·4
Sitka spruce	603·5		603·5	492·3		492·3	7·6	1,103·4
Norway spruce	34·5	17·8	52·3	117·3	36·0	153·3	0·8	206·4
European larch		5·3	5·3	0·3	89·2	89·5	0·1	94·9
Japanese larch	33·0	6·4	39·4	309·8	0·3	310·1	0·3	349·8
Hybrid larch	20·0	10·9	30·9	33·4	7·7	41·1	0·8	72·8
Douglas fir	51·8	8·7	60·5	81·0	71·5	152·5	2·5	215·5
Western hemlock	27·9		27·9	59·0		59·0	0·8	87·7
Western red cedar	10·3		10·3	26·6		26·6	0·2	37·1
Grand fir	154·7	10·3	165·0	152·7		152·7	5·0	322·7
Noble fir	47·3	27·1	74·4	108·4	2·5	110·9	0·6	185·9
Lawson cypress	0·5	0·7	1·2	13·2	0·9	14·1	0·3	15·6
Other conifers	65·1		65·1	17·7		17·7	64·4	147·2
Total Conifers	1,271·1	161·4	1,432·5	1,710·0	308·1	2,018·1	189·2	3,639·8
Oak	128·0	422·6	550·6	23·4	1,967·8	1,991·2	61·9	2,603·7
Sycamore	2·6		2·6				0·8	3·4
Ash		5·2	5·2				0·2	5·4
Other broadleaves	13·4		13·4	15·1		15·1	5·1	33·6
Total Broadleaves	144·0	427·8	571·8	38·5	1,967·8	2,006·3	68·0	2,646·1
Grand Total	1,415·1	589·2	2,004·3	1,748·5	2,275·9	4,024·4	257·2	6,285·9

larches which in the Commission's planting programme have ceased for some time to be major species.

The statistics in Table 3 do not include the dispatches of seed stored for people and institutions outside the Commission, which amounted to about 200 kg. The majority of these dispatches were carried out on behalf of the Commonwealth Forestry Institute and were directed to many Commonwealth countries.

RESEARCH

Tubed Seedling Work

Research was carried out on two specific problems raised by Silviculture (North) in their work with tubed seedlings. Firstly, the benefits in cost and control to be gained by germinating at a constant temperature made it desirable to add to work done in 1970 on this topic. Secondly, a more convenient method than sand of stratifying dormant seed lots was desired. Both lines of research were carried out on Sitka spruce and Lodgepole pine seed only. The 1970 results were generally confirmed in the germination temperature study, and the following conclusions were drawn. Seed of Sitka spruce definitely benefited in both speed and total germination from germination at 25°C rather than at alternating 20–30°C. This was in contrast to seeds of Lodgepole pine, which performed marginally better in both respects at 20–30°C. All seeds, whether or not they were dormant, benefited in rate of germination from a 21–day pre-treatment at 3°C, with insignificant changes in total germination. This pre-treatment, however, more than compensated for the reduction in germination vigour of untreated Lodgepole pine germinated at 25°C.

It was found that it was quite possible successfully to pretreat seeds in bulk in the absence of sand. Soaking of seed for 1–3 days at 3°C followed by bulk treatment either in polythene bags, or between blotters, resulted in germination which was actually better than that obtained by the theoretical optimum prechilling conditions prescribed for germination tests. Non-dormant as well as dormant seeds again benefited in respect to their germination vigour. These observations are being extended to nursery trials in the present year.

Pinus merkusii

An investigation was carried out with the close co-operation of the Commonwealth Forestry Institute into the collection, extraction and germination quality of *Pinus merkusii* from Zambales, Philippines. Representative samples of cones, collected on two occasions (two and a half week interval) in May 1970 were immediately dispatched to Alice Holt by air. On arrival they were categorised into three sizes and three stages of maturity. They were subjected to heat, gradually being brought up to 50°C. Unopened cones were wetted, redried and reheated. Seed extracted at each stage from each fraction were kept separate and subjected to germination tests. The following conclusions were drawn. If green cones are to be collected a more efficient extraction procedure is urgently required. The quality of seed from the first collection and from green cones was inferior to seed from

the second collection and brown cones. The overall mean germination percentage of the seed was 71 per cent. Many of the fractions showed germination percentages of over 80 per cent. The best germination percentage was 92 per cent. The quality of this seed was still >90 per cent after nine months storage. *P. merkusii* has very low germination quality (often as low as 10 per cent) after normal handling in the countries of origin. This evidence suggests that improvements in handling the seed should result in improved quality of seed. Cones should be collected when the largest proportion of cones have just turned brown, unless they can be collected at intervals as they turn brown.

Other Projects

Research is continuing along previously detailed lines and includes seed storage, seed grading, and cone processing. The final results of ten years storage of *Abies procera* are being analysed on the computer and will be reported next year. New lines of research have been instituted. They include a physiological study of conifer seed dormancy and an investigation into the fate of non-productive seeds in the nursery, which should give some comprehensive contribution towards the interpretations of the laboratory test results. In co-operation with both Silviculture Sections the work was continued on a quick method of determination of seed origin.

G. M. BUSZEWICZ

A. G. GORDON

PRODUCTION OF PLANTING STOCK

In 1970, there were fewer investigations into improved methods of raising conventional planting stock than in the previous years. Kennington Research Nursery, Oxford, was closed at the end of 1970; many experiments testing slow-release fertilisers at other centres were in their last year. This decrease was to some extent balanced by a further increase in investigations into techniques of raising new types of planting stock.

Conventional Planting Stock

There were five main subjects for research; fertilisation (slow-release fertilisers and late topdressings); effect of simazine residues on transplants; methods of precision sowing; soil sterilants; and root dips for seedlings and transplants.

Fertiliser Experiments

The performance of the slow-release fertilisers "Enmag" and potassium metaphosphate was similar to that over the last five to six years (see *Reports* 1966 to 1970) and continued to demonstrate what a safe fertiliser "Enmag" is at recommended rates. However, applications of three to four times the normal rate depressed height growth of the crop in long-term experiments in Scotland.

Experiments testing the effect of topdressings of nitrogen as "Nitrochalk", and potassium as potassium sulphate, on transplants in September confirmed that such late applications of nitrogen could increase nitrogen concentrations in the plant. Extension of transplants similarly treated in 1969 to the forest in 1970 provided further evidence that increased nitrogen concentrations do not make plants more sensitive to exposure or other testing environmental conditions in the first year after planting; in one of the extension experiments the increased nitrogen concentrations again increased growth in the first season (see *Report* for 1970, Part II, pp. 168-170).

Simazine Residues

Simazine residue experiments (see *Reports* 1963 to 1970) produced results very similar to those of previous years.

Sowing Methods

Investigations into methods of precision sowing showed again that both paper mounting and pelleting seed were satisfactory techniques although the number of usable seedlings of Sitka spruce (the only species tested) was slightly reduced with both methods. Three years of testing these techniques suggest that neither will have sufficient advantages over normal broadcast sowing to justify their cost. However, if precision sowing was required for other reasons (e.g. undercutting systems or lifting machinery) either technique might be suitable.

Soil Sterilant

In further trials at three Scottish research nurseries, soil sterilisation with dazomet gave a high degree of seedbed weed control and growth of Sitka spruce seedlings was almost as good as in formalin-treated beds. There may therefore be a place for dazomet as a seedbed treatment in the more weedy nurseries because it is not always easy to obtain adequate weed control by means of herbicide sprays. The material is expensive (around £250/ha) but easy to apply because of its granular form. A possible drawback is the need for late summer or early autumn application, necessitating fallow land for treatment.

Root Dips for Seedlings and Transplants

The value of dipping plant roots to protect them from desiccation was examined at Wareham Nursery, Dorset. A 1·0 per cent solution of sodium alginate was used to dip seedlings of Sitka spruce and transplants of Sitka spruce and Corsican pine.

Plants were dipped immediately after lifting in March 1970, and then stored in a cool slatted shed either without further protection, or packed tightly upright, in wooden boxes deep enough to enclose the plants to just above the root collar. For comparison undipped plants were packed and stored similarly in wooden boxes or in closed polythene bags. Plants were removed at intervals and planted out, a representative sample being taken at the same time to determine the moisture content of the tops just prior to each planting date for each storage treatment.

The results of these experiments gave useful indications of the possible role of such root dips.

First, it was clear that root dips of sodium alginate were no substitute for complete enclosure in polythene bags or even for the partial enclosure of wooden boxes (as described above). Dipped plants given no additional protection in store did not survive satisfactorily after more than three days' storage, the highest survival rate being 16 per cent. Survival and growth after storage for three days was satisfactory for Sitka spruce (seedlings and transplants) but only marginally acceptable for Corsican pine. It should be noted that in preliminary trials in 1969, plants neither dipped nor protected by boxes or polythene bags and given similar storage treatment, did not survive satisfactorily after even one day's storage.

Secondly, for the periods of storage covered by the experiments (0 to 30 days), there was very little difference between the subsequent survival and growth of root dipped plants which had been kept tightly boxed and undipped plants kept enclosed in polythene bags, except for Corsican pine, which stored better for the longest periods in polythene bags. Generally, survival and growth was always better, even if differences were small, after storage in polythene bags.

However, the third and possibly most interesting result was that dipped and boxed plants survived and grew better than undipped plants which were simply boxed for storage. This suggested that root dipping might be useful in improving *short-term* storage in boxes of seedlings and transplants. Also, because the storage treatments were identical except for the

sodium alginate root dip, it provided evidence that the role of moisture retentive root dips may be more than that of simply preventing loss of moisture from the roots. Table 4 shows how the presence of the sodium alginate root dip maintained the moisture content of the plant *tops*.

TABLE 4

PER CENT MOISTURE CONTENT* OF TOPS AND SUBSEQUENT PER CENT SURVIVAL† OF TRANSPLANTS STORED IN WOODEN BOXES WITH AND WITHOUT ROOT DIPPING

Species	Treatment	Assessment	Days Stored				
			0	6	12	24	30
Sitka spruce	No dip	Per cent M.C. of tops	122	112	108	88	81
		Per cent Survival	96	92	86	78	62
	Dipped	Per cent M.C. of tops	124	132	135	120	125
		Per cent Survival	100	99	99	95	96
Corsican pine	No dip	Per cent M.C. of tops	146	138	125	116	92
		Per cent Survival	83	30	17	11	12
	Dipped	Per cent M.C. of tops	144	135	130	108	114
		Per cent Survival	79	59	50	17	20

* Moisture content expressed as a per cent of oven-dry weight after drying for 18 hours at 105° C.

† Percentage survival of transplants assessed at the end of the season.

The poor survival of Corsican pine should be noted, especially after any length of storage. Survival after storage in polythene bags was better, but still poor after 30 days (41 per cent).

These experiments suggest, therefore, that the value of root dips of water-holding media may be as an aid to short to medium-term storage (e.g. wooden boxing) or in providing adequate protection for otherwise unprotected plants over a very short interval of time. Experiments are continuing in 1971 to see if these useful properties can be combined to give reliable short-term storage plus adequate protection, over the short intervals of time between store and planting, when roots might be exposed to more fiercely drying conditions for periods up to half an hour.

A. J. LOW
R. M. BROWN

Special Types of Planting Stock

Tubed Seedlings

Work on the development of a reliable method for the production of tubed seedling stock continued at Inchnacardoch (Inverness-shire), Tulliallan (Fife) and Newton (Moray) research nurseries. Most of the experiments dealt with the fertiliser regime, but further studies were also made of fungicidal treatments and of graded seed. Results led to some changes being made to the "standard" technique (see *Report* for 1969, pp. 36-37). The procedure for

producing Lodgepole pine and Sitka spruce tubed seedling stock to be adopted as a consequence during 1971 is as follows:—

Side-slit polystyrene tubes (7·5 cm x 1·3 cm) are filled with a 1:1 mixture of peat and sand to which has been added "Enmag" fertiliser (1·5 kg/m^3), ground limestone (2·0 kg/m^3) and fritted trace elements (0·2 kg/m^3). One seed is sown in each tube and covered with a 3 mm layer of medium sand. No seed dressing is applied. Seed lots are graded to remove the lightest seed, and are moist pre-chilled at 3-5°C for three weeks prior to sowing to promote rapid even germination. After sowing, trays of tubes are watered from below and then kept for seven days at 25°C before being placed in a greenhouse with day and night temperatures of 21°C and 15°C respectively. Watering is carried out as required and a Captan drench is applied twice during the first month. Two weeks before planting (and usually six weeks after sowing) trays of seedlings are placed out of doors to harden-off. With seed of over 85 per cent viability it is possible to obtain 70-80 per cent germination of both Lodgepole pine and Sitka spruce three weeks after sowing, and a usuable eight-week seedling yield of 65-75 per cent of tubes sown.

Similar or slightly better results can be obtained using an alternative but less convenient fertiliser regime in which "Enmag" is omitted and Fisons "FL3P" at a dilution of 3 ml/litre applied at weekly intervals beginning three weeks after sowing, using an application rate of 2·5 litre/m^2 of bench area. In addition, the ordinary ground limestone is replaced by ground magnesian limestone.

Little further nursery experimental work is planned for 1971, but it is hoped to begin development of automated tube handling equipment.

In the many forest trials planted on ploughed peatland, results have for the most part continued to be very encouraging. They suggest that, in the absence of serious animal damage, tubed seedlings are likely to be suitable for use in the afforestation of upland peat sites where early weed growth is not normally a problem. With the aid of early shelter provided by step planting, both Lodgepole pine and Sitka spruce seedlings have proved capable of high survival and vigorous early growth despite their small size when planted. For example, in a trial at Naver Forest (Sutherland), Lodgepole pine planted as eight-week-old seedlings in September 1967 averaged 0·51 m in height at the end of the 1970 growing season and survival was 94 per cent. The effective planting season is likely to be from mid-April to late August. For most of this period, eight-week-old seedling should be satisfactory, but for spring planting, particularly with Sitka spruce, it may be better to use ten-week-old stock.

The most important factor likely to restrict use of tubed seedlings on peatland is the incidence of animal browsing damage. However, it is possible that animal curiosity has led to a higher level of damage in some of the relatively small experiments than would be the case if seedlings were planted on large areas. Guidance on this will soon be available from four relatively large (3 to 4 ha) blocks planted at selected forests during 1970.

During 1971, a large-scale user trial will take place in the North Scotland Conservancy. Almost 300,000 Lodgepole pine seedlings will be raised at Inchnacardoch and planted at various forests with peatland planting

programmes. This will provide an excellent opportunity for studying production, handling and planting methods in co-operation with Work Study and Conservancy staff. Planting will be done with the aid of a special manual planting tool devised by Work Study staff, capable of giving planting rates well in excess of 3,000 seedlings per man day on previously stepped peat ridges.

A paper describing research and development work to date on the production and use of tubed seedlings has been published in *Forestry* (Low, 1971). This paper deals with the problems encountered in afforestation trials on ploughed mineral soils and with regeneration trials as well as with the peatland trial results which are summarised above.

A. J. Low

Roll Transplants from Conventional Seedlings

A number of aspects of raising roll transplants (see 1969 *Report*, pp. 39–40, for description) were investigated at Alice Holt (Hampshire) during 1970, defining suitable fertiliser regimes and developing techniques to improve the sturdiness of plants. Sitka spruce, Corsican pine and Grand fir were included in all trials.

Increasing the amount of "Enmag" fertiliser in the peat medium from 1·5 to 3·0 kg/m^3 significantly depressed the height growth of all three species (at 0·1 per cent level) and significantly reduced survival of Sitka spruce (at 1·0 per cent level) and Grand fir (at 5·0 per cent level). The need for micronutrients in these peat media was demonstrated by height growth responses from Sitka spruce and Corsican pine to the addition of 0·5 kg/m^3 of a micronutrient frit containing boron, copper, iron, manganese, molybdenum and zinc.

The possibility of improving the sturdiness of roll transplants by removing roots extending from the base of 12½ cm deep rolls at monthly intervals was examined. This treatment markedly reduced height, but it also reduced root collar diameter, and in the end, no significant difference in sturdiness was produced. Fertiliser regimes incorporating high levels of nitrogen or potassium topdressings were also examined for a similar purpose, but results are not yet available.

Roll Transplants from Intensively Raised Seedlings

Experiments have shown that it is feasible to raise ½ + ½ roll transplants by raising seedlings in a greenhouse for three to four months and then transplanting them into rolls where they grow on a further three to four months outside.

Sitka spruce roll transplants from seedlings raised in the first half of 1970 were 19–25 cm tall by October 1970, and although rather less sturdy than the normal type roll transplants should be suitable for forest planting stock.

Planting Stock Raised in Japanese Paper Pots

Preliminary trials at Alice Holt during 1970 of this new system of raising container stock gave promising results.

The system was devised in Japan for raising sugar beet seedlings, and is now widely used in Scandinavia for raising forest planting stock. The container consists of a hexagonal-sided tube of paper, the tubes being stuck together with a water soluble glue to form sets of convenient size for bulk filling, sowing and subsequent handling. After sowing, normal watering causes the glue to dissolve and enables each pot to be easily separated from its neighbours at the end of the nursery phase for planting out in the forest.

Preliminary trials at Alice Holt in 1970 tested paper pots ranging in size from 4 to 8 cm in diameter × 7·5 cm in height.

Using growing media and fertiliser regimes similar to those used in tubed seedling work, four to five months' growth in a greenhouse produced Sitka spruce seedlings 18 cm (4 cm diameter pot) to 27 cm (8 cm diameter pot) and Corsican pine 9 to 10 cm tall (height not varying with pot diameter).

Table 5 gives details on the performance of both Sitka spruce and Corsican pine in the 4 cm diameter pots, which is the size most commonly used for forest planting stock in Scandinavia.

TABLE 5

PERCENTAGE OF POTS CONTAINING SEEDLINGS—TOTAL SEEDLINGS AND USABLE* SEEDLINGS

Measurement	Sitka spruce	Corsican pine
Per cent pots with any seedlings	69	94
Per cent pots with usable seedlings	56 (>12 cm)	74 (>8 cm)

* Usable seedlings arbitrarily chosen on heights shown. Further experience should produce a more reliable definition of a usable seedling.

Information from Scandinavia suggests that both the nursery and field handling of Japanese paper pots can be highly mechanised, giving hope that this method could become an economic proposition in Great Britain.

R. M. BROWN

REFERENCE

Low, A. J. (1971). Tubed seedling research and development in Britain. *Forestry* **44** (1), 27–41.

PLANTING

Forest Use of Roll Transplants

Experiments planted in 1969/70 were assessed at the end of 1970, the results providing the first reliable indication of the performance to be expected from roll transplants. Table 6 gives the mean heights and survival percentages of the species in these experiments.

TABLE 6

MEAN HEIGHTS (CM) AND SURVIVAL (%) OF TREES AT END OF 1970 ROLL TRANSPLANT EXPERIMENTS

Forest	Species	Assessment	Roll Transplants planted			Control (1+1) planted
			July 1969	September 1969	Spring 1970	Spring 1970
Towy (mineral soil)	Sitka spruce	Height	39	34	36	27
		Survival	99	90	100	100
Towy (peat soil)	Sitka spruce	Height	47	39	45	39
		Survival	99	99	98	99
Thetford (mineral soil—no overhead cover)	Corsican pine	Height	118	128	129	104
		Survival	65	93	92	96
Thetford (mineral soil–overhead cover)	Corsican pine	Height	172	158	152	105
		Survival	85	87	95	91

With one exception survival of roll transplants was high, and the results suggest that they should survive at least as well as conventional transplant stock. More interesting is the fact that roll transplants are taller than conventional plants. This is partly due to their greater height when leaving the nursery, but with Corsican pine, it is also a fair reflection of more rapid growth in the forest. It should be noted that both roll and conventional transplants in these experiments were raised from the same seed, and are an identical age from sowing.

Forest Use of Tubed Seedlings

The results from 1969 and 1970 experiments testing tubed seedlings in the south generally confirm the results of tubed seedling experiments elsewhere (see *Report*, 1970, pp. 47–49). The account of the extensive northern trials has been combined, for convenience, with the account of tubed seedling production in the previous section of this *Report* under "Special Types of Planting Stock" (pp. 31–33).

R. M. BROWN
A. J. LOW

Planting Mechanisation

Further modifications have been made to the Finn Forester Tree Planter to enable it to perform on spaced furrow ploughing. A private forestry organisation has co-operated and financially assisted in this project. However, the machine cannot yet be recommended for standard ploughed ground presenting the normal degree of irregularity.

S. A. NEUSTEIN

Spacing

A study of the effects of spacing upon wood density in Norway spruce was carried out in co-operation with the Forest Products Research Laboratory at the Forest of Ae (Dumfriesshire). The conduct of the study was similar to the study on Sitka spruce reported last year. The findings confirm the pattern revealed in the previous investigation.

G. G. M. TAYLOR

CHOICE OF SPECIES

High and Exposed Sites

Scotland and Northern England

Two trial plantations and an associated fertiliser experiment were planted at Hamsterley Forest (County Durham) at elevations up to 650 m. At Queen's Forest (Inverness-shire), where two similar experiments were planted up to an elevation of 655 m, it was noted that on mineral, as opposed to peaty soils, nitrogenous fertiliser has improved foliage colour in the first year.

The intensive study of airflow by means of tatter flags at Wauchope Forest (Roxburghshire) described in the 1968 *Report* is being used as a bridge between exposure appraisal of bare ground and a forecast of the onset of windthrow on the same ground. The method being used is to apply a mathematical correlation between flag tatter and angles to the skyline at Wauchope Forest, to the distribution of windthrow at Kershope Forest (Cumberland). If this model explains a significant proportion of the actual damage, it might be used with some confidence in delineating future critical tree heights in new acquisitions in this region.

The influence that windthrow susceptibility can have on the internal rate of return has been investigated in several test cases and an improved acquisition procedure which takes into account estimated terminal height has been proposed. Under conditions of high estimated hazard, the economic planting limit could thereby be lowered.

Several appraisals of yield potential on the oldest post-war trial plantations in North Scotland have indicated that early exposure troubles were often overcome at the thicket stage and Yield Class 8 might be quite widely attainable assuming the best current techniques were used overall.

Wales

Four experiments which tested above-standard establishment techniques for Sitka spruce in very severely exposed conditions at Radnor Forest (Radnorshire) (see *Report* for 1969 and 1970) have terminated. The best of the techniques tested is summarised below and can be recommended where assured establishment and rapid early growth is of more importance than the cost of planting ; e.g. in landscaping on difficult sites.

(1) Plants should be potted in sphagnum peat without added fertiliser, in pots through which roots can penetrate. They should be potted up in the winter before planting so that some root growth can take place in the pots before trees go to the planting site.

(2) Transplants are more robust and are more able to recover from unseasonable frosts than seedlings.

(3) The tree is planted *with* pot and its rooting medium, so that there is minimum root disturbance. Planting should take place in late spring before the new leaders exceed 5 cm in length. Phosphate should be applied at planting.

(4) The larger the pot, the better the growth, but even the smallest pots used (150 cm^3 capacity) result in significantly better growth than bare-rooted plants.

(5) Sheltering each plant with an encircling plastic screen for the first year is highly beneficial.

Atmospheric Pollution

Improvements in growth have been noted on some previously very slow-growing trials in the South Pennines. It is open to speculation whether this is due to the generally acknowledged regional decrease in smoke or whether the trees have grown beyond a limiting phase in relation to their overall environment. Supplementary studies in what had been a relatively quiescent field are proposed.

S. A. NEUSTEIN

J. EVERARD

PROVENANCE

Lodgepole Pine

Alaskan Provenances

Good resistance to exposure and straight growth of an Alaskan provenance from Hollis, Prince of Wales Island, in many trial plantations in the north of Scotland led to increased interest in seed from the northern coastal part of the species range. The first experiments testing two Alaskan provenances were noted in the *Report* for 1965. Five years later, trees of Hollis provenance were still superior to those from Haines near Skagway, Alaska.

Experiments established in 1967 at very exposed sites at South Kintyre (Argyll) and Shin (Sutherland), contain three other Alaskan provenances (Sitka, Petersburg and Juneau), together with plants originating from the earlier Hollis plantations and a home-collected lot originally from Queen Charlotte Islands. Two possible intermediate types from Terrace, Skeena River, and Hope, Fraser River, were included together with a Washington coastal lot from Long Beach.

Sheep caused damage initially at South Kintyre, which is the more exposed site. After three years there was no significant height difference among the Alaskan or Queen Charlotte Islands provenances, though they were all very much shorter than that from Long Beach. Terrace and Hope were intermediate in height. The home-collected Hollis provenance was shortest at both sites. Some foliage browning has taken place on all provenances at South Kintyre, but is almost absent at Shin. This can be compared with an observation at Rumster Forest (Caithness) where trees of Hollis origin were undamaged while an adjacent stand from Petersburg had brown foliage.

Studies of Factors Leading to Basal Bowing

Further studies of root/shoot ratios were made using seedlings of the same provenances sampled as 1+1 transplants a year earlier. This investigation has two objectives : to see whether provenances with an inherent tendency to severe early windsway can be detected as soon as possible, and to give a better understanding of basic provenance differences. The results showed a very large individual tree difference in root-shoot ratios both as one-year seedlings and as transplants. The ratios were not closely correlated with plant size within a provenance. As noted in the 1970 *Report,* the Alaskan provenance from Glacier Bay had a very high root/shoot ratio while the southern coastal provenances had low ratios. Figure 1 shows the relationship between the root/shoot ratios of the one-year seedlings and the 1+1 transplants. It should be noted that the samples were taken in different years and from different sites. Correlation between the two was $r=0{\cdot}68$, significant at the 1 per cent level.

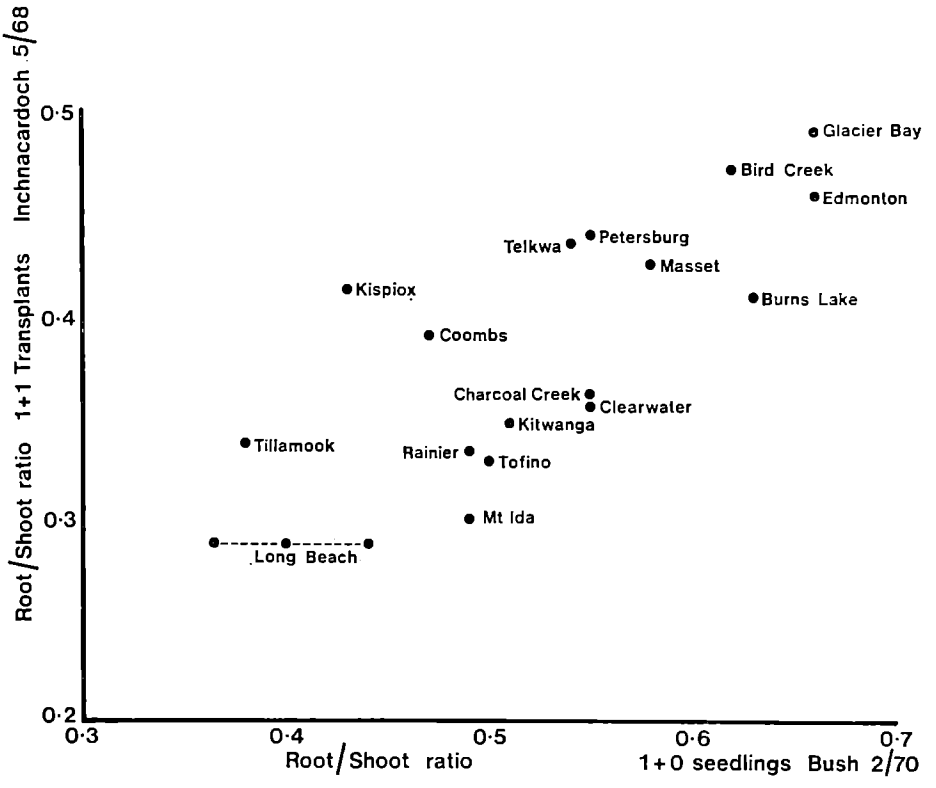

Figure 1: Comparison of root/shoot ratios of Lodgepole pine provenances as seedlings and transplants (ratios based on dry weights).

Experiments Planted in 1970

Up to 86 provenances were successfully established at eight sites in the North and at six sites in the South. In most cases survival was high, despite a very dry period in June. Only at Glengarry (Inverness-shire) was the survival of many provenances poor. One provenance, from Mendocino, California, had heavy losses on several sites. This provenance has grown very fast in the nursery but it had a very low root/shoot ratio ; the deaths were not caused by winter injury. One further experiment was planted with this set of provenances at Rumster (Caithness).

IUFRO Collection

Seed sown at Newton Nursery (Moray) showed considerable variation in germination (24–55 per cent) after a cold spring and dry period in early summer, whereas at Wareham Nursery (Dorset) germination was normal at 85–90 per cent. Height growth varied as would be expected from earlier experiments, the US coastal provenances being best. Tallest was Vail near Rainier, Washington, which was second tallest in the earlier experiment. Two seed lots from the Yukon were poorest for height.

On appointment as Co-ordinator for the International Trials with this species (which includes 146 provenances), R. Lines sent out questionnaires to discover what kind of experiment the twenty-seven co-operators envisaged.

Based on the replies and on subsequent discussions and correspondence, a plan for both short-term and medium-term experiments was issued in October 1970 for the 100 experiments proposed (Lines, 1971).

Scots Pine

The experiment comparing the progeny from eleven seed stands in East Scotland on three sites was assessed for height after fifteen years. Results are given in Table 7. The order of ranking is similar to that at six and ten years (see *Report* for 1963) and it is encouraging to note that experimental design has successfully kept the standard error of the provenance differences to a low level. Ballochbuie is the only stand of certain native origin, while the Drummond Hill stand possibly represents an imported lot from Germany. All the others are of unknown origin, probably consisting of various mixtures of native and imported strains and their resultant hybrids. Some light has been thrown on this by biometrical studies in these three experiments by A. S. Gardiner (1970), who kindly provided the data on needle length shown in Table 7. There is a highly significant correlation (r=0·8) between mean height and needle length. This parallels the correlation found by Genys (1970) of r=0·88 in a collection of 80 provenances covering the entire range, and suggests a practical use for needle measurements as a predictive guide to relative performance.

TABLE 7

DOMINANT HEIGHT OF SCOTS PINE PROVENANCE (M) AND NEEDLE LENGTH (MM) AT 15 YEARS ON THREE SITES

Provenance	Dominant Height				Needle Length
	Culloden (Laiken)	Glenlivet	Glen Isla	Mean	Mean of three sites
Drummond Hill Forest, Perthshire	6·36	3·15	2·45	3·99	51·9
Altyre Estate, Moray	6·09	3·13	1·97	3·73	51·0
Crathes Estate, Aberdeenshire	6·11	3·08	1·87	3·69	46·6
Orton Estate, Moray	6·06	3·05	1·89	3·67	45·2
Balnaboth Estate, Angus	5·54	2·91	1·80	3·42	48·0
Ballindalloch Estate, Moray	5·46	2·84	1·70	3·33	44·2
Glentanar Estate, Aberdeenshire	5·81	3·13	1·85	3·60	46·2
Rannoch, Creagan-na-corr, Perthshire	5·95	3·22	1·98	3·72	48·9
Meggernie Estate, Perthshire	6·12	3·17	2·22	3·84	48·6
Rannoch, Allt-na-Bogair, Perthshire	5·27	2·72	1·70	3·23	46·7
Ballochbuie, Aberdeenshire	5·57	2·70	1·62	3·30	44·3
Standard error ±	0·09	0·09	0·23		
Differences significant at per cent level	1%	1%	5%		

Sitka Spruce

Identification of Origin of Home-Collected Seed Lots

There were heavy cone crops on many older British stands of Sitka spruce in 1969 and over 900 kg of seed were collected. The seed origin of these stands is largely unknown, though since seed was not collected commercially in the Queen Charlotte Islands, British Columbia, before 1922, the source is most likely to have been Washington. To check on this supposition, samples of unknown provenance from 21 stands were sown at Alice Holt (Hampshire) and Bush (Midlothian), together with several known provenances. Due to the unusually mild conditions in autumn, frost damage was negligible and the best guide to the identity of the unknown provenances was their rate of bud formation and needle colour, which allowed a separation of the majority of the seed lots.

Survey of Young Plantations of Washington Origin

A survey was made of the large-scale planting of Washington provenances during the period 1968–1970, when there was difficulty in obtaining planting stock of Queen Charlotte Islands origin. An unusually severe frost had caused damage to the seedlings at several nurseries but the surviving plants were used at 80 forests. A sample of one third of these forests showed that survival and later growth was usually satisfactory, with a few notable exceptions. The major risk with these southern provenances is clearly in the nursery, though in a severe winter they may suffer heavily in the forest as well.

Experiments Planted in 1960–61

The collection of fourteen provenances planted in 1960–61 (see *Report* for 1968) has been assessed at ten years.

The results are presented in Table 8 as percentages of the mean height of the tallest provenance at each site ; the mean height of the latter is given as an indicator of the growth at each site, and, as a standard of comparison from site to site, the mean height of the one provenance from Queen Charlotte Islands. This gives equal weight to each site in provenance comparisons.

The fifteen sites can be grouped on the basis of fertility and elevation into " Good " (Numbers 15, 3, 4, 13, 14 and 2), " Moderate " (7, 10, 6, 8, 5 and 9) and " Difficult " (1, 12 and 11). They range from a sheltered bracken slope close to the influence of the Gulf Stream (Ratagan) to a severely exposed site at 744 m elevation.

Alaskan provenances have shown relatively good growth only at Shin, in the far North of Scotland, and at the high elevation site at Mynydd Du (Breconshire). The British Columbian provenances showed wide variation in performance, Terrace being no taller than the best Alaskan ones while Sooke was second tallest overall. Sooke was consistently tall, never falling below 83 per cent of the tallest provenance at any site. The other Vancouver Island provenance (San Juan River) was less tall. The widely-used Queen Charlotte Islands provenance was fairly consistent in height growth over a broad range of sites although less tall than the mean of the provenances from Washington and Oregon. However, such was the variability of growth between the provenances, that on ten out of fifteen sites, the Queen Charlotte Islands provenance was taller than one of the four southern provenances.

TABLE 8

MEAN HEIGHT AS A PERCENTAGE OF THE TALLEST PROVENANCE OF SITKA SPRUCE AT 10 YEARS ON 15 SITES

Site of Experiment (North to South)

(See key in right hand column)

Provenance	*Site* ° N	*1* 58	*2* 57½	*3* 57¼	*4* 56	*5* 55	*6* 55	*7* 53	*8* 52½	*9* 52¼	*10* 52½	*11* 52	*12* 51¾	*13* 51½	*14* 50½	*Over-all Mean*	*15* 52	*Key to Sites*
Cordova, Alaska	60½	99	(59)	35	(46)	(84)	65	63	54	63	65	94	62	53	65	65	51	*1.* Shin, Sutherland
Lawing, Alaska	60	100	79	60	(58)	76	58	—	65	52	66	82	52	49	—	66	—	*2.* Deer, Aberdeenshire
Seward, Alaska	60	(91)	(80)	(63)	—	(82)	—	—	—	—	—	70	—	—	56	74	—	*3.* Ratagan, W. Ross
Juneau, Alaska	58¼	89	85	54	—	76	72	—	—	—	—	83	—	—	60	74	—	*4.* Loch Goil, Argyll
Sitka, Alaska	57	82	(68)	63	(62)	—	62	—	60	63	63	100	55	57	73	67	52	*5.* Glentrool, Kirkcudbrightshire
Terrace, B.C.	54½	94	82	69	—	75	66	83	69	71	70	83	63	60	73	74	59	*6.* Wark, Northumberland
Skidegate, B.C. (Q.C.I.)	53	96	95	76	82	84	92	78	88	81	83	92	72	82	86	85	77	*7.* Clocaenog, Denbighshire
San Juan R, B.C. Vancouver Is.	48¼	98	82	90	(80)	72	92	77	87	77	80	82	85	78	80	83	83	*8.* Taliesin, Cardiganshire
Sooke, B.C. Vancouver Is.	48¼	92	85	100	89	99	87	93	95	94	95	92	100	88	84	93	100	*9.* Tarenig, Cardiganshire
Forks, Wash.	48	93	100	83	82	—	89	76	92	83	93	78	76	85	86	86	96	*10.* Myherin, Cardiganshire
Hoquiam, Wash.	47	93	(81)	96	—	82	100	76	93	90	79	78	78	80	84	85	92	*11.* Mynydd Du, Brecon
Jutland ex Washington	?	(78)	98	—	100	—	—	100	94	100	100	84	64	100	100	93	—	*12.* Bannau, Brecon
Jewell, Oregon	46	88	99	86	83	100	97	88	100	85	92	94	72	86	93	90	88	*13.* Rheola, Glamorgan
North Bend, Oregon	43	95	87	85	75	82	94	82	100	93	82	83	74	81	85	86	79	*14.* Wilsey Down, Cornwall
																		15. Killarney, Kerry (Ireland)
Tallest at site = 100%, m		1·83	3·17	4·28	4·24	2·53	2·98	3·02	2·37	2·48	2·87	1·02	2·05	3·66	3·48		5·03	
Mean Height Skidegate, m		1·75	3·04	3·25	3·49	2·13	2·74	2·36	2·08	2·01	2·37	0·93	1·48	2·99	2·98		3·89	
Standard error ±		0·11	0·21	0·20	0·18	0·13	0·20	0·26	0·18	0·08	0·11	0·06	0·12	0·12	0·11		0·24	
Significance of Difference		N.S.	N.S.	***	*	**	***	N.S.	***	***	***	N.S.	***	***	***		***	

Notes: 1. Figures in parentheses are from incompletely replicated or unreplicated plots.
2. Significances: NS=Not significant; *=S.D. at 5%; **=S.D. at 1 %; ***=S.D. at 0·1%.
3. Sites 7 and 14 measured at 9 years after planting.
4. Overall mean excludes data from Killarney, Republic of Ireland.

The Washington provenances were rather similar in growth and slightly shorter than those from Oregon, of which Jewell was taller. The provenance collected in Jutland from stands believed to be of Washington origin was tallest overall. This could be partly due to phenotypic selection over several thinnings or a gain from out-breeding in Jutland.

The pattern of growth in the Killarney experiment was very similar to the overall pattern in Britain.

The incidence of lammas or secondary growth was recorded at seven sites with an overall range of nil (Seward) to 25 per cent (Jutland). Other provenances with much lammas growth were Sooke and Jewell, but Hoquiam (12 per cent) and North Bend (14 per cent) showed that this character was correlated more with vigour than with latitude. Forking or presence of two or more leading shoots was assessed at ten sites. Overall occurrence was worst in the tallest provenances. The Alaskan lots had little forking except for Juneau, and the Skidegate provenance had as many forked trees as those from Washington.

Silver Firs

The first assessments from three small experiments with *Abies grandis* in England and one in Scotland show that two Vancouver Island provenances and one from Darrington in northern Washington are taller than two lots from Randle and Wind River in southern Washington. A general survey of provenance performance in this species points strongly to the superiority of Vancouver Island provenances. *Abies grandis* was also used in the experiments comparing a large number of *Abies alba* provenances planted in 1965–66. The best of the latter (Juras, Jugoslavia, Calabria) are nearly as tall as the *A. grandis*. Fourteen additional provenances of *A. alba* from selected stands in Czechoslovakia have been added to the Drummond Hill (Perthshire) experiment.

Douglas Fir

Forty-six of the 1966 IUFRO collections of Douglas fir (*Report* for 1970, p. 63) were successfully re-sown at Wareham Nursery in 1970. Provenances from Central and Southern Interior British Columbia were the first to germinate and had terminated growth by the end of August—early September. This group had a mean end of season seedling height of 7·68 cm. Provenances from Vancouver Island (British Columbia), Washington, Oregon and California were slower to germinate and had an extended growing season. This group had a mean end of season seedling height of 16·60 cm. Vigour as indicated by seedling height shows no clinal variation related to elevation of origin, and very little related to latitude, except within the extreme northerly British Columbia origins.

A severe frost (−5 °C) in mid-November caused heavy losses to provenances from Oregon and California.

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ARBORICULTURE

Conifer Conference

During the year, 120 estates were visited to obtain up-to-date measurements of specimen conifers, with special reference to the present condition and size of original or very old specimens. The results, together with those of the preceding years and giving information on nearly 300 estates, were assembled for the Report of the Conifer Conference, 1970 and are now being prepared for publication in Forestry Commission Booklet No. 33, *Conifers in the British Isles*. Broadleaved specimen trees were also measured and two accounts of the trees found in Scotland are being published in periodicals.

Bedgebury Pinetum

The collection at Bedgebury Pinetum (Kent) has now been extended to include dwarf conifers. More than 100 dwarf cultivars have been acquired and the majority have been planted in beds formed at the western end of Yew Bank.

Kilmun Arboretum

In Kilmun Arboretum (Argyll) almost all plots windblown in 1968 have now been replanted. A cloudburst in June caused further damage but this too has largely been made good.

Removal of windblown timber was completed at Crarae Forest Garden (Argyll), thus allowing replanting to proceed. The difficult task of replacing footbridges over the Crarae River has also been completed.

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NUTRITION OF FOREST CROPS

Presenting the Results of Nutrition Experiments

Because the responses of young crops to fertiliser treatments are usually judged by height growth, experimental results are usually presented in terms of mean height. Mean height however has two serious disadvantages when trying to apply experimental results in practical forest management: it is of little value when several species are being considered; and it is difficult to compare a number of experiments with similar treatments but differing ages.

In presenting some of the results in this section, an attempt has been made to predict the General Yield Class (GYC) the crops are likely to achieve. This has been done by translating mean height to top height and determining the GYC from top height/age curves. These curves have been produced by the Mensuration Section of Management Services Division and are based on data obtained from stem analysis of sample plot trees.

While such prediction may be acceptable to compare relative growth rates, the bases cannot be used to predict yield classes of crops less than 10 years old. Variability of response in some young crops is great and expectations of continued response are too uncertain. Results from longer established experiments, where a consistent growth pattern has been established, are more reliable.

Phosphate and Potash Fertilisers

One of the long-term phosphate trials comparing rates and types of rock phosphate has shown that Kola phosphate produces poorer growth of Sitka spruce after three years, than other types. Kola phosphate has the lowest citric-soluble P content of the types tested, nearly five times less soluble than Gafsa phosphate. The site, at Glenorchy Forest (Argyll), is one of the most testing for phosphate availability for spruce in the series. Other experiments, more favourable either climatically or edaphically, do not show significant growth differences between rock phosphate types; this has also been the result so far in the series planted with Lodgepole pine.

A further experiment at Mabie Forest, on a lowland raised bog, confirms that potash as well as phosphate at planting significantly improves height growth of Lodgepole pine after only three years. This experiment also shows that potash application heavier than the standard rate of 100 kg K/ha has made no significant difference to height growth at this stage.

There are indications that in the colder areas of the far north fertiliser inputs may be less effective than in warmer zones. For example, the standard input of 50 kg P/ha may last only six to seven years, instead of the expected ten to twelve years, while 200 kg K/ha input does not appear to maintain satisfactory foliage concentrations longer than the six years expected with the standard rate of 100 kg.

TABLE 9

RESPONSE OF SITKA SPRUCE IN WALES TO PK FERTILISERS

Forest and Experiment Numbers	Rate of fertiliser at planting kg/ha		Foliar nutrient levels before experimental treatment		Experimental treatment			Crop response			
					Age when applied	kg/ha		Age when measured	Mean height	Calculated top height	Current growth rate expressed as equivalent GYC (metric)
	P	K	%O.D. Wt. P	K		P	K		(m)	(m)	
Towy 10	0	0	0·21	0·47	2	0	0	5	0·79	1·26*	13·5*
						50	0		0·73	—	—
						0	94		0·89	1·38	15·0
						50	94		0·86	—	—
Rheidol 5	15	0	0·21	0·31	1	0	0	6	0·64	1·32	12
					1	0	62		0·88	1·62	14·5
					4	0	62		0·77	—	—
Tarenig 7	15	0	0·18	0·44	3	0	0	13	2·59	3·6	11
						19	0		2·49	—	—
						0	55		2·11	—	—
						19	55		3·14	4·05	12·5
Tarenig 9†	20	0	0·21	0·51	3	0	0	9	1·63	2·8	15
						25	0		1·77	2·9	15·5
						50	0		1·76		
Tarenig 11	12	0	0·17	0·44	3	0	0	11	1·47	2·67	11
						85	95		2·16	3·24	13
Clocaenog 53	26	0	—	—	—	—	—	6	1·38‡	2·0	18
	41	47							1·64	2·32	21·5
	83	94							1·71	—	—
	166	188							1·87	2·6	24·5
	332	376							1·78	—	—

* Conversion into top height and GYC have only been done where mean heights differ significantly ($p=0·05$).

† Four rates of potash were applied without a significant effect.

‡ All PK treatments are significantly taller than P only; within PK rates, only P166/K188 is significantly greater than P41/K47.

Sitka spruce on unflushed hill peats in the Scottish Border area is showing very early K deficiency, within three years from planting. This together with the lithology aligns these soils with Welsh peats. Further work on potash input is planned for these areas.

The results from six Welsh experiments dealing with PK fertilisers are brought together in Table 9. The first four experiments (Towy 10, Rheidol 5, Tarenig 7 and 9) are on peats dominated by *Molinia*. The other two are on less fertile peats, which are dominated to varying extent by *Calluna* and *Trichophorum*.

It should be borne in mind that all experiments, except Towy 10 and Clocaenog 53, had been given phosphate at planting (albeit at a low rate) in addition to the experimental treatments. In no instance, except Towy 10, is there an unfertilised control. In general there has not been such a good response to fertilisers as was hoped for; this is in contrast to the results for some mineral soils in south-west England, reported below.

In the experiments in Wales neither the ground vegetation nor the peat type would have been a clear guide to the response of the crop to added fertiliser, though the growth response, in general, accords with what might have been predicted using the foliar nutrient levels shown in Table 9. It is to be hoped that the results of chemical analysis of peat from these sites, already in hand, will help prediction. Until such time the use of potash in addition to phosphate on Welsh peats seems to be justified.

Phosphate Fertilisers in South-West England

Assessments have recently been made in experiments which deal with rates of phosphate fertiliser in Devon and Somerset. The results are given in Table 10 together with data from older experiments at Wilsey Down Forest (Cornwall). There is a good and consistent response to phosphate up to 100 kg P/ha on all sites.

In addition to this evidence, data taken from a cultivation experiment at Haldon, Exeter Forest, Devon (again on Eocene flint/gravel soil) and shown in Figure 2 illustrates the benefit of top dressing with phosphate. This experiment, which received 22 kg P/ha in 1957 at planting, began to show signs of phosphorus deficiency about 1964 and was top-dressed with 75 kg P/ha in 1966.

Fertilisers and Herbicides

Early control of *Calluna* is necessary for maintaining initial fast growth of Sitka spruce on lowland peats. After four years the spruce in untreated control plots planted in mixture with pine or larch are now in check. On these sites of very low nutrient status control of heather also initially improves the uptake of phosphate.

Experiments involving application of fertilisers to checked crops confirm that on deep peat, where herbicide is not used to control heather, response of Sitka spruce to nitrogen is unlikely to last for more than three years. However on some slightly better peaty ironpan soils nitrogen fertiliser appears likely to have a longer effect without herbicide. On these sites the initial dramatic uptake of all nutrients, when herbicide alone is used, is

apparently short lived. However, growth patterns have yet to indicate which is the most favourable treatment in terms of length of response. First indications are that for spruce crops in check on deep peat and less than 2 metres tall, a combination of a phosphate/potash fertiliser and 2,4–D herbicide may produce the most economic response.

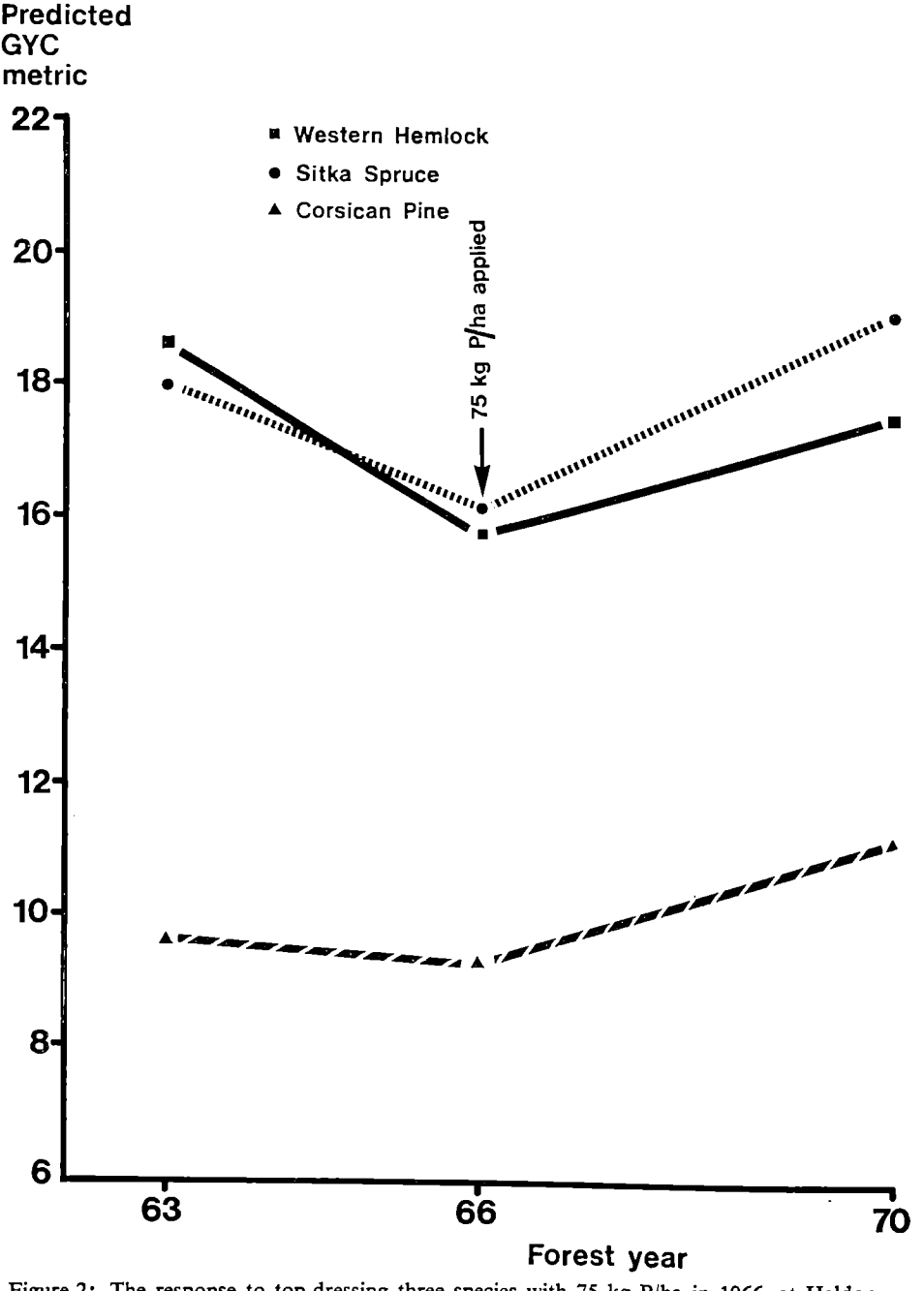

Figure 2: The response to top-dressing three species with 75 kg P/ha in 1966, at Haldon, Exeter Forest, Devon.

TABLE 10

RESPONSE TO PHOSPHATE FERTILISERS IN SOUTH-WEST ENGLAND

Forest and Experiment number	Geology/ lithology	Soil type	Species	Age		Rate of phosphate (kg P/ha)	Mean height (m)	Calculated top height (m)	Current growth rate expressed as equivalent GYC (metric)
				When treated	When assessed				
Wilsey Down 5	Lower Culm shales/ slates	Peaty gley/ ironpan	Sitka spruce	5	9	17 50 100	1·39 1·96 2·35	2·2 3·0 3·5	12 16 18·5
Wilsey Down 8	Lower Culm shales/ slates	Peaty gley/ ironpan	Sitka spruce	5	12	0 17 34	0·94 2·41 2·87	1·5 3·6 4·2	6·5 12·5 14
Halwill 4	Culm shales/ slates	Surface water gley	Sitka spruce	6	9	Basic* 16 Basic 16+53 Basic 16+168	2·48 2·72 3·15	3·4 3·7 4·3	18 19 22·5
Haldon 12	Eocene flint/ gravel	Ironpan/ humus iron podzol	Sitka spruce	0	7	22 45 90 180	2·06 2·39 2·50 2·45	2·7 3·06 3·17 3·12	20·5 23 25 24
Haldon 15	Eocene flint/ gravel	Ironpan/ humus iron podzol	Corsican pine	0	8	25 50 100 150	2·26 2·50 2·85 2·94	3·25 3·45 3·75 3·8	13 14 15·5 16
Neroche 1	Eocene flint/ gravel	Humus iron podzol	Sitka spruce	5	9	Basic 12 Basic 12+50 Basic 12+105	1·94 2·75 2·94†	2·8 3·9 4·2	15 20·5 22

* The basic rate quoted is that given at planting.

† The response at this rate is not significantly different from the 12+50 rate.

The trials laid down in the south in 1965 (see *Reports* for 1966 p. 33, and 1969 p. 80) are being reviewed. Preliminary conclusions on the nutritional importance of herbicides vary with both soil type and species, as might be expected, but some generalisations are possible.

Sitka spruce on one ironpan soil and on one peaty gley has clearly benefited from extra phosphorus, and from nitrogen and potassium. The benefit appears to be more marked in the absence of chemical weeding ; this effect is partly explained by the increased nitrogen concentration in the needles when herbicides are used. In contrast, on another ironpan soil, which was completely ploughed and where the weeds are grassy rather than ericaceous, little effect of either fertiliser or herbicide has been seen.

Western hemlock in two trials has been adversely affected by the use of paraquat or 2,4–D or both. However, the appearance of hemlock is so much improved by the removal of competing ericaceous vegetation, which again shows in improved nitrogen uptake, that one feels sure that this species would show growth responses if heather killing could be achieved without damage to the tree. There is thus a clear difference between the tolerance of Sitka spruce and hemlock to herbicides while both are sensitive to ericaceous competition.

In contrast to Sitka spruce and hemlock, Scots, Corsican and Lodgepole pines show little improvement with the removal of competing vegetation, indeed in several cases growth has been adversely affected, both with low and high nutrient inputs.

Distribution Patterns of Fertilisers Applied from the Air

Fixed line sampling tests across flight lines have been done in South and West Scotland to check the distribution of fertilisers applied both by helicopter and fixed-wing aircraft.

Results have shown that while there has been considerable variation between individual samples, ranging from a quarter to twice the recommended rate, the mean values were within acceptable limits. It is normally considered unlikely that there will be large continuous areas of low application but some results from samples taken in an area free flown in South Wales by fixed-wing aircraft have suggested that the rate can fall unacceptably low, though the distribution may still be even.

One description of evenness is the Distribution Quotient, calculated from the weights of fertilisers collected in randomly distributed containers, where

$$Q = \frac{\Sigma \text{ heaviest 50 per cent}}{\Sigma \text{ lightest 50 per cent}}$$

In Sweden contracts contain a penalty clause which is invoked if Q is above 3·0. Another possible guide for acceptable distribution is the " half value ", which may be used in New Zealand ; this is the percentage of sampling points which receive less than half the designated application rate. An acceptable " half value " may be 33 or less. It appears that where a sound system of ground control is used the distribution is reasonably uniform, but regular sampling should be considered.

Analysis of Soils and Foliage

Mineral Soils

In addition to routine analyses for the Site Survey Officer, a start has been made on analysing a large number of soils in connection with Project 391, the treatment of checked crops by Conservancy Management (see *Report* for 1970, p. 76).

Foliage

Last year we reported a steady increase in the number of samples being received for analysis in the laboratory at Alice Holt; this has taken a further jump this year. Some 4,600 samples have been received and only about half had been analysed by the end of the year under review. A breakdown of the samples shows that two-thirds come from nutritional or other silvicultural forest experiments, 13½ per cent are being analysed so as to help us give advice to Forestry Commission managers, 11½ per cent are for nursery experiments or from other Research Division sections, and only 6½ per cent are from outside the Forest Commission. It is clear, therefore, that the main work load on the analytical laboratory comes from within Research Division.

Foliage samples must be stored so that they can be located quickly and accurately, yet do not take up much room. This problem was solved three years ago by modifying the system used at East Malling Research Station (*Report* for 1968, p. 51). Each of three wall racks holds 1,519 samples (see Plate 11); a fourth is now needed.

Quality Control in Analysis

A project launched by the International Union of Forestry Research Organisations in which standard foliage samples were sent to a large number of forest research stations and other organisations doing analysis in connection with forestry research, allowed us to check on the accuracy of our chemical determinations. There were some rude shocks. We were able to detect a slowly developing fault in one of our processes. When this had been put right we were pleased to find that our determinations for nitrogen and phosphorus were reliable; potassium determinations were a little less satisfactory. In contrast it was clear that calcium and magnesium determinations both by ourselves and by many of the people contributing to this study were rather unreliable. This project will continue, as a calibration service for laboratories concerned with foliage analysis.

We wish to pay tribute here to our Dutch colleagues at Wageningen who have been responsible for the organisation of this project and the collation of the results.

Permanent Foliage Sampling Plots

The results from these plots will not be reported each year from now on, but a progress report indicating the trends and changes will be made at intervals of three years or so. We can then include southern plots (which have been established this year) and it should be possible to get a better picture of the year-to-year variation in nutrient concentration over the country as a whole, for a larger number of species than previously.

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FOREST WEED CONTROL

Research was concentrated on developing herbicides for controlling specific weed problems, and in investigating particular aspects of safety in the employment of two of our commonly used herbicides. The results of these investigations are reported below.

CHEMICAL CONTROL OF SPECIFIC WEED POPULATIONS:

I. HERBACEOUS WEED CONTROL

Chlorthiamid (" Prefix ")

Further information on the sensitivity of young crop trees to chlorthiamid was gained from two sources during the year.

Firstly, experiments started in 1969 (see *Report* 1970, p. 81) and designed to test for crop damage, were re-treated with chlorthiamid. Assessments at the end of the year confirmed that Western hemlock is sensitive to chlorthiamid, survival being reduced and many trees showing typical symptoms of chlorthiamid damage. Norway spruce, classed as intermediate in sensitivity has so far been unaffected (but see below). Probably the most interesting result is that Corsican pine (a " resistant " species) at Thetford Forest (Norfolk) was markedly reduced in height by repeated chlorthiamid applications, although there was no effect on survival. Growth reductions in " resistant " species has not been detected in previous experiments, and it is useful to have evidence that it may occur.

The second source of evidence was a series of Conservancy trials, testing, in conjunction with the Work Study Section, a new granule distributor, which were monitored by Research staff for crop damage to Corsican pine, Norway spruce and beech. Generally, both Corsican pine and beech were undamaged, although slight chlorthiamid damage symptoms were observed at some sites, but the reaction of Norway spruce was variable. At four sites out of six, it showed little damage, but at the other two sites it was damaged by the chlorthiamid application.

Generally, therefore, the new evidence supports current recommendations for the use of chlorthiamid.

Atrazine

The results of experiments from 1967 to 1970 with atrazine have been fully reported elsewhere (Brown, 1970). These experiments have shown that atrazine provides a good kill of a range of fine and soft grasses at 2–4 kg a.i./ha applied from February to May, control persisting for most of the growing season. Coarser grasses (e.g. *Deschampsia caespitosa* (L.) Beauv.) and non-graminaceous species were not well controlled at these rates, and further investigations are in hand to see if the spectrum of control can be broadened by the addition of oil or other chemicals to the spray.

All coniferous species seem to tolerate overall sprays of atrazine without serious damage, suggesting that this herbicide will be easy and cheap to apply because trees will not need to be protected.

II. WOODY WEED CONTROL

Tree Injection on Broadleaved Species

Assessments of experiments laid down in 1968 and 1969 confirmed that injections of 2,4,5–T or 2,4–D into standing trees can give control as good as basal bark applications in diesel oil, provided at least 1 ml of a solution containing 50 per cent active ingredient of herbicide is injected at centres not more than 7·5 cm apart. There appears to be no date at which injection gives a better kill than at other dates during the year.

The relative effectiveness of 2,4–D amine and 2,4,5–T ester should be clear by the end of 1971.

Picloram, cacodylic acid and 2,4,5–T were compared as injection herbicides in oak in another experiment, and although it is too early to be sure of the final result, picloram gives every indication at this stage of being the most effective herbicide, with cacodylic acid being less effective than 2,4,5–T.

Tree Injection on Coniferous Species (Chemical Thinning)

2,4,–D amine, picloram, picloram plus 2,4–D amine, and cacodylic acid were injected into pole stage Sitka and Norway spruce crops at 1 ml per cut per 2·5 cm diam bh for dormant season application (February), and half that rate for growing season application (July). Picloram and its mixture with 2,4–D amine and cacodylic acid were all equally effective in causing complete browning of foliage. 2,4–D amine alone was less effective than the other materials. Dormant season application was more effective than application in the growing season. However, both picloram products affected adjacent untreated trees, especially after dormant season application. This leaves cacodylic acid (" Silvisar 510 ") as the most successful chemical tested. Further work on rates and application times will be carried out (bh=breast height).

Ultra Low Volume Spraying of 2,4,5–T

Ultra Low Volume (ULV) spraying equipment was used to test the effectiveness of ULV foliage sprays of 2,4,5–T in typical woody weed situations in 1969 and 1970.

In the 1969 experiments, a battery-driven ULV applicator producing droplets of mainly 60–100 μ diameter was used to make applications of 1½ kg/ha of 2,4,5–T in 5 or 10 litres of non-phytotoxic oil. A normal mistblower application of 1½ kg 2,4,5–T in 100 litres of water per hectare was used as a control.

Assessments in June 1970 showed that these ULV applications provided control quite as good as mistblower applications on species susceptible to 2,4,5–T (e.g. birch and bramble), but control of moderately resistant and resistant species (e.g. hazel and ash) was not as good.

Although damage to the crop in the form of scorch and needle twist from ULV sprays was slightly more pronounced than that from the mistblown application, it was still at an acceptable level.

In the 1970 experiments, three different types of ULV sprayers were used: a petrol-driven machine which incorporated a fan to disperse droplets of mainly 60—100μ (" Mini-Micron ") and two battery-driven machines without dispersal fans, one producing droplets of mainly 60–100μ (" Ulva ") and the other droplets of mainly 200–300μ (" Hulva "). The names in brackets are trade names of Micron Sprayers Ltd.

The " Mini-Micron " was found to be unsuitable because considerable swirling and blow-back from the fan meant that the operator was saturated with spray solution. Both the " Ulva " and " Hulva " appeared to give satisfactory distribution in a wind speed gusting up to 10 km/h, but quite different swathe widths were required for each. Drift from the " Ulva " carried for about 20 m, most of the spray falling with 5 m. Drift from the " Hulva " carried about 5 m, most falling within 3 m. The method of application was to walk at right-angles to the wind direction holding the head of the sprayer still.

It is too early for results of treatments, using these machines, to be assessed.

Control of Heather (Calluna vulgaris)

Further experiments, testing the effectiveness of spraying heather with 8 litres of 60 per cent 2, 4-D ester in 225 litres/ha of water by mistblower at intervals from March to October, confirm indications gained in 1969 that heather can be successfully controlled in May before tree flushing when air temperatures at spraying rise above 10°C. Earlier application can result in some control (from 40 to 80 per cent) but results are less reliable than summer application. Later applications into September and October are progressively less successful even in good weather conditions, and on green heather not yet browned by winter cold.

Application of 2, 4-D at intervals through the winter by low and high volume methods has shown that November and January application resulted in only a 25 per cent control regardless of method. September and March applications produced a 40–60 per cent control, the high volume method then being better. May application produced the best kill (70–90 per cent) with, again, high volume being best. The addition of diesel oil at the rate of 10 per cent of spray emulsion was beneficial to the September, March and May applications.

It appears that heather on mineral soil is less successfully controlled than that on deep peat, when low volume methods are used. This supports and complements earlier observations that vigorous heather is easier to control; the nitrogen released from the ploughing ridge on deep peat creates the vigorous growth more susceptible to 2,4-D.

The most satisfactory control is obtained in summer, when temperatures are high and growth is most active. Control of heather as a remedial measure in checked Sitka spruce could be extended into July with no more crop damage than might be expected in similar weather conditions in the latter half of August, which is the currently recommended period.

The experiment, mentioned in the 1970 *Report*, in which picloram, and picloram/2,4-D, were being tried to control older leggy heather, indicates that these chemicals do control heather but no better than the standard 2,4-D, regardless of age or legginess. While initial observations indicated that Lodgepole pine foliage was not browned by picloram spray, new growth was seriously damaged, presumably through up-take by root contact of pine roots with affected heather roots.

Although it can be difficult to separate the effects of technique, weather conditions at spraying, vigour and age of the heather, it appears from research experience that technique plays a major part in ensuring successful control. If the 2,4-D can be distributed evenly on to the heather foliage then good control can be achieved. Ultra-low volume techniques are to be examined this coming season with the aim of achieving good distribution, with less volume of herbicide mixture.

SIDE EFFECTS OF CHEMICAL CONTROL

Risk of Operator Ingesting Paraquat

Concern over operator safety when applying paraquat led to a small test in the Forest of Dean (Gloucestershire) in which a "Casella Personal Sampler" was worn by an operator during normal spot spraying operations using a plastic knapsack spray and lance with a Polytec guard. The sampler, which used a membrane filter to catch airborne droplets down to 5μ, was worn on the chest and the aspirating pump of the sampler run at 3 litres per minute.

Ten consecutive samples were taken between 23rd October and 13th November 1970, sampling time varying from 40 minutes, during which period the operator applied 9 litres of spray solution through his sprayer, to 3 hours 46 minutes (45 litres of spray solution). After sampling, filters were carefully transferred to polythene bags which were sealed and sent to the Industrial Hygiene Research Laboratory of the Imperial Chemical Industries who kindly agreed to extract the filters and analyse for paraquat residues.

No paraquat residues were found on the filters, the analysis technique detecting quantities down to 2·0μg of paraquat ion.

The Effect of 2,4,5-T on Fruiting Bramble

In an experiment at Alice Holt Forest, fruiting brambles were sprayed with 2,4,5-T emulsifiable ester at 3 kg a.i. per hectare at weekly dates from 5th August to 2nd September 1970, and the subsequent development of flowers and fruits monitored at weekly intervals.

Unripened fruit did not ripen but instead developed moulds after three to four days and fell off; fully ripened fruit showed no effect of being sprayed for three to four days, but then developed a mould, acquired an unattractive bloom, and began to drop.

Certain plots were earmarked for sampling for analysis of residues but the rapid development of symptoms made it unrealistic to sample unattractive or inedible blackberries. A separate area was sprayed on 4th September and a sample of blackberries taken three days later. Analysis of this sample by the Laboratory of the Government Chemist showed that the blackberries held (inside and on their surface) 100 ppm of their fresh weight of 2,4,5-T acid.

R. M. BROWN
J. M. MACKENZIE

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SOIL STUDIES

FOREST AND LABORATORY STUDIES

Physical and Mechanical Properties of Soil Types

The Northern Research Station's Soils Sub-Section has been formed during the year and a good deal of time has been spent in the training of staff and the selection, testing and modification of methods of measuring certain soil physical and mechanical properties. Particular importance is attached to the measurement of soil bulk density, and three alternative methods are now available. In compact soils (for example those developed in indurated material) and in stony soils the excavation method (sand-replacement method) gives precise results but involves slow and painstaking work. The use of glass beads of 0·5 mm diameter instead of sand increases the precision and convenience of the method, but it is also essential to use a well-designed pouring cylinder to ensure a consistent packing density of the beads in the excavation.

The well-known core cutter method gives adequate precision and is rapid but its use is restricted to stone-free or slightly stony soils without severe compaction ; it will be used to provide undisturbed samples suitable for the study of moisture tension and porosity. Portable gamma-ray transmission equipment is now available commercially and our early trials indicate that the method can give adequate precision for a wide range of soils excluding the very stony and compact ones. A twin probe assembly is pushed into the soil or inserted into holes prepared by spiking and the counting time on the scaler/timer for one measurement is approximately one minute. The speed and convenience of this method will greatly assist our studies of bulk density of forest soils and will for the first time make practicable an assessment of the effects of cultivation treatments on this soil property.

Studies of the compactibility of soil materials, including mixtures from different soil horizons, are being made in an attempt to predict the short and long-term effects of deep cultivation treatments. After trying several methods, including the British Standard compaction test (BS 1377: 1967), a device based on the Dietert principle has been designed and will be constructed in the Research Workshop. This will provide compacted samples which can also be used for measurement of shear strength, penetration resistance and pore-size distribution.

Four more soils developed in indurated material have been subjected to field testing and analysis in the laboratory. Results will be presented in some detail next year when the initial sampling scheme for indurated soils has been completed ; meanwhile a few interesting indications can be mentioned. In surface-water gley soils the indurated material is encountered at very shallow depth, often within 20 cm of the surface. In ironpan soils the usual depth to the indurated material is 20-30 cm and in freely drained podzols it is 40-50 cm. The upper 20-30 cm of the indurated material is usually harder

and more platy structured than below, but most of the characteristic properties of the material (Pyatt, 1970) are present to the base of the drift, which is 100-130 cm in the examples studied. Bulk density values were quoted in the 1970 *Report*, values for the fine earth fraction (after allowing for the contribution made by stones) being in the range 1·70-2·00 g/cm^3. Penetration resistance is measured very crudely with a Proctor penetrometer; this gives extremely high values in the range 75 to more than 200 kg/cm^2, at the natural moisture content of 10-13 per cent oven-dry weight. Shear strength tests on undisturbed cores have been impracticable in many instances due to stoniness, but have demonstrated that most indurated material in its natural moist condition exhibits a well defined brittle fracture suggestive of some kind of cementation being present. Where the soil is more saturated at depth due to the presence of a ground-water table, it may exhibit plastic failure in the compression test. Due to the high bulk density the moisture content of such soil may still be only about 13 per cent. Detailed analysis has so far revealed a particularly narrow range of particle size distribution and it is tempting to suppose that here we have a mixture of particle sizes which is especially prone to the development of close packing and high bulk density; typical values are shown in Table 11. They all fall within the sandy loam class.

D. G. PYATT

TABLE 11

SIZE FRACTION DISTRIBUTION IN INDURATED MATERIAL

Fraction	Size range, mm	per cent range	
Clay	<0·002	8–13	
Fine silt	0·002–0·006	3–5	
Medium silt	0·006–0·02	6–14	24–41
Coarse silt	0·02 –0·06	12–23	
Fine sand	0·06 –0·2	23–36	
Medium sand	0·2 –0·6	20–26	49–70
Coarse sand	0·6 –2·0	4–9	

INSTRUMENTATION

Reading Water Levels in Boreholes

Manual Methods

The design of the electric dipstick described last year has been finalised, and a description submitted to the *Journal of Agricultural Engineering Research.*

Automatic Methods

A complete system for automatic recording, based on the system described last year, has been constructed and should be in use this year. A note describing the circuit we have devised, which will enable us to use the capacitance of a partly immersed insulated metal rod as the transducer, has been accepted for publication (Hinson, in press).

W. H. HINSON

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DRAINAGE

Ploughing and Drainage of Deep Peat

The drainage experiments at Clocaenog Forest (Denbighshire) and Achray Forest (Stirlingshire), both on raised bog sites with fairly similar treatments, have been assessed after five and six growing seasons respectively.

The *Report* for 1969, pp. 87 to 89, gives details of the effect of drainage intensity on soil-water levels and the observed effect on plant weight and root development of Lodgepole pine and Sitka spruce.

Height growth at six years shows a close correlation between rate of growth and depth to soil-water.

There was a growth response in both species to the size of turf ridge produced by three methods of ploughing. Early growth was best on the largest turf ridges and poorest on the smallest ridges, but the early advantage is now beginning to disappear. At Clocaenog only two drainage intensities (10 m and 20 m spacing of drains 0·9 m deep) are represented and no marked response has been observed. At Achray the drainage intensities cover a wider range, from nil to drains 1·2 m deep at 7·6 m spacing.

At both sites PK fertilisation has given a marked improvement in the growth.

It is as yet too early to obtain a reliable prediction of the long-term pattern of growth, but the rate of growth to date in both experiments indicates a potential Yield Class of 20 for Sitka spruce and 16 for Lodgepole pine. Strong heather growth on both sites indicates the need for herbicide control to ensure that the spruce continues to grow on unchecked, but Lodgepole pine is now close to canopy closure and should not require herbicide treatment.

Drainage of Gleys with Clay Subsoils

Reference was made on p. 88 of last year's *Report* to the effect of mole drains on borehole water levels. Studies carried out at Halwill Forest (Devon) showed that the drainage achieved by mole drains at 1·5 m intervals, with cross drains at 50 m spacing, compares favourably with the treatment with cross drains at 8 m intervals but without mole drains. The height of the Sitka spruce at eight years was not affected by the mole drainage nor by the spacing of the open drains. In an experiment nearby, mole drainage has not produced a growth response in Sitka spruce or Lodgepole pine planted in 1962.

Another experiment at Halwill Forest examines the effect of three drain spacings: 15 m, 30 m and 45 m, two drain depths: 0·6 m and 0·9 m, and an undrained control on the growth of Sitka spruce. After five years there were no significant differences between the various treatments. In a similar experiment at Towy Forest (Brecon) the height of Sitka spruce at five years was slightly poorer (5 cm) in the plots drained at 45 m intervals than in those drained at 30 m and 15 m intervals.

Drainage experiments at Rosedale, Allerston Forest (Yorkshire), Kershope Forest (Cumberland), Kielder Forest (Northumberland), Newcastleton Forest (Roxburghshire), Forest of Ae (Dumfriesshire), and Lennox Forest (Stirlingshire) demonstrate no appreciable growth response to varying intensities of normal forms of drainage.

Taken together these results suggest that conventional drainage alone on such sites is unlikely to show a significant effect on the rate of growth of forest crops. The observed differences in water levels may yet, however, prove to be significant in their effect on crop stability.

The most promising results to date have been obtained in response to cultivation rather than drainage (see Cultivation, p. 63).

It has been suggested that natural soil density values in such soils may limit root penetration despite the removal of surplus water by drainage. If true this would indicate that site treatments combining cultivation with drainage might be more appropriate than drainage alone.

On p. 92 of the 1970 *Report* the rigg and furr system was described and the appearance of the crop established on this treatment is illustrated in Plate 4.

To examine the possibility of forming riggs and furrs on a field scale at reasonable cost a trial was conducted at Pickering Forest, employing a large motorised grader. The machine, a Caterpillar No. 16 with a power unit developing 167 kW, is normally employed upon motorway construction. With excellent co-operation from the hiring firm, Stokey Plant Hire of Wolverhampton, a suitable technique was evolved, and used to prepare an area of three hectares in one operation. On this basis, the cost of forming riggs and furrs was about £30 per hectare. It was clear, however, that the cost could be reduced by using smaller machines for part of the operation. The appearance of the equipment and the nature of the work is shown in Plates 2 and 3.

G. G. M. TAYLOR
J. E. EVERARD

CULTIVATION

Cultivation of Ironpan Soils

New experiments have been established at Exeter Forest (Devon), Brendon Forest (Somerset) and Ringwood Forest (Hampshire) using the deep tine plough shown in the *Report* for 1970. A wide range of intensities of cultivation are being tested, together with various species and fertiliser regimes.

Similar experiments on felled woodland sites are being established at Wykeham Forest (Yorkshire) and at Inshriach Forest (Inverness-shire). In these experiments the objective is to determine the best combination of cultivation, species choice and fertiliser regime for second rotation crops on extensive sites which are at present carrying pine crops of low productivity.

Cultivation of Gleys with Clay Sub-soils

The rigg and furr system referred to in the *Report* for 1970 is included as a treatment in a new experiment at Clocaenog Forest (Denbighshire). Other treatments include complete cultivation, rotovation and ploughing at planting intervals with the deep draining plough.

The experiment at Harwood Dale, Langdale Forest (Yorkshire), described in the *Report* for 1964 has been assessed after fifteen years' growth. The best growth for all species has been achieved on deep complete ploughing. On this treatment, Sitka spruce has achieved a mean height of 5·45 m with an estimated Yield Class potential of 14. In the same locality, conventional practice employing spaced furrow ploughing with Scots pine has an estimated Yield Class potential of 6 and Sitka spruce on similar ploughing may achieve Yield Class 10. It appears that the rooting conditions provided by complete ploughing are more favourable for tree growth than those provided by conventional methods. The soil processes involved are as yet incompletely understood, and offer a profitable field for further study.

G. G. M. TAYLOR
J. E. EVERARD

CROP STABILITY

Windthrow Recording

A modification of the simple form of 35 mm vertical aerial photography mentioned in last year's *Report* has been investigated. A camera with automatic wind-on mechanism is mounted on a light aircraft, and overlapping vertical pictures can be taken (for stereo-viewing if required) by reference to calibrated sighting marks on the wing strut. Preliminary attempts at quantification of sporadic windthrow by projecting the colour slide onto a systematically dotted screen have been sufficiently accurate to undertake a larger flying programme. The standard of the pictures has enabled individual trees to be distinguished in an unthinned plantation or groups of two to three trees in a thinned one.

The same technique has also been tested using various " true " colour films as a means of locating and quantifying slow growing and checked crops, and is associated with the Remote Sensing Project, which is discussed below (p. 67).

Thinning

In recent years several experiments comparing the stability of crops thinned normally, line-thinned, and unthinned have been established in the Border region on soils classified as windthrow-susceptible. In four of these experiments, some windthrow has occurred—approximately 27 trees per hectare overall. For every one tree windthrown in the unthinned assessment area, four were thrown in the normally thinned one and eleven in the line-thinned area. It is premature to read too much into these figures, especially as they do not yet indicate the time lag for significant damage between thinning treatments.

S. A. NEUSTEIN

REGENERATION

ARTIFICIAL REGENERATION

Freely Drained Soils

A new experiment has been designed and demarcated for felling on the dune sand of Tentsmuir Forest (Fife). The existence of ground water at various depths suggests that Sitka spruce (or Grand fir in view of its relative resistance to *Fomes annosus* which is prevalent here) may have a wider application. As frost and drought are likely to be limiting, the experiment will include overwood treatments as well as stump removal to lessen the risk of *Fomes* infection. Evidence from at least fifteen years' growth of the experimental species on each of three natural drainage classes will be available before widespread regeneration of the local Scots pine is due.

At Thetford Chase (Norfolk), where more than 200 ha of Scots pine are being felled annually, the successful establishment of Corsican pine, the main replacement species for Scots pine, and of Grand fir, the highest yielding alternative species, remains the important subject for experimentation. Both species have responded well in current trials to planting below an overwood, and further work has been planned to see if any strip felling technique acceptable to managers provides similar benefits. Grand fir, in particular, shows significant improvements in both survival and vigour due to overwood protection, and after only four years under a pine cover may be 80 per cent taller than trees planted at the same time in the open. Present experimental evidence suggests that to prevent die-back and stem deformation of this species due to late spring frosts, the overwood stocking should be at least 250 stems per ha. Western hemlock and *Nothofagus obliqua* remain the quickest growing of eighteen species planted in exploratory overwood trials in 1964, many trees having reached a height of 5 m in seven years.

The case for replacing Douglas fir with Sitka spruce on valley slopes at Bodmin Forest (Cornwall) will be examined in a provenance experiment presently being planned for this forest.

Ironpan Soils

At Speymouth Forest in Moray a new experiment has been designed and demarcated for felling to compare the growth and form of four species following a Scots pine crop. Various widths of strip felling (ranging from a half to twice the height of the surrounding Scots pine crop) are being compared with a clear-felled control, this form of protection being the only one which would allow deep cultivation, easy extraction and protection against frost.

At Wykeham Forest (Yorkshire) various methods of establishing Grand fir are being compared in a new strip felled regeneration experiment. This species, whose survival and early growth has been erratic in past experiments, may have greater use in regeneration on *Fomes* affected sites, or with the more intensive cultivation now being practised.

S. A. NEUSTEIN
J. JOBLING

SITE CLASSIFICATION

In the *Report* for 1967 reference was made to a new project entitled Site Classification. This was followed in 1968 by an account of two pilot studies dealing respectively with Corsican pine and the Minor Species. Now that the Minor Species Survey has been completed (see 1970 *Report*) the more general question of Site Classification has been resumed.

The original concept of the project envisaged a system of classification for forest sites, whereby the performance of a range of species could be predicted in terms of measured site variables. Its primary aim was improvement in choice of species when planting or replanting, and identification of site factors limiting growth, or which might become limiting during the life of the crop. The two studies referred to used, as their main source, available data on yield in existing crops, relating this to measured site variables.

However, increasing emphasis is being placed on improvement of site conditions for currently planted crops in order to increase yields and the predictive value of data collected from older crops established under a less intensive silviculture is limited.

The direction of the project has, accordingly, been reviewed, and an alternative approach is being developed, based on the concept of a mathematical simulation model of a forest ecosystem, initially to help in understanding the complex relationships between site factors and the growth of a tree crop ; and ultimately, it is hoped, to predict crop response to a range of possible treatments.

An initial model has now been written down in mathematical terms, and some of the more important unknowns identified. The work of the next year or two will be directed at evaluating these unknowns, and testing the model against the performance of a crop.

A. I. FRASER

REMOTE SENSING

In the past year or so there has been a great increase in interest in remote sensing techniques, which it is anticipated will make important contributions to a number of projects in at least two ways. For example, evidence suggests that nutrient deficiencies and moisture stress significantly influence the amount of light reflected in certain wavebands (e.g. Myers, 1970); some multiband evaluation flights have been planned in conjunction with the Natural Environment Research Council to evaluate the technique. A second application is with thermal imagery using emitted infra-red radiation for studying the water and thermal relations of crops in relation to growth. These techniques have been tried for detailed observations under laboratory conditions as well as with an airborne sensor to provide information on the large-scale variations in surface temperature as influenced by other environmental factors.

In the area covered by the Northern Research Station the potential of 35 mm aerial photography for both managerial and research purposes is being tested (see Crop Stability, p. 64).

A. I. FRASER

S. A. NEUSTEIN

REFERENCE

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ECOLOGY

Tree Growth in Forests of the South Wales Coalfield

Survey work in 1970 was mainly in the Glyncastle section of the Cwm Nedd forests (Rheola, Pelena and Margam), where a large area of Sitka spruce of uniform age (30 years) gave opportunity for intensive examination of the influence of topographic and soil changes on performance.

These stands occur at 250–450 m on north-west slopes enjoying some shelter from coastal winds. Peaty gley soils of the Hirwaun and Rhondda Series (Crampton, 1965, 1966) are most frequent: peat more than 40 cm deep is widespread on the flats: while well drained " Intergrade " soils (" Gelligaer " Series, with only superficial gley) are generally restricted to gradients exceeding 9 degrees.

Topography, in effect, appears to be the master factor in determining how climate and soil parent rock interact to produce the wide variations in plant cover and growth of spruce. Where the slope is sufficient to give adequate site drainage, a satisfactory milieu for root development may be provided even on the peaty gley soils ; nonetheless, deep cultivation, to reach the more porous, stony, B horizon, may greatly improve both drainage and root penetration. On the moderately steep slopes, characterised by soils of the Gelligaer, or Garth Hill (Upland Brown Soil) Series, site drainage is brisk, root exploitation by spruce is good and trees suffer no early check. The peat-covered flat summits, and the almost equally wet shelves of the valley sides, pose difficult cultivation and drainage problems in the creation of healthy, wind-firm stands.

On most of the ill-drained flats, groups of trees in " check " show visual symptoms of phosphate deficiency, which the analysis of needles for nutrient concentrations has confirmed. The better phosphate uptake which is associated with better growth on the slopes may be due in part to deeper exploitation of the soil by the roots and in part to rejuvenation of the soil by erosion in post-glacial times. Diagnostic trial applications of phosphatic fertiliser have been made in two checked areas of spruce in Glyncastle, and in a slightly older Bryn stand marked by declining height increment. Checked trees in peat have shown some evidence of potash deficiency which may be given more prominence by application of phosphate only.

K. BROAD
J. M. B. BROWN

Responses of Young Trees to Shade

The closure of an experiment at Headley (Hampshire) Research Nursery, in which seedling trees were grown for three seasons under artificial shade, has supplied a great deal of information about the responses, in terms of top and root growth, of 12 species. In the strongest shade the light was 10 per cent, in the intermediate shades approximately 20, 35 and 60 per cent of the light received by the unshaded plants. Genera represented were *Fagus, Abies* (3 species), *Picea* (2), *Pinus* (3), *Pseudotsuga, Thuja, Tsuga.* The soil is a sandy

podzol, developed under *Callunetum,* with, at 30-35 cm depth, humus-iron pan, here and there broken by decaying roots of former sporadic pines and birches. As the trees were dug up for laboratory examination, accurate data were obtained for the maximum depth of root penetration, as well as the extreme horizontal spread, supplementing the data for height and diameter, needle length and dry weight of top and root in the five environments.

Whereas the relatively intolerant pines (Scots, Lodgepole and Corsican, or the genus *Pinus*) showed the deepest root penetration (in many plots challenged, however, by the beech *Fagus*), they were clearly distinguished from the other species by the relatively low contribution of the root to the total dry weight. In relation to their modest height, the Silver firs (*Abies* spp.) showed deepest root penetration. Interactions between species and degree of shade were marked, following, in general, the expected trends.

In some details the results are in disagreement with recent evidence of Fairbairn and Neustein (1970): this may be due in part to the poorer Headley soil, in part to climatic differences between Midlothian and Hampshire. It will be possible to include some information for root and shoot growth of Corsican pine transplants in full light: as Jones (1968) and others have shown, transplanting commonly shifts the balance in favour of the root. The results are being prepared for publication.

P. MARSH
J. M. B. BROWN

The Weather of the Year 1970

For people in the south, at least, the year 1970 will remain in memory for the superabundance of fruits and nuts, especially acorns and apples. Few, even among the old, will recall an equal natural bounty. Dry sunny weather around midsummer 1969 favoured flower bud formation ; while the lack of spring frosts in 1970, with, for the fruit trees, warm sunny days at pollination time, no doubt ensured a good set.

The severe cold at New Year ended with a rather sudden change to mild rainy weather and in west Scotland three people were killed by an avalanche caused by rapid melting of snow. Relatively cold weather persisted late, however, February, March and April all being colder and wetter than average in almost every part of Britain. Consequently, when warm sunny days offered a welcome change in early May, spring came quickly, with almost a continental fervour. These features were well exemplified in Wales and north-west England, where Stonyhurst (Lancashire) had the wettest April since records began in 1848, with temperatures much below average, and the driest May since 1895, with temperatures above average.

Dry weather in May and June did not generally impair the good results of tree planting in the cool moist conditions which went before, though losses of Corsican pine in some forests of east England were again considerable. Whereas October in south and east England was a benign month, appropriate to the good apple harvest, the autumn was often very stormy in the north and west ; the trend towards reduced windiness, which has been a feature of the weather at Alice Holt during the past few years, is probably not general. In England and Wales, November was by far the wettest month of 1970 ; but the rains which caused material damage were those of the third week of

TABLE 12

MONTHLY WEATHER RECORDS, ALICE HOLT LODGE, HAMPSHIRE, FOR THE YEAR 1970 (ALTITUDE 115 m)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Apr. to Sept.
Air temperature, screen (°C)—														
Mean daily maximum	6·4	6·3	7·4	10·4	18·3	22·6	20·2	20·9	19·4	14·4	11·1	6·1	13·6	18·6
Mean daily minimum	1·3	−0·4	−0·1	2·8	7·3	10·6	10·7	11·4	9·4	6·8	4·4	0·8	5·4	8·7
Monthly extreme grass minimum temperature (°C)	−12·2	−15·0	−10·6	−7·8	−1·1	2·2	2·2	0·0	1·1	−4·4	−6·1	−11·1		
Soil temperature (°C) at 9 hours—														
Mean at:														
10 cm under bare soil	3·4	2·2	2·6	6·2	13·5	18·7	16·6	16·5	13·9	9·7	6·5	3·4	9·4	14·2
20 cm under bare soil	4·0	3·1	3·6	6·6	13·0	18·0	16·5	16·7	14·5	10·7	7·7	4·4	9·9	14·2
60 cm under short grass	5·2	4·4	4·7	7·4	12·4	16·3	16·6	17·0	15·8	12·9	9·9	7·0	10·8	14·3
Precipitation (mm)	107·8	66·8	41·9	66·3	30·5	31·0	51·3	56·6	61·2	14·7	208·2	41·4	777·7	297
Number of days with rain (·2 mm or more)	23	18	17	23	9	7	15	11	11	10	22	15	181	76
Number of days with rain (1 mm or more)	17	14	10	17	8	5	12	10	10	7	17	11	138	62
Lysimeter evaporation losses (mm):														
Garnier Gauge A	−1·3	1·0	13·0	32·8	59·7	105·5	72·2	73·6	57·9	28·2	14·2	9·7	466·5	401·7
Garnier Gauge B	−17·0	−7·1	17·5	18·5	66·3	106·2	80·8	91·7	56·9	23·9	19·8	8·1	465·6	420·4
Estimated evaporation (Et)*	6·3	10·2	25·4	45·7	81·5	102·6	89·7	73·2	41·9	16·5	5·8	3·8	502·6	434·6
Total hours bright sunshine	34·4	105·1	112·7	127·5	213·6	258·0	179·6	175·7	139·4	105·8	63·3	52·8	1,567·9	1,093·8
Mean daily run of wind (km)	76·8	104·6	71·9	79·5	45·7	66·9	70·6	49·1	64·8	63·6	79·8	47·9	68·4	

* See *The Calculation of Irrigation Need*, Ministry of Agriculture, Fisheries and Food Technical Bulletin No. 4, HMSO. 1954.

August in Scotland, particularly in the Moray Firth area, where the rivers Spey, Lossie and Findhorn overflowed. The monthly records for Alice Holt are given in Table 12.

The difficulties which beset the accurate measurement of rainfall are most formidable on windy upland sites: but they are more general, as the following note makes clear.

Standard and Ground-Level Rain-Gauges

It has been known for many years that the catch of rain in a rain-gauge is affected by wind, and the Institute of Hydrology have been conducting rain-gauge performance studies, for some years, from which they have evolved a standard ground-level gauge surrounded by a plastic grid.

The siting of the gauge lip at ground level eliminates eddies caused by the gauge itself; the surrounding grid is necessary to prevent rain splashing into the gauge. We have introduced ground-level gauges at five sites, and the ground-level gauges consistently catch more than the standard gauges; at Alice Holt about 6 per cent during 1970 (see Table 13). This is in line with the differences recorded in comparisons elsewhere. The increased catch in ground-level gauges (or more correctly the loss in the standard gauge) will be greater the higher the wind speed, and rainfall in many upland catchments may well turn out to be very much higher than the already depressingly high values shown on the rainfall map.

TABLE 13

A COMPARISON BETWEEN THE RAINFALL CATCH BY STANDARD AND GROUND-LEVEL GAUGES AT ALICE HOLT IN 1970 mm

	Jan.	Feb.	Mar.	Apr.	May	June
Standard	108	66	42	66	30	31
Ground level	111·5	86	44	71	31	31
	July	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
Standard	51	57	61	5	209	41
Ground level	55	58	64	6	213	43

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FOREST GENETICS

Seed Crops

Moderately heavy crops of cones were produced in the Scots pine tree bank at Newton (Moray) and in the main Scots pine seed orchard centre at Glenalmond Forest (Perthshire); crops in the English orchards in East Anglia and at Bradon (Wiltshire) were much lighter than in the previous year. Corsican pine crops were generally poor in the main collection areas of East Anglia, the Midlands and south-east England. "Inland" and "Alaskan" provenances of Lodgepole pine produced light to moderate crops in west and north Scotland; crops on "Coastal" USA provenances were again very poor in all regions. Douglas fir crops were quite good in Moray and around the Beauly Firth and parts of the Great Glen; in south-west England prolific male flowering led to over-optimistic forecasts of heavy general cone crops throughout the region. Larch crops were heavy in several localities in north and east Scotland and notably at Monaughty Forest (Moray), The Bin Forest (Aberdeenshire) and Birkhill estate (Fife). The first good collection of cones was obtained from a twelve-year-old hybrid larch seed orchard at Newton. Sitka spruce coned well in isolated patches in west and northern Scotland and modest collections were made as far north as Borgie (Caithness); the heaviest crops occurred in north-east Scotland. In Wales coning was generally restricted to scattered individual trees.

In contrast to the conifers the commercially important hardwoods beech and ash, and to a slightly lesser extent oak, all yielded extremely heavy crops of good quality seed with only slight regional variation in quality.

Survey of Plus Trees

During the year, ninety-four new Plus trees were selected and registered, of which seventy-eight were Sitka spruce. The surveys for Sitka spruce Plus trees in pre-war plantations were completed for Wales and southern England; it is intended to complete the survey in Scotland and northern England during 1971. Surveys for additional Sitka spruce Plus trees will be resumed in approximately five years' time and will be concentrated on post-1945 plantations which, in many cases, were established on more difficult sites which had been improved by the use of mechanical draining and soil cultivation practices and often coupled with fertilizer additions. Table 14 gives details of the numbers of Plus trees at 31st March 1971.

Vegetative Propagation

Research investigations into the rooting of cuttings are now being continued by the Physiology Section (*See* Review of the Year's Work, page 11).

The main propagation centre at Grizedale Forest (Lancashire) was closed during July 1970 and the work transferred to the new Northern Research Station, near Edinburgh. The facilities provided include a 6·4 m x 3·4 m mist-house which is shared with the Physiology Section, two grafting houses each

13·8 m × 6·8 m, and an experimental house of 10·8 m × 3·4 m. All the glasshouse frames are constructed of aluminium alloy and both the experimental and propagation houses are divided by a central fully-glazed partition. Heat is supplied from the main station boilers and piped under pressure to heat-exchangers located against the end walls of each section.

TABLE 14

NUMBERS OF PLUS TREES AT 31ST MARCH 1971

Species	Number of Plus Trees
Scots pine	924
Corsican pine	174
Lodgepole pine (Coastal)	365
Lodgepole pine (Inland)	132
Lodgepole pine (Alaskan)	28
Sitka spruce	836
European larch	434
Japanese larch	144
Douglas fir	506
Western hemlock	46
Western red cedar	59
Oak	173
Beech	128
Totals	3,949

Electronically operated valves control the heat supply ; they are regulated by an air-temperature sensing device mounted in an aspirated screen suspended above the benches in the centre of each section. Air at the ambient glasshouse temperature is drawn through a filter at the base of the heat exchangers and expelled at a height of approximately 2·5 m above floor level ; a roof-mounted paddle fan assists in mixing the air. Four wall-mounted air-extraction fans automatically come into operation when the inside air temperatures rise above the specified setting ; hand-operated ridge ventilators are provided for additional ventilation if required. Each section of the propagation house contains two side-benches and a large central island-bench which are all equipped with soil-warming cables to provide bottom-heat and a sub-irrigation system to minimise the need for hand-watering pot-raised plants. Using standard 128 mm diameter pots the total capacity of the two propagation houses is 7,200 plants. A combined pot, fertiliser and compost store, and potting-up and grafting area is conveniently located in the nearby main building.

Tree Banks

The twelve-hectare Sitka spruce National Tree Bank at Wauchope Forest (Roxburghshire) is nearing completion, and planting started in spring 1971 at a second fourteen-hectare extension at Glenalmond Forest (Perthshire). The on-site grafting of Douglas fir in the National Douglas fir Tree Bank at

Westonbirt (Gloucestershire) in spring 1969 and 1970 appears to have been quite successful and additional rotstocks have now been established to provide additional scope for future extensions.

Controlled Pollinations

Sixty-nine mostly "coastal" type Lodgepole pine clones in the National Tree Bank at Newton were used as female parents for a series of test-crosses in which a mixture of pollen based on nine selected " coastal " USA trees growing at Alice Holt, was used as the male component. Lodgepole pine pollen in south-east England was released two weeks ahead of the period of general female flower receptivity at Newton, which is 500 miles further north. Using pollen collected in the south in this way has two advantages, namely, the pollination programme can be planned well in advance and without undue interruptions and breaks for pollen processing operations and, secondly, that fresh pollen, as opposed to pollen stored for a year, can be used ; this normally ensures a higher set of fertile seeds. A 5 x 5 diallel crossing programme was also undertaken at Newton on five Douglas fir clones ; apart from some of the "selfs" all the crosses produced a satisfactory yield of seeds.

At Saltoun (Stenton Forest, East Lothian) over 1,100 female flowers, evenly distributed over fifteen selected seedling Lodgepole pine trees of Albertan origin, were isolated and hand-pollinated with a mixture of pollens from "coastal" USA parents. If successful the pollinations will provide a considerable amount of seed of a potentially valuable infra-specific hybrid for more extensive forest-scale testing.

Progeny Testing

The 1969 and 1970 *Reports* referred to a 7 x 7 diallel cross of Sitka spruce, plants from which had been successfully raised in the Alice Holt glasshouse. Data on the following eight characters, which were collected at the end of the first growing-season, have now been analysed.

(1) Tip displacement. Deviation of the leading bud from the vertical.

(2) Maximum stem displacement. The most extreme deviation of any point on the leading shoot from the vertical.

(3) Number of dormant buds.

(4) Branch-angle.

(5) Height.

(6) Number of branches.

(7) Length of longest branch.

(8) Total dry weight of stem, branch-wood and needles.

For purposes of statistical analysis these characters were considered in two groups, namely, those mainly related to *tree form*, i.e. shoot tip and extreme deviations, number of dormant buds and branch-angle ; and those mainly related to tree *vigour*, namely, height, dry-weight, number of branches, and length of longest branch.

All the crosses involving one of the seven parents had to be omitted either because of poor germination or survival. The analysis was restricted to the remaining thirty-six "families" which resulted from a complete 6×6 diallel crossing pattern using the analysis of variance proposed by Hayman (1954a) and the methods of Jinks (1954) and Hayman (1954b). The analysis clearly showed that most of the variation for the four "form" characters could be accounted for in terms of additive differences between the parents; the level of dominance was found to be very low. The interpretation was much more complicated for the four "vigour" characters because additive genetic differences between parents continued to account for the greatest part of the variation in all the characters but significant dominance effects, and to a lesser extent maternal effects, also figured prominently. A complicated picture of gene interaction for these characters was suggested by the data but part of this complication was very probably due to the heterozygous nature of the parent tree material. It was also clear that a large amount of the observed variation for all the characters could be attributed to the superiority of one parent at both the array and specific-cross levels.

So far it has been found that similar patterns of inheritance exist for the characters within each of the two groups in which they were considered, and for the "vigour" characters this was reflected when pair-correlations were made; the appropriate correlation coefficients were based on family means and were all very highly significant (p=0·001), even the lowest accounted for sixty-four per cent of the variation.

Height			
Dry weight	0.875		
Branch no.	0.904	0.824	
Length of longest branch	0.869	0.891	0.799
	Height	Dry weight	Branch no.
	(p=0.001)		

All these characters clearly reflect the vigour of the progenies; strong correlations were not obtained between any of the "form" characters.

The reported methods of diallel analysis for other crops depend on the use of homozygous inbred lines for the basic parent material. The parent material used in this experiment was probably very heterozygous and as a result produced a number of unfamiliar patterns in the analyses. It cannot be assumed that the inheritance patterns determined in this experiment will apply to the species in general, and further studies using different parent material will be required to obtain confirmatory evidence. The experiment is the first to be successfully completed on a fully balanced series of test-crosses on forest trees in Britain; this and subsequent data together with data from additional experiments, will provide essential information on heritability patterns of characters important to commercial forestry.

Biochemical Variation

The new laboratory at the Northern Research Station is equipped for qualitative and quantitative determinations of polyphenols and tannins in plant tissues using thin-layer chromatography techniques. It is hoped that

methods of analysis will be developed which will assist in the selection of parents and progenies of special merit as part of the research into the development of early-test techniques. Techniques may also be developed which will assist in the detection and labelling of hybrid components at both the inter- and intra-specific levels.

Gene-pools

The 1966 Visiting Group recommended that "gene-pools" be established for the conservation of forest tree genetic material. Gene-pools should have a broad genetic base and be composed of material advancing under minimal selection and giving maximum opportunity for the formation of new combinations under the shortest feasible generation cycle.

Recent introductions of numerous provenances of Lodgepole pine, collected under the aegis of the International Union of Forest Research Organisations, from a large number of sources throughout its natural range, together with numerous collections from home sources and Plus tree collections provided excellent basic material for several gene-pools. The seed was mixed and plants were raised at Dornoch nursery (Ross-shire) by the Conservancy staff. Gene-pools were planted on contrasting site types each up to eight hectares in area, at the Ulbster Section of Rumster Forest (Caithness); Fiag Section of Shin Forest (Sutherland); Farigaig Forest (Inverness-shire); and Rannoch Forest (Perthshire). Cones will be collected after the first good general flowering and the seeds obtained will be stored for several years before raising plants for a second series of gene-pools.

Similar Scots pine gene-pools, based on mixed material derived from several Scandinavian, central and eastern European countries and numerous British sources, were raised by the Conservancy staff at Newton nursery and planted on contrasting sites up to ten hectares in area at Monaughty Forest (Moray), Inshriach Forest (Inverness-shire), Kynachan Section of Tummel Forest (Perthshire) and Thetford Chase (East Anglia).

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FOREST PATHOLOGY

Death and Decay Caused by Fomes annosus

The work on *Fomes annosus* (Fr.) Cookes was concentrated on three main aspects of the disease.

(a) *Deaths on Alkaline Sites*

In Thetford Chase (Norfolk and Suffolk) it is necessary to identify sites which, after clear-felling, will suffer severe losses through *F. annosus* in the replanted crop. A survey method designed to identify these sites was described in the *Report* for 1970. The survey is now carried out by Conservancy staff and the area included in the clear-fell programme for five years from 1968 to 1973 has been assessed. Each compartment (or part of a compartment) is allocated to a replanting " risk " category, based on the information collected in the survey. Crops which are included in the high " risk " category are left standing for later special attention and alternative, " safer " crops are felled. A total of 1,280 ha have been surveyed and 25 ha have been allocated to the high " risk " category. Thus about one-fifth of the future clear-fell area appears unsuitable for routine felling and replanting. On these areas remedial treatment such as stump removal will be required to ameliorate the effects of *F. annosus*.

(b) *Butt Rot*

The *Report* for 1970 confirmed the previous findings (see *Report* for 1969) that Grand fir is relatively resistant to butt rot caused by *F. annosus*, but mentioned that significant decay had been discovered in Grand fir on three sites. An investigation on one of these sites (at Eggesford Forest, Devon) showed that decay was present in about 15 per cent of the 42-year-old trees, which were the second or third rotation of conifers on the site. In the infected trees, the average loss through decay was 23·5 per cent of the volume. Several trees were severely decayed and invariably in such cases the roots were extensively rotted. Although the decay was severe in a few individual trees, the overall loss in timber volume in the crop to date was less than five per cent.

(c) *Biological Control*

The packaging for *Peniophora gigantea*, the competitive fungus used to treat pine stumps against *F. annosus*, was changed to a sachet during the year. Each sachet contains a concentrated suspension of *P. gigantea* and is mixed with five litres of water, a dye is added and the suspension is then ready for use. A new suspension has to be prepared each day. The sachet suspensions are a more reliable product than the preparation in glass phials previously used and are much easier to handle. The Pathology Laboratory at Alice Holt checks the quality of the product by testing a sample of the sachets from all forests using *P. gigantea*. An insulated box to store the *P. gigantea* sachets in the forest has been designed by the Alice Holt Research Workshop and will be issued to all Forestry Commission forests that use *P. gigantea*. A total of 22 forests now use *P. gigantea* as the routine stump treatment for pine and its use is currently being further extended within the Forestry Commission.

Pathology staff give demonstrations on the use and concept of this stump treatment to supervisory staff before it is used at a forest.

D. A. BURDEKIN
B. W. J. GREIG

Phytophthora Diseases

A project on *Phytophthora* diseases was initiated during 1970–71 to assess the distribution and frequency of *Phytophthora* damage to forest and amenity trees and to study the biology of these diseases. As knowledge of *Phytophthora* diseases on trees in Britain is largely confined to " ink disease " of Sweet chestnut and beech, much of the initial work has involved close collaboration with the Section's advisory service.

In suspected cases *Phytophthora* damage, infected material is inoculated into apples according to a technique developed by Campbell (1949). It is important that the infected material should be at the right stage. Successful isolations from trees have been made from water-soaked margins of lesions in which the pathogen is currently active.

Following the isolation of *P. cactorum* from a slime flux on a Horse chestnut (*Aesculus hippocastanum*) in Surrey (see *Report* for 1970), a second case of this disease was observed last summer in Somerset. (See Plate I) In both cases the disease was characterised by a reddish brown flux, drying to a crusty black, oozing from large areas of dead bark on the trunk and larger branches. *P. cactorum* was isolated from the edges of the lesions.

During the winter and spring of 1970 *P. megasperma* v. *megasperma* was isolated from necrotic areas on roots of several dying Horse chestnut trees on a wet clay site in Northamptonshire. This appears to be the first record of a *Phytophthora* root rot of Horse chestnut and may also be the first record of *P. megasperma* on a tree species.

At Alice Holt, death of several Snake-bark maples (*Acer pennsylvannicum*) was first thought to be due to *Armillaria mellea,* but the presence of *P. cambivora* in tissue surrounding *A. mellea* mycelium has cast doubt on this diagnosis. In one instance fans of young *A. mellea* mycelium were found following within 1–2 cm of an actively developing *P. cambivora* lesion. The occurrence of *P. cambivora* causing root collar lesions, in the apparent absence of *A. mellea,* also supported the hypothesis that *P. cambivora* may be the primary pathogen in such cases. This appears to be the first record of *P. cambivora* root rot on *Acer* in Britain.

During the past year three species of *Phytophthora, P. cactorum, P. cinnamomi* and *P. cambivora,* have been isolated from roots and soil in association with dieback of Lawson cypress, and *P. cambivora* and *P. cinnamomi* have been isolated from roots of Sweet chestnut affected by the " ink disease ".

In cultural studies it has been confirmed that *P. cambivora,* in common with many other *Phytophthora* species is heterothallic, requiring the presence of both compatibility types, A^1 and A^2 for sexual reproduction (oospore formation). Of eight recent isolates from tree species in this country, seven were

of the A^2 and one of the A^1 compatibility type. Oospore formation may occur where both compatibility types are present in nature.

Further cultural studies have shown that the fungus *Trichoderma viride* stimulates sexual reproduction by selfing in single A^2 compatibility type isolates of *P. cambivora, P. cinnamomi* and other heterothallic *Phytophthora* species (Brasier, 1971). This effect, which appears to be due to secretion of a volatile chemical stimulus by *T. viride,* has enabled identification of several otherwise unknown *Phytophthora* isolates. This effect may also have significant ecological and genetical implications.

C. M. BRASIER

Dutch Elm Disease

During the last few years there has been an alarming increase in Dutch elm disease in parts of lowland England. The most serious outbreaks are in the counties of Gloucester, Hereford and Worcester in the Vale of Severn, and alongside the Thames Estuary in Essex and Kent. Thousands of trees of all sizes from young suckers to mature trees have died and in some localities the loss has been total.

To meet this situation the Forestry Commission is greatly increasing its research both on the biology of the disease and into the problems of control. At present the only measure which can be recommended is the reduction in the breeding grounds of the vector beetles in recently killed trees, and to publicise this approach an emergency leaflet *The Dying Elms* (Forestry Commission Research and Development Paper No. 78) was issued.

The main long-term approach to control is through the use of resistant varieties, and the screening of elms for resistance has been carried out at Alice Holt for the past ten years as a joint pathology and silviculture project. It is now convenient to summarise the results of this exercise.

The elms included a large number of clones of native species and hybrids selected for good growth and form, a number of Asian elms, and hybrids from the Dutch elm breeding programme.

Ten rooted cuttings of each clone were planted in the orchard and inoculated in the second and each subsequent year. Inoculation was carried out in June by cutting into the early wood and injecting a concentrated conidial suspension of *Ceratocystis ulmi.* After four weeks each tree was assessed for infection using the following scale: 0, no symptoms ; 1, slight ; 2, moderate ; 3, severe. Table 15 shows the mean disease rating for the four years 1967 to 1970 for a specified number of clones of each species. In addition the height of each tree was recorded in October 1970 and the annual height increment of each clone calculated.

The results indicate that native elms are much inferior to the Asian species, although the Huntingdon elm is somewhat more resistant than the other European species tested. This confirms the earlier observations of Peace (1960). It is noteworthy that those varieties and hybrids exhibiting greater resistance also show greater height increments. This, at least in part, is a measure of the severity of the dieback and subsequent recovery which has occurred.

TABLE 15

RESISTANCE OF ELMS TO INOCULATION WITH *Ceratocystis ulmi*

Elm species or hybrid	Number of clones tested	Mean disease rating* based on 4 years of inoculation	Mean annual height increment in inoculated trees (cm)
Native species			
English elm (*Ulmus procera*)	5	2·19	17·3
Smooth leaved elm (*U. carpinifolia*)	8	2·42	23·5
Wheatley elm (*U. carpinifolia* var. *sarniensis*)	4	2·31	18·2
Cornish elm (*U. carpinifolia* var. *cornubiensis*)	3	2·65	20·1
Dutch elm (*U.* × *hollandica* var. *hollandica*)	5	2·50	13·7
Wych elm (*U. glabra*)	4	2·33	13·4
Huntingdon elm (*U.* × *hollandica* var. *vegeta*)	11	1·83	28·3
Asian species			
U. wallichiana	3	0·76	41·1
U. villosa	1	0·30	41·7
Dutch hybrid			
Commelin elm 274 (*U. carpinifolia* × *hollandica vegeta*)	1	0·73	60·0

* On scale: 0, no symptoms; 1, slight; 2, moderate; 3, severe.

The hybrid Commelin elm shows considerable resistance and vigour and in consequence this tree is now being recommended for amenity plantings in Britain. As yet too little is known about its timber qualities for it to be used as a forest tree on a large scale.

J. N. GIBBS

Beech Bark Disease

This disease has become serious in the last few years in 30-40-year-old *Fagus sylvatica* crops on the chalk downlands of southern England. Infestations of a sap sucking insect, the Felted Beech coccus, *Cryptococcus fagi*, are considered responsible for causing small necrotic spots in the bark through which spores of *Nectria* sp. can infect the trunk. The fungus causes death of larger patches of bark often with associated sap flow, subsequent chlorosis of the crown, and finally death of the tree, followed by production of red perithecia of *Nectria* sp. through the dead bark.

A spore trap was installed in an infected compartment, and counts of ascospores of *Nectria* sp. were made over a period of ten months. Peaks of spore discharge followed rainfall and occurred throughout the period, indicating that inoculum for the spread of the disease was present during most if not the whole of the year.

Survey data indicated that the incidence of both *Cryptococcus fagi,* and chlorotic crowns was higher in compartments which have been thinned. The reason for this is not fully understood and intensity of thinning experiments have been established to help elucidate this situation. The disease also appears to be worse in the more vigorous stands.

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E. J. PARKER

Dieback of Corsican Pine

An investigation of Dieback of Corsican pine associated with *Brunchorstia pinea* was started following a second outbreak of the disease in Thetford Chase (Norfolk and Suffolk). Young trees up to 20 years old were affected, mainly in hollows and in the shelter of adjoining older stands.

Much of the damage observed in May was not the gradual dieback of shoots progressing from the buds and starting in the lower crown in the way previously described for *Brunchorstia.* Complete death of 1969 shoots, often in the upper rather than the lower crown, was seen. In many cases green, healthy-looking buds had failed to flush ; shoots bearing these buds usually but not invariably had one or more randomly situated patches of dead bark, but commonly these patches were not extensive enough to account for the failure of green buds.

From growth measurements and from the dating of injury to trees, it appeared that a sudden and very localized outbreak in 1963 subsided in 1967 and 1968, and that this was followed by a more widespread outbreak in 1969, with increasing damage in 1970.

C. W. T. YOUNG

Disease Survey in Scotland

The methods used in the survey and the results obtained in the West and East Scotland Conservancies were given in the 1970 *Report.* North Scotland Conservancy was surveyed during the year ended March 1971 and the results are summarized in Table 16.

TABLE 16

INCIDENCE OF UNHEALTHY CROPS IN NORTH SCOTLAND CONSERVANCY

	Scots pine	Lodge-pole pine	Japanese and hybrid larches	Norway spruce	Sitka spruce	Douglas fir	Western hem-lock	Total
No. crops sampled	56	7	12	49	74	26	0	224
Per cent affected	41	86	0	53	26	58	0	39

Although nearly 40 per cent of crops sampled are recorded as affected, a large proportion of these records signify only the presence, frequently on less than 5 per cent of crop trees, of such relatively minor diseases as those caused by *Chrysomyxa abietis* on Norway spruce and *Phaeocryptopus gäumannii* on Douglas fir.

The majority of diseased Scots pine crops were infected by *Peridermium pini* which has long been known in North East Scotland and the Moray Firth area. A few examples of killing by *Fomes annosus* were also seen in Scots pine crops.

Only a few stands of Lodgepole pine were examined but the incidence of disease was high. Two of the seven crops examined were severely affected by dieback. This is particularly significant as it has been observed in other parts of Scotland.

As in other Conservancies stem damage by deer was common on Norway spruce and Lodgepole pine.

The most common "disorder" on Sitka spruce was check but in one forest an extensive area was affected by Bent top.

D. B. REDFERN

Advisory Service (Alice Holt)

Three hundred and seventy-four enquiries were received, 59 of them from the Forestry Commission. One hundred and nine concerned trees in woods and plantations, 218 concerned trees in parks and gardens, along roads and in other ornamental plantings, and 21 were enquiries about nursery trees. Eighty-nine visits were made in the course of investigations. Fifty-five queries remain unsolved and 41 are still under investigation. There were 104 cases of damage from parasites and 42 from non-living agencies.

The most frequently recorded diseases were those caused by *Ceratocystis ulmi* (Dutch elm disease), *Armillaria mellea* (Honey fungus) and *Phytophthora* species (mainly root and collar diseases). Damage from non-living agencies was most often caused by cultural malpractice, drought, losses on planting, lightning, and compaction of the soil during building operations.

Notable Features

A *Kabatina* species was consistently isolated from girdling shoot cankers affecting large numbers of young Leyland cypress (*Cupressocyparis leylandii*) plants in two nurseries near Alice Holt, and from similar damage to an older juniper in Westonbirt Arboretum, Gloucestershire. Mycelial reinoculations into Leyland cypress induced lesions which extended for a few weeks before becoming arrested at the end of summer. These and the report below from Scotland appear to be the first reports of damage by this fungus to Leyland cypress.

It now seems likely that the *Phomopsis* sp. damaging junipers (see *Report* for 1970) is *P. juniperovera*. However, as the shape of the B spores does not agree with G. G. Hahn's description of the type, isolates have been sent to the Commonwealth Mycological Institute for identification.

The *Calocedrus decurrens* (Incense cedar) in the Queen's private garden at Frogmore, Windsor, which is figured in Dallimore and Jackson's *A Handbook of Coniferae*, was badly damaged by lightning, probably late in 1969. The tree stood 30 m high in 1964.

At Goldsborough Hall, Yorkshire, the remains of iron tree guards, which were cut off at ground level some years ago, were found strangling a number of 40-year-old lime trees.

In May and early June the weather was unusually dry over most of England and Wales ; in general it was the driest May since 1959. Apparent drought damage to spruce and larch in nurseries was recorded ; two species of *Sorbus, S. majestica* and *S. intermedia,* as well as ash, were particularly affected in a semi-mature tree bank in Herefordshire, while lesser damage occurred on London plane and lime. In plantations, Japanese larch was the species most affected.

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

Advisory Service (Northern Research Station)

One hundred and sixteen enquiries were received during the year and 69 of these were from the Forestry Commission. Seventy-two concerned disorders occurring in woods and plantations, 26 concerned disorders in nurseries and 17 disorders in parks, gardens, roadside trees and other ornamental plantings. Fifty visits were paid to deal with enquiries. Sixty-five of the disorders investigated were caused by parasites.

One of the more important diseases that occurred in nurseries caused death of first-year Sitka spruce seedlings at two heathland nurseries. Extensive seedling death occurred in patches in seedbeds from July onwards. Affected seedlings exhibited extensive root mortality and a *Pythium* species was isolated from damaged roots and from soil. More than 30 per cent of Sitka spruce seedlings grown from test seeds sown in soil from an affected area of one nursery damped-off, compared with only two per cent of seedlings damped-off in soil from an unaffected part of the nursery. A similar *Pythium* species was isolated from these seedlings as from those killed in the nursery.

A fungus tentatively identified as a *Kabatina* species was isolated from cankers associated with dieback of Leyland cypress. In one case in South Scotland almost all trees (0·3–1 m tall) in a research plot were infected and some had been killed. The same fungus was isolated from a nearby plot of *Chamaecyparis nootkatensis* showing similar symptoms, and inoculations on Leyland cypress plants have demonstrated that the fungus isolated is pathogenic. The fact that cankers often occurred at the base of branchlets and that dieback was most prevalent on the windward side of trees suggests it may be a wound parasite. Furthermore, some inoculations caused the formation of cankers which subsequently healed.

Nine enquiries concerned shoot dieback of Lodgepole pine. In two cases this had apparently been caused by *Brunchorstia pinea* but this fungus was not associated with damage in the remaining seven cases. A variety of fungi including *Crumenula sororia* were isolated by culturing and several fruited after material was incubated in a moist atmosphere. These fungi will be inoculated into Lodgepole pine in spring 1971.

Phomopsis conorum was associated with dieback of 40-year-old Norway spruce from two forests in East Scotland. In both cases affected trees occurred in a group and some had been killed. Inoculations have so far failed to demonstrate pathogenicity.

Chrysomyxa abietis was common on Norway spruce in spring and *Rhabdocline pseudotsugae* and *Phaeocryptopus gäumannii* were recorded several times on Douglas fir.

The most important non-parasitic disorder dealt with concerned a 3 ha plantation of sycamore and ash which was severely affected by dieback; many trees were dead. Damage may have been associated with the removal of emergent Douglas fir and Scots pine from the crop thus exposing previously sheltered hardwoods to winter conditions which have been postulated (see *Report* for 1970, pp. 117–118) to cause dieback.

D. B. REDFERN

General

In July 1970, Pathology Section staff helped to organise a field meeting of the Federation of British Plant Pathologists in the Forest of Dean (Gloucestershire), where a number of forest pathological problems were demonstrated. The meeting was held in conjunction with the fifth meeting of the British Forest Pathology Group.

D. A. BURDEKIN

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FOREST ENTOMOLOGY

Pine Looper Moth, Bupalus piniarius

The pupal survey in the winter of last year (1970–71) showed very high numbers at Wykeham Forest (Yorkshire). It was clear, barring unexpected natural mortality, that insecticidal control would be necessary. In order to obtain a clear picture of the parts damaged by larvae of the moth during the summer of 1970, the forest was photographed in "false colour" from the air, through the kind offices of the Aerial Photography Unit of the University of Cambridge (see plate on front cover).

Choice of Insecticide

In the past DDT has given effective control but it was decided to look again for an alternative which would not have its extreme persistence, and high toxicity to fish and bees. Nine insecticides were selected for testing. They were sprayed on to potted Scots pine plants at four rates and bioassays were carried out using ten reared *Bupalus* larvae per plant. Results indicated that Phosalone, Tetrachlorvinphos and Fenitrothion would give adequate control. Tetrachlorvinphos was finally selected because of its very low toxicity and moderate cost. A small field trial confirmed its effectiveness. (See Plate 10).

Aerial Spraying

Egg counts indicated that populations of infestation proportions had been reached in five areas totalling 538 ha. The average number of eggs per tree was 9,550 but in some trees there were over 20,000. The percentage egg hatch was recorded and used to confirm the estimated date of aerial spraying. This was finally carried out on 18/19th August using a helicopter. The rate of application was 0·6 kg/ha in 9 litres water. (See Plate 9).

Assessments of the percentage kill were made by collecting dead falling larvae in trays. After one week 87 per cent kill was obtained, and it was thought that this could have been rather higher after a further week.

Salvage clear-felling of completely defoliated trees was carried out in early summer 1970 to avoid the build-up of populations of the Pine shoot beetle, *Tomicus piniperda*. Although crown recovery of remaining less damaged trees is progressing satisfactorily, careful management of felled produce is still required.

Pupal Survey

The annual survey carried out during the pupal season of the 1970/71 winter now covers 51 units, the latest being Slaley Forest (Northumberland). All figures are now expressed as number of pupae per $\frac{1}{4}$ square metre.

After spraying, Wykeham has this season a *highest compartment* count of 2·4 per m^2 as compared with 235·2 per m^2 last year. The *overall forest mean* has dropped from 81·73 per m^2 to 0·93 per m^2.

Over the whole country 31 areas have returned lower *compartment means*, eleven are the same, and eight show an increase. Speymouth (Moray),

Tentsmuir (Fife) and Ampleforth (Yorkshire) have very low populations. Cannock Chase has dropped from 11·5 per m^2 to 2·8 per m^2. In contrast to the general reduction there are two forests of particular interest. Montreathmont (Angus) has continued to increase, having its highest count this year since 1954, i.e. 10·8 per m^2 as against 9·1 per m^2 in 1970. Sherwood Forest, Clipstone (Nottinghamshire) shows a rise from 6·6 per m^2 to 14·0 per m^2, and even more significant than this *highest compartment* figure is the overall *forest mean* which has moved up from 1·70 per m^2 to 5·27 per m^2 this year. These last mentioned increases are of interest only, and the overall picture is one of low populations.

Pine Shoot Beetle, Tomicus piniperda

In past experiments it was found that excellent control was obtained when log stacks infested with *Tomicus piniperda* were sprayed with a mixture of BHC in diesel oil at the rate of 4·91 litres/10 m^2 of overall bark surface. It was appreciated that in practice this method would only be economic if the quantity of solution applied could be reduced. So a field trial was carried out, and large stacks were sprayed using the formula:—

$$\text{Dosage per stack (litres)} = \frac{\text{Superficial area of stack in } m^2}{1 \cdot 4}$$

The results gave rise to some doubt as to the efficacy of this reduced rate (about half the earlier one) in controlling the beetle.

During 1970 an experiment was laid down at Bramshill Forest (Berkshire) with the object of retesting this rate. Freshly felled log stacks were exposed to attack, before spraying with a 0·5 per cent solution in diesel oil. In the autumn sample logs were removed from both inner and outer parts of the stacks. The number of emergence holes, and successful and abortive mother galleries were counted. At the same time 1 inch (2·54 cm) diameter discs of bark were punched out of the upper and lower sides of each log and analysed for residue of BHC present.

It was found that there was no reduction in numbers of emergence holes as between treated and untreated logs, but there was a significant reduction in the proportion of successful mother galleries. Residue analysis show that although distribution of insecticide throughout a stack was variable, there was no difference between inner and outer logs. There was a 5 per cent significant correlation between residues in ppm and the number of abortive mother galleries.

The level of control obtained was very low, and suggests that the rate could not be recommended for field use. However, it is possible that emerging adults consumed a lethal dose, but this is difficult to prove.

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

Systemic Insecticides

During 1970, trials were laid down to test a number of organophosphorus insecticides against *Hylobius abietis*. Although all these materials are considerably more toxic than DDT or Gamma BHC, and need very careful

handling, they do not have the extreme persistence of the organochlorine insecticides in the soil and watercourses. Other workers using potted plants have obtained promising control with Phorate—one of the materials included in the trial—but no work has been done on field application.

In the 1970 trials, granulated insecticides were applied in the split at planting time. Assessments included damage to plants by weevils, effect on caged weevils of feeding on the treated plants, and analysis of the bark and phloem for residues of insecticides. Results to date are not very promising. Quantities of residues found in the plants were small and very variable. The control and percentage kill of *Hylobius* was not significant. The dry summer may have been partly responsible for very little insecticide being taken up by the plants, but further tests will be made in 1971.

As an adjunct to the work on alternative control systems further investigations were started examining the build-up of populations and period of maximum attack of transplants in relationship to date of felling.

Dipping Treatments

An experiment started at Kielder (Northumberland) in 1969 comparing control of *Hylobius* and *Hylastes* provided by Gammacol (a fine suspension of gamma BHC), Didicol (a fine suspension of DDT) and Didimac (an emulsion of DDT), was assessed for the second year. Results showed in the case of *Hylobius* that while all treatments reduced heavy damage, Gammacol was the best treatment in reducing overall damage. These results are very encouraging, particularly since the rainfall at Kielder is relatively high. It is intended to carry out further trials comparing control provided by Gammacol and Didimac on a range of wetter sites in the West Scotland and South-west England Conservancies during 1971.

Green Spruce Aphid, Elatobium abietinum

Previous observations on the incidence of severe attacks by *E. abietinum* indicated, among many factors, that mild winters were invariably followed by heavy spring populations and defoliation of Sitka spruce. Cold weather periods of certain types can cause considerable mortality in the numbers of over-wintering aphids. Results of temperature experiments so far show that this aphid is very hardy, since it can survive temperatures as low as $-15°C$ for six hours after being reared under cool ($+8°C$) constant temperature conditions. However, if reared under fluctuating temperatures ($15°C \pm 5$), 50 per cent of the individuals may be killed when subjected to a temperature as high as $-9°C$ for six hours.

Adelgids and Die-back of European Larch

During a number of visits to forests showing European larch die-back symptoms it was observed that large populations of adelgids were, or had been, present. As a result experiments were set up to test if these insects could cause loss of growth and die-back without the presence of fungal infection. Small larch trees were grown in a greenhouse and artificially infested with adelgid eggs. The species used was *Adelges laricis* Vallot, the one most frequently found on European larch. Large colonies developed on the needles, giving the plants a characteristic bluish appearance. At the end of the first year the average leader growth of the infested trees was reduced by 50 per cent and

the total shoot growth by 30 per cent compared with the controls. Japanese larch, although not normally attacked by this insect, showed a similar reduction. In the following spring, the weakened shoots on half the infested trees failed to flush. Those plants that did so had died back and only managed to survive for a few weeks. This work is being continued in the field, using various provenances of European larch.

Control of Adelgids

Winter Washes

Both DNOC/Petroleum and Tar oil have shown promise of providing good control of adelgids when applied as winter and summer washes. An experiment was started in 1969 to test the phytotoxic effects of these insecticides on a range of tree species when applied throughout the year. The background of this work was given in the 1970 *Report.*

Both insecticides were applied at rates normally recommended for winter application, DNOC at 1 litre in 12 litres (7·5 per cent emulsion) and Tar oil at 1 litre in 14 litres (6·5 per cent emulsion).

The species under test were European larch, Norway and Sitka spruce, Douglas fir, Noble fir (*Abries procera*), Scots pine and beech, but unfortunately losses in the Noble fir prevented any useful conclusions being drawn about this tree. Assessments included growth in height and extent of foliage browning and shoot death.

Results show that Tar oil caused no loss in height growth in any of the species at any time of the year of application. It did, however, cause browning in European larch when applied from May to August. DNOC on the other hand, when applied between May and December, caused severe height loss and browning in all species other than beech and Norway spruce. European larch was particularly sensitive, damage being caused with application in every month of the year. Apart from beech which suffered no damage at all, Norway spruce was the least sensitive with damage only resulting from the applications between July and October.

It is intended to test DNOC at a lower rate on two species of *Abies* in 1971.

Factors Affecting Growth and Survival of Young Crops

Assessments for the two projects have been carried out now for three years. The sample sites are spread over England, Wales and Scotland.

New Planting Survival

This investigation has been confined to Scotland. Results showed again that frost, drying winds, weeds, Black game, and hares were the major factors causing plant losses and damage. Insect attack in general was slight, being in the region of 2–3 per cent except in one small area. In this case 20 per cent of leading buds of Sitka spruce had been eaten by the larvae of the moth *Clepsis senecionana* Hübn. The commonest occurring species of moths were *Amelia viburnana* Schiff., *Argyrotaenia pulchaellana* Haw., and *Philedonides prodromana* Hübn.

During this study larvae have been found of an interesting moth *Rhyacionia logaea* Durr. Up to this time it was only known from the adult which was first recorded at Forres (Moray) in 1890. All the specimens were mining in

PLATE I. Forest Pathology (p. 78)
" Bleeding canker " of Horse chestnut. The dark areas on the bark, and the knobbles hanging below the branch, are black and rusty red encrustations of dried sap which has characteristically exuded from bark killed by *Phytophthora cactorum*. Taunton, April 1970.

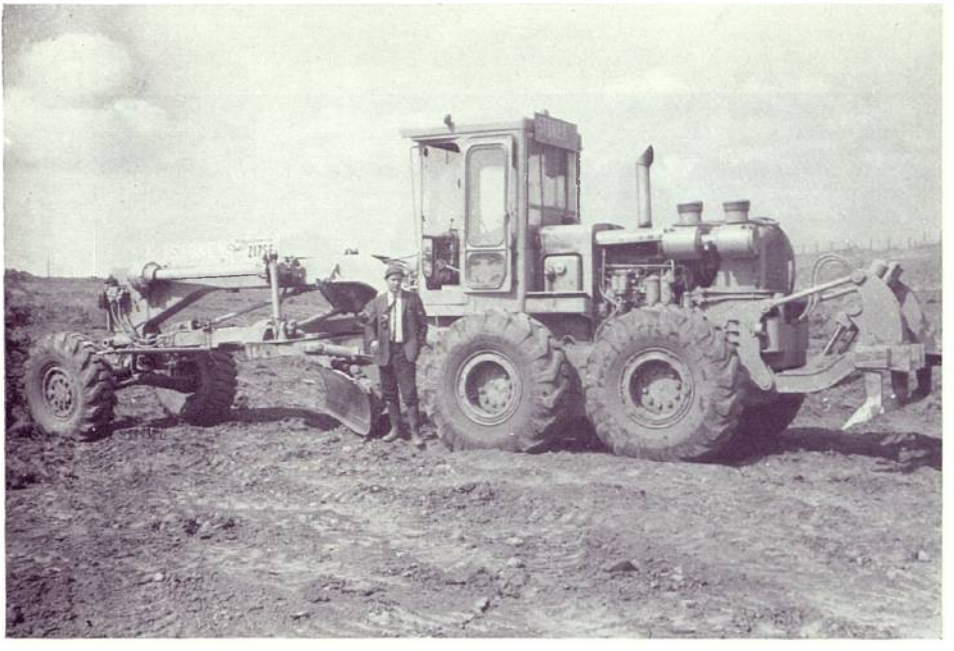
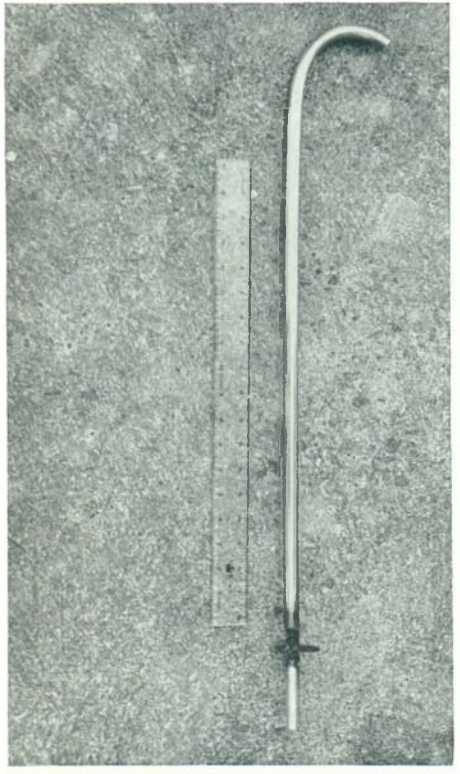


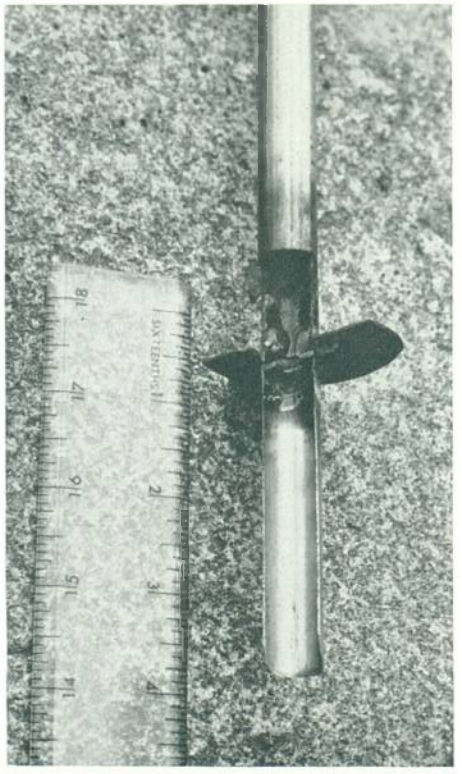
PLATE 2. Drainage (p. 62)
Caterpillar No. 16 Motor Grader used in field trial for the preparation of riggs and furrs at Pickering Forest, Yorkshire.

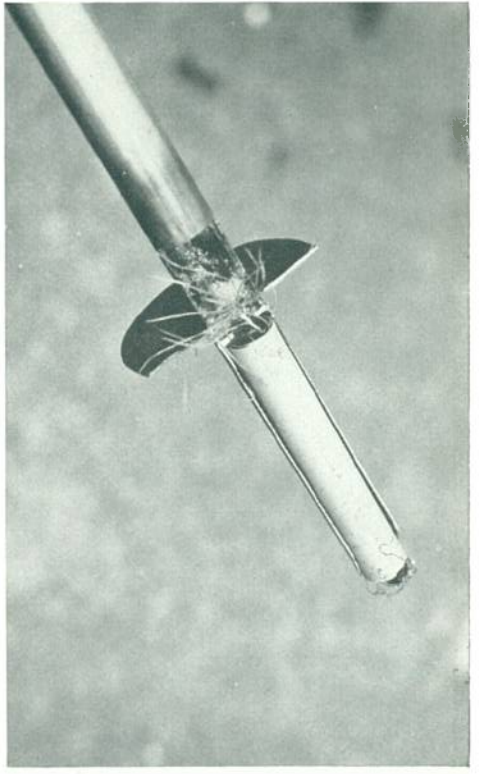
PLATE 3. Drainage (p. 62)
General view of partially formed rigg prepared by Caterpillar No. 16 Motor Grader.

PLATE 4.
Drainage (p. 62)
View of tree growth seven years after planting on riggs and furrs. Rosedale, Pickering Forest, Yorkshire.

PLATE 5.
Work Study (p. 109)
Drain produced by Lokomo plough in sticky gley soil.







PLATES 6, 7 AND 8. Work Study (p. 108)
Three views of a tool for planting tubed seedlings.

PLATE 9. Forest Entomology (p. 85)
Spraying Tetrachlorvinphos against a heavy infestation of Pine looper moth at Wykeham Forest, Yorkshire, in mid-August.

PLATE 10. Forest Entomology (p. 85)
Screening insecticides to select an alternative to DDT for controlling the outbreak of Pine looper moth at Wykeham.

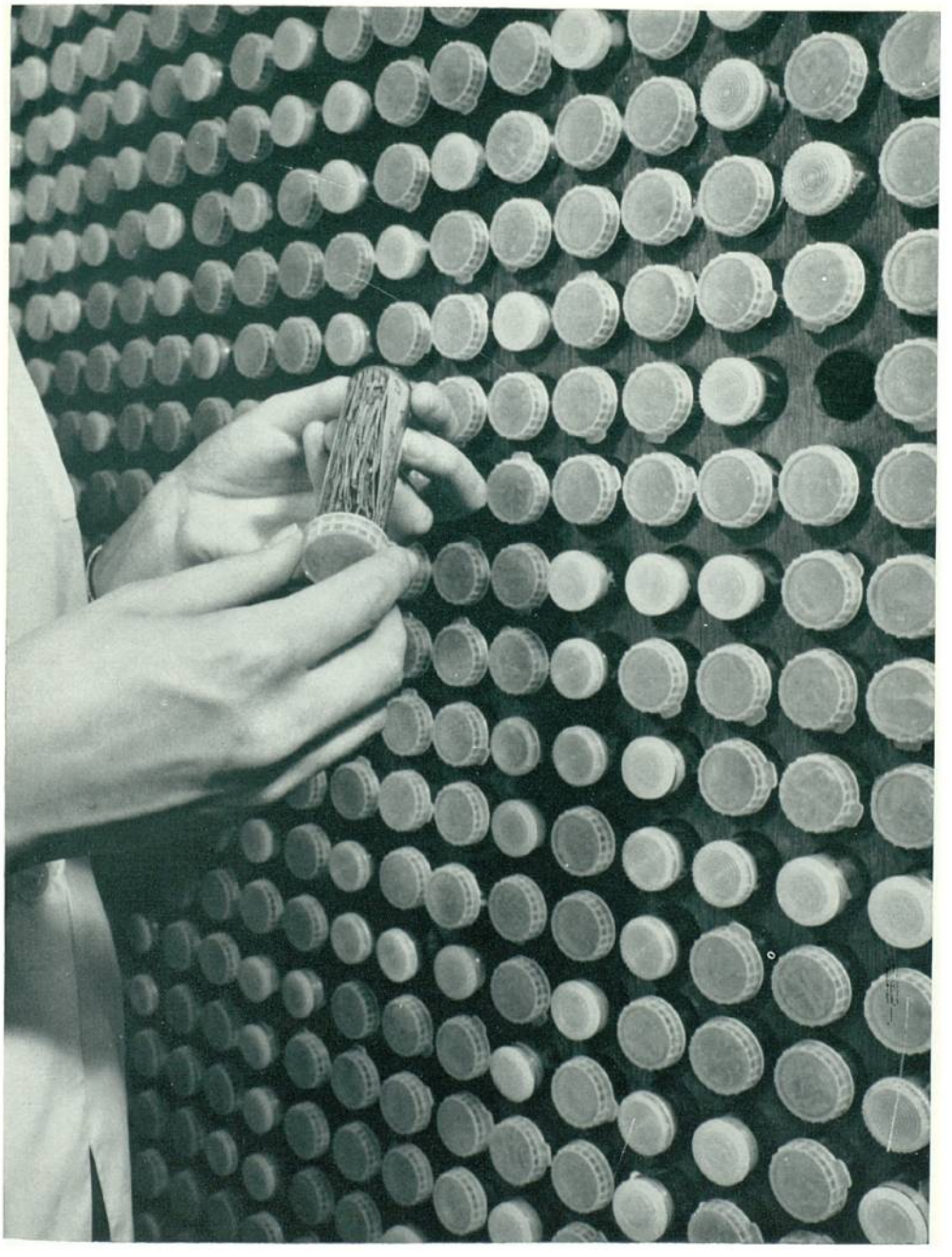


PLATE 11. Nutrition of Forest Crops (p. 53)
Wooden wall rack for storing dried foliage samples. Two perforated sheets of five-ply, with a 5 cm gap between, take 1,519 25 × 100 mm glass tubes with polythene caps. The rack measures approximately 1·9 by 1·4 metres and is backed with foam plastic to prevent breakage.

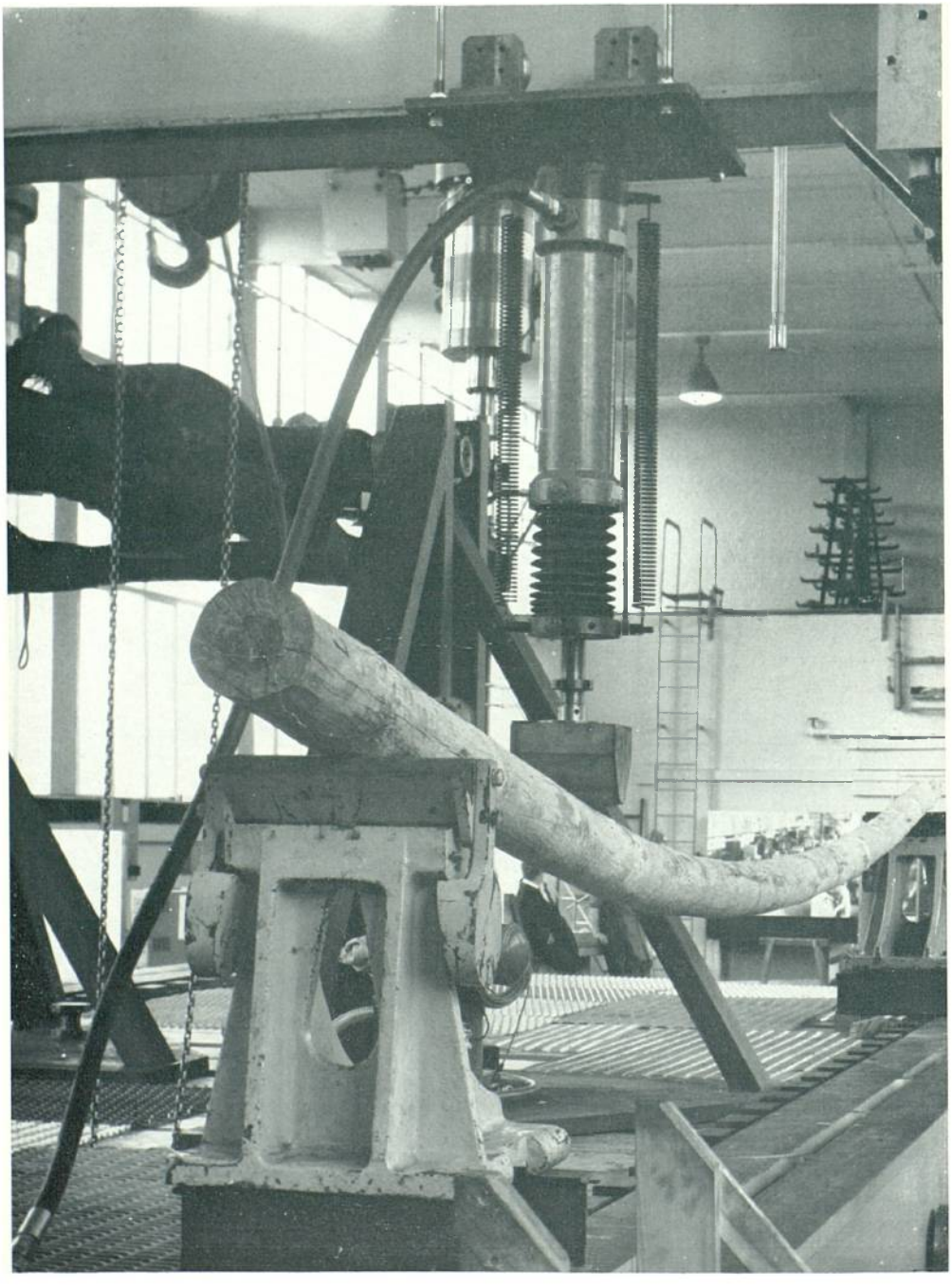


PLATE 12. Timber Utilisation (p. 114)
Destructive testing of home grown Lodgepole pine telegraph poles at the National Engineering Laboratory, East Kilbride.

the leading and lateral shoots of *Pinus contorta* (Lodgepole pine), except for a single larva found on Sitka spruce. They occurred at Aultmore (Banff), Glen Garry (Inverness-shire), Shin (Sutherland), Strathy, Borgie Forest (Sutherland) and Rumster (Caithness).

Effect of Fertilisers

Observations on the effects of fertilisers, shade and drainage on the incidence of insects continued throughout the country. Although the main host tree being examined is Sitka spruce the others included are: Lodgepole pine, Corsican Scots and Mountain pine, Japanese larch, Douglas fir, Norway spruce, *Abies alba, A. grandis,* and Western hemlock.

Insect populations are generally too low to show significant differences between different fertilizer treatments. It appears that high application rates of nutrients, particularly nitrogen, can increase the numbers of and defoliation by *Elatobium abietinum.* Despite this, growth is far better than in the untreated areas which are virtually free of aphids. This is most noticeable in the experiment of Neroche Forest (Somerset). Populations of aphids increased slightly on sites where herbicides have been used. There are indications that increasing shade results in larger populations of *E. abietinum.*

The insects listed in the *Report* for 1970 remain the same except for *Evetria purdeyi* Durr, which was included in error. There are two moths and a mite which can be added to this last year's work: firstly *Epinotia pygmaeana* Hübn. which was found on Sitka spruce in Wilsey Down Forest (Cornwall) and Dartmoor Forest (Devon); and second, a well-known, widespread insect, *Zeiraphera griseana* Hübn. Despite present low numbers it has an outbreak potential and a close watch is being kept on the population at Selm Muir Forest (Midlothian). Finally, a mite, probably *Trisetacus* sp., was found to be causing death of buds of Sitka spruce on a large scale at Halwill Forest (Devon). So far the most northerly record of its presence is at Clwyd Forest (Denbighshire).

A Spruce Sawfly, Gilpinia hercyniae

On the continent *Gilpinia hercyniae* Htg. occurs as a pest of all spruces. It was first discovered in Britain in 1906 in Hampshire. Although mentioned in the *Reports* of the early 1950s, it has not occurred in great numbers anywhere in Britain until 1970.

In Canada this insect became a serious pest during the 1930s. Effective control was obtained by introducing from Europe a natural virus specific to *Gilpinia hercynide* Htg. This same virus has not yet been identified in Britain.

An infestation was reported in 1970 on Sitka spruce of Planting Year 1956 at Hafren Forest (Montgomeryshire), where approximately 16 ha have suffered very severe defoliation. Damage to both Norway and Sitka spruce has been observed in many other parts of Hafren Forest and also in Tarenig and Myherin Forests (Cardiganshire). The first signs of defoliation appear in the upper part of the crown, and become noticeable when the current year's shoots show up as a reddish yellow colour.

Surveys to find out the extent of *G. hercyniae* population are being carried out and a small-scale control trial using the virus is planned for the season.

Pine Needle Midge, Cecidomyia baeri

Although no studies were made on this insect, it is worth recording that infestations occurred in 1970 in some Scots pine areas, particularly in East England and South-east England Conservancies. The minute orange larvae of this Cecidomyiid feed at the needle bases and cause defoliation which is noticeable because it affects the current year's shoots in the upper parts of the crown.

Enquiries

There were 80 written enquiries in the south and 20 in the north from the Forestry Commission, and 96 in the south and 5 in the north from private sources during the year.

D. BEVAN
JOAN M. DAVIES

MAMMALS AND BIRDS

Grey Squirrel

Trials of Warfarin poison against grey squirrels were made in eight forests during the period May-July 1970. A modified ground hopper with a perforated metal door designed to exclude all animals other than squirrels was used in all trials. In one trial 0·02 per cent Warfarin was applied to whole-grain wheat with a latex sticker. In the remaining seven trials 0·02 per cent Warfarin was applied to whole-grain wheat using the oil-sticker technique developed in earlier trials. These trials were carried out by Conservancy staff under the supervision of Conservation Foresters.

The importance of siting the hoppers to make them readily accessible to the majority of squirrels was again demonstrated. The bait with latex sticker was taken as readily as the oil-sticker bait. The problem of designing a cheap hopper specifically for squirrels has not been overcome. When the animals have to pull open a door to reach the bait there appears to be a delay of up to four weeks before bait-take reaches a peak. This compares unfavourably with the one to two weeks required when an open ground hopper is used.

A comparison of whole-grain wheat with cut wheat as bait for squirrels showed that whole-grain wheat was taken more readily by a greater number of squirrels. Even though cut wheat may be less frequently carried away and buried than whole-grain wheat, sufficient difference in acceptability was demonstrated to make it clear that cut wheat is not a useful alternative as a vehicle for Warfarin poison.

Investigations have begun of the influence of Warfarin on bank-voles (*Clethrionomys glareolus*), wood-mice (*Apodemus sylvaticus*) and yellow-necked mice (*A. flavicollis*) in the vicinity of squirrel poison hoppers.

Deer

Trials of various catching and marking methods for roe deer have continued. Three different traps for roe were tested without success during the winter. Self-attaching collars are undergoing preliminary trials for marking roe and red deer. Freeze-marking of red and roe deer has shown promise but it appears that a wider brand is required to prevent narrow strips of white hair being overlain by the long pigmented hairs of the winter coat.

A variety of licks and baits were tested both for use in conjunction with traps and as a possible aid to management in difficult control situations. Cut ivy and sugar-beet pulp were compared as attractants for roe deer. The ivy was taken only during the few brief spells of hard weather. No response was noticed to the sugar-beet pulp for about twelve weeks when an increasing take was observed. Enclosed fallow deer failed to take sugar-beet pulp though taking potatoes readily. A glucose-based lick proved more palatable to both roe and fallow than the more usual salt-licks; of the latter, a clove-flavoured lick produced more response than did molasses, urea, peppermint or plain salt-licks.

An infra-red image converting telescope was borrowed from the Opto-electronics Group, RAE Farnborough, together with a signal lamp fitted with an infra-red filter which provided a source of infra-red radiation. This was tested for observing deer at night. The image converter could not be used satisfactorily to find deer because the image produced was too small to be readily identifiable in a fairly large field of view in which the vegetation reflected similar wavelengths to the animals.

Chemical Repellants

Four chemical repellants were tested during the 1970–71 season against fallow deer browsing. Two of these, Repel and a variety of Cribox, were ineffective. A new development of Rotan R55 appeared more promising than the version available for test last year. Monacol (last season's unidentified candidate) appears to be as satisfactory as Aaprotect in giving protection for some three months to dormant shoots without phytotoxicity.

Powdered Rotan R55 at 15 per cent w/w rate of application was applied as a seed dressing to Corsican and Scots pine seed. It was found that it significantly depressed germination of both species.

Damage

An investigation of grey squirrel damage to beech and other hardwoods in the Chilterns confirmed the vulnerability of beech less than thirty years old compared with other hardwoods and with older beech.

Squirrel Questionnaire

The annual questionnaire for red and grey squirrel for the year ended September 1970 showed the grey spreading slowly in both east England and east Scotland. Damage by both species was recorded.

JUDITH J. ROWE

STATISTICS AND COMPUTING

General

The Section ran two courses on Elementary Statistical Methods for research foresters, one in Edinburgh and one at Alice Holt. Guest speakers for the former included Professor D. J. Finney of the University of Edinburgh, and Mr J. N. R. Jeffers and Mr D. K. Lindley of the Nature Conservancy. The Section is grateful for their help. Unlike the course given in the previous year these courses were each concentrated into a single week.

Five of the present members of the Section are studying for qualifications in statistics or computing science by means of day release courses.

An order was placed with I B M for an 1130 computer, and main components of the system were delivered at the end of March, but just too late for the system to be accepted in the year under review. The configuration includes a central processor with a 3.6 microsecond 8k core store, integral disk, a 1442 card reader/punch, a 1132 line-printer and a 1134 paper-tape reader. In order to allow its use alternately as a stand-alone computer for smaller jobs and as a remote-job-entry terminal for larger jobs it has been decided to connect it to the University Computing Company's UNIVAC 1108 Computer.

Throughout the year regular use has been made of time-sharing bureaux via teletype terminals at both Research Stations, and these terminals have also been used as teleprinters to communicate directly between the two Stations. Use of this facility increased during the postal strike.

Service Work

The main work of the Section has continued to be in providing an advisory, computing and programming service to the Research and Management Services Divisions, and this work is generally included under other headings in Part I of this *Report*.

One of us (C.J.A.S.) has made an extensive analysis for the Genetics Section of data from a Sitka spruce diallel cross (see under Genetics, p. 74), W_r/V_r graphs being produced by the Sirius computer on the graph-plotter.

A contribution (by D.H.S.) was made to a paper on blue-stain of pine.

Initial results of a continuing staff-time survey were produced as an aid in directing the work of the Research Division. They have made it clear that more thought needs to be given to the purpose and possible use of this survey.

For Work Study an analysis of data on clearing windthrown areas has been made and the presentation of felling tables on a national basis is being standardised.

For the Career Development Branch, questionnaires on the present practice of appraisal interviewing were designed and analysed using the Multiple Variate Counter Program, and this was run on the Atlas Computer at the Chilton Computing Laboratory.

Development Work

Further exploratory work (by D.R.C.) was done on the properties of least-squares estimators for the Richards function (see *Report* 1970) and a paper on the estimation of low-degree polynomials for functional relationships has been prepared for publication.

A draft revision of the Research Division Code of Assessments was produced and given restricted circulation.

Further trials of audio data-capture methods have been made and a general computer programme has been written for the Edinburgh Regional Computing Centre's machines to accept research data, construct a data bank and produce summaries and some statistical analyses. Trials are continuing.

R. S. HOWELL
D. H. STEWART
C. J. A. SAMUEL
C. J. HALL
D. R. CAUSTON

RESEARCH WORKSHOP

During October a workshop was opened at the Northern Research Station, and it has already proved advantageous to have on-site engineering services available there. Equipment for the North will continue to be designed at Alice Holt and will be made as appropriate at either Alice Holt, the Northern Research Station, or by commercial contractors.

A production version of a single-man high seat for controlled shooting of deer has now been made and a sample will shortly be offered to the Conservancies for assessment. Work has continued on the design of experimental equipment for the Silviculturists' project on tubed seedling production, design emphasis now being on possible adaptation to fully automatic production.

Sophisticated environmental chambers are very expensive and often cannot be economically justified for simple research experiments. Two cheap automatically controlled chambers have been designed and made for pathology experiments on effects of low temperature. They operate at temperatures from $-4°C$ to $+60°C$.

Aerial spraying at Wykeham Forest (Yorkshire) to control the Pine looper moth produced a problem in providing markers for the aircraft. A portable extending unit was designed to attach to a tractor and two units were made.

Items of equipment designed and made for the fencing team of the Mammals Section include a three-tier fencing unit, tension gauge for use with the Trewhella strainers and a complete hydraulic test rig for testing the strength of wire fencing and netting. Investigations are currently continuing to obtain a quick, simple tool to measure the tension of wire fencing.

A considerable amount of experimental work has been undertaken for the Conservation and Recreation Branch on the design and manufacture of wooden signs and notices. Production centres to produce the signs will shortly be set up with advice and assistance from the workshop. As a pre-production run, over 100 boards have been made for use in the New Forest. Experimental work into new techniques and useful life will continue. Polyester encapsulated notices, which can complement the engraving process used for many notices, have been satisfactorily used at Bedgebury and other areas.

The wildlife audio-visual quiz unit (*Report* for 1970) has now been used satisfactorily by the Show Unit of the Commission's Information Section for a full season, and has received good reports in the national press and television as well as some trade papers. Two further display ideas are being developed for next season.

Six sample fire-beaters have been made. They will be field-tested to enable a specification to be drawn up for a fire-beater for professional use, particularly in areas of high fire risk.

A simple adjustable nozzle was made to enable the Policlair sprayer to be used as a fire-fighting aid. Details of manufacture of this unit have been made available to Conservancies on request.

Engraving work has continued to increase. Over 7,400 plastic labels, as well as 250 wooden boards, have been produced this year. With the present techniques and staff it is not possible to increase this figure, and ways to off-load some of this work will need to be found.

R. E. STICKLAND

PUBLICATIONS

The following twelve new priced publications were issued through Her Majesty's Stationery Office during the course of the year ; previous issues are shown in Sectional List No. 31, available free of charge from the Publications Section or Her Majesty's Stationery Office.

Reports

Fiftieth Annual Report of the Forestry Commissioners, 1969/70 (HC 141, Session 1970/71) (70p).

Report on Forest Research for the year ended March 1970 (£1.50).

Census of Woodlands, 1965/67, by G. M. L. Locke (60p).

Bulletin

No. 44. Operational Research and the Managerial Economics of Forestry, by P. A. Wardle (£1.55).

Forest Records

No. 71. Soil Groups of Upland Forests, by D. G. Pyatt (40p).

No. 73. Ploughing Practice in the Forestry Commission, by G. G. M. Taylor (20p).

No. 75. Design, Construction and Maintenance of Earth Dams and Excavated Ponds, by E. F. Granfield (17½p).

No. 76. Polecats, by T. B. Poole (12½p).

No. 77. Hedgehogs, by P. Morris (12½p).

Booklets

No. 26. Metric Volume Ready Reckoner for Round Timber (25p).

No. 31. Metric Top Diameter Saw Log Tables (12½p).

No. 32. Thinning Control in British Woodlands (Metric), by R. T. Bradley (70p).

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

One new unpriced publication for the general public was issued during the year, *Recreation in Your Forests,* and sixteen others were revised and reprinted.

Five unpriced Research and Development papers were produced, mainly for internal use. Their titles are included in Appendix I, p. 45.

H. L. EDLIN

RESEARCH INFORMATION

Library

Despite a seven-week postal strike, total loans for the year increased to 3,602, with 717 items requested from other libraries. Two hundred and sixty-one books were acquired, 26 new periodicals taken, and 27 translations commissioned.

The revised library catalogue was with the printers for most of the year. It has been a major task to reclassify and rearrange the references in subject order, and to check and correct the proofs, but the resultant publication promises to give considerable assistance to library users. (This catalogue was published in May, 1971.)

The library facilities at the Northern Research Station were reviewed during the year. The entire book stock was reclassified, a new Accession Register prepared, and work is in progress to provide a new Card Index. The Station's library will serve only the resident staff, and loans, enquiries etc. will continue to be dealt with by the main Alice Holt library.

Visitors

The work of planning programmes and tours, arranging accommodation and facilities, and receiving and generally handling visitors falls on this Section. Considerable effort is put into making visitors feel welcome and ensuring that personal contact is made with the most appropriate members of our staff.

Two courses for Conservancy District Officers were held during the winter, at Alice Holt for the Southern Conservancies and, for the first time, at the Northern Research Station for the Northern Conservancies. These were both highly successful, and are likely to be repeated annually.

Exhibitions

During the year a programme of small exhibits was mounted in the hall of the old Lodge building. These have covered various aspects of work at the Station, including Operational Research, Silviculture, Genetics and Information Services. They have been well received by both visitors and Station staff.

Mechanisation

This year saw a considerable increase in the use of computer techniques for both library housekeeping jobs and information services.

Literature references are now punched on to paper tape. Computer programmes have been written by the Section so that this single operation provides us with:

(a) Library index cards—for subjects, authors and geographical locations.

(b) A library bulletin of edited references to literature received and articles referenced in the library.

(c) A card-altering SDI Service (Selective Dissemination of Information) for research and specialist staff. By selecting their personal interests from ninety-nine subject terms, a hundred and twenty-one members of staff receive copies of reference cards for their own indexes.

(d) A record in "machine readable" form which will eventually go into the store of the new computer in Statistics Section. This will enable us to create a data bank suitable for information retrieval.

The helpful co-operation of Statistics Section's staff has been much appreciated and is gratefully acknowledged.

O. N. BLATCHFORD

MANAGEMENT SERVICES

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

D. R. JOHNSTON

PLANNING AND ECONOMICS

POLICY AND CORPORATE PLANNING

Corporate Plan

Continuing work on the preparation of a corporate plan for the Forestry Commission has concentrated on four themes.

First, statements of objectives for internal management guidance have been prepared: these deal with activities in some detail. The definitions of objectives are qualitative: they are not expressions of quantitative goals set for various future years. In practice the application of the objectives may alter, even though their form may not, owing to changes in the emphasis which it is desired to give to Forestry Commission activities. In addition, of course, objectives may alter as the result of re-thinking what the response to changed circumstances should be. Secondly, appropriate economic criteria have been set against the individual operations or activities. Thirdly, broad appreciations on such subjects as the prospects for productivity changes and for wood ulitization, and hence price, are in course of preparation. Fourthly, using a range of price and cost assumptions, the resource requirements and cash flows associated with different programmes of operations have been studied with the aid of the simulation programme described in the *Reports* for 1969 and 1970.

A. J. GRAYSON

AIDS TO MANAGEMENT AND PLANNING

Training

Four courses entitled "Economic Appraisals" have been given to Conservancy and Headquarters staff at and above the level of Assistant Conservator (or equivalent grade). These courses have aimed to familiarise staff with the identification of projects requiring appraisal, the quantification and evaluation of inputs and outputs and the criteria to be used.

Control procedures

Collaboration in the work of the Financial Control Project Team was mentioned in the *Report* for 1969. The project team was set up in January 1969 with the task of designing and installing a revised system for financial control in the Forestry Commission to be effective from April 1970. One member of the Branch has worked full-time on this project.

The main functions which had to be served by the system were planning, budgeting, and reporting back through budgetary control to allow adjustment of performance or plans. The planning is of three kinds: strategic planning and decision making relating to the type and level of activity of the enterprise and its objectives, tactical planning of such things as the specification of operations to fulfil the strategic plan and the resources to carry them out, and thirdly the operational planning of specific jobs and the deployment of particular resources. Reporting back is designed to show correspondence between local plans and central plans and between actual performance and planned performance to indicate the need for adjustment of either plans or performance.

An important consideration in making the system effective is the identification of the responsibility of particular persons in the organisation for carrying out the various functions. Responsibility in the Forestry Commission for strategic planning—represented by the corporate plan—is at the Headquarters level, responsibility for tactical planning—represented by the Conservancy plan and detailed investment appraisals—is at the Conservancy level, while responsibility for operational planning is with the District Officers, Foresters, and other professional and technical managers. In order to ensure personal involvement and responsibility the aim has been to delegate to the greatest possible extent. Operational plans, though they have to be brought into adjustment with higher level plans, are agreed between managers rather than imposed from above and the operational standards are set locally.

The procedures for budgeting and budgetary control have been introduced and operated in all Conservancies over the past year. Introduction of the mechanical procedures through written instructions and central and local training courses, combined with the necessary sense of urgency on the part of those who had to apply them, has been reasonably smooth.

It is early to comment on the effectiveness of control reports beyond saying that they appear to be directing attention to questions appropriate to the role of the managers receiving them. The control reports provide statements of actual and standard expenditure and income, variance and forecasts of variance for the year, and together these form a succinct yet comprehensive report of performance within the year concerned. This is the first time such a report has been available to management, and initial difficulties have been due to the unfamiliarity of the quantities and absence of supporting explanation. Unfamiliarity will be overcome through further training and experience gained over time. The appropriate form for supporting explanation has to be worked out between the managers concerned.

The essential framework of the system of financial control is provided by the corporate plan and Conservancy plans. Work on the establishment of

the corporate plan is mentioned above. Further development of Conservancy plans will follow the decisions on objectives and main programmes in the corporate plan.

The design of the financial control system is reported in Forestry Commission Bulletin 44, *Operational Research and the Managerial Economics of Forestry*, published by HMSO in 1970 at £1·55.

P. A. WARDLE

Recreation

Potential Demand : Day Visitors

A study was undertaken for the Commission's Conservation and Recreation Branch of potential demand for day visitor recreation. A questionnaire on 210 forests which are easily accessible from urban centres or within major holiday areas revealed that approximately half are subject to some legal constraints which precludes immediate development of recreational facilities.

The remaining forests were examined to produce a short list of forests where expenditure on recreational facilities for day visitors would be most likely to be rewarding. The population of cars within a 30-mile radius was estimated by allocating the resident population of each local authority area arbitrarily into one of five zones. The zones were 0-5, 5-10, 10-15, 15-20 and 20-30 miles from the centre of each forest. The relevant car ownership factor for that Licensing Authority was used to calculate the number of cars. The number of cars in each zone was weighted by a distance factor on the principle that more recreation visits are made from towns lying close to a forest than from towns farther away. Data from a survey made in 1968 in the Forest of Dean were used for this weighting and the values in each zone summed to produce a " potential demand score ".

Further allowances were made, first for the different densities of road network in different parts of the country which affects the relationship between distance as measured by radius and road miles, secondly for the likelihood that visitors would not cross London to a forest on the outskirts of the metropolis, and thirdly holiday populations. It was assumed that the relative proportions of holiday-makers to visitors from home, taken from on-site questionnaire surveys, would remain constant over time.

A short list of 22 forests was obtained. These are both suitable for recreational development and have a high potential demand for day visitor recreation. Additional calculations were made for some of the legally constrained forests to suggest where it ought to be worth while to try to remove these constraints. The main opportunities for recreational development of this type appear to lie in South-East England, South Wales, the Midlands, the Tyne/Tees area and the Central Lowlands of Scotland.

Day Visitor Survey 1970

A further observation survey was undertaken during the summer of 1970 of recreational day use of the forests. On 17 recreation areas selected by Conservators, observations of the numbers of arriving and departing vehicles,

of the weather and of the number of cars parked at hourly intervals were recorded on fifteen days chosen at random from the months June to September. In six areas the observations were augmented by daily readings of pneumatic traffic counters. The areas included scenic drives at the following forest locations: Pickering (Yorkshire), Hamsterley (Co. Durham) and the New Forest (Hampshire); car parks and picnic places in Glen Affric Forest (Inverness-shire), Glenmore in the Queen's Forest (Inverness-shire), Tummel (Perthshire), Grizedale (Lancashire), Dovey (Merioneth), Dean (Gloucestershire), Thetford (Norfolk), Wendover (Buckinghamshire) and Slindon (Sussex) Forests; beaches at Tentsmuir (Fife) and Newborough (Anglesey) Forests; and roadside parking in Delamere Forest (Cheshire) and at Haldon in Exeter Forest (Devon).

The data will be analysed to provide seasonal estimates of seasonal visits and visitor-hours for each area, with details of average length of stay per party and car occupancy. It is also hoped to demonstrate the effects of weather on visitor attendance and to develop ideas on the selection of convenient indices with which to estimate recreational use.

R. M. SIDAWAY
R. Q. OAKES

Economic Appraisals

Respacing

An evaluation of the costs and revenues of " respacing " has been carried out. Respacing is defined as the deliberate removal of crop trees at any time between planting and the usually accepted age of first thinning. The removed trees are usually of no value. The object of respacing is to induce increased girth increment in the remaining trees. Though there seems to be a case for carrying out the operation in certain crops, particularly where no thinning is planned (or otherwise where the minimum size of exploitable tree is large), the net discounted revenue attributable to the operation is sensitive to any decrease in the timber quality of respaced trees relative to normal trees. A general recommendation on the operation must await the result of a review of the relationship between spacing and timber quality being currently carried out in the Research Division.

Fire

Studies on fire protection have continued. A methodology has been worked out for specifying the probability of a fire outbreak over daily periods in a given locality. The factors which need to be taken into account are determined as part of the method. In the particular area studied, the factors of significance were:

(a) month of year,

(b) whether the day was (i) a Sunday or (ii) a normal weekday or Saturday or (iii) a weekday or Saturday forming part of a Public Holiday,

(c) the average annual number of fires experienced over the last five-year period,

(d) a measure of the current weather and condition of the local vegetation.

The pattern of spending on fire protection has also been examined. This has indicated that the most scope for cost reductions lies in the " non-fiery " forests. The " non-fiery " forests are defined as those which have experienced less than some given number of fires over the most recent five-year period, the given number varying between three and six according to the size of forest (see *Report* 1970, p. 137).

These forests account for just over 50 per cent of annual expenditure, while they experience only about 20 per cent of the total Forestry Commission reported fire starts. Their expected loss per fire seems to be roughly equivalent to that for " fiery " forests.

Optimal Felling Ages

An optimal felling age is regarded as that which maximises net discounted revenue. The interactions between the factors affecting the optimal felling age have been studied. These factors include the price/size assumption for trees, the stocking and rate of growth of the existing crop, the expected costs and revenues associated with the successor crop and the discount rate. Where there is a risk of windblow the loss of future net revenue (or penalty cost) occasioned by windblow is a further factor to be taken into account. This factor includes all the extra costs associated with windblow, including any organisational costs if they arise. Providing a manager summarises his views on the windblow risk in probability terms, an optimal felling age can be calculated for any defined set of circumstances.

In general, the optimal felling age is not much influenced by the net discounted revenues assumed for the successor crop. Where an area is to be treated as a whole, the optimal felling age is surprising insensitive to the stocking of the existing crop. Where a crop has been thinned normally there is not a strong case for planning to fell at an age much earlier than the normal optimum unless there is a comparatively high risk of windblow. If there is a need to fell at an earlier age than the optimum in order to meet timber contracts, the opportunity cost of felling in low yield class crops may be higher than that incurred in felling crops of the same age in a high yield class—this is contrary to the usual assumption that premature fellings should always take place in the lowest yield class crops available.

A computer programme has been written which defines the optimal felling policy in a given situation and which also indicates the opportunity cost of felling prematurely. This will enable advice to be quickly given to local managers. The importance of any uncertainties in the manager's information can be assessed using the programme.

Vehicle Replacement

Work carried out on vehicle and plant replacement during the year tended to confirm earlier work which suggested that the total annual cost of capital and repairs is not very sensitive to replacement age. The primary effect on cash flows of altering replacement age is the change in the relative proportions of capital and repair costs.

J. F. MORGAN
E. R. ADAMS

FIELD SURVEYS

Topographic Surveys and Assessments

The metric revision and updating of area and yield class data covering 123,000 ha of plantations completed the country-wide exercise started in November 1968.

All teams resumed work on routine topographic survey and the work completed is summarised in Table 17.

TABLE 17
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	35,450	10	9,340	5	44,790	15
England and Wales	14,800	10	21,900	3	36,700	13
Total Great Britain	50,250	20	31,240	8	81,490	28

Data was collected in Scotland from fertiliser trials and for studies of log moisture content.

L. M. SIMPSON

Site Surveys

Soil surveys were completed on 26,200 ha in five Conservancies. The development of windthrow in relation to soil types was charted on Margam Forest (Glamorgan).

Five teams of two foresters each are currently surveying at the following centres:

Centre	County	Soil region
Elgin	Moray	Eastern Igneous Dalradian Moine
Moffat	Dumfriesshire	Silurian
Lochgilphead	Argyll	Western Dalradian
Glengarry	Inverness-shire	Highland Moine Basalt
Neath	Glamorgan	South Wales Carboniferous

A major project was the completion of an estimate of the areas of soil groups and soil types by geological regions for Forestry Commission forest land, based on existing sample surveys and Soil Survey sheets. This estimate is being used to identify the scale and location of managerial and research problems where site type is involved.

Two courses were held at Pickering and Fort Augustus respectively to instruct Conservancy and District Managers in the use of site survey information. There will be two further courses in 1971. Two courses were also held for Research Foresters at the same locations, completing the programme of courses on identification and description of upland soils.

Training of Site Survey teams in the use of panchromatic photographs as an aid to rapid survey of pre-planting areas has been started.

D. B. PATERSON

Mensuration

The Forestry Commission changed over to using metric units during the year under review, the operative date being February 15th 1971. The more essential tabular aids to measurement were produced during the year and are listed among the publications on page 97 and also in Appendix I. *Forest Management Tables* (*Metric*) are currently in the press as FC Booklet No. 34, and the main publication still to be completed in metric units is a *Forest Mensuration Handbook* which will contain all measurement procedures and relevant tables used in Forestry Commission practice.

With the aim of extending sample plot coverage in Lodgepole pine, some twelve sites have been selected for new permanent sample plots, mostly in the North Scotland Conservancy. In addition, the Mensuration Section has established permanent sample plots in an existing Research Division Lodgepole pine provenance experiment at Millbuie in the North Scotland Conservancy.

Some of the more recently established replicated thinning experiments are now producing useful information. In line thinning the distribution of increment between the remaining rows is of considerable interest at present, and the results of a line thinning experiment in Sitka spruce at Glen Trool (Kirkcudbrightshire) three growing seasons after thinning are briefly recorded here. The experiment includes three line thinning treatments, namely the removal of one row in three, the removal of two rows in six (leaving four adjacent), and the removal of three rows in nine (leaving six adjacent). The control consists of a selective thinning in which one-third of the standing volume was removed. There are three replications. The relative basal area increments in each row, expressed as a percentage of the initial basal area stocking, over the four-year period, are shown in Figure 3.

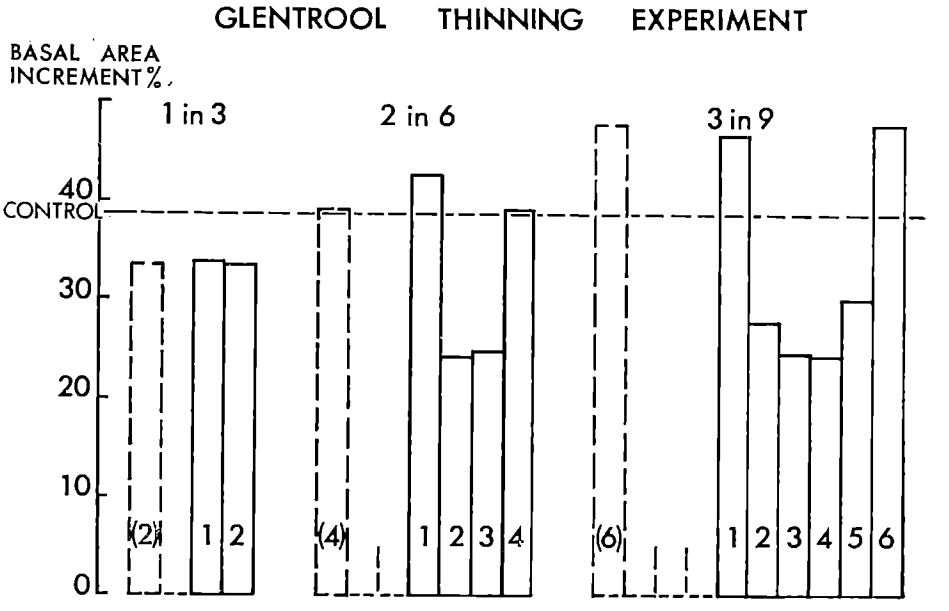


Figure 3: Glentrool line thinning experiment. Relative distribution by rows of basal area increment expressed as a percentage of initial basal area.

The dotted line shows the increment per cent achieved by the selective control. The increment pattern demonstrated here shows that appreciable responses are obtained only in the rows adjacent to rows removed. While the response of the outside row rises markedly as the number of adjacent rows removed increases, it is as yet too early to compare total production of the treatments on an area basis.

In yield table construction, a computer programme has been developed to compile yield models for given combinations of initial spacing, thinning intensity, cycle and type of thinning for all major species, but only within the limits imposed by the present state of knowledge of the effects of varying these factors. Input data consist largely of functions describing the relationships beween basic crop parameters.

G. J. HAMILTON

WORK STUDY

I. FOREST MANAGEMENT STUDIES

General

Work was mainly a consolidation and development of projects in train during the previous year. The production and successful trials of a tubed seedling planter and the resolution of some of the problems which stood in the way of predicting outputs of ploughing tractors were useful advances. The Lokomo plough continued to do sterling work on the indurated soils and proved effective over stump-ridden ground. Mechanical weeding is normally the cheapest possible form of vegetation control but is limited by terrain ; whilst existing equipment—particularly the front-mounted brush-cutter—has been successful there is need to extend mechanical weeding to more difficult terrain. The self-powered pedestrian controlled machine being designed is one step in this direction but we are also giving thought to the use of powerful forest tractors appropriately equipped with brushcutters.

PLANTING

Step and Notch Planting

A guide to outputs which might be expected under different conditions has been prepared and found satisfactory for most cases.

Tubed Seedlings

Work continues in cooperation with Research Division. Thus far a cheap and satisfactory planting tool has been devised (Plates 6, 7 and 8) and short trials have shown that up to 700 trees per hour can be planted. Current tasks include the provision of a frame to fit a Ford Transit van to hold up to 80,000 seedlings. Carrying frames to enable plants to be transported over short distances have been made and a carrier for the planting trays evolved. All these developments are under trial in conjunction with Conservancy staff. The design of a plough attachment to produce shelter for the seedlings is in hand ; early work has had mixed results.

Finn Forester Tree Planter

The machine has broadly confirmed its early promise in the East England Conservancy although further modifications have been necessary. Trials on spaced furrow ploughing in the Borders have continued with some success ; these are under the control of Research Division.

PLOUGHING AND DRAINAGE

Outputs of Ploughing Outfits

Following further analysis of past and current studies it has been found that, within the three broad classifications given in last year's *Report*, slope does not play a significant role by itself. It has proved possible to relate the time to plough a given length of furrow to an Index of Difficulty (an objective assessment of ground and tractor characteristics). This concept has still to be refined but results have proved to be statistically significant.

For each type of ploughing there is also a statistically significant relationship between the time to plough a length of furrow and other ploughing work, eg travelling light, raising and lowering the plough.

These relationships have opened the way towards the evolution of an output guide.

Lokomo Plough and BTD 20 Tractor

Work in East Scotland has continued and a total of approximately 342 km of drain has been ploughed in mainly surface-water gley and other indurated soils. The most interesting development has been the use of the equipment on cleared windblow areas at Blairadam Forest (Fife) (Plate 5). Drains 0·6 to 0·7 m deep have been produced through ground with stumps 20–40 cm diameter. The drain was clear in sticky gleys, less so in friable gleys, but stumps were removed in all cases and future maintenance and deepening will be possible without resort to back-acting diggers. The major hindrance lies with brash and lop and top which can build up under the plough beam and bring the operation to a stop. Costs in the region of £0·75 per 20 m are feasible.

Development of this technique is planned taking into consideration alternative ploughs and towing unit.

Parkgate Deep Drainer with Double Mouldboard

This plough has been tested and modified in conjunction with Research Division. It has two possible roles:

(*a*) *As a Cross Draining Plough.* It has produced a more uniform and cleaner drain than the single mouldboard with less tendency to "crab" and more effective mouldboard extensions. Greater drawbar pulls are required. On cross draining the plough has a tendency to throw the bulk of the spoil to one side and work to date suggests that this can be controlled by adjustment of the cutting discs. With hydraulic control of the latter it might be possible to achieve the benefits of a reversible plough (giving two way ploughing across a slope) without the disadvantage of a large reversible body. This work is planned by staff of our research and development workshop. In addition it will be made possible for the driver to vary the plough depth, simultaneously reducing ground pressure on the plough wheels. A drawbar shock absorber will be incorporated, permitting

faster working speed and preventing shear-pin breakages: this development would be applicable to any of our existing trailed ploughs.

(b) *Ploughing for Planting.* It has been successfully used on deep peat and also at Clocaenog (Denbighshire) on peaty gley. Drains are at about 5 m espacement and the spoil turned out on each side is the planting medium.

Oja-Viska Rotary Ditcher

Following initial and rather unpromising work in South Scotland on a County Super 4 with Sea Horse tyres the ditcher was mounted on a Roadless 115 tractor for further trials in North Wales. On 3-4 year old drains made by a Parkgate plough, and which had grassed over, satisfactory cleaning was obtained and depth increased by 10–15 cm. It is possible that this machine may have a place for drain maintenance over more peaty conditions if mounted on a crawler tractor.

WEED CONTROL

Chlorthiamid Application

A full report of experience to date awaits Research Division assessment of weeds controlled and species resistance. Horstine proprietary equipment, i.e. a portable motorised knapsack granule applicator, is likely to be suitable so long as the degree of usage of chlorthiamid remains as at present. If the scale increases then some further work may be needed.

Front-mounted Brush Cutter

This machine, designed by our machinery research and development workshop, has proved to be very successful and more are likely to be ordered either for relatively light ground preparation or for mechanical weeding. The hydraulic drive to the cutting head has proved to be particularly successful.

Self Powered Pedestrian Controlled Weeding Machine

Enquiries have suggested a need for this type of machine and a prototype using hydraulic drive to the blade is to be constructed. Design work has begun.

Grass Rollers

The double roller produced in 1969 proved to be difficult to operate on rough terrain and its poor turning circle resulted in too many trees being damaged at the end of rows. To overcome these difficulties a single roller has been designed, with transportation wheels added. Width variation if required can be obtained to some degree by altering the tractor rear wheel spacing, as they give a similar effect.

FENCING

High Tensile Spring Steel Fencing

An output guide has been prepared and is now being tested.

II. HARVESTING STUDIES

General

Priority within the Research and Development Workshop programme was given to the design and development of a 45 BHP hydrostatic tractor and to cable crane development. First trials of the tractor, which is frame-steering and articulated, have been encouraging. On cable cranes, the standard equipment is likely to be a skyline capable of transporting 1·5 tonnes over 300 metres. Useful progress has been made in resolving the stacking space problems which result from the increased length of skyline.

45 BHP Hydrostatic Forest Tractor

The need for a satisfactory articulated frame-steering machine of about this size became increasingly apparent during the year. One has been built to the following specification.

Engine: 45 BHP.

Total Steering Angle: 110°.

Total Articulation: 60°.

Weight: 2,858 kg.

Overall Length: 4·3 m.

Overall Width: 1·73 m.

Inside Turning Radius: 1·07 m.

Tyres: 14·9 × 24 Suregrip 6 Ply.

Ground Clearance: 0·53 m.

The machine build-up was started in September and the tractor was running in early November. After a period of testing at Alice Holt, the tractor was despatched to Kielder, Northumberland, in February for field evaluation. Preliminary reports are encouraging.

75 BHP Hydrostatic Forest Tractor

This machine, produced in the previous year, greatly helped in the design of the 45 BHP model which was given priority. However, this machine has not been neglected. Its weight has been reduced, power increased, and hydraulic circuitry and cooling system improved. Further field evaluations will follow.

Hydraulic Tongs

These are now being manufactured commercially by K. and M. Engineering Ltd. of Alderbun, Shrewsbury, Shropshire. This model is suitable for approximately a one-tonne load. Additionally a prototype two-tonne model has been produced and is under trial. Yet larger grapples may be required in connection with highly mechanised harvesting but several models are commercially available from overseas.

Hydraulic Stackers

Stackers to fit on the front end of tractors equipped with hydraulic tongs have been designed and are being tested. On other extraction tractors the need has become increasingly apparent for front-mounted stacking devices to replace conventional log-rolling blades. Suitable models are being designed

both for conventional and frame-steering tractors. These devices are not intended for lorry loading but to reduce the manual burden of stacking at conversion sites.

Other Tractor Studies

(*a*) A County 754 tractor was modified to enable more efficient working in the forest. The recommendations will be applied to other machines of this type.

(*b*) A Hough Paylogger has been provided with new wheels and wide tyres, 23 × 26, in order to investigate the degree of improvement in trafficability so secured.

(*c*) Tractor movement times vary according to the terrain traversed. Earlier studies revealed approximate relationships between movement time and certain key factors such as slope, soil type, degree of soil wetness and numbers of impediments. Studies are being made in Southern England in an attempt to rationalise the problem and provide workable solutions.

Cable Cranes

Investigations have continued jointly with Harvesting and Marketing and Engineering Divisions. Most work has been aimed at producing a skyline capable of transporting 1·5 tonne loads over 300m. For the longer ranges required in some circumstances satisfactory equipment appears to be available from overseas—we are particularly interested in the Norwegian Vinje radio-controlled cable crane concept, and the Communications Section is studying problems of radio frequency as a preparatory measure. We also believe that capstan control may improve the performance of current winches and Engineering Division is building and testing a simple prototype capstan. In the longer term hydraulic capstan winches may be considered.

Stacking problems have also received attention. Various solutions are available. Cable crane trailers were discussed in the last *Report* and subsequent experience has confirmed their technical feasibility. Other work includes duplication of skylines with one tractor serving each alternatively ; under this system the tractor will move to the next skyline set-up when the timber pile at the winch end becomes too large for further economic working ; the system works well in practice. One further possibility is to turn the load through 90° when it reaches the road and to transport it down the road in order to increase stacking space ; design studies are in hand. For some situations a heel-boom loader (capable of picking up timber lengths away from their centre of gravity) may be the answer. It is likely to emerge that no single solution will answer all the problems but there is some hope that the current round of studies will provide feasible answers for most circumstances.

The laying-out of rack systems, particularly through unbrashed stands, has always been something of a problem. A short trial using a laser beam as a layout aid was unconvincing and gave little promise, and attention has been turned to the use of coloured lights and to radio. Tests with lights have revealed likely savings ; tests with off-phase radio signalling have yet to be carried out.

Multilift Detachable Lorry Body

Equipment belonging to a contractor in North Wales is being studied. Trials have so far been limited to one forest and to the use of this system linked with tree-length tractor extraction followed by crosscutting and hand loading of the body at ground level. Speed of turnround has been demonstrated, i.e. 5–10 minutes to pick up the loaded body. A drawback has been the amount of room required for the body prior to and during loading operations. Work continues.

III. OTHER STUDIES

Roads

Work on pre-planting roads has concluded and the results will appear as a Forest Record.

Communications

Radio control was provided for the double drum winch of the 45 BHP hydrostatic tractor referred to earlier. The equipment operates in the UHF band on 458.6 MHZ and allows the tractor driver to operate each winch from the ground whilst guiding in the load.

Deer tracking equipment has been provided and is being evaluated by Research Division. Further work may be needed.

The Commission's Education and Training Branch requested provision of communication between the instructor and trainee in noisy environments, e.g. during chainsaw and tractor driving instruction. UHF radio together with a noise reducing head-set was provided to give one-way communication from instructor or trainee. Trials were successful and the equipment adopted.

L. C. TROUP

HARVESTING AND MARKETING DIVISION

TIMBER UTILISATION

Destructive Testing of Telegraph Poles

Joint trials were undertaken with the Post Office to examine the suitability of Lodgepole pine for use as telegraph poles. Twenty-one poles from Dornoch Forest (Sutherland) were delivered to the Post Office depot at Grangemouth, where five were creosoted under pressure by the treatment schedule used for Douglas fir and larch, and six were subjected to the Scots pine/redwood pressure treatment schedule. The results were as follows:

Treatment schedule	*Oil pressure*	*Net retention of creosote*	*Condition of poles after treatment*
Larch/Douglas fir	12 bar for 120 mins	208 kg/m^3	Wet
Scots pine/redwood	10 bar for 60 mins	88 kg/m^3	Almost dry

It appears that a treatment schedule intermediate between the above would be suitable for this species.

The treated poles are being put into service and the untreated remainder were delivered to the Department of Trade and Industry's National Engineering Laboratory at East Kilbride, Scotland, for testing to destruction (See Plate 12). At the same time the opportunity was taken to test Corsican pine poles. of which ten were selected from Bennan Forest (Kirkcudbrightshire) and eight from Thetford Chase (Norfolk and Suffolk), while five Scots pine poles from Post Office stocks were tested for comparative purposes. The following results were obtained:

Mean Bending Strength (Modulus of Rupture)

Lodgepole pine (Dornoch) 44.7 MN/m^2 (6486 $\pm$ 710 lbf/in^2)

Corsican pine (Thetford) 47.4 MN/m^2 (6904 $\pm$ 1091 lbf/in^2)

Corsican pine (Bennan) 43.0 MN/m^2 (6242 $\pm$ 1223 lbf/in^2)

Scots pine (Post Office stocks) 43.1 MN/m^2 (6251 $\pm$ 643 lbf/in^2)

The moisture content at the time of testing was 15½–33½ per cent of the over dry weight, the drier wood being associated with the outer layers.

Fence Post Trials

Results of experiments at eight sites in Scotland after 13 years' service are given in Table 18.

TABLE 18

FENCE POST TRIALS IN SCOTLAND

PERCENTAGE OF POSTS REMAINING

Species	Treatment		
	Untreated	Waterborne preservative*	Creosote
Sitka spruce	2·6	72·6†	100
Birch	3·1	64·0	99·3

* This proprietary preservative is no longer marketed for use in contact with the ground in Britain.

† The apparent increase over the 1970 percentage is due to the loss of the site at Bush Estate in Midlothian, where spruce treated with waterborne preservative gave poor results.

The figures for the eleven sites in England and Wales after 12 years' service are given in Table 19.

TABLE 19

FENCE POST TRIALS IN ENGLAND AND WALES

PERCENTAGE OF POSTS REMAINING

Species	Number of sites (out of 11)	Treatment			
		Untreated	Waterborne preservative	Creosote	Charring
Scots pine	11	0·9	89	99·4	—
European larch	1	75	93	100	—
Japanese larch	1	44	87	100	—
Ash	3	Nil	27	77	Nil
Birch	5	12	42	97·5	—
Elm	2	6	6·2	97·5	—
Oak	1	Nil	56	95	—
Sweet Chestnut	1	69	69	100	44
Sycamore	2	3·1	69	93	—

Arrangements have been made to terminate the Scottish Experiments after the 1972 assessments, and most of those in England and Wales after 1973.

Reduction of Needle Fall and Improvement of the Fire Resistance of Christmas Trees

Further experiments were undertaken at the Ministry of Agriculture, Fisheries and Food's Experimental Horticulture Station at Efford in Hampshire, in which replicates of four different treatments were installed in a

polythene-lined chamber where living room conditions were simulated, and the dry weight of needles shed 15, 22, 25, 28 and 31 days after setting up the experiment was recorded.

This experiment was duplicated, one series with the treatments applied to freshly-cut Norway spruce Christmas trees, and the other to trees which had been harvested a fortnight earlier. The results are given in Table 20.

TABLE 20

CHRISTMAS TREE TRIALS

TOTAL DRY WEIGHT OF NEEDLES SHED AFTER THIRTY-ONE DAYS

Grammes

Treatment	Freshly cut trees	Trees treated two weeks after harvesting
Controls (no treatment)	23·69	22·05
Dip in ½ per cent sodium alginate solution	9·68	4·38
Dip in 3 per cent gelatine solution	6·06	5·22
Dip in a proprietary water-soluble resin	14·62	10·27
Immersed butts	6·52	4·34

As with the 1969/70 series of experiments, organic gels are effective in reducing needle fall, and there is probably little to choose between dipping in alginate or in gelatine, or keeping the butts immersed in water. Furthermore, under the climatic conditions experienced in early December 1970, harvesting the trees two weeks before treating them appears to have no adverse effect on needle retention.

Two series of experiments were undertaken to investigate the effect of dip treatment on the flammability of the foliage. This was done by applying a butane blow torch to the tree and recording the lapse of time before ignition occurred. The results of these are given in Table 21.

TABLE 21

FLAMMABILITY OF CHRISTMAS TREES

First Series

Time in Seconds to Ignite with a Blow Torch
(means of two replicates) 31 Days after Treatment

	Freshly cut trees	*Trees treated two weeks after harvesting*
Controls (no treatment)	1·8	2·25
½% Sodium alginate dip	4·2	3·0
3% Gelatine dip	5·1	5·0
Water-soluble resin dip	3·0	4·0
Immersed butts	4·5	7·0

Second Series

Time in Seconds to Ignite with a Blow Torch
(mean of five replicates) Three and Fifteen Days after Treatment

	Third day	*Fifteenth day*
Controls (no treatment)	2·5	1·6
½% Sodium alginate dip	2·7	2·2
Immersed butts	2·9	2·2

At the final assessment in both of the above series it was observed that the controls usually continued to burn with bright flames after the removal of the blow torch, while the trees with immersed butts and those with treated foliage merely smouldered for a few seconds.

The Use of Bark in Horticulture

Further growing trials using bark as the main constituent of "potting composts" have shown that some ornamentals such as *Coleus* species and *Begonia semperflorens* can flourish in a medium of pure pulverised bark providing that they are fed adequately with a high-nitrogen fertilizer.

A commercial grower in Buckinghamshire has successfully used the bark as a cover for bulb forcing with hyacinths and tulips, but found that the addition of lime is desirable for the latter. Bark was preferred to loam for this purpose because it reduces the weight of the containers considerably.

Pilot experiments at the Glasshouse Crops Research Institute, Littlehampton, using bark as a medium for mushroom culture have been promising, and two mushroom growers are using it for trials.

Bark has also been supplied to a number of orchid growers with encouraging results, and one of them is now using a bark-based "compost" for his main crop of *Cymbidium*. Arrangements were made for trials to be undertaken at the John Innes Research Institute, Norwich, and at the Royal Horticultural Society's Gardens at Wisley.

Most aspects of the development work were exhibited at the 1970 Chelsea Flower Show, and at a number of agricultural shows.

J. R. AARON

THE JOINT PROGRAMME ON HOME-GROWN TIMBER: FOREST PRODUCTS RESEARCH LABORATORY AND FORESTRY COMMISSION

The Joint Programme of Work on home-grown timber, carried out by the Department of the Environment's Forest Products Research Laboratory at Princes Risborough and by the Forestry Commission, has been continued in an effort to meet the Commission's need for further information on home-grown wood.

The following is an account of the work done during the year under this Joint Programme.

Stress Grading of Home-Grown Softwoods to Determine their Suitability for Building

Investigations have shown that machine stress grading can provide a better forecast of the bending strength of timber than is possible by visual inspection. The practical implications of this are either higher yields to present grade stress values with increased values of modulus of elasticity, or a change in grade definitions to permit higher grades than those presently specified in British Standard Code of Practice CP 112:1967 *The Structural Use of Timber*. CP 112 is being studied in co-operation with the appropriate authorities in Sweden and Canada but inevitably some time will be needed before any final recommendations can be made as to appropriate grade boundaries. As an interim measure, and to allow machine grading to be employed, machine selection is at present being operated to the bending stress values specified in CP 112:1967 for the 50 and 75 grades. For these machine selections it has also been possible to recommend higher modulus of elasticity values than those given in CP 112: 1967 and the immediate advantages of machine grading over visual grading are therefore better yields and higher modulus of elasticity values.

Machine stress grading depends for its operation on the establishment of relations between strength and modulus of elasticity, measured under certain conditions. These can only be determined from tests and accordingly a programme was initiated (last year's *Report*, p. 164) to explore the application of machine stress grading to home-grown Scots pine, Sitka spruce and Douglas fir, using the Computermatic Stress Grading Machine. More recently it has been agreed that home-grown Corsican pine should also be included.

The objectives of this investigation are:

(1) To establish the basic relations between bending strength and modulus of elasticity.

(2) To determine machine settings for selection by the Computermatic machine to the 50 and 75 grade stresses in bending as specified in CP 112:1967.

(3) To examine the effectiveness of Computermatic selection to these grades and to determine interim stress values.

(4) To establish the probable yields by machine grading from material from the five Conservancies having the greatest volume of each species.

(5) To examine the relation between log grade and yields of graded timber.

To date, the first three objectives have been attained for Scots pine. The results have indicated that home-grown Scots pine can be machine graded satisfactorily and that considerably improved yields of the better grades can thereby be achieved. Some 70 per cent of the pieces tested were rated by the machine as 75 grade compared with less than 10 per cent by visual inspection.

Wide variations in dimensions can, however, adversely affect machine grading and if there is overcutting the machine setting should correspond to the actual, not the nominal, size. For effective operation it is desirable that dimensional tolerances should not exceed those specified in BS 4471 and that the allowance for shrinkage should be realistic.

This investigation has provided the information needed to prepare programme cards for the Computermatic machine to stress grade Scots pine, in sections ranging in thickness from 30 to 50 mm and in widths up to 200 mm, to the two grades designated M75 and M50. Within these sizes stress values for the two grades have also been determined.

Work on Sitka spruce is now well-advanced and this will be followed by Douglas fir and Corsican pine.

The Effect of Fertiliser Application on Growth Increments and Wood Density in Sitka Spruce

Earlier studies have shown that when Sitka spruce is grown vigorously as a result of forest management practices which encourage increases in crown volume, additional wood formation occurs mainly as early wood, resulting in an increase in the proportion of early to late wood and a lowering of wood density. Application of fertilisers and, in particular, phosphate has been shown to stimulate growth in stands of Sitka spruce. Fertiliser treatment is reputed to affect crown development by increasing the photosynthesising surface and possibly by increasing the photosynthetic efficiency of the foliage. Few studies have been made of the consequences of this on wood yields, either in qualitative or quantitative terms. It was, therefore, recommended that the effect of fertiliser treatment on wood production in young plantation stands, managed under the comparatively vigorous growth conditions prevailing in Britain, should be examined. During discussions it was suggested that the effect of fertiliser application was to enhance wood production at the base of the crown compared with that at lower levels in the stem. Thus an effect of fertiliser treatment could be to reduce taper which is in contrast with the effect of other management techniques, such as spacing and thinning, which encourage crown development, stimulate increased wood production near the base of the stem and increase taper.

A programme is now under way, the two main objectives being to examine:

(*a*) Whether or not the character of the wood produced as a result of stimulation to growth following fertiliser application differs from that produced by growth which is enhanced by other forest management

practices. In particular, it is proposed to examine for Sitka spruce whether or not the regression of wood density on growth rate for untreated and fertiliser-treated stands is the same. If this is so, it might then be reasonably accepted that the result of fertiliser treatment on wood properties and timber performance is similar to that of any other management practice which enhances vigour of growth. If, however, the effect of fertiliser application is to result in a different relationship for growth rate and density, the reasons for this, in terms of the within-ring components, that is the proportions and density of early and late wood, will be sought.

(*b*) The effect of fertiliser treatment on growth increments at different heights in the tree. This to be compared with trees which have not been stimulated to growth in order to assess the effects of fertiliser applications on taper, volume production and wood yields.

Samples for the investigation, consisting of disc material sampled at proportional heights of the tree, and breast-height borings, have been taken from the Forestry Commission fertilising experiments in Sitka spruce at Glasfynydd (South Wales).

The breast-height borings are being used to observe the radial increment and wood density immediately prior to fertiliser treatment, and following treatment for periods of growth corresponding to the intervals at which the crop performance was assessed. These results will be used to compare the relationship between radial increment and density for stems which have responded, and those which have *not* responded, to fertiliser treatment.

Using the disc material, studies are being made of the increment following treatment at different levels in the stem. If there are marked differences between trees which have responded to fertiliser treatment and those which have not, the density of the wood laid down in the years following treatment, its volume and the yield of dry wood substance will be compared.

The Effect of Spacing on Wood Density and Wood Yields of Norway Spruce

Previous work to examine the effect of spacing on wood density and wood yields has been done on Sitka spruce (see last year's *Report*, p. 163). Because of the interest and importance of the results obtained, it was considered desirable to repeat the study using Norway spruce obtained, as was the Sitka spruce, from the Forest of Ae (Dumfriesshire).

As before, the main objects of the study were:

(*a*) To examine the effects of spacing on wood yields, both in quantitative and qualitative terms.

(*b*) Using the experimental data obtained, to examine the relationship between wood density of a breast-height boring and the mean density of the stem.

The Norway spruce study, to a large extent, complements and confirms some of the observations made earlier on the effect of planting distance and thinning regimes on the yields of Sitka spruce. Perhaps the point of particular interest is a comparison of the ability of the two species to respond to wider (2·5m) spacing, and their yield when managed under the "P" thinning

regimes. With Sitka, the standing crop volume and weight of wood substance exceeds that on the other plots and, even when yields from past thinnings are added, compares favourably with that from the more closely-spaced plots. With Norway, however, there is little evidence for an enhanced standing crop volume or wood yield, and when past thinnings are added, the present study suggests that the site yield from the 2·5m plot, managed to a " P " regime, fails to meet that from plots with more closely-spaced trees. It suggests that Norway, unlike Sitka, is unable to take advantage of the growth potential offered by the wider spacing and as a consequence this results in some loss of yield. From a production point of view there must be some uncertainty, on the basis of the present study, as to the wisdom of establishing Norway spruce at spacings of 2·5m even where the crop is being grown for pulp use. When considered for saw-timber the low density of Norway spruce must be some cause for concern. At Ae, Norway spruce produces a lighter-weight wood than Sitka spruce at comparable rates of growth and there is evidence that a somewhat lighter weight for Norway compared with Sitka is general for growth in Britain (Johnston, 1966). Therefore, management practices which select for, or enhance, vigour need to be adopted with some caution if too high a proportion of vigorous-growth, low-density wood of uncertain value for saw-timber use is to be avoided.

This study also confirmed the view that sampling by breast-height boring can be a satisfactory technique for determining whole-tree density and wood yield, although it must be emphasised that the results obtained, although derived for trees of very variable rates of growth, refer to an even-aged population.

Sitka Spruce for Constructional Grade Plywood

The commercial interest in plywood manufacture, including the prospect of investment in combined sawmill and plywood plants, led to a decision to make further limited investigations into the suitability of Sitka spruce veneer as a core for constructional grade plywood. It was agreed to make peeling tests on a billet from each of six trees, the 3mm veneer to be used as core for plywood with 1½mm Scots pine faces. The criteria of suitability were considered to be an adequate glue bond and an absence of " telegraphing " of the roughness of the Sitka spruce through to the surface.

The logs were supplied from Glengarry Forest (North Scotland), from a stand in the forty to fifty year (P21–30) age-class. They were intended to provide a representative range of growth rate, and this was the only basis of selection.

The trials indicated that 3 mm veneer of satisfactory quality for constructional grade plywood can be obtained from home-grown Sitka spruce logs. Steaming the billets at a temperature of about 50°C is necessary to soften the knots and the use of a knife with a main bevel angle of about 21½° and a 5° microbevel on the face opposite to the main bevel is recommended.

The wide variation in initial moisture content, 60 per cent to 230 per cent, must result in overdrying of some of the heartwood, which can be corrected by subsequent conditioning.

Satisfactory plywood can be made though bonding pressure must be limited to a maximum of about 7 kg/cm^2 (0·686 N/mm^2) if excessive compression is to be avoided. Nevertheless, even at the highest pressure used in these tests, (11·9 kg/cm^2, or 1·167 N/mm^2) no pronounced " telegraphing " of grain was apparent. The bond quality was not as high as could be desired, though with the lowest bonding pressure consistent with reasonable compression it meets the requirements of British Standard 1455 : 1963 for WBP type (weather and boil-proof).

Properties of the More Important Minor Species

Work is continuing on a programme to examine the timber properties of Western hemlock, Grand fir, Noble fir and Western red cedar. The main object of the investigation is to compare the sawmilling characteristics of these four minor species in terms of the yield and quality of the sawn material. In addition, the machining properties of the four species will also be compared from the results of standard ripsawing, surface planing, moulding and nailing tests. Sawmilling trials are expected to be completed by mid-1971 and it is hoped that some assessment of the result can be given in next year's *Report*.

Whole Tree Utilisation

At the present time, about 20 to 40 per cent only of the whole tree is utilised. A more complete utilisation is obviously desirable, and a survey has been initiated to assess the possible limits to the utilisation of both softwood and hardwood trees.

A critical appraisal is being made of the types, quantities and distribution of forest residues and also those residues resulting from primary sawmilling operations.

If technical problems arise to which a solution appears possible, or if areas are identified where more information is required, then the necessary work will be initiated by the Forest Products Research Laboratory.

Blue-Stain Experiments at Thetford

A slight improvement in the control of blue-stain was obtained in laboratory billet trials when aqueous solutions of sodium salts of tribromophenol and of pentachlorophenol were compared with similar formulations in an oil solvent on wetted billets. Accordingly, a supplementary forest trial was carried out on April- to July-felled Scots pine in Thetford Chase.

Aqueous solutions of sodium pentachlorophenate, buffered and not buffered, to which lindane had been added in an emulsifiable concentrate, were compared with a formulation of pentachlorophenol and lindane in light mineral oil, using billets that had been deliberately wetted.

The four assessments made during the 1970 season indicate that each of the five chosen chemical treatments can reduce blue-stain significantly.

Unbuffered sodium pentachlorophenate/lindane at 2 per cent can reduce blue-stain to less than a third of that measured on untreated logs.

Buffered sodium pentachlorophenate/lindane or pentachlorophenol/lindane in mineral oil can reduce staining to below one tenth that of the untreated controls.

Differences in staining attributable to lowering the concentration of buffered sodium pentachlorophenate are small and require further statistical examination.

T. HARDING

Forest Products Research Laboratory.

REFERENCE

JOHNSTON, D. D. (1966). The specific gravity and moisture content of conifers. *Scott. For.* **20** (4), 255–260.

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PART II

Research Undertaken for the Forestry Commission at Universities and Other Institutions

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NUTRITION AND FOREST SOILS

SEED AND FOREST NURSERY EXPERIMENTS IN TREE NUTRITION

By BLANCHE BENZIAN

Rothamsted Experimental Station, Harpenden, Herts

Extracts from *Rothamsted Report* for 1970

Micronutrients

Soaking Conifer Seed in Micronutrient Solutions.

Gribkov (*Vest. sel'. Khoz. Nauki, Mosk.* (1960), No. 4, 129–131) reported improved germination in the laboratory, and increased growth of seedlings in the field, from soaking seed of several species in solutions of micronutrients. We soaked seed of Sitka spruce (*Picea sitchensis*) from Washington State, for 18 hours at room temperature in Mn- and Cu-solutions (and in distilled water) before sowing them in pots containing a 1:2 (w/w) mixture of quartz and soil from Wareham Nursery (a podsol with very small nutrient reserves). All pots were given NPKMg. The solutions tested were: 0·1, 0·2, 0·4 g/l Cu (as $CuSO_4 \cdot 5H_2O$) and 0·05, 0·1, 0·2 g/l Mn (as $MnSO_4 \cdot 4H_2O$). The copper solutions increased Cu in seed from about 20 to 2000 ppm without affecting germination or growth. (The amounts given may have been too large.) The manganese solutions (Table 22), which increased Mn in seed by between 80 and 140 per cent, did not affect germination or colour of crop, but increased seedling height by 13 per cent and dry weight of tops by 23 per cent; none or only trivial responses resulted from treating the seed with the most concentrated solution. Mn in the crop increased from 33 to 40 ppm in dry matter with increasing strength of solution. Sitka spruce seedlings grown in the nursery can contain from about 20 to more than 1000 ppm of Mn without showing signs of deficiency or excess, and it is surprising that growth was substantially increased by such small increases in concentration. These results may have practical implications for raising young conifers intensively as, for example, in plastic tubes. Because this method increases Mn in the crop without affecting the soil, it may help in understanding the benefits from partial sterilisation, in which manganese nutrition is one of the many factors involved. (Benzian, Mitchell and Smith, with Hill, Biochemistry Department.)

TABLE 22

EFFECT OF SOAKING SITKA SPRUCE SEED IN MN-SOLUTION ON THE SUBSEQUENT GROWTH AND MN CONCENTRATION OF THE SEEDLINGS

Treatment Seed soaked in solution containing Mn(g/l)	*Seed* Mn (ppm in dry matter)	Seedlings			
		Height (cm)	Dry matter (mg/plant)		Mn (ppm in dry matter) tops+roots
			Roots	Tops	
None	808	7·9	174	324	32·6
0·05	1,487	8·4	197	365	33·2
0·1	1,720	8·9	195	397	37·2
0·2	1,973	8·1	160	340	40·1
S.E.	—	±0·26	±12·6	±16·9	±1·10
cv%	—	6·4	14·0	9·6	6·2

Isobutylidene diurea (IBDU) in Forest Nurseries

This granulated slow-acting nitrogen fertiliser (29·5–32·0 per cent N), made in Japan, was tested with seedlings and transplants of Sitka spruce (*Picea sitchensis*) on a very sandy podsol (Wareham) and a sandy loam (Kennington). Three compounds—two particle sizes of IBDU (0·8–1·5 and 1·5–2·4 mm) and formalised casein (already shown to be a good source of slow-acting N) —were applied before sowing or transplanting, and compared with four top-dressings of " Nitro-Chalk " and with no N. Four amounts of each fertiliser were tested ; all plots were given basal P, K and Mg. The experiments with seedlings lasted four years, those with transplants three ; all ended in 1969.

TABLE 23

COMPARISON OF PRE-SOWING OR PRE-TRANSPLANTING APPLICATION OF IBDU (MEDIUM AND COARSE) AND FORMALISED CASEIN WITH FOUR TOP-DRESSINGS OF " NITRO-CHALK " FOR SITKA SPRUCE

Height (cm)

Treatment	Seedlings					Transplants	
	Wareham				Kennington	Wareham	Kennington
	1966	1967	1968	1969	1966–69	1967–69	1967–69
Without N	1·0	0·9	1·1	1·7	3·3	13·0	25·8
Increases from							
IBDU (0·8–1·5)	4·4	2·0	2·1	0·6	2·2	10·4	8·3
IBDU (1·5–2·4)	5·1	3·0	2·0	0·9	2·8	10·8	8·5
Form. casein	4·4	3·6	4·9	3·7	2·8	11·7	9·6
" Nitro-Chalk "	5·1	5·2	6·4	4·2	3·8	11·0	9·8
S.E. ± of increases	0·28	0·45	0·39	0·25	0·23	0·84	0·45

Table 23 shows responses to "Nitro-Chalk" were large, especially in wet seasons. Formalised casein again proved a good source of slow-release N under all conditions tested—almost equivalent in effectiveness to four separate top-dressings of "Nitro-Chalk". IBDU (especially the coarse fraction) was equally efficient for transplants at both nurseries and was safe up to the largest dressing tested (280 kg N/ha). It was also as good as formalised casein for seedbeds on the loamy sand at Kennington, but after a promising start (*Rothamsted Report* for 1966, p. 44), it became steadily less effective at Wareham. No satisfactory reason can be offered for this decline; it is not because IBDU failed to decompose, because analyses of soil at the end of the experiment, and results from associated pot experiments with ryegrass, showed that nitrogen had not accumulated. There was no evidence of consistent temperature or rainfall changes with years to aggravate leaching. The soil became increasingly more acid during the first three years, but liming to near optimum (pH 4·5 in $CaCl_2$) for Sitka spruce at the beginning of the last season did not improve the efficiency of IBDU. There were no indications that the seedlings were harmed: germination was not retarded, plant numbers were as in other plots, and seedlings usually grew better with the large than with the small dressings—never the reverse. (Benzian, Freeman and Mitchell.)

RESEARCH ON FOREST SOILS AND TREE NUTRITION

By H. G. MILLER and B. L. WILLIAMS

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Nutrition of Pines

Close attention continues to be given to the two nitrogen fertiliser experiments in middle-aged pine stands growing on wind-blown sand at Culbin Forest (Moray) (*Reports* for 1965 to 1970). The older of these two experiments involved annual applications of ammonium sulphate to Corsican pine over a period of three years, following which the tree crop was sampled for weight determination and chemical analysis. Some 75 sample trees were felled and the opportunity was taken to cut a series of discs from the stems of these in order that examinations could be made of (a) the pattern of change in basal area and height growth that occurred with the onset of deficiency conditions and (b) the pattern of response of stem growth to the fertiliser applications, both at different heights up the tree and between different tree sizes. In order to facilitate measurements of ring widths, radiographs of these discs were prepared, using facilities kindly made available by the Research Division of the Forestry Commission. In addition to this detailed study of past growth, a total enumeration of basal area growth has been made after each growing season, and the height growth that has occurred over recent years has been assessed on trees felled for this purpose in early 1971.

In terms of basal area the trees in this experiment grew very rapidly until the age of 12 years, after which, instead of showing the expected continuing rise, growth per tree became fairly constant. Some years later this was followed by an actual decrease in the rate of basal area growth per tree, a trend that started at age 22 and has continued up to the present (age 42 years). This decrease from age 22 is probably the result of continuing immobilisation of nitrogen in the newly formed humus layer, as has been discussed previously (*Reports* for 1969 and 1970), but the extent of the change in growth pattern at age 12, probably coinciding with canopy closure, was greater than had been anticipated. The pattern of decline in height growth is similar to, although less dramatic than, that for basal area. The addition of nitrogen fertiliser to this crop produced no immediate response, but in the year following first application basal area growth increased several-fold, and continued to increase until 1968, two years after fertiliser application had ceased. In 1969, the heaviest treatments were able to maintain this high rate of growth but by 1970 basal area increment was falling in all treatments. Foliar nitrogen concentrations, on the other hand, started to fall in 1967—that is, immediately fertiliser application ceased. However, by 1970 the concentration of nitrogen in foliage from the heaviest treatment was still as high as 1·75 per cent, more than twice the value of 0·78 per cent for the untreated control trees.

The second pole-stage fertiliser experiment in this forest was designed to compare the response of Scots pine to differing forms of nitrogen fertiliser, these being applied in both 1968 and 1969 at a standard rate of 250 kg nitrogen per ha per annum (*Report* for 1969). In the first year ammonium nitrate produced the greatest increase in foliar nitrogen concentrations, whereas the least increase occurred in those plots given either urea or sodium nitrate, the increase in response to ammonium sulphate occupying an intermediate position. In the second year of application the level of nitrogen in foliage of urea-treated trees was second highest, although still well short of that produced by ammonium nitrate. By the end of 1970, the first year in which no fertilisers were applied, the foliar nitrogen concentrations with respect to fertiliser treatments were approximately 2·2 per cent for ammonium nitrate, 2·1 per cent for ammonium sulphate, 2·0 per cent for urea, 1·8 per cent for sodium nitrate and 1·2 per cent in the untreated control trees. Basal area growth in 1968, the first year of treatment, showed no response, but by 1969 considerable variations appeared that largely paralleled the pattern of foliar nitrogen values found at the end of the previous year. Thus a maximum growth of 1·2 m^2 per ha was stimulated by ammonium nitrate, the untreated control plots producing only 0·7 m^2 per ha.

Nutrition of Sitka Spruce

As described in the previous *Report* a new series of investigations has begun into factors that may control nutrient uptake and diagnostic levels of foliar nutrients in Sitka spruce. Different methods of sampling whole trees of this species have been tested (*Report* for 1969), and following on from this a valid sampling technique has been devised and used in sampling sixteen trees from a 21-year-old stand of this species growing on thin hill peat at a Fetteresso Forest (Kincardineshire).

During the summer months a greenhouse experiment was performed to test the response of Sitka spruce to various forms and rates of introgen supply. As was found in earlier experiments on Corsican pine (*Reports* for 1966 to 1967), Sitka spruce shows a marked preference for ammonium sources of nitrogen. Thus when grown for 204 days at a supply of 3·5 ppm nitrogen (with continuous nutrient renewal and regular adjustment of pH) the weight of plants relative to those grown in ammonium nitrate (taken as 1·0) were 3·0 for ammonium sulphate, 0·9 for calcium nitrate and 1·2 for urea ; similarly at a supply of 28 ppm nitrogen the weights, relative to those in ammonium nitrate, were 1·4 for ammonium sulphate and 0·2 for calcium nitrate ; insufficient plants survived to give an adequate figure for urea. However, variation between plants within treatments was very great and steps are therefore being taken to enable production of clonal material for future experiments.

Effect of Shade on Nutrient Uptake

The short-duration study described in the previous *Report* has continued. Samples of foliage have been taken at monthly intervals over the period November 1969 to December 1970 from five different coniferous species, including Sitka spruce, planted beneath a range of over-cover densities.

Chlorophyll concentrations in these showed a marked variation with time and shade, there being a fairly consistent increase in concentration with decrease in intensity of incident light. Nutrient concentrations are also markedly time-dependent but appear to be less affected by shade. These samples are now being analysed for free amino-nitrogen and soluble sugars.

Nitrogen Mineralisation in Peat and Humus

As the result of preliminary work on this problem (*Reports* for 1969 and 1970) it has been possible to define those factors most likely to be limiting release of nitrogen in available forms from acid peat and mor humus. This, in turn, has enabled the use of more concise experimental approaches, in particular the complementing of investigations of field-treated samples with detailed studies on samples carefully modified under strict laboratory conditions.

Samples of humus were taken in June 1970 from the Scots pine experiment at Culbin Forest (Moray), this experiment having last received fertiliser nitrogen in June 1969. As was found with samples taken prior to the 1969 fertiliser application, the highest concentrations of mineral nitrogen occurred in humus taken from those plots given nitrogen fertiliser, the quantities varying with forms of fertiliser applied and increasing in the order sodium nitrate $<$ urea $<$ ammonium nitrate $<$ ammonium sulphate. Acidity of the humus, measured in a 2·5:1 (v/v) suspension in 1·0 M solution of KCl, also increased in the same order and, with the exception of sodium nitrate, all forms of nitrogen fertiliser depressed the pH of the humus relative to that in samples taken from the untreated control plots. The addition of lime or triple superphosphate, or both, with any of these nitrogen fertilisers tended to both increase the pH of the humus and reduce the proportion of the nitrogen present in mineral form.

Following incubation of these humus samples for nine weeks at 30°C, it was found that the net increase in mineral nitrogen that had occurred was marginally highest in humus samples taken from plots treated with urea, irrespective of whether lime or phosphate had been added. Sodium nitrate, on the other hand, depressed the net production of mineral nitrogen relative to the values found for the control, and the application of either ammonium sulphate or ammonium nitrate appeared to have no significant effect. Recent measurements of the rate of carbon dioxide evolution on incubation suggest that the fertilisers applied to this experiment have altered the rate or pattern of biological activity in the humus, and laboratory experiments are now in progress to establish the extent of these changes and their relation to nitrogen mineralisation.

Samples of peat taken from field plots treated with phosphate and potassium have again shown increased rates of mineral nitrogen production on incubation (*Report* 1970). Laboratory experiments are now under way to investigate more closely this effect of the addition of phosphate and potassium and to determine their optimum concentrations. Samples of peat taken in October 1970 from the drainage experiment at Inchnacardoch Forest (Inverness-shire) were incubated for 120 days at 30°C under both aerobic and anaerobic (waterlogged) conditions. In samples taken from the waterlogged

plot and from the intensively drained plot (water levels in perimeter ditches maintained at depth of 0 and 0·5 m) the highest rates of production of mineral nitrogen occurred under anaerobic conditions, whereas with samples from the less intensively drained plots (water levels in perimeter ditches maintained at depths of 0·1, 0·2 and 0·3 m) this situation was dramatically reversed with highest net production occurring under aerobic conditions. Measurements of carbon dioxide evolution during incubation failed to distinguish between treatments, there being a wide variation in results between samples. A factor contributing to this variation may lie in differences in the quantities of methane produced. Certainly, mass spectrographic analysis of the gases above a sample incubated under anaerobic conditions revealed the presence of greater quantities of methane than of carbon dioxide.

FOREST PATHOLOGY

CONIFER SEEDLING PATHOLOGY

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The pH range trials started in 1948, on sandy loam at Kennington Extension and on acid heathland soil at Wareham Nurseries, show that on both soils Sitka spruce grows best around pH 4·5. The growth curves follow a parallel course in the two soils, and plants become severely stunted as the pH approaches and exceeds 6·5 (Benzian, 1965). In nurseries sited on near neutral soils growth is dramatically improved after the soil has been partially sterilised, but it has not been possible to show clearly whether this response is mainly from the control of soil-borne pathogens, from increased availability of plant nutrients, or other causes. On acid soils near the optimum for growth, responses to soil fumigation are usually small, but direct comparisons of growth responses to soil fumigation over a wide range of soil pH seem to have been neglected. New experiments were started at Kennington and Wareham, during the winter of 1968–69, to measure the effect of treating soil with formalin on the growth of Sitka spruce on soils previously treated with lime to give pHs ranging from 4·3 to 6·6 at Kennington and from 3·5 to 6·3 at Wareham.

At Kennington in 1969 and 1970, as pH increased, the growth curve fell more steeply in untreated than in formalin-treated soil. Thus at pH 6·6 formalin increased height by 87 and 68 per cent respectively, whereas at pH 4·3 the increases were 30 per cent and *nil* respectively in the two years. At Wareham in 1969 seedlings grew better over the whole pH range and at pH 6·3 were more than twice the height of those at Kennington. Responses to formalin were small and erratic, but in 1970 they followed the same pattern as at Kennington and ranged from 39 per cent at pH 4·0 to 75 per cent at pH 6·3. An unexpected result was that seedlings grown at pH 3·5, where stunting was caused by acidity, also responded strikingly to formalin, which increased their growth by 50 and 65 per cent in 1969 and 1970 respectively.

The numbers and species of fungi isolated on water agar from washed roots changed with both soil type and pH, and although formalin decreased numbers of some species there was no clear association between these changes and growth responses. *Cylindrocarpon*, the most prevalent fungus on roots at both nurseries over the whole pH range, was decreased by formalin especially at Kennington, and was more prevalent at pH 4·3 than at pH 6·6. Roots infected by *Pythium*, also fewer after formalin, were common only in July samples from Kennington where 66 per cent were infected at pH 6·6, 16 per cent at 5·5 and 4·8, and 1 per cent at pH 4·3. *Pythium* probably accounted

for most of the seedling losses at Kennington at pH 6·6, where formalin increased survival by 40 and 21 per cent in 1969 and 1970 respectively. At Wareham, where *Pythium* was rare, survival was good at all pHs and was unaffected by formalin. *Fusarium* species were present in small numbers only and were unaffected by formalin. *F. oxysporum* was present throughout the pH range, whereas *F. roseum* (*sambucinum*) was more prevalent at pH 4·3 than at 6·6. Numbers of *Penicillia* and *Actinomycetes* were increased by formalin treatment. The former were prevalent at pH 4·3 and the latter at pH 6·6. *Mortierella* was prevalent at Wareham throughout the pH range.

Systemic Fungicides

Benomyl applied to seedbeds in 1970 at 4 g per square yard had no effect on growth but increased seedling numbers at all pHs by an average of 10 per cent at Kennington and 2 per cent at Wareham. It decreased numbers of *Cylindrocarpon* and *Penicillium* isolated from roots but slightly increased numbers of *Pythium*. It improved germination both in untreated and formalin-treated soil, probably by controlling seed-borne fungi.

Nematicides

Aldicarb (Temik 10 per cent granules), raked into the soil surface of selected plots in the pH range trial at Kennington (KE 27) at 2 g/sq yd in March, and applied again in June at 4 g/sq yd, had little effect on seedling growth although it killed many free-living and plant parasitic nematodes (Gowen and Hooper, 1971). It had no effect on numbers or species of fungi isolated from roots in July and October, and seems to be the first powerful nematicide we have used that has not acted as a partial sterilant on the rest of the soil micropopulation.

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ROLE OF LOPHODERMELLA SULCIGENA IN PREMATURE DEATH OF PINE NEEDLES IN SCOTLAND

By C. S. MILLAR

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This report relates to an investigation into the causes of premature browning and death of needles of Corsican pine (*Pinus nigra* var. *maritima* (Aiton) Melville) at Culbin Forest, Moray. It supplements a previous report (Millar, 1970) and covers the final six months during which the investigation was supported by a grant from the Forestry Commission.

The pattern of deposition of ascospores of *Lophodermella sulcigena* (Rostr.) v. Höhn, established previously using a Burkard volumetric spore trap, was confirmed in 1970. Spores were trapped between 24 June and 16 August with peaks on 8 July and 27 July. More detailed records of relative humidity in the forest were obtained and it was shown that, at the periods of peak spore deposition, spores could be trapped before the humidity reached 90 per cent, whereas at the start and, more especially, at the end of the sporing season up to six hours of high humidity were required for deposition.

The deposition of the spores of 20 other fungi has been examined. Of particular interest to the present work are *Lophodermium pinastri* (Schrad. ex Hook) Chev. which was deposited throughout the year, *Lophodermella conjuncta* Darker mainly from June to December, and *Hendersonia acicola* Tubeuf which also appears to sporulate throughout the year with a small peak in October.

Further work using " Dithane " in an attempt to control *L. sulcigena* has led me to the conclusion that it is important not only to predict the periods of spore release but also to predict periods of maximum infectivity if control is to be successful. High spore deposition followed by dry weather is of no consequence, whereas low spore deposition followed by sustained high humidity can cause severe browning of the current year's foliage.

Further measurements on Corsican pine have shown that of five classes of diseased trees, based on foliage discolouration, the four most severely diseased classes showed a considerable reduction of ring width in 1963 and 1967, in each case as compared with the previous year. In contrast, the slightly diseased or healthy trees showed little or no reduction in ring width in the same years. Both 1963 and 1967 were noted for the severity of browning attributed to *Lophodermella sulcigena*. Height growth was only slightly affected over the same period.

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VIRUS DISEASES OF FOREST TREES

By P. G. BIDDLE

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The surveys made in many of the Forestry Commission nurseries and forests have confirmed the widespread occurrence of virus-like symptoms on spruce. The vivid yellow chlorosis of both Sitka and Norway spruce is only occasionally seen, and there is evidence suggesting that this chlorosis is the initial symptom produced after infection, and that it only develops on a low proportion of infected trees. The chlorosis is followed by defoliation of all except the current year's needles, which is the characteristic symptom of the suspected virus infections. This variation in symptom development could reflect either infection by more than one virus or virus strain, or differences in host response.

Attempts have been made to transmit the pathogen which might be causing these symptoms. These tests have used grafts and the suspected aphid vectors, *Cinara pilicornis* and *Elatobium abietinum*. It is to be expected that symptoms may take one or more years to develop and until such results can be obtained the evidence for this condition being caused by a virus is entirely presumptive.

Attempts have also been made to transmit the condition known as bushy stunt of Scots pine using grafts and aphids. The distinct brooming symptoms of this condition in young trees is caused by a failure of development of the apical bud resulting in production of fascicular shoots and loss of apical dominance. This failure of bud formation is closely mirrored by about 5 per cent of Scots pine in the nursery, which suggests that a condition of similar aetiology may be widespread, although the symptoms are generally less noticeable.

Investigations have started on a condition affecting some poplar clones, known as stem fluting. Macroscopic symptoms of this are conspicuous flutings up to three inches deep on the basal five feet of the bole, and shallower fluting on the underside of branch bases. These flutes result from a failure of correct differentiation of the phloem and xylem. Cambial derivatives fail to elongate resulting in apparent production of masses of lignified parenchyma. The rays become enlarged, more frequent and multiseriate, while xylem vessels are absent or infrequent. *Populus* x *euramericana* ' Gelrica ' is the most severely affected clone, although the branch base symptoms have also been noted on the cultivars ' Eugenei ' and ' Heidimij '.

FOREST ENTOMOLOGY AND ZOOLOGY

STUDIES ON INSECT VIRUSES

By T. W. TINSLEY, J. S. ROBERTSON, J. F. LONGWORTH and K. A. HARRAP

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The research projects in which the technician, supported by the Forestry Commission, has assisted have been described in the *Reports* from 1968 onwards. A full list of publications based on this work is attached.

These projects have included purification and characterisation of occluded and nonoccluded viruses of the following forest pests ; *Anoplonyx destructor* from England, and *Gonometa podocarpi* and *Pachymetana* species ; both being Lasiocampids affecting *Pinus patula* in Uganda. Investigations into the antigenic properties of the granulosis virus of *Pieris brassicae* have provided information vital to unequivocal serological comparisons of the occluded viruses.

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RESEARCH ON THE GREEN SPRUCE APHID ELATOBIUM ABIETINUM

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As in previous years aphid sampling was again carried out at the Forest of Deer (Aberdeenshire) in 1970. However, as virtually no aphids were observed throughout the summer the sampling intensity was reduced in comparison with earlier years. The low number of aphids recorded prevented adequate testing of the formula designed to predict aphid peak levels described in the 1970 *Report,* but the formula did confirm that virtually no aphids could be expected at Deer in the summer of 1970. Temperature records for Deer are still being obtained, and sufficient data should soon become available for winter temperatures to be related to aphid densities during the succeeding summer.

To test the hypothesis that the amino acid levels of the plant sap are mainly responsible for the population fall which occurs in mid-summer, an analysis of the soluble amino acid levels in Sitka spruce needles was carried out at weekly intervals in the months of May, June, July and August, 1970. This showed that the total soluble nitrogen in the needles exhibits a decrease in concentration from May onwards reaching a minimum level in the beginning of July, at about the time that the population decrease occurs. Of the individual amino acids, the most marked decreases were observed for aspartic and glutamic acids and their amines, proline, phenylalanine, threonine and serine. Other amino acids were present in smaller quantities so that the data obtained was not as precise in these instances, but the same general trend of a decrease in their level from May through to July was exhibited. It is intended to repeat this experiment in 1971 to obtain more precise data on the relative concentrations of these amino acids.

In conjunction with the analysis of spruce sap, work has commenced on the dietary amino acid requirements of *E. abietinum.* To date, 19 amino acids have been isolated from the aphid including the 10 generally regarded as nutritionally essential to all insects, namely phenylalanine, leucine, iso-leucine, methionine, valine, threonine, histidine, arginine, lysine and tryptophan. Also isolated were five other ninhydrin sensitive compounds, provisionally regarded as peptides. Further experiments are in progress to attempt to determine the nitrogen requirements of the insect more precisely.

The sticky aphid traps described in the 1970 *Report* were again set up in the Countesswells Section of Midmar Forest (Aberdeenshire). The two main peaks of flight activity previously noted were again recorded but the total number of aphids and the number of species trapped was reduced in comparison with 1969. Alate *E. abietium* captures were again confined to the first peak and, as expected from the general scarcity of the aphid in the north-east of Scotland, were much less frequent than in 1969.

Following the observations of Parry (see *Report* for 1969, p. 152) that very little aphid mortality occurred at temperatures just below freezing point a more thorough study of the effects of low temperatures on the survival of the aphid has been initiated. It has been shown that the aphid is able to supercool to temperatures of $-10°$ to $-12°C$ and even lower in some cases. The effect of temperature has also been found to be correlated with time; at $-20°C$ aphids survived for a few seconds while at higher temperatures the time taken until death was increased. Work on these aspects of the effects of low temperatures on aphid survival are currently in progress.

The probing behaviour of *E. abietinum* on Sitka and Norway spruces has received further attention. By incorporating ^{32}Phosphorus into the plants it has been shown that sap uptake occurs after a shorter feeding period on Sitka spruce than on Norway spruce, despite the fact that the aphids reach the phloem earlier on Norway spruce. Thus the suggestion made by Parry (see *Report* for 1969, p. 153) that the Norway spruce is a relatively unsuitable host in which the probing stimulus is easily elicited, while the feeding stimulus has a high threshold value, has been corroborated by this experiment. It is hoped that the complete results of this facet of the work will be published in the near future.

STUDIES ON TIT AND PINE LOOPER MOTH POPULATIONS AT CULBIN FOREST

By MYLES CROOKE and ANDREW DEADMAN

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The planned development of work aimed at providing survivorship curves or life tables for various populations of the Pine looper, *Bupalus piniarius L.*, at Culbin Forest in Moray was frustrated during 1970 by the very low densities of that insect. In 1969 the pupal densities had been only 0·5 pupae per square yard in Plot 1 and 0·3 pupae per square yard in Plot 2 ; in 1970 they remained at about the same low level, the mean counts in both plots being slightly less than 0·3 pupae per square yard. This, coupled with a failure to quantify accurately the numbers of emerging adults, has led to the abandonment of the life table approach since this of necessity requires sensitive and statistically reliable indications of the mortality losses between successive life cycle stages of the moth.

In consequence of this it was decided to concentrate on the bird aspect of the work, and a study of the population of tits in the forest has been instituted with emphasis on population dispersion and dispersal. Little work on this aspect has been carried out on Coal and Crested tits (the two main species at Culbin) in Britain.

A large-scale bird ringing programme in the winter of 1969/70 provided a good basis for initial work on dispersion, and in the breeding season all tit nestlings in the two smaller study plots (both natural and nest-box nests) and also birds from the boxes in the larger boxed plot, were ringed with an individual plot colour ring. A considerable number of sighting and recaptures of these marked birds has provided many data on the post-fledging dispersal of the tits. After fledging the broods form " family parties ", the fledglings remaining with the parents for a period of about two weeks. A series of plot censuses during which the relative numbers of ringed and unringed birds in the plot were noted, indicated that this dispersal was " explosive " in nature, the juveniles moving rapidly away from the breeding area. In addition some work on family party movement was carried out, in an effort to obtain data on feeding range and to see whether the parties were in any way territorial.

Winter flocking commenced in the middle of August, and regular plot censuses showed that by the beginning of September quite large flocks, of up to 30–40 birds, were present in the forest. At the beginning of October artificial feeding commenced in the two boxed plots as in previous years, and in addition four temporary feeding tables were brought into use, basically as ringing points. These were moved progressively outwards from the plots at fortnightly intervals. They have provided valuable information on the extent of bird movement in the forest area, and have indicated that the majority of birds move only short distances although there are a number of long range recoveries from 1.5 to 2.0 miles from the table at which they were ringed.

Regular monthly plot censuses in the two small study plots have provided information on the trends in population numbers throughout the winter.

Flock tracking, which involves following a flock for as long a period as possible, in two or three cases over two consecutive days, has provided data on the range of the flocks. This ties in with the ringing work, as well as providing information on the relative speed of movement and size of flocks under different weather conditions and in different habitat types. In addition, separate from the plot censuses, flock-size counts have been made along transects covering large areas of forest, and these have provided evidence of the changes in flock size and structure.

Expansion and intensification of work along these lines will be carried on in 1971.

THE ECOLOGICAL RELATIONSHIP OF BROWN TROUT AND SEA TROUT IN FOREST STREAMS

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During the last year, trout populations in both Glentress Burn, Glentress Forest, and Kirk Burn, Cardrona Forest (Peeblesshire), have been investigated. These forest streams were chosen because they were reasonably accessible, large enough to possess a full biota, and small enough to be experimentally fished at reasonable cost. Also, they permit complete counts of all upstream and downstream migrants and, thus, avoid sampling errors.

Glentress Burn has a resident population of slow-growing brown trout. This was sampled by means of a fish trap to capture downstream migrants, and by electrofishing gear. Kirk Burn, on the other hand, contains both brown trout and sea trout. Over the year emphasis has been placed on a study of the sea trout. Sections of the burn were electrofished monthly to calculate changes in production, distribution and vital statistics of young fish. During the autumn, box traps were erected to capture upstream and downstream migrant fish. A total of 41 adult sea trout and 112 brown trout were captured during their ascent and tagged and released upstream.

Environmental factors such as stream flow, discharge, temperature fluctuations, and water chemistry of Kirk Burn have been monitored. The effect of these and other physical characteristics on the biomass of fish present is being prepared for publication.

ENVIRONMENT

ENVIRONMENTAL EFFECTS ON SHOOT GROWTH IN CONIFERS

By D. C. MALCOLM and E. A. CALDWELL

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There is accumulating evidence from field studies that temperature has a marked influence on shoot extension and bud dormancy in the commonly planted conifers. The initial aim of this project is to define the important formative and qualitative effects of temperature and other factors on the growth phases of species of contrasting growth habits. Subsequently these effects will be compared for different provenances also.

The study is being conducted jointly with the Physiology Section of the Forestry Commission's Research Division, utilising the growth room facilities at their Northern Research Station. The experimental material used so far has been clonal cuttings and grafts of Sitka spruce and Western red cedar, and seedling Lodgepole pine. The use of clonal material is important as it allows comparisons to be made of the responses by plants of different physiological ages and removes a major source of variation.

An initial experiment with Sitka spruce and Western red cedar compared the effects of different daylengths on shoot extension, branching and needle length. For the clones of Sitka spruce used, a $16\frac{3}{4}$-hour day proved optimal; shorter daylengths resulted in terminal bud formation and longer daylength in a reduced rate of extension. Growth of Western red cedar proved erratic both between plants and treatments but indicated a critical daylength of around 15 hours for the faster rates of growth. Production of lateral apices in Sitka spruce is apparently related to the amount of terminal growth made but has a curvilinear relationship with increasing daylength if expressed in mm height growth per lateral apex formed. By contrast Western red cedar produced a lateral apex every eighth leaf pair on the terminal shoot. No effect on needle length was found.

Using the same plants from the first experiment, the effects of differing day/night temperature regimes are currently being investigated. Initial indications are that the previous treatments have marked effects on dormancy, continued growth and form of needle produced in Sitka spruce. Lodgepole pine extension growth appears to be affected by accumulated temperature while Western red cedar is again erratic in the extension growth made.

Using the basic information derived from these experiments a more detailed study of the responses of different provenances of Sitka spruce to temperature is envisaged as the next stage.

HYDROLOGICAL RELATIONS OF FORESTS

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The Measurement of Leaf Surface Area of Complex Shoots

A method has been devised to measure, simply and rapidly, the leaf surface area of conifer and other complex shoots (Thompson and Leyton, 1971.) The shoot is dipped in a diluted impact adhesive, weighed, covered with small glass balls (*ballotini*) and re-weighed. The gain in weight is proportional to the surface area and the conversion factor is determined from measurements on known surfaces. This technique should facilitate studies on transpiration, interception and other processes that require a knowledge of leaf surface areas.

Tree Root Studies

The interpretation of the distribution of tree roots in terms of hydrological activity has progressed to the stage of testing the hypothesis of cycles of death and regrowth of fine roots in discrete volumes of soils (Reynolds, 1970). This hypothesis was based on root data from core samples taken from soil transects below a Douglas fir stand. The effect of soil moisture on the longevity and distribution of rootlets is being studied experimentally by irrigating plots weekly at 0, 0·5 and 1·5 times the mean potential transpiration.

The Determination of Rainfall below Tree Canopies (Net Rainfall)

As a guide to future studies on environmental factors that vary both spatially and in time, comparisons were made of six different sampling procedures for estimating net rainfall using standard (127 mm diameter) rain gauges. Measurements were made in the 28-year old Norway spruce stand in Bagley Wood described in an earlier report on the effect of thinning on interception (Leyton *et al.*, 1969).

Five gauges were sited at random in each of the two lightly thinned plots (970 stems/ha ; 25·3 m^3/ha basal area). Four were kept stationary whilst the fifth was moved to a new random position after each measurement of the catch (between 1 and 3 days after rain). Gross rainfall was measured by two other gauges sited in a clearing 318 m away. Over the period February 23–July 15, 1970, 29 catches were recorded free of snow.

The following procedures were adopted :

(i) The simple mean was calculated from the total catches of the 8 stationary gauges over the period.

(ii) A linear regression was calculated for the catches of each of the 8 stationary gauges on their respective distances from the nearest tree stems and the mean catch then estimated for the average distance of all positions sampled, including the roving gauges (Leyton

et al., 1969). This method makes allowance for the pattern of net rainfall below the canopy.

(iii) The simple mean was calculated from the total catches of the two roving gauges over the period (Wilm, 1946). By regularly moving the gauges, many more points are sampled.

(iv) A linear regression was calculated for the mean catches of the two roving gauges on the corresponding gross rainfall for each of the 29 records. From the mean gross rainfall over the period an estimate was made of the corresponding net rainfall and from this the mean value for the 29 records could be calculated (covariance method of Wilm, 1946).

(v) As (iv), but using data from the stationary net rainfall gauges, instead of gauges in the open (Rieley *et al.*, 1969).

(vi) As (v), but arranging that the regression line passes through the origin (Rieley *et al.*, 1969).

In methods (v) and (vi), various combinations of 1 or 2 roving gauges with 1, 2, 4 or 8 stationary gauges, selected at random, were used.

TABLE 24

ESTIMATES OF MEAN NET RAINFALL (MM) BELOW LIGHTLY THINNED NORWAY SPRUCE CANOPY USING DIFFERENT SAMPLING METHODS

Corresponding gross rainfall, 152 mm

Sampling method	Roving-stationary gauges		Mean net rainfall	Standard error
(*i*)	—	8	86	±12·4
(*ii*)	(2)	8	95	8·3
(*iii*)	2	—	95	16·2
(*iv*)	2	2 (in open)	95	6·3
(*v*)	1	1	111	15·6
	2	1	95	13·5
	2	2	95	7·4
	2	4	97	5·6
	2	8	98	4·8
(*vi*)	1	1	90	15·8
	2	1	70	13·8
	2	2	93	11·3
	2	4	96	5·4
	2	8	94	4·7

As shown in Table 24, most of the methods yield reasonably consistent results, but with appreciable differences in reliability as reflected in the standard errors. In accord with the claims of Rieley *et al.* (1969), it appears that the reliability of net rainfall estimates can be maintained using many fewer gauges, provided that some of these are moved periodically. Although these results suggest substantial increases in reliability of the estimates with

an increasing ratio of stationary to roving gauges (v), (vi), similar measurements on heavily thinned plots (not reported here) indicated much smaller gains in precision. For the combination of 2 roving and 1 stationary gauge, covariance based on gross rainfall (iv) gave a much more reliable estimate than that based on net rainfall (v); for the same combination, method (vi) gave an exceptionally low value, indicating that the constraint on the regression (constant, equal to zero) when it is not justified as in the present case, can yield spurious results. The advantage of method (vi) over (v), though not apparent in the period totals, is that it yields more reliable estimates for single records.

Far less labour is required using stationary gauges, but the reliability of the estimates is low unless a net rainfall pattern can be established from which regressions can be calculated (ii). It is not known why method (iii), which sampled many more points than method (i), should have given an estimate with a higher standard error.

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LEYTON, L., REYNOLDS, E. R. C., THOMPSON, F. B. (1969). Hydrological relations of forest and moorland vegetation. *Rep. Forest. Res., Lond.*, pp. 158–61.

REYNOLDS, E. R. C. (1970). Root distribution and the cause of its spatial variability in *Pseudotsuga taxifolia* (Poir.) Britt. *Pl. Soil* **32**, 501–17.

RIELEY, J. O., MACHIN, D., and MORTON, A. (1969). The measurement of micro-climatic factors under a vegetation canopy—a re-appraisal of Wilm's method. *J. Ecol.* **57**, 101–8.

THOMPSON, F. B., and LEYTON, L. (1971). Method for measuring the leaf surface area of complex shoots. *Nature, Lond.* **229**, 572.

WILM, H. G. (1946). The design and analysis of methods for sampling micro-climatic factors. *J. Am. Statist. Ass.* **41**, 221–32.

APPENDIX I

Publications by Forestry Commission Staff

Priced publications issued by the Forestry Commission are available from H.M. Stationery Office at addresses shown on the back cover

AARON, J. R. (1970). Forestry's metric countdown. *Suppl. Timb. Trades J.* October, pp. 39–43.

Reviews the planning and progress in the change to metric measure in the forestry, home timber and related industries. The reasons for the Forestry Commission's decision to make the change in February 1971 are explained.

AARON, J. R. (1970). How the grower can use bark. *Nurserym. Gdn Centre* **151**(9), 224–225.

Outlines the use of bark for plunge beds in garden centres making reference to two commercial-scale trials: for potting composts where its suitability for growing a wide range of ornamental plants is well established; and its application as a mulch. For all these uses the importance of adding a high nitrogen fertiliser is stressed.

Mention is also made of trials in orchid culture, and the potential availability of bark is discussed.

AARON, J. R. (1970). *The utilisation of bark.* (1970 revision). Res. Dev. Pap. For. Commn, Lond. **32.**

Describes the various uses which have been suggested for bark, giving in some detail the Forestry Commission's work on the possibility of obtaining tannins from spruce bark. It considers that the most promising outlet is as a substitute for peat in horticulture, especially for mulching, plunge beds and potting composts.

ALDHOUS, J. R. (1970). UK : Trends in forest weed control. *Span* **13**(1), 21–23.

A review of current practice in British forestry and likely new developments.

ALEXANDER, A. C. (1970). Shortwood system in the Border. *Suppl. Timb. Trades J.* April, p. 24.

After clear-felling on badly drained peaty gleys a layer of brash is left on the ground so that shortwood timber carriers can move more efficiently.

BINNS, W. O. (1970). Some effects of tree growth on peat. *Proc. 3rd Int. Peat Congr., Quebec* 1968, 358–365.

At the Lon Mor, Inchnacardoch Forest (Inverness-shire), the peat under two thirty-year-old plantations of Lodgepole and Scots pine and from unplanted ground was analysed. The ground had been shallow drained and part of each plantation fertilised with rock phosphate or basic slag. The profiles have been compared as a whole, fitting regression equations by orthogonal polynomials.

There was a marked reduction in moisture content, due not to shallow drainage but to evapotranspiration of the trees. Shrinkage associated with drying was not shown by subsidence but by the formation of underground fissures.

Potassium and phosphorus were lower under the fertilised Lodgepole pine, and similar trends were found under the less vigorous Scots pine. The pH was reduced where the peat had dried. There was a marked increase of sodium under the vigorous trees.

The need for PK fertilisers is accepted; the physical changes, however, may be important for the next crop.

BLATCHFORD, O. N. (1970). Information by exception. *Suppl. Timb. Trades J.* April, pp. 14–15.

A brief account of the library and services provided by the Research Information Section of the Forestry Commission.

BRADLEY, R. T. (1971). *Thinning control in British woodlands (metric).* Bookl. For. Commn **32** (HMSO 70p.)

This booklet provides a simple guide to the volume to be removed when thinning pure even-aged stands or, with suitable modifications, when thinning woods of mixed species and/or of uneven age. It replaces Booklet No. 17, which gave similar values in Imperial units and was first published in 1966.

BRASIER, C. M. (1970). Variation in a natural population of *Schizophyllum commune. Am. Nat.* **104** (136), 191–204.

When a sample of 77 wild dikaryotic isolates of *Schizophyllum commune* from an extremely local population (ca. 1,000 fruit bodies in less than 100 square yards) was examined by biometrical methods, considerable variation was present in growth rates (at 20°, 25°, 30° C) and fruiting characteristics (fruiting time and number of fruit bodies) of the isolates, and in their cultural and fruit-body morphology. This evidence, together with the identification of 12 distinct dikaryotic combinations of six A and six B incompatibility factors in 12 isolates, indicated a highly variable population consisting of a large number of genetically unique dikaryons. The distributions for fruiting time and number of fruit bodies were suggestive of directional selection, with a stabilizing component, toward early fruiting and small numbers of fruit bodies. Pleiotropic correlations were demonstrated between two fruiting characters (fruiting time and number of fruit bodies) and growth rate at 20°, but not with growth rate at 25° or 30°. Fruiting time was correlated with number of fruit bodies; the distributions of these two characters also appeared to be related to fruitbody morphology.

BROWN, R. M. (1970). Atrazine and ametryne for grass weed control in British forestry. *Proc. 10th Br. Weed Control Conf.* **2**, 718–726.

In trials from 1967 to 1970 atrazine provided a good kill of a range of fine and soft perennial grasses (e.g. *Agrostis* spp.) at 2–4 lb a.i./acre applied from February to May, control persisting for most of the growing season. Coarser grasses (e.g. *Deschampsia caespitosa* (L) Beauv.) and non-graminaceous species were not well controlled at these rates, and some tended to spread in plots where atrazine had provided control of other weeds. Limited trials with ametryne suggested that it was less effective than atrazine.

All coniferous species appeared to tolerate overall sprays of atrazine at rates up to 4 lb. a.i./acre without serious damage. Some signs of atrazine damage were seen, however, and the tolerance of crop species requires more study.

Generally, the results suggest that atrazine should be a very useful herbicide for controlling predominantly grass weeds in British forestry.

BURDEKIN, D. A. (1970). Man management of research workers. In the *Record of a course on the organisation and methods of agricultural research, sponsored by the Ministry of Overseas Development and held in the University of Bristol, 2–15 April,* pp. 143–147. Ministry of Overseas Development, London.

BURDEKIN, D. A. (1970). Review of *Tree pathology,* by W. H. Smith. *Nature, Lond.* **228,** 1234–1235.

BURDEKIN, D. A., and PHILLIPS, D. H. (1970). Chemical control of *Didymascella thujina* on Western red cedar in forest nurseries. *Ann. appl. Biol.* **67,** 131–136.

Didymascella thujina causes a serious needle blight in nursery stock of Western red cedar. It may be controlled by cycloheximide applied at a concentration of 85 ppm

of active ingredient and at a rate of 100 gal/acre (1123 litres/ha) at the end of March and again at the end of April. In south Wales and south-west Scotland a third application may be needed in mid-June.

Other fungicides tested were not effective against this disease.

CARTER, C. I. (1971). *Conifer woolly aphids (Adelgidae) in Britain.* Bull. For Comm, Lond. **42** (HMSO 75p.)

This investigation has been mainly confined to providing descriptions for the identification of the various winged morphs of the adelgid species occurring in Britain. Morphological keys and descriptions, together with 32 original figures by the author, are given for the determination of the 14 winged morphs of the 9 species having alatae. In addition, a key to the adult apterae of the genus *Pineus* is included so as to enable identification to be made of those species which do not have a winged form. Only in the cases of *Adelges viridis* and *A. abietis* gallicolae, and *Pineus orientalis* and *P. pini* sexuparae, is it still necessary to depend upon life cycle information for separation down to species. Three of the species described, *A. viridana, P. pineoides* and *P orientalis,* have not previously been recognised in Britain. Details are given of transfer experiments carried out to check host alternation pattern in the alatae of certain species. A world check list of adelgids, their common hosts and distribution, is appended.

DAVIDSON, J. L. (1971). The coastal shipment of roundwood. *Suppl. Timb. Trades J.* March, pp. 16–17, 27.

Considers some advantages and problems of sea transport in relation to road haulage of timber, and concludes that there may be a case for coastal shipping if terminal handling techniques can be improved.

DAVIES, E. J. M. (1970). Recent increases in productivity in Scottish forestry. *Scott. For.* **24**(3), 195–199.

On the basis of statistics and personal experience the author notes the changes which have come about in labour productivity in Scottish forestry. He discusses the reasons why this has risen annually at a rate of about six per cent over the past fifteen years.

EDLIN, H. L. (1970). Collins guide to tree planting and cultivation. Collins, London. £2.10.

A practical guide, with diagrams and photographs, to the choice, planting, and maintenance of trees in gardens, streets, parks, and woodlands.

EDLIN, H. L. (1970). Woodland notebook : Trees in parklands. *Q. Jl For.* **64**(2), 123–132.

Parks, which originated as enclosed permanent pastures neighbouring the larger country houses, have been increasingly used by landscape planners to display the true forms and charm of individual trees. The resulting values are largely scenic, though shelter is provided for livestock against sun, wind, rain and snow. Timber yields are negligible since most specimens are retained for display long past their prime. Changes in agricultural practices threaten rural parks, unless they enjoy planned protection and rejuvenation.

EDLIN, H. L. (1970). Woodland notebook : Broadleaved trees in blossom. *Q. Jl For.* **64**(3), 226–234.

Few of our larger broadleaved trees carry conspicuous flowers. Most of the timber producers are wind-pollinated and bear greenish coloured catkins. Except for members of the rose tribe or Rosaceae, nearly all brightly flowered trees cultivated in Britain are introductions from warmer climates. They merit more widespread planning for landscape effect.

EDLIN, H. L. (1970). Woodland notebook : Orienteering. *Q. Jl For.* **64**(4), 314–321.

Orienteering is a new outdoor sport, introduced from Scandinavia in 1965, which combines cross-country running with rapid and accurate map reading. Men and women race against time, along compass bearings. Wooded country is generally used since

it enables essential control points to be hidden, and screens competitors from one another. Events are carefully organised by the British Orienteering Federation, whose officers survey the course, get special maps printed, supervise each event, and ensure that no damage is done to woodlands. An international meeting at Sherwood Forest, Nottinghamshire, in March 1970, is described.

EDLIN, H. L. (1971). Woodland notebook : Conifer boles. *Q. Jl For.* **65**(1), 22–30.

The bole, or lowest ten-foot (3-metre) length, of a coniferous tree is a valuable aid to recognition. It is readily seen and has characteristics—ignored by most botanical textbooks—additional to bark texture. It is also the source of most economic value, yielding large diameter saw-logs which may have a high proportion of clear knot-free timber. Decay in the bole is, therefore, the greatest source of economic loss. Swollen boles, a sure sign of decayed heartwood, arise through abnormal cambium activity aimed at supporting the tree's weight on a greater thickness of sapwood, when its heartwood support is progressively removed through internal rot.

EDWARDS, M. V.,* and LINES, R. (1970) *Bibliography on international provenance experiments begun in 1938 with Pinus and Picea and in 1944 with Larix.* Res. Dev. Pap. For. Commn, Lond. **76.**

Gives a brief account of the history of the provenance trials with *Pinus sylvestris, Picea abies* and *Larix decidua* organised by IUFRO, followed by a bibliography of papers describing these trials in sixteen countries.

EVERARD, J. E. (1971). *Metric conversion tables and factors for forestry.* Bookl. For. Commn **30** (HMSO 50p).

This booklet replaces *Conversion tables for research workers in forestry and agriculture,* Booklet No. 5, and is intended to be of use to all foresters. Particular care has been taken to comply with the recommendations of the British Standards Institution, and the International System of Units (SI) is explained.

Tables are given for the conversions most frequently made, whilst for the less frequently used ones a factor is given. The proper symbols/abbreviations are shown against each unit in an alphabetical index, and these are repeated in the tables.

FAULKNER, R. (1970). Some characters of secondary importance to stem straightness in the breeding of conifers, *Proc. FAO 2nd World Conult. Forest Tree Breeding,* Washington DC, 1969. FAO-FO-FTB-69-3/2, FAO, Rome.

A review of recent research into the inheritance of branch arrangement, branch size, branch-angle, crown width and stem taper. The importance of these characters and methods of assessing them are discussed.

FAULKNER, R (1970). *Trials with a mechanical tree-shaker for harvesting cones and beech nuts.* Res. Dev. Pap. For. Commn, Lond. **79.**

Describes trials with a modified fruit-tree shaker on Scots pine, Corsican pine, Norway spruce, Sitka spruce, Douglas fir, Noble fir, Western hemlock and beech. Some success was obtained with Sitka spruce, Douglas fir and beech but between-tree variation in cone yields was quite high and unpredictable. Early-season shaking was more effective on Sitka spruce than the mid- and late-season shaking. Beech responded well when the nuts were fully ripe ; the costs of the operation, including depreciation which was very high, were uneconomic. Flat, clean, stump-free ground is essential for manoeuvring the shaker into position.

FLETCHER, A. M. (1970). Report on visit to tree-breeding establishments in Scandinavia. *J. For. Commn, 1968-69,* **36,** 32–34.

A short commentary on tree-breeding techniques in Norway, Sweden and Denmark. Comparisons are made between British and Scandinavian practices.

* Late Head of Silviculture (North) Section.

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

The annual cycle of water movement has been studied over five growing seasons in adjacent semi-mature stands of Corsican pine and Douglas fir, growing on deep porous soils in Bramshill Forest, Hampshire.

Periods of soil water deficit in the two stands have been identified from records of gypsum block resistance measurements of soil moisture tension. Rainfall over this period has been equated with total evaporation and compared with values of open-water evaporation (E_o) calculated from climatic records.

Estimates have been made of water use by the two species, and the site factors affecting these estimates have been examined. It is concluded that the Corsican pine, which dries the soil more deeply and intensely than the Douglas fir, uses more water during the period of deficit.

The causes of these differences are not fully understood, but it is possible that wind may interact with the distinctive species canopy structure and leaf pattern, and thereby affect transpiration, though the rates of loss of intercepted rainfall seem to be similar.

There may be differences in the rate of uptake of water as affected by rooting pattern, and its subsequent movement to the transpiring surfaces, and the effects of the bracken understorey and humus layers should also be considered.

GIBBS, J. N. (1970). The role of resin in the resistance of conifers to *Fomes annosus*. In *Root diseases and soil-borne pathogens* (ed. T. A. Toussun, Robert V. Bega and Paul E. Nelson), pp. 161–163. University of California Press.

A review of the resistance processes of conifers to *Fomes annosus*, with particular emphasis on the importance of the anatomy and physiology of the resin duct system.

GIBBS, J. N. (1970). *The dying elms.* Res. Dev. Pap. For. Commn, Lond. **78**.

A leaflet describing control measures against this disease.

GIBBS, J. N., and GREIG, B. J. W. (1970). *Fomes annosus: a fungus causing butt rot, root rot and death of conifers.* Revision of Leafl. For. Commn **5** (HMSO 15p).

GIBBS, J. N., *et al.* (1971). The control of Coffee berry disease. *Ann. appl. Biol.* **67**, 45–74.

The results of field experiments into the control of this important disease of *Coffea arabica* in Kenya.

GORDON, A. G. (1970). Pre-germination in barley. *J. Inst. Brew.* **76**(2), 140–143.

Small proportions of grains of barley showing premature germination (pre-germination) were found in newly-harvested samples of good quality dormant barleys. Investigations into the cause suggested that pre-germination could result from a mechanical failure of the pericarp-testa when the moisture content of the developing grain was as high as 45 per cent. Unsuspected pre-germination was shown to occur in samples of top quality British and Canadian malting barleys.

GORDON, A. G. (1971). The germination resistance test—a new test for measuring germination quality of cereals. *Can. J. Pl. Sci.* **51**(2), 181–183.

A germination test is described which utilises conditions of germination so closely controlled that the rate of germination can be used as a measure of germination quality. From observations of the germination rate, values for the mean time for germination and the standard deviation of this mean time are computed. These values are shown to be highly reproducible. Their application is briefly discussed.

(BOYD, W. J. R.*,) GORDON, A. G., (and LACROIX, L. J.†) (1971). Seed size, germination resistance and seedling vigor in barley. *Can. J. Pl. Sci* **51**(2), 000–000.

Marked differences in seedling vigour, as measured by dry weight 2 weeks after germination, have been demonstrated in F_3 lines of a cross between C15791 and Ming C14797. These differences can be largely accounted for by differences in seed size which is itself related to segregation for head type and by differences in germination resistance. The latter character varies between cultivars and is itself influenced by seed size to some extent. It is concluded that although seed size, directly and indirectly, can influence seedling vigour, inherent differences in this respect exist between barley varieties. The significance of this is briefly considered.

GRANFIELD, E. F. (1971). *Design, construction and maintenance of earth dams and excavated ponds.* Forest Rec. Lond. **75** (HMSO 17½p).

Detailed guidance, with diagrams and photos, is given on the construction of dams and ponds, ranging from very small ponds to large dams with elaborate spillway arrangements.

GRANFIELD, E. F., and MACMAHON, C. D. (1970). Civil engineering in the Forestry Commission. *Suppl Timb. Trades J.* April, pp. 28–30.

Describes the making of forest roads to suit the needs of heavy mechanical equipment, over ground which may vary at short intervals between peat bog and solid rock.

GRAYSON, A. J., and JOHNSTON, D. R. (1970). The economics of yield planning. *Int. Rev. For. Res.* **3**, 69–122.

The pre-conditions for rational yield planning include clear objectives, adequate physical and economic data and appropriate computational aids. The role of standard treatments, such as specific thinning intensities and felling ages, in calculating the potential yield of individual stands is developed. The last section discusses the application of the preceding ideas to practical yield planning for a forest enterprise.

GREIG, B. J. W., and BURDEKIN, D. A. (1970). Control and eradication of *Fomes annosus* in Great Britain. *Proc. 3rd Int. Conf. on Fomes annosus*, Aarhus, Denmark, IUFRO Section 24, pp. 21–32.

A report is given of the work on *Fomes annosus* by the Forestry Commission Research Division, which has been concentrated on stump treatments against airborne infection and the control and eradication of the disease in crops where it is already present.

Sodium nitrite is now used as the standard stump protectant in British forests (except for pine plantations), but because of its toxic nature other chemicals are used in special circumstances. Further information is required on the use of chemical stump treatments in areas already infected by *F. annosus.*

Peniophora gigantea is recommended for stump treatment in pine plantations.

Three methods have been found experimentally for eradicating *F. annosus* from previously infected pine stands : stump removal, delayed replanting and stump treatment with *P. gigantea.* These methods have worked with varying degrees of success and the ultimate choice of the field control method will now largely depend on a detailed economic study of the alternative methods available.

GREVATT, J. G. (1970). Management information and computers in forestry. *Forestry* **43**(1), 17–30.

Management information is defined as information useful to managers in decision making at three levels—strategic, managerial, and operational. The levels most easily catered for are managerial and clerical operational. The basis of management

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information in forestry is seen to lie in units of performance and cost of forest operations, in the form of a management account. Coles are needed for each of four dimensions—operation, expenditure, location, and time—to enable the information to be analysed.

An information system is concerned with collecting data, processing, storing and presenting information when required. Computers, originally applied to scientific work, are now widely used in business information systems. The basic features of a computer system are a central store of basic data, the printing of routine reports, the answering of enquiries and the collection of data at source. Elimination of errors in data collection and rapid communication between the computer and the field are important. A comparison with clerical systems shows differences in control, flow of data, speed, and flexibility. The use of a computer may be justified in any reasonably large and stable organization.

The key man in a computer system is the field recorder responsible for the basic data. He has to record and code data accurately, although he is spared most data-processing work. If possible, data he supplies should be fed back to him in a digested and relevant fashion, to maintain his interest in creating good basic records.

HAMILTON, G. J., *et al.* (1970). *Metric top diameter sawlog tables.* Bookl. For. Commn **31** (HMSO 13p).

These tables are designed to give volumes of softwood sawlogs for given lengths and top diameters in metric units.

HAMILTON, G. J., *et al.* (1970). *Metric tariff tables.* Suppl. No. 1 to *Tariff Tables,* Forest Rec., Lond. **31** (HMSO 13p).

This supplement provides tariff tables in metric units and describes the conventions and changes in procedure required when using metric measurements.

HAMILTON, G. J., *et al.* (1970). *Metric volume ready reckoner for round timber.* Bookl. For. Commn **26** (HMSO 35p).

The tables in this booklet are the metric equivalent of the old established Hoppus tables and are used in exactly the same way. Mid-diameters in centimetres are used instead of mid-quarter girth inches, lengths are expressed in metres, and volumes in cubic metres, true measure.

HERBERT, R. B.* (1970). *Development of glasshouse techniques for early progeny test procedures in forest tree breeding.* Forest Rec., Lond. **74** (HMSO 20p).

A detailed description of the experimental glass-house facilities used for raising large seedlings for early progeny-test procedures. Experiments with pine, larch and spruce species are described in which different techniques are compared for raising the experimental materials. In contrast to the pines, larch and Sitka spruce plants appear to respond well to extended day-length, winter-chilling and higher air temperatures. It seems likely that progenies can be satisfactorily screened for stem-form and branching characters after one or two growing-seasons under glass.

HOLTAM. B. W. (1970). Co-operative marketing of roundwood in Britain. *Q. Jl For.* **64**(3), 209–226.

If the objectives of the many private woodland owners who are interested in commercial forestry are to stabilise markets and to improve prices they can only achieve them by co-operation. If they wish to be involved in, and to help to make, the changes that are necessary in sawmilling and in the integration of wood processing and forest industries they should co-operate. If they wish to profit fully from technological advances in forestry and in related industries they should co-operate. Co-operation means *working* together to common ends. The manager of co-operative marketing requires willing, full and continuing support from every member. The prime support that he needs is commitments by each member to supply wood to agreed specification by quantity, time and place. Successful management of marketing is also dependent on integrated management of harvesting and of other functions in forestry. Close co-operation of owners in all forestry activities is essential. Co-operative effort must be extensive because the variable factors which affect the

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success of marketing and of forest management are many and important in their effects. Interest in private forestry has never been so great as it is now. Markets have never been so promising. Understanding of the need to co-operate has never been so clear. The new forestry investment companies appear to provide one effective form of co-operation—mainly for non-resident owners. The main need is for resident owners to co-operate effectively; to do this they need the will to put strength into marketing and forest management.

HOLTAM, B. W. (1970). Forestry and its dependent industries in Scotland. *Scott. For.* **24**(3), 173–184.

The destruction of Scotland's forests and our failure to re-invest in forests in the past are being remedied by the Forestry Commission which has 0·73 million hectares, and by private owners who have 1·1 million hectares mainly of new forest in Scotland. Soils that can be made available for forestry are infertile or impoverished; Scots pine is our only native conifer of commercial interest, and exotic conifers have to be used. The environmental conditions vary greatly. These things add to the need for research. Forecasts of wood production show that Scotland will produce more than half of Britain's softwoods, whose production will treble in 25 years. Eighty per cent of our needs are for softwoods. The new forests contribute to employment and tourism as well as to wood supply; the productiveness of our forests has increased greatly and future prospects are good both for the Forestry Commission and for private woodland owners. Homegrown wood has proved suitable for modern industries, and the successful development of new pulp mills and wood using industries is encouraging especially in view of the young age of the forests and the small size of the total forest estate. Both quantities and the properties of the wood that we grow can only improve in future, and this is of particular importance in sawlogs. There is no lack of interest in using homegrown wood; our main task is to grow enough for all who wish to use it.

HUGHES, D. M. (1970). The Lokomo plough. *Suppl. Timb. Trades J.* October, pp. 19-20.

Ploughing is the cheapest method of forest drain construction and in 1966 the Forestry Commission introduced the Lokomo NA15 from Finland for trials in Great Britain.

The plough weighs almost 5½ tons and is operated by winching it through the ground. The tractor used is an International BTD20 with extended wide tracks. It also carries an "A" frame with winch and spikes for anchoring the tractor during winching operations.

The equipment has been used on a wide variety of sites. In soft conditions the plough cuts a satisfactory furrow to the design depth of three feet, but the risk of bogging the tractor is high.

Where, however, there are tough conditions in surface water gleys and indurated soil types, especially where stones and boulders are frequent, the Lokomo is very effective. Outputs of 15–20 chains per hour have been achieved in extensive working in East Scotland at an overall cost of about £0·75 per chain.

(LAWS, R. M.*, PARKER, I. S. C.,† and) JOHNSTONE, R. C. B. (1970). Elephants and habitats in North Bunyoro, Uganda. *E. Afr. Wildl. J.* **8**, 163–180.

This paper is concerned with the changing relation between the elephant populations and the vegetation in North Bunyoro, Uganda.

The history of the area over the past 100 years is briefly described, particularly in terms of changing human populations and contraction of the elephant range. The main features of the environment, including vegetation types and distribution, annual burning, other species of large mammals (including the results of aerial counts) and herds are described.

The main results of investigations on the elephant populations in the area, dealing with numbers, distribution and movements, population density distributions, and social

* British Antarctic Survey, Monks Wood Experimental Station, Abbots Ripton, Huntingdonshire.

† Wildlife Services Ltd, Nairobi, Kenya.

organisation including group size frequencies and structure are presented. The influence of elephants on the forest is described. Finally specific proposals that have been presented to the National Parks and Forest Departments are discussed.

KEIGHLEY, G. D. (1970). Effects of chainsaw vibration. *Suppl. Timb. Trades J.* April, pp. 39–41.

Discusses methods of overcoming Raynaud's Phenomenon, or "white fingers", caused by chainsaw vibration.

KENNEDY, J. N. (1971). Developments in the nursery. *Suppl. Timb. Trades J.* March, pp. 19–20.

Since the war there have been great changes in nursery techniques, resulting in considerable reductions in the cost of raising the plants and in the area of ground required. Discusses the part played by research into seed stocks, plant nutrition and weed control in achieving this.

LINES, R. (1971). *Current position and plan for the International provenance trials with Pinus contorta.* Res. Dev. Pap. For. Commn, Lond. **80**.

Describes the IUFRO provenance experiments with *Pinus contorta* from the first stages of planning the seed collection to the evolution of a plan for some 100 forest experiments to be planted by 25 co-operators. International co-operation has been excellent.

LOCKE, G. M. L. (1970). *Census of Woodlands 1965–67—A report on Britain's forest resources.* For. Commn, Lond. (HMSO 60p).

This Report on Britain's forest resources summarises the results of a sampling survey of woodlands under private ownership carried out between 1965 and 1967. Information on Forestry Commission woodlands has been included so as to present the complete picture, although the data relating to this class of ownership have been taken from an earlier and separate assessment. The operative date of survey for the combined data was 30 September 1965.

The Report first outlines the major changes in forest area in the last twenty years which influenced our decision to undertake the new assessment at this time, and then deals with the selection of the sampling units, the method of field survey and the subsequent processing of the data by computer. Further chapters cover the main area results for woods of one acre and over in extent and discuss their distribution by forest type, species and planting year class; these are dealt with first in broad outline for total woodlands and then separately and in greater detail for privately owned and Forestry Commission woodlands.

Information is also included on the standing volume of forest crops, the volume in hedgerow and park timber and woods under one acre, and a comparison of the present results with those of previous surveys.

LOCKE, G. M. L. (1970). Census of woodlands. *Suppl. Timb. Trades J.* October, pp. 31–33, 43.

A brief resumé of the methods used in the *Census of Woodlands 1965–67* and a summary of the main area results.

LONGMAN, K. A. (1970). Initiation of flowering on first-year cuttings of *Metasequoia glyptostroboides* Hu and Cheng. *Nature, Lond.* **227**, 299–300.

Metasequoia glyptostroboides has been grown in Britain for more than 20 years, but flowering has been confined to occasional female cones which in the absence of pollen do not set seeds. Both male and female cones have now been induced on one-year-old cuttings kept in a warm greenhouse for an extended period. The male buds were terminal on normally budless branchlets, and pollen shedding took place after a period of chilling.

Apart from the possibility of producing fertile seed in Britain, and thus new genotypes, this work is important in that the experimental study of flowering in forest trees, normally hampered or prevented by their large size, can in this species at least be carried out with small potted plants.

MEECHAN, J. (1970). *Treatment of Christmas trees to inhibit needle fall.* Res. Dev. Pap. For. Commn, Lond. **77.**

A number of treatments were applied to fresh unrooted Christmas trees in an attempt to reduce needle fall over the Christmas period. The best results were given by dipping the foliage in a one per cent solution of alginate, or alternatively by keeping the butt immersed in water. Promising results were also given by sealing the cut face of the butt with bitumen; and this method might be worthy of further study. Dipping the foliage in a latex preparation was also effective; but dipping in a solution of Epsom salts proved completely ineffective.

MITCHELL, A. F. (1970). Conifers for ornamental planting. *Arboric. Ass. J.* **1**(11), 284–292.

The importance of the role of conifers in the landscape and the immense variety of shapes, textures and colours provided by them is emphasised. In winter a deciduous landscape loses perspective but a few groups of evergreen conifers bring a sharp perspective back. Even a broadly deciduous vista is frequently given a focal point of interest by a small group of brightly coloured conifers, often in a cottage garden or a churchyard, without spoiling the general effect of an indigenous landscape. The columnar and conic neat crowns of some conifers are the right foil to offset the diffused domes of park and garden deciduous trees. Some details of desirable and undesirable uses of conifers are given concerning the planting of avenues, groups, eye-catchers and small-scale features. The place of columnar dwarf conifers is discussed with regard to their use in rock and heather gardens, to enhance both the shapes and the colours in the planting.

MITCHELL, A. F. (1970). Recent measurements of *Metasequoia* in Britain, 1970. *Jl R. hort. Soc.* **95**(10), 452.

Specimens of *Metasequoia* in Britain which exceeded 12m in height in 1970 are listed. It is noted that the tallest—now over 15m—are all in Southern England and either in partial shade or within reach of plentiful water. The tallest in Scotland is just over 9m, in Perthshire. The growth in diameter is very rapid in some trees and several are around 40 cm through at 1·5m.

MITCHELL, A. F. (1970). A note on two new hybrid cypresses. *Jl R. hort. Soc.* **95**(10), 453–454.

Two hybrids in the genus x *Cupressocyparis* are described and named as x *C. notabilis* and x *C. ovensii. C. notabilis* was raised from seed of a *Cupressus glabra* at Leighton Hall, Welshpool, in 1956. A specimen of *Chamaecyparis nootkatensis* stands 20m away and this Nootka cypress was the seed-tree of the original Leyland cypress hybrid in 1888. x *C. notabilis* has loose, pendulous, distantly branched foliage, blue-greyish in colour and densely set all the winter with yellow male flowers.

x *C. ovensii* was raised by Mr. Howard Ovens in 1962. The seed was picked from a *Cupressus lusitanica* growing among Nootka cypresses at Westonbirt, Gloucestershire. The seedlings are very vigorous with rich green foliage on orange-purple shoots.

MORGAN, J. F., (and BJORA, E.*) (1971). A simulation model for enterprise planning. *Bull. For. Commn, Lond.* **44,** 104–123. (HMSO £1.55).

The paper describes a simple model of the forestry activities of the Forestry Commission which is intended to be an aid to the corporate planning process.

The main decision variables considered are cutting and planting policies. The model allows the exploration of the effects of different policies on a set of variables which

*NLI, Norway.

include net discounted revenue, net income, timber production and employment. The relationships considered within the model are described.

The use of the model is illustrated through examples of the projection of industrial manpower requirements for different cutting policies and different productivity assumptions. Examples are also given of the effect of different cutting policies on the present value of the growing stock.

NEUSTEIN, S. A., and DANBY, N. P. (1970). Potential atmospheric pollution from the Invergordon industrial complex. *Scott. For.* **24**(4), 270–273.

Summarises in general terms what is known about the effects of fluorine on coniferous species, and indicates what action is being taken by the Forestry Commission Research Division to determine any changes following the start of industrial operations at Invergordon in Ross-shire.

(FAIRBAIRN, W. A.,* and) NEUSTEIN, S. A. (1970). Study of response of certain conifer species to light intensity. *Forestry* **43**(1), 57–71.

Investigations of controlled light intensities in the nursery for six coniferous species are described. The responses of plants to a range of light intensities (6·25-100 per cent of full light) are presented in terms of germination, survival, root and shoot weights and lengths, needle length, collar diameter and various measures of sturdiness.

OAKLEY, J. S. (1971). Tubed seedlings. *Suppl. Timb. Trades J.* March, p. 17.

Describes a simple hand tool produced by Work Study Branch for planting tubed seedlings.

ORROM, M. H. (1971). Recreation in your forests. *Suppl. Timb. Trades J.* March, pp. 7–8.

An account of how the Forestry Commission, by means of forest trails and information centres as well as camping and picnic sites, is interpreting the story of the forests and their wildlife to a 90 per cent urban population.

PHILLIPS, D. H., and GREIG, B. J. W. (1970). Some chemicals to prevent stump colonization by *Fomes annosus* (Fr.) Cooke. *Ann. appl. Biol.* **66**, 441–452.

In tests to find a replacement for creosote, widely used for painting conifer stumps to prevent colonization by *Fomes annosus*, the best all-round results were given by sodium nitrite. This has therefore been introduced in the forest, though, as it is poisonous to man and to animals, urea or disodium octoborate ("Polybor") may be used instead where labour cannot be well controlled, or there appears to be a danger to unattended livestock or to water supplies.

(SAVORY, J. G.,† NASH-WORTHAM, J.,†) PHILLIPS, D.H., and STEWART, D. H. (1970). Control of blue-stain in unbarked pine logs by a fungicide and an insecticide. *Forestry* **43**(2), 161–174.

Billets cut from unbarked Scots pine logs felled in Thetford Chase at monthly intervals from May 1966 to September 1967 were treated with 0·75 per cent lindane, 5 per cent tribromophenol, or 0·75 per cent lindane + 5 per cent tribromophenol in solution in light mineral oil. Treated billets and untreated controls were stored, in contact with the ground, in a forest ride for three months and then examined for staining after cross-cutting. Appreciable staining of the wood occurred only from March to August though staining of the log ends was never entirely absent even during the winter months. Staining was most effectively controlled by the combined lindane/tribromophenol treatment; application of this from April to August should, in practice, cause substantial reduction in log staining.

PYATT, D. G. (1970). *Soil groups of upland forests. Forest Rec., Lond.* **71** (HMSO 40p).

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*Formerly at Department of Forestry and Natural Resources, University of Edinburgh.

*Forest Products Research Laboratory, Princes Risborough, Buckinghamshire.

This paper is intended as a guide to the recognition and properties of the main groups of soils which occur in upland forests. Upland Britain is defined as those regions underlain by rocks of Carboniferous and older series, plus the North York Moors which are formed from rocks of Jurassic age. The properties of seven broad groups of soils are described, supplemented by a brief discussion of soil processes and soil-forming factors necessary to the proper understanding of the groups. The soil groups are brown earths, podzols, ironpan soils, surface-water gleys, ground-water gleys, deep peats and soils on calcareous rocks. The types of profile are illustrated by diagrams and 11 pages of colour plates.

For each group information is given on intergrading situations, distribution and forestry properties. Illustrations include full-colour photos and diagrams of soil profiles, prepared by the author.

RATCLIFFE, P. R. (1970). A method of preserving animal skins. *Deer* **2**(3), 574.

Describes an easy method of curing mammal skins to produce a clean and supple pelt.

RATCLIFFE, P. R. (1970). The occurrence of vestigial teeth in badger (*Meles meles*), roe deer (*Capreolus capreolus*) and fox (*Vulpes vulpes*) from the county of Argyll, Scotland. *J. Zool., Lond.* **162**, 521–525.

Describes the occurrence of variable dentition in small samples of badger, roe deer and fox skulls from Argyll. It is suggested that variation in the presence of vestigial teeth is more frequent, particularly in the badger, than is normally realised.

REDFERN, D. B. (1970). The ecology of *Armillaria mellea*: Rhizomorph growth through soil. In *Root diseases and soil-borne pathogens* (ed. T. A. Toussoun, Robert V. Bega and Paul E. Nelson), pp. 147–149. University of California Press.

Although rhizomorphs of *Armillaria mellea* can be found in soils differing widely in type and reaction, laboratory experiments suggest that soils of high pH may be more favourable for rhizomorph initiation and growth than more acid ones.

It is generally accepted that killing by *A. mellea* is associated with replacement of broadleaved forest by coniferous plantations and that killing is rare in pure natural forest. These and other field observations suggest that conifer stumps, although readily colonized by this fungus, do not provide a suitable substrate for it. However, doubt is cast on the validity of this simple hypothesis by experiments designed to assess the value of the food base provided for *A. mellea* by roots of various tree species.

REDFERN, D. B. (1970). The effect of plant residues on damping-off of *Pinus resinosa* seedlings. *Tree Plrs, Notes* 21(2), 13–15.

Addition of both mature and immature buckwheat (*Fagopyrum esculentum*) stem segments to a forest nursery seedbed soil increased the incidence of damping-off in *Pinus resinosa* seedlings.

REDFERN, D. B. (1970). Review of *The biology of mycorrhiza,* by J. L. Harley. *Trees Lond.* **33**(1), 31.

ROGERS, E. V. (1971). Protective clothing for forestry (Part 1: Underclothing). *Suppl. Timb. Trades J.* March, p. 21.

Considers the relative merits of wool, cotton and synthetic fibre underclothing, for conserving body-heat while keeping the skin dry.

ROOKE, D. B. (1970). The Commission and conservation. *Forester, N. Ireland* **11**(2), 26–30, and *Suppl. Timb. Trades J.* April, pp. 16–18.

Explains the Forestry Commission's policy of conserving the natural beauty and wildlife habitats of its forests.

ROSS, R. B., and KERNAHAN, K. (1970). Strain gauges. *Suppl. Timb. Trades J.* April, p. 21.

A problem in machinery development is to determine the actual stresses in components while they are working. Stresses in complex structures are often indeterminate and a solution is offered by using strain gauges. These measure electrically the amount of "stretch" in a component when in use. Possible failure points can so be defined. Strain gauges are also used in dynamometers. The latter consists of a bar of high tensile steel, with strain gauges bonded to the surface. When the bar is under tension the strain is measured, and thus the force producing it may be determined. Dynamometers of this type are ideal for tests on cable-ways, winches and tractor drawbar pulls.

SAMUEL, C. J. A., *et al.* (1970). Assessing and predicting environmental response in *Lolium perenne*. *J. agric. Sci., Camb.* **75**, 1–9.

Recently developed regressional techniques suggest that some of the problems posed by genotype-environment interactions may be solved. These techniques have been applied, therefore, to data from an extensive trial involving perennial ryegrass (*Lolium perenne*) varieties grown under various treatments at several locations throughout Great Britain. Analysis reveals that the relative performance of the varieties depends mainly upon whether they are grown as spaced plants or swards. Even though the genotype-environment interactions are large, much of their effects could be reduced to an essentially linear scale. These results are considered in the light of the known characteristics of the varieties concerned, whilst the wider implications are also discussed.

SCOTT, A. H. A. (1971). "Prefix" by knapsack. *Suppl. Timb. Trades J.* March, p. 18.

Some notes on the distribution of "Prefix" (chlorthiamid) weedkiller by means of the Horstine motorised knapsack applicator.

SHAW, D. L. (1971). *Gwydyr Forest in Snowdonia: A history.* Bookl. For. Commn **28** (HMSO 40p).

An illustrated account of how a large area of bare moorland and steep hillsides was transformed over a period of fifty years into productive forest, with appendices showing the species of trees and wildlife to be found there.

SIDAWAY, R. M. (1970). Estimation of day use recreation by the Forestry Commission. *Recreat. News* No. **20**, July

SIDAWAY, R. M. (1970). Measuring forest recreation. *Suppl. Timb. Trades J.* October, pp. 37–39.

The above two articles describe a sample census of day visitors to Forestry Commission land between June and September 1968. The sample technique involved stratification, by size, of areas used by the public. "Concentrated use" sites contained more than 15 cars on a sunny summer Sunday afternoon. 3,500 smaller areas were covered by a dispersed-use stratum. The number of cars parked at the afternoon peak was used as an index of total attendance and this relationship was calibrated on a small sample of sites over a random sample of survey days.

It was estimated that 4–8 million visits were made to the concentrated sites while the dispersed-use areas probably attracted double those figures. Sunday was the most popular day but this may not be the case in some holiday areas. The use of these statistics is considered and some thought given to the development of simple but reliable indices of recreational use.

SMALL, D. (1970). The sylvan splendours of the Chiltern hills. *Suppl. Timb. Trades J.* April, pp. 22–24.

Describes the rehabilitation of the Chiltern beechwoods by the Forestry Commission, and the steps taken to preserve the diversity of flora and fauna.

SMITH, R. O. (1970). The Cleveland and Hamilton hills. *Suppl. Timb. Trades J.* October, pp. 24–25.

Tells how the Forestry Commission has started large-scale reafforestation of this hill and moorland area in North Yorkshire.

STERN, R. C. (1970). Rotation lengths for conifers. *Q. Jl For.* **64**(4), 297–302.

There is the possibility of financial loss by retaining conifer crops beyond the age of maximum mean annual increment, particularly as modern sawmills will not normally be equipped to process the larger logs.

On the other hand, there is likely to be a financial loss by felling crops before the age of maximum m.a.i., for example for pulpwood. A pulpwood rotation is the same as, or not very different from, a sawlog rotation, unless there is a very abnormal price/size gradient; the choice will generally be between conventional thinning in accordance with the Forestry Commission's management tables and not thinning at all.

Examples are given of simple calculations to assess the financial implications of alternative courses of action.

STICKLAND, R. E. (1970). Three-tier wire and netting dispenser. *J. agric. Engng Res.* **15**(3), 314–316.

Describes a dispenser made by the Research Workshop to reduce the time taken to erect high tensile spring steel fencing.

STICKLAND, R. E., and DELAP, P. (1970). A Forestry Commission high seat. *Deer* **2**(2), 526.

Describes a two-man high seat which can be made in a small workshop on the do-it-yourself principle.

STICKLAND, R. E. (1971). Going metric. *Q. Jl For.* **65**(1), 72–74.

The brief article describes some of the special-purpose measuring equipment designed and made for the field staff of the Research Station.

STROUTS, R. G. (1970). *Coryneum* canker of Cupressus. *Pl. Path.* **19**(3), 149–150.

A note on the discovery and present known distribution of the disease in this country on *Cupressus macrocarpa.*

STUMBLES, R. E. (1970). The optimum siting of roads for winch extraction. *Forestry* **43**(2), 175–179.

When timber is extracted by double-drum winch there will be an optimum extraction distance, which will give lowest over-all extraction costs. A method is suggested of calculating this optimum distance, and from this a guide is obtained as to the best position for road construction in small woods where only one road is required.

TAYLOR, G. G. M. (1970). *Ploughing practice in the Forestry Commission.* Forest Rec., Londn. **73** (HMSO 20p).

Presents a short description of the principal soil groups encountered in forest areas in Great Britain, with a discussion of their limitations for tree growth and their treatment requirements. Ploughing equipment currently available is described and illustrated together with diagrams of soil effects and an appendix giving technical specifications. Evidence to illustrate the benefits which can be obtained by ploughing is presented and discussed in relation to matching practice to site requirements. Prescriptions for recommended practice are given, with a brief description of future lines of development.

An appendix by D. G. Pyatt provides a brief definition of the soil groups and a glossary of soil terms.

VOYSEY, J. C. (1970). A forest in the marches. *Q. Jl For.* **64**(4), 339–345.

Describes one of Britain's oldest forests, Mortimer in Shropshire and Herefordshire, (Welsh marches) with emphasis on the woodland history of this part of the country.

WALLACE, D. H. (1971). Forest vehicles. *Suppl. Timb. Trades J.* March, p. 18.

Recent steep rises in interest rates have penalised long-term investment in forest roads, leading managers to look for alternative methods of transport Various types of cross country vehicles are considered here.

WARDLE, P. A. (1970). Operational research in forestry. *Span* **13**(1), 17–20.

The use of techniques of operational research to tackle specific management problems of forestry, is discussed. The use of stimulation to solve problems involving biological variability, forecasting models to cope with the long production period and investment models to assess the profitability of the long-term investment involved are described. It is suggested that the important contribution of operational research is to bring logical analysis to bear where management may be preoccupied by the dominating biological problems rather than the economic ones.

WARDLE, P. A. (1971). Operational research and the design of a management control *of forestry*. Bull. For. Commn, Lond. **44**, 140 pp. (HMSO £1.55).

Report of a Working Group of Section 31, Economics, of the International Union of Forestry Research Organisations, held at Alice Holt in September, 1970.

WARDLE, P. A. (1971). Operational research and the design of a management control system for a forestry enterprise. Paper in *Bull. For. Commn, Lond.* **44**, 79–91. (HMSO £1.55).

The paper describes the approach to the design of a management control system for the Forestry Commission, through identification of the functions to be performed and the role of particular managers. Features of the system developed are the prime importance attached to the strategic and tactical planning function, the need for operational planning to be within the framework of tactical plans, and the provision for reporting back to show the correspondence between actual performance, operational plans and tactical and strategic plans.

WITTERING, W. O., and PLATT, F. B. W. (1971). BM-Volvo equipment for use in forest operations. *Suppl. Timb. Trades J.* March, pp. 22–23.

A range of forest machinery was seen at an Open Day at the BM-Volvo demonstration area at Brunnsta, Sweden, and descriptions are given of forwarders, an inverted grapple skidder, a feller buncher, a planting machine, front-end loaders, a long-reach crane and other equipment.

YOUNG, C. W. T. (1970). Dutch elm disease. *Suppl. Timb. Trades J.* April, p. 15.

A brief description of the disease and of its history in Britain and America, with reference to the contention that, without sanitation measures enforced by law, the disease will become as catastrophic in Britain as it is in America. American elm is more susceptible than are most British species and hybrids.

APPENDIX II

Staff Engaged in Research and Development

As at 31st March, 1971

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 Forest Products Research Laboratory of the Department of the Environment, Princes Risborough (Tel. 3101), Aylesbury, Buckinghamshire. The Forestry Commission keeps in close touch with this work, some of which is done jointly by the two organisations.

RESEARCH DIVISION

Director	. G. D. Holmes, B.Sc. (*Alice Holt*)
Administration and Finance Officer	. G. H. Bowers (*Alice Holt*)
Director's Secretary . . .	. Mrs. V. O. C. Lampard (*Alice Holt*)

Chief Research Officer (South) . D. H. Phillips, M.Sc., Ph.D., F.I.Biol. (*Alice Holt*)

(With general responsibilities for research in the Southern areas, and with special responsibilities for research in seed, ecology, pathology and entomology, and for seed supply, publications and photographic services).

SEED (*Alice Holt*)

G. M. Buszewicz, Mgr. Eng.(For.), Head of Section
A. G. Gordon, B.Sc. Agric., Ph.D.

Laboratory:	D. C. Wakeman: Mrs. E. M. Boswell: Miss R. E. Crumplin, Mrs. E. Hart-Dyke
Seed Store and Extractory:	M. D. Witts (Research Forester): T. A. Waddell: L. Crumplin
Office:	Mrs. B. P. Hartley, B.A.: Mrs. J. E. Woolford

ECOLOGY (*Alice Holt*)

J. M. B. Brown, B.Sc., Dip.For., Head of Section
Research Foresters: K. Broad (Tair Onen), P. Marsh

PATHOLOGY

Alice Holt

D. A. Burdekin, B.A., Dip.Ag.Sci., M.I.Biol., Head of Section
C. M. Brasier, B.Sc., Ph.D., M.I.Biol.
J. N. Gibbs, M.A., Ph.D.

Research Foresters: C. W. T. Young: B. W. J. Greig, J. E. Pratt, R. G. Strouts, P. J. Webb
Laboratory: E. J. Parker: Mrs. J. Fletcher: Miss A. Trusler
Office: B. D. Higgins: Mrs. B. A. Reynolds (Typist)

Northern Research Station

D. B. Redfern, B.Sc., Ph.D.
Research Foresters: J. D. Low: M. Cruickshanks
Laboratory: Mrs. D. S. Woolford

ENTOMOLOGY, MAMMALS AND BIRDS

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, T. J. Smith
Office: J. Ellison

Northern Research Station

J. T. Stoakley, M.A.*

MAMMALS AND BIRDS (*Alice Holt*)

Miss J. J. Rowe, B.Sc., Head of Sub-Section
Research Foresters: L. A. Tee: R. A. Baldwin, D. Elgy (Elgin), H. W. Pepper, P. R. Ratcliffe

PHOTOGRAPHY (*Alice Holt*)

I. A. Anderson, F.I.I.P., Head of Section
Mrs. T. K. Evans, F.R.P.S.
Miss H. J. Turner
R. W. Genever (Head Forester)
J. Williams (Illustrator)
Miss M. Trusler
Office: J. G. Jackman

RESEARCH WORKSHOP (*Alice Holt*)

R. E. Stickland
H. G. W. Bodkin, M. F. Johnston, C. H. Bodkin

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* On detached duty at Imperial College Field Station, Silwood Park.

PUBLICATIONS (*London*)

H. L. Edlin, M.B.E., B.Sc., Dip.For., Head of Section
P. A. Mayne
Miss M. J. Thompson

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*)

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