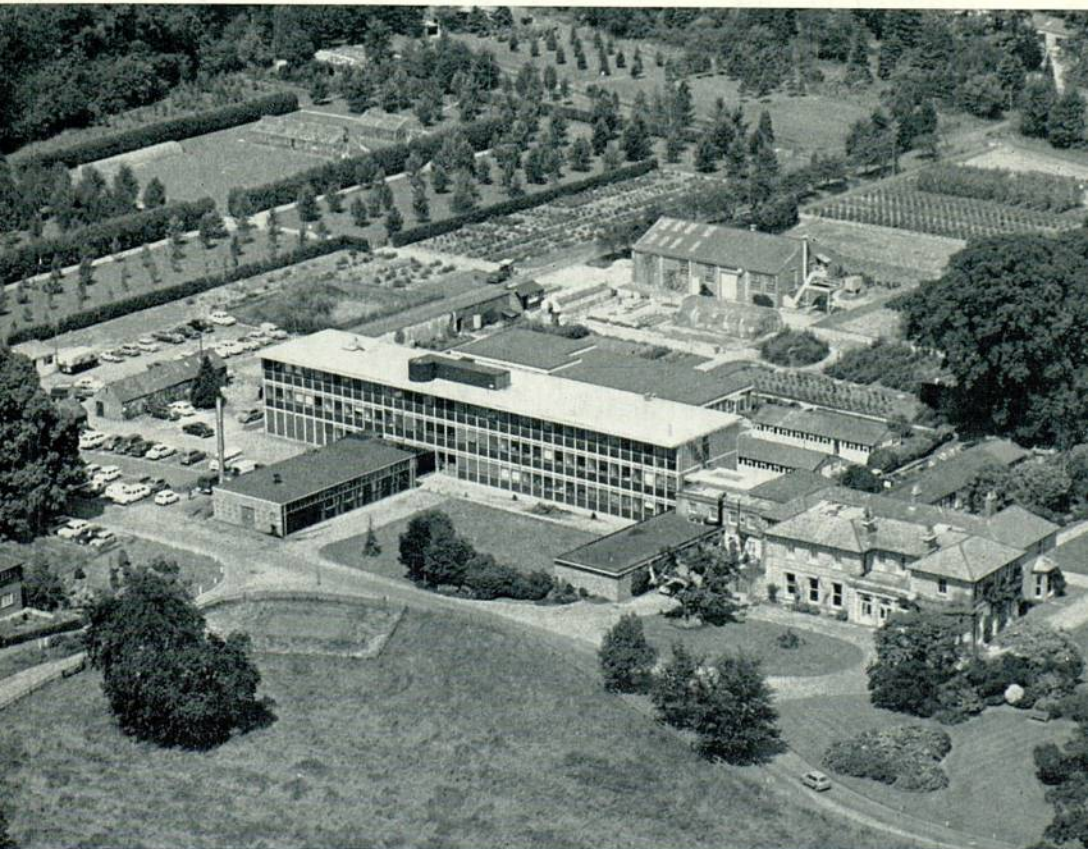


REPORT ON

FOREST RESEARCH

1972

FORESTRY COMMISSION



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ARCHIVE

FORESTRY COMMISSION

REPORT ON
FOREST RESEARCH

for the year ended

March 1972

LONDON

HER MAJESTY'S STATIONERY OFFICE

1972

ADVISORY COMMITTEE ON FOREST RESEARCH

Membership as at 31st March 1972

The Chairman of the Committee until his death on 8th February 1972 was SIR FREDERICK BAWDEN, F.R.S., Director, Rothamsted Experimental Station, Harpenden, Herts. The Chairmanship is at present vacant.

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Professor of Forestry, University of Oxford.

MR. J. F. LEVY,

Department of Botany, Imperial College of Science and Technology,
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PROFESSOR P. F. WAREING, F.R.S.,

Professor of Botany, University College of Wales, Aberystwyth.

Secretary

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042 04).

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CONTENTS

	<i>Page</i>
INTRODUCTION by G. D. Holmes, <i>Director of Research</i> . . .	1
REVIEW OF THE YEAR'S WORK by D. H. Phillips, <i>Chief Research Officer (South)</i> and B. W. Holtam, <i>Chief Research Officer (North)</i> . . .	7

PART I

WORK CARRIED OUT BY FORESTRY COMMISSION RESEARCH AND DEVELOPMENT STAFF

RESEARCH DIVISION

FOREST TREE SEED	2
PRODUCTION AND USE OF PLANTING STOCK	27
PLANTING	33
CHOICE OF SPECIES	34
PROVENANCE	37
ARBORETA	42
FOREST WEED CONTROL	43
NUTRITION OF FOREST CROPS	47
SOIL STUDIES	57
DRAINAGE	61
CULTIVATION	62
CROP STABILITY	64
REGENERATION	67
SITE CLASSIFICATION	69
REMOTE SENSING	70
ECOLOGY	71
FOREST GENETICS	76
TREE PHYSIOLOGY	83
FOREST PATHOLOGY	88
FOREST ENTOMOLOGY	99
WILDLIFE	104
STATISTICS AND COMPUTING	107
ENGINEERING SERVICES	110
PHOTOGRAPHY	111
PUBLICATIONS	113
RESEARCH INFORMATION	115
PLANNING AND ECONOMICS	116
AIDS TO MANAGEMENT AND PLANNING	117
RECREATION	117

MANAGEMENT SERVICES DIVISION	<i>Page</i>
FIELD SURVEYS	121
WORK STUDY .	124
SYSTEMS DESIGN	131

HARVESTING AND MARKETING DIVISION

TIMBER UTILISATION	132
THE JOINT PROGRAMME ON HOME GROWN TIMBER: PRINCES RISBOROUGH LABORATORY AND FORESTRY COMMISSION	134

PART II

RESEARCH UNDERTAKEN FOR THE FORESTRY COMMISSION AT UNIVERSITIES AND OTHER INSTITUTIONS

NUTRITION AND FOREST SOILS

COMPARISONS OF CROP ROTATIONS, AND OF FERTILISERS WITH COMPOSTS, IN 15-YEAR EXPERIMENTS WITH SITKA SPRUCE <i>by</i> Blanche Benzian, S.C.R. Freeman <i>and</i> H. D. Patterson, <i>Rothamsted Experimental Station,</i> <i>Harpenden, Hertfordshire</i>	139
RESEARCH ON FOREST SOILS AND TREE NUTRITION <i>by</i> H. G. Miller <i>and</i> B. L. Williams, <i>Macaulay Institute for Soil Research, Aberdeen.</i>	143
THE EFFECT OF SOIL PREPARATION ON WATER POTENTIAL AND OXYGEN STATUS OF A WET HEATHLAND SOIL IN RELATION TO AFFORESTATION <i>by</i> D. J. Read <i>and</i> W. Armstrong, <i>Department of Botany, University of</i> <i>Sheffield,</i> <i>and Department of Botany, University of Hull</i>	148

FOREST PATHOLOGY

CONIFER SEEDLING PATHOLOGY <i>by</i> G. A. Salt, <i>Rothamsted Experimental</i> <i>Station, Harpenden, Hertfordshire</i>	150
VIRUS DISEASES OF FOREST TREES <i>by</i> P. G. Biddle, <i>Commonwealth Forestry</i> <i>Institute, University of Oxford</i>	153

FOREST ENTOMOLOGY AND ZOOLOGY

RESEARCH ON THE GREEN SPRUCE APHID, <i>ELATOBIMUM ABIETINUM</i> <i>by</i> W. H. Parry <i>and</i> W. Powell, <i>Department of Forestry, University of Aberdeen.</i>	154
TIT POPULATION STUDIES AT CULBIN FOREST <i>by</i> Andrew J. Deadman, <i>Department of Forestry, University of Aberdeen</i>	156

HYDROLOGY

	<i>Page</i>
HYDROLOGICAL RELATIONS OF FORESTS by L. Leyton, E. R. C. Reynolds and F. B. Thompson, <i>Department of Forestry, University of Oxford</i> .	158

RECREATION

THE RECREATIONAL POTENTIAL OF FORESTRY COMMISSION HOLDINGS by Brian Goodall and John B. Whittow, <i>Department of Geography, University of Reading</i>	159
---	-----

APPENDICES

I Publications by Forestry Commission Staff	166
II Staff Engaged in Research and Development as at 31st March, 1972.	182
<i>INDEX</i>	189
<i>PLATES 1 to 10</i> .	<i>Central Inset</i>

ACKNOWLEDGMENTS

All the 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.

INTRODUCTION

By G. D. HOLMES

Director of Research

An Anniversary

This year's cover design celebrates the 25th Anniversary of the Commission's Research Station at Alice Holt which has developed from small beginnings into a major centre of international repute. Research started at Alice Holt in 1946/47, but its origins go back to 1920 and to the Cabinet Committee on Coordination of Research by Government Departments which recommended, amongst other things, that a research institute be set up by the Forestry Commission to deal with problems of growing tree crops. Owing to shortage of funds and the onset of the second World War the new research centre did not materialise until 1946. Meantime, the Commission's research programme from 1920 onwards was conducted by a small number of research officers based on Oxford and Edinburgh.

The 1920 proposal was reaffirmed in the Commission's 'Post War Forest Policy' statement, and in 1945 the decision was taken to locate the new Station at Alice Holt Lodge, near Farnham in Surrey, a country house in its own woodlands already owned by the Crown. Alice Holt is located within easy reach of three major centres of administration and research, i.e. London, the University and the Commonwealth (then Imperial) Forestry Institute at Oxford, and the Princes Risborough Laboratory of the Department of the Environment (then the Forest Products Research Laboratory of the Department of Scientific and Industrial Research) in Buckinghamshire. From 1947 the Commission's research resources were concentrated at Alice Holt and at a smaller centre in Edinburgh. In 1970 the Edinburgh centre was transferred into modern laboratories on the Bush Estate in Midlothian to become our Northern Research Station.

In 1947 the functions centred on Alice Holt included Silviculture (for southern Britain), Pathology, Entomology, Ecology, Forest Mensuration and Woodland Census. One of the first developments was the formation of a Forest Genetics Section in 1947, followed by a Soils Section in 1955. Mensuration and tree growth studies developed rapidly and provided the origins of the Statistics Section and several of the branches of the Management Services Division as we know them today.

By 1959 the pressure on space in the old house at Alice Holt Lodge had led to the addition of a major new wing which now houses most of our laboratory and specialist facilities.

In 1947, research objectives were linked to the national strategy at that time which was to build up a reserve of growing timber as quickly as possible. A dominant feature was the urgent need for new technology to assist the rapidly expanding afforestation programme on heathland and moorland, to improve the low productivity of many nurseries supplying plants.

for this programme, and to help rehabilitate the woodlands, mostly privately owned, which were devastated by wartime fellings.

There have been many changes since then, and an account of the changing scene and the progress achieved in research in the last 25 years will be included in a special publication in 1973.

The Research Programme and Report

The present report is set out in a manner which I believe makes for ease of reference via the table of contents, the index, the list of separate publications, and the Review section on pages 7 to 19.

This last Section takes the form of short notes on each of the broad project groups and should serve to give an overall view and also provide leads to more detailed progress reports within.

The programme is wide and varied and as always is aimed primarily at resolving practical problems existing or foreseen in national and private forestry. These problems continue to be predominantly those concerned with wood production, protection of forest trees against pests and diseases, and the cost/efficiency of forestry operations and systems of management. However, to an increasing extent, work is being tackled relating to the non-timber benefits of forestry and woodlands, particularly those affecting the quality of the human environment. I cannot comment at length, but there are four features of the current programme which illustrate trends.

Firstly, as a result of increased interest in the human environment and especially visual amenity, there is a new emphasis on the silviculture of broadleaved species. This has given a fresh relevance and importance to our many field trials concerned with systems of growing broadleaved species, some of which go back as far as 1927. Also, in this context the greatly enlarged programme of research on the pathology and pests of broadleaved species deserves mention, particularly that part of it directed against Dutch elm disease which has involved a major redeployment of effort to create a team of Pathologists, Entomologists, and Silviculturists to work on this problem. Other examples include the development work on control of the Grey squirrel menace and research on dieback of London plane in the Greater London area.

Secondly, the recreational value of our forests is well recognised, and research has expanded into visitor use patterns and into studies of the recreation potential of various types of forests.

Thirdly, concerning the wood production aspects, an increasing share of research effort is being devoted to methods of increasing production of *existing* forests by means of a range of projects including nutrient uptake studies, spacing and re-spacing studies, and studies of pests, notably Spruce sawfly (*Gilpinia hercyniae*) and the Green spruce aphid (*Elatobium abietinum*).

Fourthly, some of our research has become more analytical, aimed at assisting interpretation and shortening of the long time-scale associated with some empirical research. Particular examples are in the physiology field in which biochemical tests and studies of performance of plants in controlled environments may accelerate progeny testing, selection and use.

Similarly, some of the recent work on soil physics, including that on water seepage and root growth in relation to soil compaction and aeration, may assist in earlier prescription for improvement of site treatment or silvicultural technique.

Organisation

The Genetics Section was reorganised and all scientific and professional staff concerned with the breeding programme are now located at the Northern Research Station. Another important change was the addition of a Systems Design Section to the Organisation and Methods Branch located at Alice Holt.

The specialist staff of both Research and Management Services Divisions work closely together and both are concerned very much with translating research findings into terms understood by management. This year they were intimately involved in management problems, including investment appraisals, and projects concerned with land and forest classification systems for purposes of forecasting crop yield and responses to silvicultural treatments.

There is continuing close collaboration with the Natural Environment Research Council, the Universities and the Princes Risborough Laboratory and closer ties have been established with the Timber Research and Development Association than hitherto.

Conferences and Courses

Staff members attended several scientific and technical conferences abroad during the year, including:—

International Union of Forest Research Organisations (IUFRO) meetings in Warsaw, Arnhem and Dublin ;

An Organisation for Economic Co-operation and Development (OECD) meeting in Paris on Control of Forest Reproductive Material ;

A European Economic Community (EEC) Symposium in Geneva on Wood as a Competitive Material ;

The FAO/ECE/ILO* Study Group on Mechanisation of Forest Work and the Training of Forest Workers, in Geneva ;

FAO/SIDA† Seminar on Forestry Development Planning, in Rome ;

A symposium in Switzerland and Italy on Seed Extraction Plant Management ;

A meeting of the Scandinavian Seed Orchard Group in Denmark.

Staff took part in 22 Conferences at home including the International Mycological Congress, the Congress of the Federation of British Plant Pathologists, the Annual Meetings of the British Ecological Society and the British Association of Soil Scientists, and the Society of Foresters' Symposium on Wildlife Conservation.

* Food and Agriculture Organisation/Economic Commission for Europe/International Labour Office: All agencies of the United Nations.

† Food and Agriculture Organisation/Swedish International Development Agency.

The Commission's Research Conference was held in November 1971 at Alice Holt for three days and guests included the Director of the Princes Risborough Laboratory, the Director of the Merlewood Research Station, and the Director of the Institute of Tree Biology. Conservators from South Wales and North-East England represented field staff.

Seminars and courses aimed at presenting research findings to management included meetings with the Scottish Woodland Owners Association, the Timber Growers Organisation, the Home Timber Merchants Association of Scotland and the Nature Conservancy, several courses for Forestry Commission Forest Officers and a Wildlife Management Course for Conservation Foresters and Rangers. Work Study Branch organised a two-week course on work study in forestry on behalf of the joint FAO/ECE/ILO* Committee on Forest Working Techniques and Training of Forest Workers. A special exhibition on pests and diseases of conifers was arranged at the Natural History Museum in London in the summer of 1971.

Visits Abroad

D. Bevan visited the Escuela Tecnica Superior de Ingenieros de Montes in Madrid, to deliver two lectures.

R. M. Brown and Dr. A. J. Low went to Sweden and Finland to discuss techniques for raising container plants.

Miss J. J. Rowe visited the Danish Game Biology Station at the Royal Agricultural and Veterinary College, Copenhagen, to discuss forest wildlife management and research.

Dr. J. N. Gibbs made a tour of German research stations to see work in progress on *Fomes annosus*. He also went to the Stichting Bosbouwproefstation De Dorschkamp at Wageningen, Netherlands, to see elm breeding work there, and to discuss experiments on the virulent strain of the fungus *Ceratocystis ulmi*.

D. H. Stewart attended a multivariate analysis course organised by the Institute of Statisticians, in Majorca.

Dr. A. G. Gordon visited the National Centre for Forestry Research at Nancy, and a supplier of tree seeds in Le Puy, France.

Visitors

The total of visitors rose to 883 and showed an increase of almost 50 per cent on the previous year's figure. They came from over 30 countries and included 33 parties.

Visitors included:

Mr. X. Le Chatelier (Forestry Officer, European Economic Community, Brussels),

Prof. R. Morandini (Professor of Forestry, University of Florence),

* Food and Agriculture Organisation/Economic Commission for Europe/International Labour Office: All agencies of the United Nations.

Mr. K. Koster (Forestry Research Institute, University of Wageningen), and Mr. G. Elzenga (Director, NAKB (General Netherlands Inspection Service for Woody Nursery Stock), Netherlands), on matters connected with membership of the European Economic Community.

The Forestry Commissioners.

Representatives of the Timber Growers' Organisation to discuss the Grey squirrel problem.

Economic Forestry Group Board.

Japanese Air Pollution and Nature Conservation Group.

Senior staff of the West German Forest Service.

International Dendrological Society.

Forestry students from Aberdeen, Bangor, Oxford, and Zagreb University.

Staff Changes

Transfers in : Dr. M. P. Coutts (Senior Scientific Officer, Physiology). Dr. R. Bowen (Higher Scientific Officer, Physiology). I. A. D. Grant on promotion from North-East England Conservancy as Chief Work Study Officer. G. D. Keighley (District Officer I) to Work Study, Alice Holt, from Education and Training Branch, Basingstoke. R. J. N. Busby (District Officer I) to Planning and Economics on promotion from South Wales Conservancy. P. A. Merker (Senior Executive Officer, Organisation and Methods) from Headquarters, London. G. M. Cowie (District Officer, II, O & M) from Education and Training Branch (Dean). Dr. G. J. Mayhead (District Officer II) to Silviculture S from East England Conservancy. Ure (Chief Forester, Silviculture S) from Santon Downham to Alice Holt. J. Lax (Higher Executive Officer) from Forest Management Division, Basingstoke, as Deputy Administration and Finance Officer.

Transfers out : L. C. Troup (Chief Work Study Officer) to South-West England Conservancy. J. V. St. L. Crosland (Work Study) to New/South-East England Conservancy. G. G. M. Taylor (Silviculture N) to East Scotland Conservancy. T. W. G. Coulson (Work Study) to West Scotland Conservancy. A. H. A. Scott (Work Study) to East Scotland Conservancy. P. A. Hills (Deputy Administration and Finance Officer) to East England Conservancy.

Resignations : Dr. A. I. Fraser (District Officer I, Silviculture S). R. Hendrie (Chief Forester, Silviculture S). R. W. Genever (Head Forester, Photography).

Awards

A. W. Westall (Silviculture S) received the Royal Horticultural Society's Veitch Memorial Silver Medal for services to horticulture, especially for his work at Bedgebury Pinetum. J. T. Stoakley (Entomology) was awarded M.Sc. and the Diploma of Imperial College, London University. E. R. Adams (Planning and Economics) was made an Associate of the Institute of Statisticians. St. J. G. D. Bland-Flagg (Work Study) became a member of the Institute of Work Study Practitioners.

Obituaries

Sir Frederick Bawden, M.A., D.Sc., F.R.S., Director of Rothamsted Experimental Station, and Chairman of our Research Advisory Committee since 1964, died on 8th February 1972. His loss is an incalculable one to science, to agriculture, and to organisations such as our own which he guided so ably.

John Q. Williamson died at Santiago de Chile on 7th November 1971. He retired in 1970 as the Commission's Director of Management Services to take up an FAO appointment in Chile. He was a distinguished forester whose humour and energy will be sadly missed.

We also regret to record the death in February 1972 of G. Rawlinson, a Forest Worker in the Genetics Section. He had been a valued member of staff since 1952.

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

Service work in connection with the processing, testing and supply of seed continued to occupy much of the time of the Seed Section. Home collections of seed were disappointingly low, as crops were generally poor. It is now also becoming difficult to buy seed of some species and provenances from abroad, and supplementary sources for these are therefore being sought. Seed stocks of the major species to cover immediate needs are available in store, however.

The seed research programme was further developed. Some work was done to compare the effects on germination of different methods of cone treatment and seed extraction. In the case of Noble fir, different methods of testing, packing and storing cones at the time of collection markedly affected germination quality and the seed-borne microflora.

In studies to improve methods available to break dormancy, naked stratification in cold store gave very promising results, though the so-called psychrophilic seed fungus (known for some years but not yet fully described or named) caused heavy losses in some lots of stratified seed and in early-sown nursery beds.

Work continued to identify and quantify more precisely the causes of loss of seed in nursery beds, and to improve and standardise seed testing methods in collaboration with the International Seed Testing Association.

Production and Use of Planting Stock

In the work on growing conventional nursery trees, methods of pre-chilling coniferous seed have been tested in relation to breaking dormancy and to speed of germination. Much attention has been given to careful screening of 16 seedbed herbicides, 11 of which have been selected for re-testing in 1972. Studies of the effects of late top dressings of nitrogen and of potassium on transplants in the nursery and in the forest are nearing completion. Tests of sodium alginate as a root dip for seedlings and transplants have demonstrated its value in controlling desiccation of plants in store.

Work on tubed seedlings and other types of containers for raising trees has included a large-scale user trial in seven forests in North Scotland Conservancy, the study of Scandinavian methods, and a review of research to date. The available evidence supports the tentative conclusion that tubed seedlings are suitable for use in afforesting upland peats provided that sites

are avoided which are weedy or browsed by animals. Experience in the user trials has shown the desirability of developing mechanical handling techniques.

Experiments on production of Sitka spruce and Corsican pine seedlings in Japanese Paperpots included tests of pot size and of mixtures of peat and sand and of fertilisers. Growth of Corsican pine was especially good. Work continued on growing transplants in plastic rolls and in comparing the performance of such trees in the forest with the performance of trees raised in other ways. A re-appraisal of results of post-war experiments which took account of tree survival, early growth, early windsway, and long-term stability, confirmed earlier conclusions that the plough-ridge is the most effective location for trees when planting heathland. Data from other experiments designed to test the effects of spacing at planting on subsequent growth, tree and wood properties, and silvicultural needs, have been analysed with help from Management Services Division and the Princes Risborough Laboratory of the Building Research Establishment, Department of the Environment.

Choice of Species

Past experiments with the Macedonian pine (*Pinus peuce*) have shown that, on peat and heathland sites, trees whose parents had passed one generation in Ireland have grown faster than trees with a seed origin near Bitola in Yugoslavia. Macedonian pine has been shown to grow quite well on peat bogs provided it is given adequate fertiliser; it stands exposure well, and shows consistently good health; its bluish green foliage might introduce pleasing colour and texture variation in predominantly pine or spruce areas in the uplands.

Broadleaved Trees

A new appraisal has begun of the results of past experiments on broad-leaved species. Many of these date from 1927, and include some which are of special interest in dealing with current forest management problems and options. It is hoped to publish the results in 1973.

Provenance

Seed of 24 provenances of Lodgepole pine collected by the International Union of Forest Research Organisations (IUFRO) was sown in a nursery in 1970; the growth of the seedlings has been compared and the trees have been planted at six forest sites. Work continued on the 1965 IUFRO collection of Lodgepole pine as well as on Douglas fir and Western hemlock, and a first experiment has begun with 25 provenances of *Abies grandis*.

Nutrition of Forest Crops and the Use of Herbicides

In the continuing attempt to use research resources more effectively new experiment designs have been introduced which make possible the use of smaller plots for fertiliser experiments. It has been deduced that phosphate alone can be detrimental to tree growth on Welsh peaty soils, particularly on those derived from Silurian and Ordovician rocks, and that potash is necessary. Combined phosphate and potash applied as top dressing on deep peats and peaty gleys overlying Moine rocks results in a better growth response

from Sitka spruce than is obtained by either fertiliser applied alone ; early growth of Sitka spruce on deep peat is helped more by uptake of potash and phosphorus than of nitrogen.

Early control of heather on peatland has proved a more effective way of improving growth of young Sitka spruce than has the application of nitrogen, but decreasing levels of nitrogen in Sitka spruce foliage indicated that to apply a top dressing of phosphate and potassium plus the use of herbicide might only delay the need for nitrogen until later on the poorest unflushed deep peats.

In experiments and trials to test the effects of herbicides on various weed species, continuing attention has been paid to their side effects on trees as well as on weeds, to the method, concentration and season of application among other things. One interesting effect is that May applications of atrazine gave better control of coarse grasses than those in March, but spruces, larches and beech suffered more damage from the May applications. Further work was done on bracken control and to test the effect of aminotriazole, MCPA and asulam. Results of ultra low volume (ULV) spraying in 1969, 1970 and 1971 were appraised and the "Ulva" ULV sprayer was first used for heather control trials to compare this method with medium volume and low volume applications.

Soil Studies

Good progress has been made in examining the physical and mechanical properties of soils which have developed in indurated conditions ; further work will attempt to measure their relative permeabilities and to examine penetration by tree roots. Work began on assessing the physical conditions of soils in cultivation experiments. Much of the effort has been devoted to the difficult problem of finding effective ways of measuring properties ; portable gamma-ray transmission equipment has been used to measure soil bulk density *in situ*.

A new system is being tried in the forest for automatic measurement of water levels in soils to help in assessing water movement and its response to drainage. It is hoped that this will provide information necessary for more effective design of drainage systems.

Cultivation and Drainage

New experiments have begun to compare cultivation intensities on ironpan soils. These are necessary because recent assessments of earlier work suggest that the better height and basal area growth of trees on completely cultivated soils has decreased over 15 years compared with their growth on spaced furrow ploughing. It is hoped that new plough bodies for mounting on the Parkgate "humpy" carriage will enable foresters to cultivate a wide range of soils. Further work has been done on the use of the deep double drainage mouldboard plough on the "humpy" carriage to provide planting turves on wet soils in Wales. Elsewhere riggs and furs of bold dimensions have been made by a mechanical excavator ; some of the land under the riggs has been deep cultivated before making the riggs. Such extreme cultivation of wet soils might indicate prospects for economically feasible but less intensive cultivations.

Studies of water levels in boreholes have been supported by bio-assays, using clonal Sitka spruce. Changes in ploughing prescriptions for peatlands have been based on results of drainage experiments to test treatment differences at Rumster Forest (Caithness) and on tree pulling and stability studies.

Crop Stability

A study of the history and of the factors contributing to windthrow in Kershope Forest (Cumberland) suggested that the "Topex" method of assessing site hazard is too coarse to characterise the complex topography of the Scottish borders, and that the best assessment of hazard and of risk may be derived from combined consideration of elevation plus aspect plus (for risk) tree height; this combination is now used in practice. Monitoring of windthrow continued in thinning experiments; the greatest windthrow occurred in line-thinned plots.

Studies of basal bowing were made in 8-year-old crops of Lodgepole pine and were coupled with stability studies. The greater part of the "tree pulling" programme was at Inchnacardoch Forest (Inverness-shire) to begin a three-year study of Lodgepole pine rooting systems and stability on ironpan soils and on deep peats. It appeared that trees of this species were more stable on the deep peats, although deep cultivation of ironpan soils might alter the relative stability of the species on these.

Artificial Regeneration

Studies began of the difficulties experienced on some gley soils in south-west England in regenerating felled Sitka spruce by planting. Studies of planting losses in regenerating felled spruce on peaty gleys at the Kielder forests in Northumberland were extended to twelve sites using the most successful technique tried to date, of notch planting trees in the slightly raised position adjacent to stumps of felled trees.

The Scottish Woodland Owners' Association was helped to design two questionnaires for use in the private forestry sector in Scotland, firstly to ascertain the nature and extent of forest regeneration problems, and secondly, to assemble the collective experience of private forestry managers on the limits of the planting season in different regions for the main species and techniques of planting that have been used so far. Comparable information on season of planting is being collected from the Forestry Commission's management staff in Scotland. The results of these enquiries should help in designing any necessary future research as well as in making managers aware of their options and of flexibility in planting and re-planting times. Studies on site classification should also help in these fields.

Remote Sensing

Results of preliminary investigations of the likely effective application of some modern remote sensing techniques to British forestry have not been encouraging. So far the use of 35 mm photographic aerial colour slides for office interpretation, and of black and white photographic aerial prints for use in the field, appear likely to be the most useful of the available aids to forest managers.

Ecology

An interim report has been prepared on the first four seasons work on the problems connected with tree growth in the South Wales Coalfield area.

Throughout an experiment in which Corsican pine was planted at monthly intervals to gather further data on optimum planting times, plants were lifted periodically to study root regeneration after transplanting. There was little or no root growth after November, while from late February or early March a time of active root growth preceded bud extension in May. Root regeneration of recently planted trees then continued throughout the time of active shoot growth to about the end of June, but growth of roots of established transplants was then much less prolific. Factors affecting the growth of the roots of these plants appeared to include the length of time since planting, as well as soil temperature. Survival of the plants was also much affected by atmospheric conditions such as cloudiness, windiness, relative humidity and air temperatures for the first few weeks after setting out.

A start was made in preparing a computer model to simulate canopy development in a young conifer crop. By use of such a model it is hoped to increase the useful information from some crop establishment experiments and particularly to provide information on leaf area development before canopy closure.

Forest Genetics

A revision was begun of the national register of forest tree seed sources in Britain, in anticipation of the United Kingdom joining the European Economic Community.

The first stage of the Sitka spruce Plus tree survey was completed; 964 trees were selected. A second successful survey for "Coastal" Lodgepole pine Plus trees was undertaken in the Republic of Ireland in conjunction with the Irish Forest and Wildlife Service. This survey resulted in the selection of an additional 97 Plus trees. The programme of establishing special Lodgepole pine seed plantations based on a variety of potentially valuable "Inland" and "Coastal" provenances was completed. A total area of 94 ha has been established since 1966.

Progeny testing of 10 different forest tree species continued to receive high priority; 109 ha of trials have been planted in 176 separate forest experiments. Further developments of "early-test" methods under glasshouse conditions have suggested that they are likely to provide useful screening for certain characters in Sitka spruce, Douglas fir and the larches.

Suitable sampling and gel-filtration techniques for the qualitative and the quantitative analysis of polyphenols in shoot samples have been developed. They have been used satisfactorily in pilot investigations to distinguish shoots from different provenances; more thorough investigations of these techniques have begun.

Tree Physiology

Two more scientists have been recruited to the Section's staff and a new large greenhouse has been nearly completed. The year's report (p. 83)

summarises two years' research. Highlights of the vegetative multiplication work have been the relative ease with which Lodgepole pine cuttings from plants of many different ages and physiological conditions have been rooted, and the discovery that auxin concentration could control the type of root formed. In the field of flowering it was found that heaviness of coning, and the proportion of cones which might be female, could be influenced in larch by complete ringing and gravimorphic treatment. Ringing also led to spectacular levels of flowering in Western red cedar in both forest-grown and potted plants. This permitted experimental elucidation of some factors which may control the periodicity of flower formation under natural conditions. A start was made on work to induce flowering in selected trees, including young seedlings. A beginning was also made in understanding the factors which lead to continued bud dormancy in Sitka spruce. Studies of root growth began.

Forest Pathology

Preliminary studies in unreplicated Scots pine sample plots gave some indication that *Fomes annosus* not only kills some of the trees but may also reduce the volume produced by some of the apparently healthy ones.

Further work on *Phytophthora* species that attack tree roots suggested that the A² compatibility type in both *P. cambivora* and *P. cinnamomi* is much commoner than the A¹, and the formation of oospores (important both as a means of survival and as a potential source of genetic variation) may be more often induced in soil in response to volatile products of *Trichoderma* spp. or other soil organisms than by pairing of the two compatibility types.

Dutch elm disease again caused much damage in southern England, and a survey in 1971 showed that of the 18 million elms in that area about three per cent were severely affected or recently killed by this disease. English elm was more affected than Wych elm. Inoculation tests made here and in Holland showed that an unusually aggressive strain of the causal fungus, *Ceratocystis ulmi*, was now present in this country in the main foci of the present epidemic. To assist further in the search for the control of this disease, our entomologists examined populations of the elm bark beetles that carry the disease, with particular reference to their chalcid, braconid and nematode parasites. Spray trials to seek safe and effective insecticides to protect trees from attack by the beetles are being carried out. A great deal of information and advice was given to local authorities and the public through the press and other means of publication, radio and television, and at courses and special meetings.

Isolates of a *Nectria* species from the trunk and branches of beech affected by Beech bark disease were used to inoculate unwounded beech trees and trees injured by knife wounds and bark perforations. Cankers formed on the trees that were both inoculated and wounded.

Experiments continued in connection with the dieback of London plane recently prevalent in Central London. Sample twigs from susceptible and apparently resistant trees were subjected to freezing and either rapid or slow thawing. The results supported the view that the disorder is associated with rapid thawing of frozen tissues, and that some clones of the tree are resistant to this dieback.

Inoculation experiments on the dieback of Corsican pine caused by *Scleroderris lagerbergii* (Stat. conid, *Brunchorstia pinea*) agreed with Dutch studies in showing that the fungus could infect undamaged developing shoots in summer, the disease progressing later during the dormant period.

Numerous requests for advice and information were again received. Many were on Dutch elm disease, but among other common subjects of enquiry were *Armillaria mellea*, *Fomes annosus*, *Verticillium dahliae* (mainly on *Catalpa bignonioides*), root rots and stem cankers caused by *Phytophthora* spp., and damage by species of *Pythium*. *Sirococcus strobilinus* was found associated with a dieback of Lodgepole pine seedlings in North Scotland.

Forest Entomology

Pupal counts of the Pine looper moth, *Bupalus piniarius*, were again generally low, though they have risen over the past few years at Sherwood (Clipstone) Forest to a dangerously high level. Continued careful monitoring is therefore particularly necessary in this area.

Large populations of the Green spruce aphid, *Elatobium abietinum*, built up in 1971 in many parts of Britain, causing severe defoliation of Sitka and Norway spruce.

Pineapple galls caused by adelgids were unusually common on Christmas tree crops in southern England, often even in spite of spraying. A more effective spraying programme is therefore being worked out.

The Spruce sawfly, *Gilpinia hercyniae*, is causing increasing damage in mid-Wales, and the possibility of controlling the pest by means of a naturally occurring virus is being investigated in collaboration with the Natural Environment Research Council's Unit of Invertebrate Virology at Oxford.

A study is being made of the biology of *Moritziella corticalis*, a phylloxerid found for the first time in this country attacking young oak in Sussex and Berkshire.

As noted above, the entomologists also collaborated in the work on the control of Dutch elm disease.

The Entomology Section played a large part in the formation of the new British Forest Entomology Group, which held its first meeting in the Allerston group of forests near Scarborough, Yorkshire, in October, 1971.

Wildlife

Research on Grey squirrels (which in 1971 were very numerous and caused severe damage) was concentrated on the completion of trials on Warfarin poisoning. The results were summarised to provide background information in connection with legislation needed to authorise the use of Warfarin against Grey squirrels in England and Wales.

The range of the Red squirrel is still contracting, and work has begun on problems involved in the conservation of this animal.

Investigations continued on the marking of deer, chemical repellants (new materials giving little promise), fencing, and sampling methods to estimate damage by mammals and birds.

In collaboration with Forest Management Division and Education and Training Branch a course on wildlife management research was held at Alice Holt for Conservation Foresters and Head Rangers.

Statistics and Computing

To improve the service given by the Section and to relieve the statisticians of routine analysis work, the staff of the Section was reorganised into four groups, of statisticians, data analysts, programmers and machine operators.

Acceptance trials for the new IBM 1130 computer were successfully completed, and a link made with the UNIVAC 1108 computer at the University Computing Company's Centre in London.

Most of the Section's advisory work was in connection with the design of experiments for the Research Division, and with time studies for the Work Study Branch of the Management Services Division. Surveys were designed dealing with the recreational use of the New Forest, and with the distribution of Dutch elm disease.

Engineering Services

The Engineering Services Section (formerly the Research Workshop) has designed equipment for use in the raising of container-grown plants, and modified and designed various pieces of spraying and tree injection equipment for use in work on the control of Dutch elm disease.

Photography

The Photographic Section is small, and was short-staffed for part of the year. Hence it was unable to arrange tours to cover all Conservancies, and there were difficulties in providing a rapid and adequate printing service. Work on the Sound Library has at present had to be suspended. Nevertheless tours to produce new photographs covered five Conservancies. Aerial photographic work is being developed.

Publications

Fourteen new priced publications were issued through Her Majesty's Stationery Office, and a further eleven were revised and reprinted. Six new unpriced publications were produced, and eleven others were reprinted after revision.

Research Information

Developments continue in the use of computers for library and information work. The calls for loans from the library have trebled in number over the past five years.

MANAGEMENT SERVICES DIVISION

Planning and Economics, Field Surveys, Work Study, and Organisation and Methods Branches form parts of the Management Services Division. For completeness and convenience, however, accounts of their research and

development work, as well as of that of the Harvesting and Marketing Division, appear in this Report.

Planning and Economics

The main effort has been concentrated on two subjects. One was work connected with the government's review of forest policy, including the associated cost benefit study, and the other was the development and implementation of methods required to set up the new system of financing of the forestry enterprise. In connection with the latter, a new and more flexible production forecasting programme was devised.

Further analysis was made of the results of the 1970 day visitor survey. Three measures of recreational use were obtained, each likely to be of use in planning and management. These were the number of visits paid, their duration and the number of cars parked on an area at some point in time. The results provided information likely to be useful in gauging potential volume, estimating recreation benefits, and in estimating the size of facilities needed to provide for existing recreational use.

A survey was made during the summer of 1971 to assess peak usage of day visitor parking space in the New Forest. Promising results were given by an experimental survey by aerial photography carried out to see how far this method could be used as an alternative to counting by observers on the ground.

Field Surveys

Following the application of fertilisers in West Scotland Conservancy assessments made two years after the treatment were analysed. It was concluded that fertiliser treatments could be expected to raise the volume production of crops following a normal yield class pattern by the equivalent of about half a yield class, and greater responses were likely in poor crops. Response was better on peat than on mineral soils and better on ploughed sites than on turfed ones.

Work is being carried out in collaboration with Research and Conservancy staff on the classification of plantable land into broad site types, with a view to the preparation of guides to aid in the estimation of likely growth patterns on given land areas.

Over 50 new permanent sample plots were established during the year, to include plots covering line thinning and respacement techniques.

A system of assessment based on the measurement of leading shoots has been devised to assist in the identification of unsatisfactory young crops that may merit fertiliser treatment.

Work Study

Work was again done to improve the methods available for the production and planting of tubed seedlings. An appraisal of a tree planting machine was done with a view to the combination of ploughing and planting operations.

Investigations on ploughing and drainage included work on the ploughing out of drains in reforestation areas. An acceptable drain could be ploughed

when stumps were small and heavy lop and top had been cleared away, but many problems in this field remain to be solved.

Mechanisation of drain maintenance was attempted both by the use of ploughs and of rotary ditching equipment. Results using ploughs have been disappointing but the rotary ditcher has distinct possibilities.

Methods for the application of various weed control chemicals were studied. A hydraulic powered ultra-low volume sprayer was used for the application of insecticides for possible use in the control of Dutch elm disease.

In the field of harvesting equipment, further work was done on hydrostatic tractors which have given encouraging results in trials. A new, third model is being built. Various mechanical handling devices have been built to aid in stocking and loading timber.

Work on cable cranes concentrated particularly on capstan controlled winches, which give a reduced haul-back brake effort and smoother running of the winch.

Studies were also made of a multilift detachable lorry body (which in suitable conditions can allow a quick turn round of the lorry) and of a tree processor.

Systems Design

The new Systems Design Section of the Organisation and Methods Branch has been engaged in the further development and refinement of the Commission's financial control system. It has worked particularly on the provision of local job control data and on improving the link between investment planning and operational budgeting systems for road building and improvement projects.

HARVESTING AND MARKETING DIVISION

Timber Utilisation

In trials with pulverised conifer bark used in the same way as peat in casing material for mushroom cultivation, yields were usually, but not always, slightly below those given with peat casing. The best results have been given with pine bark; and mixtures containing bark of other species have so far been unsatisfactory, probably because of the presence of toxic extractives.

When bark was used for bulb forcing, it was found desirable to add lime to raise the pH of the medium.

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

In the work on machine stress-grading of sawn timber, tests completed on home-grown Scots pine and Sitka spruce showed that timber of both species could be stress-graded satisfactorily; it is more important to note that 80 per cent of the pieces of Sitka spruce tested were rated by the machine as

M75 grade compared with less than 10 per cent by visual grading. M75 grade Sitka spruce was shown to have the same grade stress values as European redwood and whitewood of M50 grade. Tests on Douglas fir are well advanced ; tests on Corsican pine are planned.

Tests on wood from two provenance demonstration plots at Bush (Midlothian) and Wykeham (Yorkshire) showed a tendency for Sitka spruce to increase its production, both in volume and in weight of wood, as the provenance moved southwards in latitude from Alaska to Oregon, although there were some differences between the results from Wykeham and those from Bush in this respect.

The results of a study of sawmilling characteristics of Grand fir have been analysed ; similar tests have been done on Western hemlock, Noble fir and Western red cedar to provide information for the study of the more important of the minor coniferous species used in Britain.

A survey was made of wood residues produced when harvesting and primary sawmilling home-grown timber. This was done to find out how much residue was now produced, and how much was likely to become available in the future, to find uses for the material, and to consider the concept of whole-tree utilisation in the light of residue utilisation. Every year large amounts of green wood substance are left in the forest after harvesting, and large quantities of bark, sawdust and slabwood arise in timber processing. The quantities concerned are likely to rise substantially over the next thirty years. Some of these residues are already used for pulping, chipboard manufacture etc, but more outlets would be useful and profitable.

The possible use of mathematical models to determine the most economic conversion of home-grown sawlogs is being investigated.

PART II

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

Miss B. Benzian, Mr. S. C. R. Freeman, and Mr. H. D. Patterson, of *Rothamsted Experimental Station*, Harpenden, Hertfordshire, summarise the results of work done over 15 years in the forest research nurseries at Kennington (Oxfordshire) and Wareham (Dorset) to compare the effects of fertiliser and compost treatments on the growth of Sitka spruce seedlings and transplants. In the case of seedlings, at Kennington, growth was consistently better with fertiliser alone than with either compost or compost and fertiliser together, while at Wareham, compost and fertiliser combined gave the best results. With transplants, differences between growth with fertiliser and with compost were small, and growth was slightly better with both than with either alone.

At Kennington, soil treated with compost became richer in organic matter and in total nutrients than did that dressed with fertiliser, but the seedlings raised with fertiliser remained consistently larger throughout than those from compost-treated plots.

At Wareham, neither fertiliser nor compost gave good growth of Sitka spruce without the additional application of either slow-release fertilisers or top-dressings of N and K.

Dr. H. G. Miller and Dr. B. L. Williams, of the *Macaulay Institute for Soil Research*, Aberdeen, report further work on nutrition of spruce and pine and nitrogen mineralisation in peat and humus. In trials with Sitka spruce seedlings, the nitrogen concentration in the needles associated with maximum growth was much the same as that for Corsican pine, but the corresponding levels of P and K were much higher for spruce than for pine.

Sites have been chosen for fertiliser experiments which will be laid down in the coming season in slow-growing pole-stage stands of Sitka spruce. In fertiliser experiments in pole-stage Corsican pine at Culbin Forest (Moray) it was found that the fertiliser treatment had widened the range of tree sizes, so that earlier suppression of smaller trees might be expected where fertiliser had been applied.

To examine some of the effects of shade, needle samples were taken from a range of tree species grown as an understorey under larch. Of the nutrients studied, only nitrogen showed a change in all species in response to shade, nitrogen levels tending to rise with increasing shade density.

In aerobic incubation tests with peat sampled from fertiliser trials at Durris Forest (Kincardineshire) there was a response to applications of PK fertilisers made on deep peat but not from those on shallow hill peat. No responses were observed when samples were incubated under anaerobic conditions.

In limed plots at Culbin Forest, there was an increase in the proportion of mineral nitrogen present as nitrate ions in the humus, and a rise in the rate of carbon dioxide evolution on incubation.

Dr. D. J. Read and Dr. W. Armstrong, of the *Botany Departments* respectively of the *Universities of Sheffield and Hull*, report on work on the effect of soil preparation on water potential and oxygen status of a wet heathland soil in relation to afforestation. They measured soil water potential and oxygen diffusion rate in an experiment comparing single furrow and complete ploughing with "rigg and furr" soil treatment. They found oxygen potentials highest and soil moisture potentials lowest in the riggs. The results indicated that on the difficult North Yorkshire soils in which the experiment was laid down, the rigg and furr system was likely to produce conditions more conducive to tree growth and stability than those following single furrow and complete ploughing.

Dr. G. A. Salt, of *Rothamsted Experimental Station*, provides a short account of work on the pathology of Sitka spruce seedlings sown in an acid heathland nursery. Growth of the plants was decreased by liming but increased by treating the beds with formaldehyde. When formaldehyde was used, growth was good throughout the pH range.

Losses occurred in some of the beds leading to patches like those caused by damping off, but it appeared that the deaths were due to over-consolidation of the soil in the affected areas.

The effect of soil fungicides and a thiram seed dressing on the survival of Sitka spruce seedlings in nursery beds was also studied. Some beds were

uninoculated, and others were inoculated with *Rhizoctonia solani*. Seedling numbers were reduced in all the inoculated plots except those treated with benomyl or in which the seed was treated with thiram.

Dr. P. G. Biddle, of the *Commonwealth Forestry Institute, University of Oxford*, gives a summary of work done on suspected viruses of Norway and Sitka spruce and Scots pine. Grafting and insect transmission experiments have been set up, but the virus nature of the disorder being studied has not yet been proved.

Dr. W. H. Parry and Mr. W. Powell, of the *Department of Forestry, University of Aberdeen*, give the results of their studies on the Green spruce aphid, *Elatobium abietinum*, populations of which, following the mild winter of 1970/71, built up exceptionally early and rapidly in North East Scotland in 1971. The effect of needle age on sap uptake by the aphid is being examined. In connection with studies of the ecology of overwintering populations, supercooling points of individual aphids were determined. Evidence was found that after a drop in temperature, the aphid population undergoes some acclimatisation.

Mr. A. J. Deadman, of the same *Department*, discusses further work done on populations of tits in Culbin Forest, Moray, in connection with natural control of the Pine looper moth. The behaviour of individual birds and of family parties was followed by ringing birds in the breeding season, using a separate colour code for each brood. The movements of these birds could then be followed throughout the autumn and winter without the need for recapture.

Dr. L. Leyton, Dr. E. R. C. Reynolds, and Mr. F. B. Thompson, of the *Department of Forestry, University of Oxford*, give a brief summary of their work on forest hydrology. They have studied soil moisture conditions and root growth and distribution in Douglas fir plots receiving normal rainfall, or with the soil covered, and either no water applied or irrigation given at weekly rates corresponding respectively to 0.5 and 1.5 times the mean potential transpiration. In the dry treatment plot the roots were markedly concentrated at the top of the profile.

Mr. Brian Goodall and Dr. John B. Whittow, of the *Department of Geography, University of Reading*, report on preliminary work done in a study on the recreational potential of Forestry Commission forests, which it is considered offer substantial unrealised possibilities in this field. Commission forests were classified on a basis of size, area of planted and unplanted land, area under broadleaved trees, and situation in the lowland, highland, or intermediate parts of the country. Some further subdivisions were made of the highland areas. A range of forests was then chosen in five Conservancies to cover a wide range of conditions. A study of the recreational potential of these forests will be made, both by the use of maps and by means of field studies using methods already developed and tested in Maresfield Forest (Sussex) and Gwydyr Forest (Caernarvonshire). Much of the map analysis has already been done, and the collection of field data is proceeding, while a user requirement survey is being planned.

PART I

Work carried out by Forestry Commission Research and Development Staff

RESEARCH DIVISION

FOREST TREE SEED

SERVICE

As in previous years this report reflects the subdivision of the Seed Section's activities into service and research work. As the Section provides a central forest seed service for the whole country, including the private sector, service work absorbs the greater part of the staff resources.

The expected entry of Great Britain into the European Economic Community (EEC) requires the revision of the current seed legislation and consequently the adjustment of our seed service procedures. During the year under review the Seed Section participated in the work of drafting the new seed regulations.

Register of Seed Sources

The main changes in the register were as follows:

	<i>Number of stands</i>	<i>Hectares</i>
Areas gained	Nil	Nil
Areas lost- Total	12	52.5
<i>Clearfelled</i>	6	19.5
<i>Reduced in area</i>	3	21.7
<i>Windblown</i>	3	11.3
Stand thinned	2	14.6

Plans are in hand to revise the register in 1972/73 in order to fulfil the requirements of EEC. The new certification scheme for seed provenances and quality will come into operation in June 1973. However, in order to safeguard our seed import from the countries outside EEC appropriate steps are also being made to take advantage of the Organisation for Economic Co-operation and Development (OECD) certification scheme for forest reproductive material.

Seed Procurement (Table 1)

Home Collections

The crops were rather disappointing and much below those of the previous year. The conifer species gave 502 kg of which only about 25 per cent originated from registered sources. Sitka spruce gave the highest yield

TABLE 1
TOTAL SEED PROCUREMENT FROM 1.4.71 TO 31.3.72

Species	Imports			Home Collections						Grand Total
	General	Registered	Total	Crop 1970*		Crop 1971		Total		
				General	Registered	General	Registered			
									General	
Scots pine									27.2	27.2
Corsican pine									29.6	29.6
Lodgepole pine AL†	0.1		0.1							0.1
" NC	0.8		0.8							0.8
" SC										0.8
" SK	91.6		91.6				0.8			91.6
Silka spruce	493.2		493.2			229.3				722.5
Norway spruce	0.4		0.4							0.4
European larch	30.5		81.1							81.3
Japanese larch	130.0	50.6	130.0							130.1
Hybrid larch				4.6	25.8	3.4				35.9
Douglas fir	224.8		224.8							224.8
Western hemlock	50.5		50.5							51.5
Western red cedar										
Grand fir	886.9		886.9							886.9
Noble fir	500.7		500.7							678.8
Lawson cypress						175.7				
Other conifers							2.4			
Total conifers	2,409.5	50.6	2,460.1	4.6	25.8	408.4	63.4			2,962.3
Oak	424.4		424.4							515.1
Other broadleaves	5.0		5.0							180.3
Total Broadleaves	429.4		429.4							695.4
Grand Total	2,838.9	50.6	2,889.5	4.6	25.8	577.3	160.5			3,657.7

Notes:

* Taken in charge after 31st March 1971.

† AL—Alaska; NC—North Coastal BC; SC—South Coastal USA; SK—Skeena River BC (BC = British Columbia).

‡ Including 151.3 kg collected by Conservancies for own use, i.e. outside of the central control.

(229 kg) closely followed by Noble fir (178 kg). The greater part of all collections came from Scotland.

A similar situation occurred with broadleaved species. There was no crop of beechnuts and almost no oak seed. The majority of collections consisted of minor species collected for amenity purposes.

Imports

Seed imports continued to be necessary but due to relatively limited crops abroad it was not possible to obtain everything as planned. Altogether 2,465 kg of conifer species were imported which is over 1,000 kg less than during the last year. The main bulk consisted of: Grand fir 887 kg; Noble fir 501 kg; Sitka spruce 493 kg; Western hemlock 224 kg; and Lodgepole pine 92 kg. Lodgepole pine from Alaska, Sudeten larch and Norway spruce from Central Europe (Poland and Czechoslovakia) continued to be difficult provenances to obtain.

Due to the relatively quick disappearance of traditional seed sources on the West Coast of America it is necessary to look for supplementary sources. The most acute problems are with Noble and Grand firs. The main aim is to create a kind of catalogue of potential sources suitable for this country which will give reasonable security of future exploitation. This is being done with the close co-operation of the seed merchants involved and with advice on provenances from the Silviculture Sections.

The main bulk of broadleaved species imported consisted of oak and beech from Germany. In the case of *Nothofagus procera*, for which the demand is continually increasing, the crop in Chile was again a failure. This erratic supply from Chile is forcing us to look very thoroughly for seed crops at home from our relatively young plantations.

Finally, all precautions are being taken to ensure that the imported seed originates from the most desirable provenances and wherever possible it is certified by an official authority.

Seed Extraction

The total volume of cones was over 700 hectolitres all of which were processed at the central extractory at Alice Holt.

Generally the seed quality was up to standard (Sitka spruce being much better than imported seed) but the yields were somewhat lower than during the previous year, as shown in Table 2.

TABLE 2
SEED YIELDS (KG) PER HECTOLITRE OF CONES

Crop year	1970	1971
Scots pine	0·494	0·320
Sitka spruce	1·101	0·850
Noble fir	1·485	1·020

Seed Storage

The stock held in refrigerated storage on 31st March was 8,049 kg which is 300 kg less than last year. Yearly requirements at the level of 3,000 kg

and the policy to hold three years' requirements indicate that the stock in hand is short by about 1,000 kg. Unfortunately crop shortages prevented the procurement of sufficient amounts of Corsican pine, Lodgepole pine (Alaska), Japanese larch and Hybrid larch. Generally the situation is not critical as there is still enough seed for next year, with the exception of Lodgepole pine (Alaska) and Sudeten larch which have been difficult to obtain for several years.

Seed Testing (Table 3)

Routine quality checks of stocks in hand required 756 samples. Additionally 148 samples were received from outside sources of which 71 were from the Commonwealth Forestry Institute, Oxford (of tropical forest tree seed); 49 from the USA and 28 from private forestry in Britain.

Although the total number of samples was larger than last year altogether fewer tests were performed. The main decrease was in moisture content tests where it was decided not to repeat these tests every year on stock held for several years.

TABLE 3
TESTS PERFORMED ON SEED

Kind of test	Service	Research	Total	Total of previous year
Purity	518	—	518	563
Seed size	563	64	627	800
Germination	1,093	500	1,593	1,643
Tetrazolium	16	45	61	49
X-Ray	—	12	12	16
Cutting	5	—	5	27
Moisture content	451	30	481	814
Cone test	—	9	9	7
TOTAL	2,646	660	3,306	3,919

Seed Supply (Table 4)

Altogether the Forestry Commission and the private sector took 2,967 kg of conifer seed which is about 500 kg less than for the previous year. Eighty per cent of this decrease was in Commission sowings. The gap between both sectors continues to increase and this year the private sector took almost twice as much seed as the Commission. As regards the seed from registered sources this proportion is still larger and the private sector took more than twice as much as the Commission. From the species under review there are only two (Lodgepole pine and Sitka spruce) where the private sector uses less seed.

A comparison of the planting programme of both sectors suggests that productivity in Commission nurseries is higher than in those of the private sector.

TABLE 4
SEED SUPPLIED FROM CENTRAL SEED STORE 1.4.71 TO 31.3.72

Species	Weight despatched from general and registered sources to :										Export research gifts	Grand total
	Forestry Commission					Private forestry						
	General	Registered	Total	General	Registered	Total	General	Registered	Total			
Scots pine	7.4	38.5	45.9	60.9	78.5	139.4					116.9	302.2
Corsican pine	93.7	13.8	107.5	147.2	7.0	154.2					2.0	263.7
Lodgepole pine (Alaska)	14.1		14.1									14.1
" (North Coastal)	1.6		1.6									1.6
" (South Coastal)	11.7		11.7									49.1
" (Skeena River)	21.3		21.3									51.1
" (Cent. Interior)												4.3
" (South Interior)	46.0		46.0									60.0
Sitka spruce QCL	413.1		413.1									827.6
" Washington	80.9		80.9									109.9
Norway spruce	8.2	24.2	32.4	161.3	39.7	201.0					1.0	234.4
European larch	7.3	2.3	9.6	23.3	62.3	85.6					0.2	95.4
Japanese larch	17.0	15.2	32.2	299.4	4.0	303.4					0.7	336.3
Hybrid larch		30.9	30.9	20.4	66.5	86.9					0.4	118.2
Douglas fir	13.0	24.5	37.5	59.1	85.4	144.5					0.9	182.9
Western hemlock	12.8		12.8	62.6		75.4					0.5	75.9
Western red cedar	0.8	2.5	3.3	20.8	8.0	28.8					0.2	32.3
Grand fir	79.5		79.5	131.7		211.2					11.0	222.2
Noble fir	40.8	2.5	43.3	37.8		81.1					1.2	82.3
Lawson cypress		1.8	1.8	6.7		8.5					0.1	8.6
Other conifers	0.7		0.7	29.5		30.2					2.8	33.0
Total Conifers	869.9	156.2	1,026.1	1,589.7	351.4	1,941.1					333.4	3,300.6
Oak	289.3		289.3	97.5		386.8					29.9	416.7
Beech				10.5	3.0	13.5					31.4	44.9
Other broadleaves	2.3		2.3		10.3	12.6					3.6	16.2
Total Broadleaves	291.6		291.6	108.0	13.3	121.3					64.9	356.2
Grand Total	1,161.5	156.2	1,317.7	1,697.7	364.7	2,062.4					398.3	3,778.4

Kilogrammes

RESEARCH

Cone Collection and Seed Dormancy

The development of germinability in Sitka spruce seed was followed throughout maturation in an attempt to determine at what stage of maturity seed quality reaches a maximum. It was found that some germination took place after pretreatment as early as the eleventh week after anthesis, but that germination without pretreatment commenced some two weeks later. Within 15 weeks maximum germination was achieved after pretreatment, but not until the 18th week without pretreatment.

Several hundred cones, collected from individual Plus trees in West Scotland, were subjected to different extraction methods. Initially the seeds from the different trees showed considerable differences in their germination patterns. Different extraction treatments produced different germination qualities. Seeds of two trees tested weekly showed that maximum germination quality—absence of necessity for seed pretreatment to realise maximum germination—lasted only two weeks and fell at different times for the two trees, two to three and four to five weeks after cone collection.

Noble fir cones treated, packed and stored in different ways within minutes of collection, showed differences in germination quality with an accompanying difference in the seed-borne microflora.

Bulk Treatment of Seed to Dissipate Dormancy

It has been the general practice in the past to dissipate dormancy of conifer and hardwood seeds in the open in stratification pits. Although this technique aimed at copying nature it has been uncontrollable and its efficiency depended to a very large extent on suitable weather. Most nurseries have ready access to transplant cold stores in which pretreatment under controlled temperature and moisture conditions can take place. Early sowing also can supply the cold temperature requirement of dormant seed. An experiment at Headley, Alice Holt, (Hampshire) and Wareham (Dorset) nurseries in conjunction with the Silviculture (South) Section compared early sowing with pit stratification and cold-store stratification. The experiment was laid down also at the Bush (Midlothian) Nursery by the Silviculture (North) Section. Cold-store stratification was carried out in sand and without sand ("naked"). Over the two experiments naked cold store pretreatment proved better than any other treatments in the end of season counts. However, the experimental results were confounded to a marked degree by the presence of the cold or psychrophilic fungus (see Salt, in *Report* for 1970, p. 174) in the seed of one of the two lots tested. This fungus spread profusely in the stratification pit, killing approximately 50 per cent of the seeds at both nurseries. It also caused some mortality of seed in the early sown treatments of the infected seed at Headley but not at Wareham. Any form of pretreatment produced taller seedlings at the end of the season than the control. The interaction of the cold fungus with temperature and type of pretreatment is not fully understood but it is clear that in these experiments, and on all occasions where the technique was employed last year in conservancy nurseries, a greater degree of control and flexibility was exercised over pretreatment inside a cold store or refrigerator than in the open.

Post Sowing Seed Losses

In an attempt to identify the sources of seed losses in nurseries and thus to improve their efficiency and reliability a survey was carried out in nine nurseries in Scotland and England. The fate of the seeds and seedlings was followed from sowing to just after stock-taking (early September). The survey showed that, averaged out over the sampled sites, of the germinated seed sown a total of 25 per cent was lost and was accounted for by:

	Per cent
Removal of seed by birds (or rainwash)	4
On spot eating by birds and/or mammals	8
Fungal attack	6
Cutworm attack	4
Collembola attack	2
Miscellaneous	1

Stocktaking figures showed that the total loss of seeds and seedlings amounted to over 50 per cent for exactly the same sowings. The reasons for the discrepancy were not identified. Further work is planned of a more concentrated form to confirm, quantify and account for the losses of seeds and seedlings in the nursery.

Improvement and Standardisation of Test Methods

A considerable part of this work was done in co-operation with the International Seed Testing Association (ISTA) in preparation for the revision of the International Seed Testing Rules which will take place in 1974. The main items in which our Seed Laboratory participated are:

Excised-Embryo Tests

Many seed analysts consider this a reliable method for testing various slow-germinating species, including those for which the tetrazolium method is now prescribed, and in order to compare the merits of this a series of international referee tests were organised.

Germination Test Method for Beechnuts

Here again referee tests were found to be necessary in order to improve the present prescriptions.

G. M. BUSZEWICZ
A. G. GORDON

PRODUCTION AND USE OF PLANTING STOCK

Conventional Planting Stock

The main work in 1971 was on methods of pre-chilling coniferous seed, screening of seedbed herbicides and the effect of late top-dressings of nitrogen and potassium on the nutrient content of transplants and on the subsequent growth of these transplants in the forest. Small projects on the effect of simazine residues in transplant lines, root dips for bare-rooted seedlings and transplants and pH on transplants were also in progress during the year.

Pre-chilling Coniferous Seed

Methods of subjecting moist seed to periods of low temperatures (3–5°C) with the object of breaking dormancy and improving the speed of germination were tested as part of a joint project involving both seed laboratory and forest nursery staff. The results of both sets of experiments are reported in the section on Forest Tree Seed (p. 25).

Screening Seedbed Herbicides

Experiments at Alice Holt and Wareham nurseries tested the suitability of a number of herbicides currently used for agricultural and horticultural crops for conifer seedbeds. In 1971 the object of the experiments was to screen the herbicides for crop selectivity using Sitka spruce as the sole test species.

Fifty herbicides were selected by a "paper" screen of all the herbicides in the *Weed Control Handbook*, Volume I, 5th Edition (1970). Sixteen of the most promising were selected for the nursery trials, in which they were applied at about the lowest effective rate recommended in the *Weed Control Handbook*, Volume II, 6th Edition (1970). Most herbicides were applied both before and after emergence of the crop, but propham and EPTC were applied before sowing (with incorporation) only.

The herbicides tested were: propham, EPTC, pyrazone, chlorpropham, asulam, propachlor, alachlor, monolinuron, linuron, lenacil, cycluron + chlorbufan, chlorthal-dimethyl, diphenamid, turbuthiolazine (GS 13529), desmetryne and pentanochlor. Chlorbufan and cycluron could not be obtained separately.

EPTC, pyrazone, asulam, alachlor and pentanochlor reduced seedling numbers or height growth by more than 20 per cent, and will therefore be excluded from future trials. The other 11 herbicides will be re-tested in 1972 using a rather more rigorous and sensitive experimental design.

Root Dips of Sodium Alginate for Seedlings and Transplants

Following experiments in 1970 (see *Report* for 1971, p. 30), further trials were carried out at Wareham (Dorset) nursery during 1971 to confirm previous results.

The most attractive form of short to medium-term storage in the 1970 experiments (putting plants in boxes) was tested, with and without root-dips of 1.0 per cent solution of sodium alginate, for storage periods of seven or 28 days, in combination with out-of-store exposure periods of 0.5, 1.0 or 2.0 hours. For these exposure periods the plants were extracted from the boxes and spread out individually.

Sitka spruce seedlings, and transplants of Douglas fir and Norway spruce stored well for seven days, dipped or undipped, and no matter what exposure period was given. However, after 28 days storage many of the undipped plants of Sitka spruce and Douglas fir died. Norway spruce behaved erratically after 28 days' storage. After 28 days' storage no clear conclusions could be drawn—for any species—on the effects of the different exposure periods.

Corsican pine seedling survival was extremely poor after both seven and 28 days of storage. Dipping improved survival, but was scarcely sufficient as the best survival rates were less than 50 per cent.

Assessments of the moisture contents of plant tops again showed a close relationship between moisture content and subsequent survival, and demonstrated the value of sodium alginate root dips in reducing desiccation in this type of short to medium-term storage.

A concurrent experiment tested the effect of gelling the sodium alginate on the roots after dipping by immersing dipped roots in solutions of calcium chloride or calcium nitrate. Generally, both treatments slightly reduced either survival or growth. Also, it was considered that the handling problems involved in the extra dipping stage would more than offset the subsequent handling advantages of having a non-dripping sodium alginate gel on the roots.

R. M. BROWN.

Special Types of Planting Stock

Tubed Seedlings

In the first half of the 1971 growing season, work was carried out at the Inchnacardoch (Inverness-shire), Newton (Moray) and Tulliallan (Fife) research centres. The most important results from trials of Lodgepole pine and Sitka spruce demonstrated that by using carefully selected lots of high viability and germinative energy, it is possible with both species to obtain a usable eight-week seedling in 90 per cent of the tubes sown. Seed suitable for sowing in tubes can only be selected if results of detailed germination tests are available.

A thorough review of experimental results to date, including those from forest extension trials, confirmed the suitability of the "standard" seedling production technique as described briefly in the *Report for 1971* (p. 32) and more fully in *Forestry* (Low, 1971). The only change recommended for future work is an increase from 2 to 3 kg/m³ in the quantity of ground limestone added to the peat-sand compost.

Results from the many forest trials have continued to demonstrate the high survival and growth potential of Lodgepole pine and Sitka spruce tubed

seedlings when step-planted on ploughed peatland. A review of all available evidence has given further support to the tentative conclusion that tubed seedlings are suitable for use in afforesting of upland peat areas, provided that weedy sites or sites where serious animal browsing occurs can be avoided.

In older experiments there is nothing to suggest that established plants which originated as tubed seedlings will differ appreciably in shoot growth pattern from those originating as transplants. Provisional estimates of height growth for Lodgepole pine tubed seedling stock (of Washington Coast origin) planted in mid-summer on poor peatland in the North of Scotland (Plates 8 and 9) give the following average heights :

At the end of the second season	12 cm
At the end of the third season	25 cm
At the end of the fourth season	50 cm

A similar pattern, although with somewhat more vigorous growth, is appearing for Sitka spruce in the South and West of Scotland. The difference in height between plants of tubed seedling and of transplant origin planted in the same season seems to be equivalent to 1-1½ years' growth for both species. On exposed sites, evidence now suggests that South Coastal Lodgepole pine planted as tubed seedlings is less prone to wind loosening than plants of equivalent vigour planted as transplant stock.

Weeding has seldom been required in the season of planting but on the more fertile peats, growth of grasses (especially *Molinia*) during the second season has often proved more troublesome than was anticipated. The initial small size of the seedlings makes them not only susceptible to damage by weed growth but also difficult to find and treat safely during any weeding operation. In a small trial at Selm Muir, Clydesdale Forest (Mid and West Lothian), only dalapon showed any promise as an effective, safe alternative to paraquat for grass control on peatland ; it will be further tested during 1972. For the present, it seems best to avoid planting tubed seedlings on sites where grass growth is likely to be at all vigorous and to confine planting as far as possible to fresh ploughing.

A large-scale user trial of tubed seedlings was begun by North Scotland Conservancy. Three hundred thousand eight-week-old Lodgepole pine seedlings were successfully raised during the 1971 growing season in a new polythene house at Inchnacardoch Forest, using seed of Alaskan and South Interior British Columbian provenances. Germination and out-turn of usable seedlings were generally high, and few important problems were encountered. Automation of handling techniques will become desirable as soon as the scale of use much exceeds that for 1972. Women did this work particularly well.

The seedlings produced were planted on peatland in seven North Conservancy forests, using the special tool described by Low (1971) and Oakley (1971). The opportunity was taken by Work Study staff to check planting rates and a provisional average rate of 4,000 seedlings per man-day (normal working) was indicated by time studies. Encouraging progress was also made

in the development of a modified plough head which will produce a continuous "step" in the plough ridge and so provide very cheaply the early shelter essential for satisfactory tubed seedling growth.

A Forest Record is currently being prepared which will describe in detail the results of the Research programme on the production and use of tubed seedlings. See also Plates 8 and 9.

A. J. Low

Japanese Paperpot Seedlings

Two main factors, pot size and type of growing medium, were examined at Alice Holt (Hampshire) during 1971. Experiments tested both Sitka spruce and Corsican pine sown in late March and the seedlings were grown on until the beginning of August in a plastic house, after which they were allowed to harden-off outside for the winter. Corsican pine seedlings again grew outstandingly well under these conditions.

In an experiment testing Paperpot sizes F308 to F608*, Sitka spruce showed no differences in seedling numbers with pot size, but the height growth in the F308 pots checked from early August onwards compared with the larger pots. At the end of the season these seedlings were about 2 cm shorter than the average height of seedlings in the other pot sizes (26.3 cm). The height growth of Corsican pine did not differ with pot size, but there was a marked reduction in survival in F308 pots, and to a lesser extent in F408 pots, due to an attack by *Botrytis cinerea*. The crowded nature of the smaller pots was thought to have contributed to the severity of the attack.

The most consistent effect of increasing pot size was on root collar diameter (Table 5).

TABLE 5
MEAN ROOT COLLAR DIAMETERS OF SEEDLINGS IN PAPERPOTS

Species	Winter 1971/72			
	millimetres			
	F308	F408	F508	F608
Sitka spruce	2.75	3.08	3.74	3.91
Corsican pine	2.55	2.71	3.12	3.43

In the later stages of this experiment it proved impossible to keep the roots of seedlings, particularly Corsican pine, inside the base of the pot. Extension of roots below the pots may have masked the effect of pot size on height growth. Root collar diameter is presumably influenced more by above-ground competition for space than is height.

Another experiment, testing growing media, compared different mixtures of sphagnum peat and sand in proportions from all peat/no sand to 1 part peat/3 parts sand (by volume). Fertiliser regimes based on "Enmag" or "Fison's FL3P" were also tested. Almost without exception, for both species, the higher the content of peat, the greater the height growth. Differences between all peat and 3 parts peat/1 part sand were, however, small.

* First digit shows diameter in centimetres. Last digit indicates a depth of 7.5 cms.

The reduction in height growth with increasing amounts of sand was less under "FL3P" than the "Enmag" regime, presumably because the former entailed weekly additions of nutrients which helped to offset the losses by leaching from the media containing more sand.

Seedlings representative of all the treatments included in these two experiments were planted in forest experiments at Tywi (Cardiganshire) (Sitka spruce) Thetford (Norfolk and Suffolk) and Rockingham (Northamptonshire and Huntingdonshire) (Corsican pine) in late summer/winter 1971. Survival in mid-winter was generally above 90 per cent in all experiments.

Sitka spruce seedlings grown in F408 paperpots filled with pure peat and with 1:1 peat/sand were planted in trials along with other types of planting stock at Selm Muir Forest on peat and peaty gley afforestation sites and at Kielder Forest (Northumberland) on a clearfelled peaty gley site.

R. M. BROWN

A. J. LOW

Plastic Roll Transplants

Nursery experiments at Alice Holt examined the effect on the growth of Corsican pine, Sitka spruce and Grand fir of variations in roll size, type of peat and the type of base on which the roll stands.

Reducing the depth and width of the roll (by giving each plant less peat) generally reduced the height growth of all species, but did not affect survival. However, reducing the depth of the roll from 15 cm (the standard) to 12½ cm had much less effect than when the roll was reduced to 10 cm depth. Examination of all morphological factors (e.g. sturdiness, root development) revealed remarkably few differences.

Comparisons of "Irish Moss Peat" (the standard), "Finn Peat" and Fison's Low pH Peat (a special variant of Levington Compost) gave negligible differences in height growth or survival of Sitka spruce and Grand fir. However, Corsican pine grew better in "Finn Peat" than in the other peats. Many plants died in the Fison's Low pH Peat; no explanation has been found for these deaths, and the results should be treated with caution.

The experiment testing different types of base produced few differences, suggesting that rolls can be stood on impermeable bases (e.g. concrete) for their nursery period without harm. Fairly shallow rolls were used in this experiment, and further evidence was obtained to show that rolls of 10 cm depth may be too shallow.

Further assessments were made of forest experiments laid down in 1969 and 1970. In these trials, roll transplants of Corsican pine were planted out in the Forests of Thetford (Norfolk and Suffolk) and Rockingham (Northamptonshire and Huntingdonshire) and of Sitka spruce in the Forests of Tywi (Cardiganshire) and Lley, Beddgelert Forest (Caernarvonshire) (see *Report for 1971*, p. 35).

The results showed that Corsican pine grew faster in its first two growing seasons as roll transplants than as bare-rooted ones, but survival difference

depended on the date at which the roll transplants were planted out. June-planted roll transplants, planted in August or later, generally showed better survival than bare-rooted transplants.

In the case of Sitka spruce, differences in growth and survival in upland regions between roll and bare-rooted transplants were very small. Comparisons with spring planted (dormant season) bare-rooted stock often showed roll transplants to have grown very slightly faster in the first full growing season, but comparisons in the 1970 experiments with summer planted (cold-stored) bare-rooted stock showed roll transplants to have grown much less owing to the remarkably good growth of the cold-stored plants.

R. M. BROWN

Study of Scandinavian Methods

In June 1971, a two-week tour in Sweden and Finland provided an opportunity of studying in detail, recently developed methods for the production and use of ball-rooted planting stock, including the large-scale use of plastic houses in forest nurseries. The information obtained has helped greatly in the planning of further trials in Britain of container-grown planting stock. A report on the methods studied has now been published (Low and Brown, 1972).

A. J. LOW

R. M. BROWN

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PLANTING

Planting on Heathland

A re-appraisal was made of results from post-war experiments on heathland sites (mainly podsollic and ironpan soils), comparing various planting positions on spaced furrow ploughing. The main findings were:—

- (1) Survival was usually better with furrow planting on dry sites but not on wet sites, or sites with heavy soils ;
- (2) Early growth was often better with furrow planting but the difference tended to become insignificant as the crop grew older ;
- (3) Early windsway of susceptible species (Lodgepole and Scots pines) was much less pronounced with ridge planting ;
- (4) Long-term stability seemed likely to be better with ridge planting because of the more satisfactory root development pattern.

These reinforced the earlier conclusions that for afforestation of spaced furrow ploughing on heathland, planting on the ridge is preferable for all species.

Planting Mechanisation

With the continued co-operation of a private forestry organisation, further trials of the Finn Forester Tree Planter (see *Report* for 1970, p. 36) took place on deep peat and peaty gley sites with spaced furrow ploughing. These confirmed that the machine was capable of giving an acceptable planting standard but that its performance was being limited by the lack of a tractor capable of coping with the ground conditions involved in working on previously ploughed land. Consideration is now being given to mounting the planter directly behind a plough, thus combining the ploughing and planting operations.

Spacing

The influence of spacing at planting on subsequent crop growth, silviculture, management and wood utilization will be discussed in a report now being prepared with the co-operation of staff from Management Services Division and from the Princes Risborough Laboratory of the Building Research Station (formerly the Forest Products Research Laboratory). Data from the extensive pre-war series of spacing experiments will form the basis for this report, together with results of recent studies carried out at the Princes Risborough Laboratory and wood samples from selected experiments (see *Reports* for 1970, p. 120–121, and for 1969, p. 163–164).

A. J. Low

CHOICE OF SPECIES

Macedonian Pine

Pinus peuce Grisebach has been used on a very restricted scale in British Forestry (Macdonald *et al.*, 1957). Plots at Kielder (Northumberland), Beddgelert (Caernarvonshire) and Clocaenog (Denbighshire and Merioneth), all on exposed sites, gave promising results which suggested that further trials might be worth while.

In 1961 more plots were planted at Inchnacardoch (Inverness-shire), Glenceo (Argyll), Naver Borgie Forest (Sutherland), and Wark (Northumberland), all on peat sites, and the following year plots were established on heathland sites at Glen Prosen, Braes of Angus, and Allerston forests near Scarborough, Yorkshire. The 1961 experiments included a comparison between trees from near Bitola, Yugoslavia, where stands are impressive for their good form and absence of bad phenotypes, and one from an Irish plantation. At each site trees from Ireland grew faster than the others. Perhaps this was due to the effects of selection during one generation in a maritime environment or else to an out-breeding effect. Early survival was good on all sites except at Wark, where heavy browsing necessitated closing the experiment after six years.

The new series of experiments helps to show the place of this species in British forestry. It is one of the most resistant five-needled pines to blister-rust. It grows slowly in the nursery and in the early years in the forest growth continues slowly but evenly. When given adequate nutrition it can grow on poor peat bogs and withstands exposure quite well. On poor quality heathlands, growth is much slower than Scots or Lodgepole pine. On the peat sites, it required top-dressing with phosphate and potash fertilisers by the age of six years (which produced a marked response with current leaders up to 60 cm long on the best sites four years later).

Data from records of individual trees show that this is a tree of remarkably consistent health and growth on all sorts of sites from Sussex to Easter Ross. Annual height growth of free-grown trees is seldom much above 30 cm and diameter increment of older trees averages 0·8 to 1·2 cm per annum. The best individuals are found in the Midlands, Devon and Sussex suggesting that moderate rainfall and good summers are needed for optimum growth. The bluish-green foliage provides an interesting change of colour and texture where this is important for landscape reasons in predominantly pine areas.

R. LINES

A. F. MITCHELL

Broadleaved Trees

The current interest in broadleaved trees has led during the year to a renewed appraisal being made of their cultivation in this country. Particular attention is being given to the many experiments conducted on broadleaved tree problems. These experiments date back to 1927; some of them are specially relevant to certain present-day difficulties facing forest managers

and owners. In addition, so as to be better able to assess prospects and options in regions where conservation, recreation and amenity interests are pre-eminent, the composition of both Forestry Commission and private woodlands has been critically examined in south-east England by species, woodland type and age class. It is hoped to publish the results in 1973.

Trials of Species with Special Cultural and Site Requirements

Elms

Work was confined largely to developing techniques for raising plants from softwood cuttings in mist and to producing trees for use in trials on Dutch elm disease. Horticultural trays were used on a substantial scale for the first time; several types and sizes were compared, with sufficiently encouraging results to justify further work. Insertion of cuttings in small blocks of polyurethane foam led to variable though mostly disappointing results, and little additional work on this technique seems to be warranted.

Leyland Cypress

Exploratory trials were conducted on the behaviour of cuttings directly inserted into Japanese paperpots. Four sizes of pot were used, namely, 4, 5, 6 and 7.5 cm diameter \times 7.5 cm depth, and two clones, Haggerston 2 and Leighton 11. Following preparation and insertion of the cuttings in a potting shed, the filled trays of pots were placed in a heated frame equipped with mist and left for six months, by which time most of the cuttings were believed to have rooted. The trays were then transferred for a further six months to an unheated plastic house where hand-watering was carried out as required. Assessments of total height carried out at the end of this period disclosed that in the twelve months from cutting insertion the two clones had increased in height by an almost identical amount and that the height increase had been unaffected by pot size. The mean heights of the plants were 20 cm (4 cm pot), 19 cm (5 cm pot), 18 cm (6 cm pot) and 19 cm (7.5 cm pot). The plants were planted at Halwill Forest (Devon) in late winter, particularly to see if propagation in pots leads to increased instability. Leyland cypress has a reputation for wind-rocking in the early years after planting, which is said to be accentuated by plant production in pots. Cuttings raised in paperpots may be less susceptible to this defect.

Trials of Species on Other Soils

Industrial Waste Sites

Sites at Bramshill Forest (Hampshire and Berkshire) that formerly carried tree crops are being returned to forestry after completion of open-cast quarrying for sand and gravel. The compacted and water-logged conditions left after the return of the over-burden by heavy plant appear unsuited to tree survival and early crop establishment, and an experimental programme has been started on the first available site to provide guidance on the ameliorative measures required to ensure successful re-forestation.

The first experiment was planted in late winter to study the effects on tree survival and vigour both of deep cultivation immediately prior to planting

and manuring at the time of planting. Seven species including two broadleaved ones were planted.

In late summer, 1972, a start will be made on a second experiment, comparing Corsican pine raised in paperpots with bare-rooted plants, planted in successive years over a four or five-year period, to study the effects of delayed planting after the completion of site restoration.

J. JOBLING

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PROVENANCE

Lodgepole Pine

IUFRO Collection

Twenty-four provenances collected by the International Union of Forest Research Organisations were sown at Newton Nursery (Moray) in 1970. Highly significant differences were found in height as one-year seedlings, germination percentage and autumn needle colour. A multiple regression of height on seed weight, latitude and elevation showed that these factors in combination accounted for 70 per cent of the variation (latitude alone accounting for 63 per cent). Provenance No. 2092 Pacific City, Oregon, was poorer in height than the rest of this latitudinal group; also its needle colour resembled that of more northern provenances. Subsequent enquiries in Oregon showed that the parent stand was planted and there are no records of the original provenance. Height, percentage of trees with lammas shoots and length of lammas shoots of 1+1 transplants all gave significant regressions on latitude. The southern (coastal) provenances were tallest and had the longest lammas shoots; up to one-third of the total plant height was lammas growth. Using the regression of lammas shoot lengths on latitude as a guide, the Pacific City stand may have been planted with seed collected 3 to 4 degrees of latitude further north than would appear from the records.

These provenances have been planted at six sites in 1972. Short-term experiments with nine-plant plots are at Fiunary (Argyll) and Rumster (Caithness); medium-term experiments with thirty-six-plant plots are at Shin (Sutherland); Farigaig (Inverness-shire); Arecleoch (Ayrshire) and Langdale, Broxa (Yorkshire).

TABLE 6
HEIGHT OF LODGEPOLE PINE PROVENANCES (CM) AT THREE YEARS ON THREE SITES

Provenance	Experiment site			Provenance mean	Provenance group mean
	Rumster	Strathardle	Glengarry		
<i>Alaska</i> Sitka	41	33	40	38.0	
Juneau	41	33	38	37.3	
Petersburg	38	36	41	38.3	38.6
Ketchikan	43	34	41	39.3	
Watten 10 ex Hollis	47	33	40	40.0	
<i>Vancouver Island</i> Coombs	48	50	54	50.7	50.7 (52.1)
Tofino (1+1+1)	49	—	58	(53.5)	

Provenance	Experiment site			Provenance mean	Provenance group mean
	Rumster	Strathardle	Glengarry		
<i>Washington Coast</i> Long Beach	47	62	55	54.7	53.4
Shelton	47	53	56	52.0	
<i>Oregon Coast</i> Tillamook	44	53	57	51.3	
Waldport	48	55	56	53.0	50.7
Bandon	(37)	50	56	47.7	
<i>Skeena River</i> Terrace	51	49	48	49.3	
Hazelton	42	45	38	41.7	46.4
Carnaby	—	49	—	49.0	(46.9)
Kitwanga	47	48	44	46.3	
Kispiox	52	51	41	48.0	
Cedarvale	52	44	45	47.0	
<i>Bulkley River</i> Bulkley Canyon	46	47	47	46.7	
Moricetown	40	45	45	43.3	44.8
Smithers	49	41	43	44.3	
<i>Central Interior, British Columbia</i> Quesnel	45	43	37	41.7	40.5
Burns Lake	39	42	37	39.3	
<i>Southern Interior, British Columbia</i> Falkland	42	45	44	43.7	
Mt. Ida	46	46	40	43.3	43.5

Standard error + 2.4 2.3 2.2
Differences significant at 0.1% 0.1% 0.1%

Note: Means in brackets () are not strictly comparable with the rest. Their omission, however, in no way affects the grouping of provenances as indicated in the text.

1965 Collection

Twenty-four out of this set of 86 provenances were planted in 1969 at Rumster, Glengarry (Inverness-shire) and Strathardle (Perthshire). Early establishment was excellent, exceeding 90 per cent for all provenances at each site. Subsequently some damage has occurred randomly from grazing animals and game birds. The third year heights are shown in Table 6. Differences between provenances were highly significant at each site and a partition of the analysis of variance shows that almost all of the variation can be

explained by the differences between the groups of provenances. This is of practical significance, as it is frequently difficult to obtain seed in bulk from a point source.

In the Alaskan group it is encouraging to find that the home-collected lot from Watten, Caithness (ex Hollis) was tallest. Differences within the Skeena River group were significant, with Terrace uniformly good and Hazelton poor.

The results from the experiments planted the following year which include a wider range of provenances at more sites will shortly be available to supplement these results.

1938 Experiments

Sample plots established in the experiments planted in 1938 at Millbuie, Black Isle (Ross) and Wykeham (Yorkshire) have continued to yield useful information and are described elsewhere (Lines and Booth, 1972).

Douglas Fir

The subsidiary collection of seven IUFRO seedlots sown in 1970 at Fleet Nursery (Kirkcudbrightshire) showed only small differences between provenances, and two commercial lots from Elma, Washington, included as controls, were tallest at the end of the second year in the nursery. These provenances have been planted adjacent to the existing IUFRO experiments at Culloden (Nairnshire) and Craigvinean, Dunkeld (Perthshire). One additional experiment using the plants from Fleet was established at Inchnacardoch (Inverness-shire).

Western Hemlock

Eighteen provenances, covering the natural range very broadly from Alaska to mid-Oregon, together with one each from a stand in Scotland and in Ireland, have completed ten years' growth in full-scale trials. Early results up to and including the sixth year were given in the *Reports* of 1961, 1962 and 1969. The current results reflect closely the pattern of those based on six years' growth. Rankings in order of height are identical at six and ten years in 30 per cent of the results and within one position in 40 per cent. This is important in that it shows a good probability that the results in this species, from ten-year-old experiments, will be valid for the commercial life of the crop, for most provenances.

Figure 1 gives details of the 16 sites with the extreme ranges of height growth, and illustrates that overall growth differs widely between sites. Which provenances grow best on a given site is governed by the conditions at the site. Two groups of sites can be distinguished, one group of northerly sites with generally low fertility, moderate or high exposure, mainly high elevation and absence of cover at planting, and the other group, more southerly sites, generally of higher fertility, less exposure and local protection from overhead cover from the previous crop. Rainfall apparently is not a useful discriminant in relation to these results.

The positions of most of the provenances, and particularly those from Alaska, Queen Charlotte Islands and Oregon (including also Inveraray, Scotland, derived from trees from Oregon) are very clearly related to the two

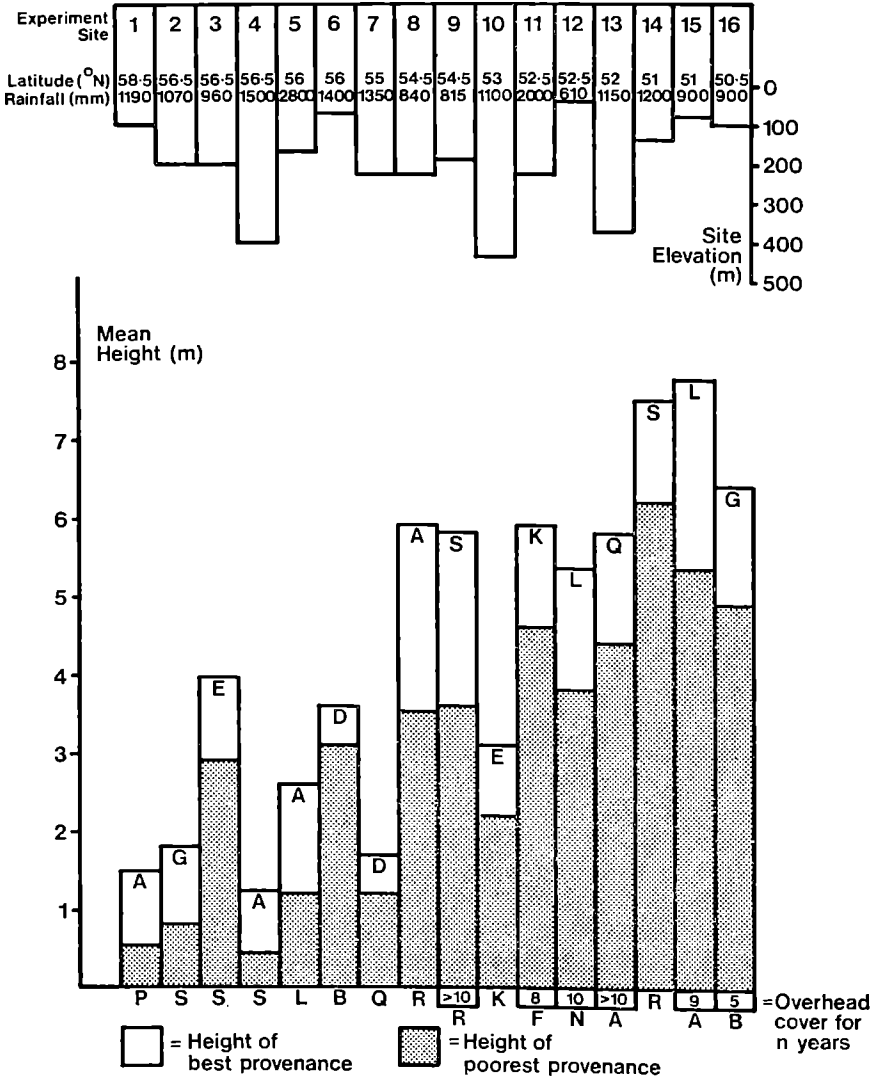


Figure 1: Western hemlock provenance, 1962 series, 10th-year mean heights at 16 sites, indicated in the facing Key.

Note: The letter at the top and foot of each column indicates respectively the tallest and shortest provenance at that site.

groups, with contrasting effects on the growth of northern and southern provenances. The Alaskan and Queen Charlotte Island provenances are both in the top eight (usually the top three) tallest provenances at all sites where the mean height of the tallest plots is below 4 m (see Figure 1), i.e. at all the sites in Scotland, and at high altitude in Wales. At all these sites also, except the mild, maritime site of Benmore and at Gisburn, Oregon plots are in the bottom eight for growth. At all the sites south from Wykeham (Yorkshire) (but excluding Clocaenog at high altitude) the mean height of the tallest plots exceeds 5 m; Alaskan and Queen Charlotte Island plots are everywhere below ninth place in rank of height while all the Oregon plots are usually in the top half of the list and often in the first three.

On the better sites for hemlock, growth is very good and there is generally less difference between the best and the worst provenances. On the drier sites, Camano Island is plainly the best among those in the trial, but Inveraray is among the best on a wider range of sites, perhaps due to outbreeding and selection in Scotland. On less fertile more elevated sites, predicted General Yield Class is below 14 m³/ha/year, so Western hemlock may not be the species chosen very often. Where it is, Juneau, Alaska, or a Queen Charlotte Island origin give the best results, with Prince Rupert as next choice.

These results will be presented more fully in a Research and Development Paper.

Silver Fir

A preliminary experiment with 25 provenances of *Abies grandis* was sown at Newton Nursery in 1972.

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

REFERENCE

LINES, R., and BOOTH, T.C. (1972). Investigation of basal sweep of Lodgepole and Shore pines in Great Britain. *Forestry* **45**, (1), 59-66.

KEY TO FIGURE 1

<i>Provenances</i>	<i>Experiment Sites</i>
A Juneau, Alaska	1 Naver, Borgeie, Sutherland
B Prince Rupert, Northern British Columbia	2 Strathardle, Perthshire
C Terrace, Northern British Columbia	3 Faskally, Tummel, Perthshire
D Masset, Queen Charlotte Is., BC	4 Glenclova, Braes of Angus
E Skidegate, Queen Charlotte Is., BC	5 Loch Goil, Ardgartan, Argyll
F Shuswap Lake, Central Br. Columbia	6 Benmore, Argyll
G Courtenay, Vancouver Is., BC	7 Laurieston, Fleet, Kirkcudbrightshire
H Alberni, Vancouver Is., BC	8 Gisburn, Bowland, Yorkshire
J Ladysmith, Vancouver Is., BC	9 Wykeham, Yorkshire
K Sooke, Vancouver Is., BC	10 Clocaenog, Denbighshire
L Camano Is., Northern Washington	11 Rheidol, Cardiganshire
M Forks, Northern Washington	12 Thetford, Norfolk
N Enumclaw, Washington	13 Brycheiniog, Breconshire
O Randle, Southern Washington	14 Brendon, Somerset
P Cascadia, Oregon	15 New Forest, Hampshire
Q Leaburg, Oregon	16 Wareham, Dorset
R Avondale, Ireland	
S Inveraray, Scotland	

ARBORETA

Bedgebury

The east and south banks of Marshall's Lake have been much cleared in order to open views to the lake and to make new decorative plantings. A large collection of dwarf conifers has been planted.

Westonbirt

The clearance of Palmer's Glade has been completed ; this glade has been largely replanted. A fine collection of maple plants, of species new to the collection, has been acquired from Mr. G. Harris, and many new species of oak are being raised for the extension to the oak collection.

Tree Records

Over a thousand specimens, mainly of rare species in Cornwall and Sussex, were re-measured, after periods of up to 15 years, and about another thousand new specimens were recorded from all over Britain. The records now include nearly 33,000 specimens of 1,100 species and 500 cultivars.

A. F. MITCHELL

FOREST WEED CONTROL

CHEMICAL CONTROL OF SPECIFIC WEED POPULATIONS:

I. GRASS AND HERBACEOUS WEED CONTROL

Atrazine

Experiments and trials in 1971 attempted to improve the control of coarse grasses by atrazine, and to check on the safety of atrazine to forest trees.

A series of forest experiments tested applications of 4 and 6 kg a.i. per hectare as a wettable powder in March and May, the water diluent with and without the addition of 5 per cent w/w of non-phytotoxic mineral oil. Six kg/ha always provided better control than 4 kg/ha, and the addition of non-phytotoxic oil improved the control of three grasses, namely *Deschampsia caespitosa*, *Dactylis glomerata* (on one site out of two) and *Holcus lanatus*. Generally, 6 kg/ha plus oil in May provided excellent control, and 6 kg/ha with or without oil at either date gave adequate control with little necessity for subsequent weeding in the season. May applications provided better control than those in March, on three sites out of four; this is contrary to most previous experience (see also report on Conservancy Trials below).

Crop damage was generally small, even with oil in the spray. However, Western hemlock was depressed in height growth by all May applications, especially at 6 kg/ha and when oil was added to the diluent.

In special toxicity trials at Alice Holt Forest (Hampshire), 4 and 6 kg/ha were applied to a wide range of newly planted forest species on a heavy clay site (Gault) and a light sandy site (Lower Greensand). Results suggest that pines, Douglas fir, Grand fir, Western hemlock and Red cedar were unaffected by any application. Spruces, larches and beech were rarely damaged by March applications, but did not tolerate applications in May so well, particularly at 6 kg/ha. Damage was much worse on the clay sites, possibly because trees were rooting more shallowly.

Several Conservancy trials were carried out in 1971, using 4 kg/ha as a wettable powder. Work Study Section used the opportunity to produce output guides, and Research Division assessed weed control and crop damage. Generally, weed control was disappointing. Applications were made in early May, which is usually considered a little too late in the year for atrazine. No crop damage was observed.

Aminotriazole

An experiment at Alice Holt Forest showed that newly planted conifers would not tolerate overall applications of aminotriazole of over 1 kg a.i. per hectare. Even 1 kg/ha caused a little damage. When the foliage was protected from the spray, no damage was observed.

II. BRACKEN CONTROL

Aminotriazole and MCPA

Following the series of experiments on bracken control using dicamba, three experiments were laid down in the north of England and in Scotland to test the effect of chemicals which have had some success in controlling bracken in agricultural situations, and which are likely to be cheaper than dicamba. Aminotriazole was applied at three rates (2.8, 5.6 and 8.4 kg/ha) in June, July and August, 1970. MCPA was applied at three rates (22.5, 34 and 45 kg/ha) in November, December and February/March 1970/71. Dicamba at 4.5 kg/ha was included as a control. Planting of Sitka spruce and Douglas fir was carried out in March/April 1971.

With all herbicides, and with aminotriazole in particular, bracken control was more successful in the drier, eastern trial area, with the wetter western area often giving the poorest control. Aminotriazole gave the most satisfactory results (>80 per cent reduction in bracken cover) in July at 8.4 kg/ha rate in the central and eastern areas.

MCPA gave consistently good results (>80 per cent reduction) at all sites at the heaviest rate applied in November. The middle rate also gave fairly good cover reduction (>70 per cent) at all three sites in November, and also in December at the heaviest rate.

Results from two similar experiments in the south of England indicate that aminotriazole gave inadequate control. MCPA was more successful, although only just adequate at a rate of 45 kg/ha.

An earlier experiment in which MCPA was applied at similar rates in January, February and March, 1970, was still giving 60–70 per cent reduction in cover from the January application at the middle and heavy rates in the second season after application. In all experiments to test winter application, the planted crop suffered no apparent damage.

Dicamba gave satisfactory control only at the eastern site, although this, of course, is a comparison of second year control by dicamba with the first year of the other chemicals.

Where successful, MCPA treatment in winter has the double advantage both of being easily applied because the bracken is largely flat and also of allowing trees planted at the end of the same winter to benefit from the first year's bracken control. Neither dicamba nor asulam have *both* these advantages.

Asulam

Asulam at 2, 4 and 8 kg a.i. per hectare was applied overall to several conifer species on either the 1st July 1971 or the 1st September 1971 to test for crop tolerance. A cultivated nursery site was used since asulam is known to be capable of giving very good control of bracken (Holroyd *et al.*, 1970).

2 kg/ha of asulam caused negligible damage to Sitka and Norway spruce, Douglas fir, Grand fir and Scots pine, but Western hemlock showed damage,

although height growth was unaffected. At higher rates, particularly 8 kg/ha, only Norway spruce and Scots pine were unaffected. The effect on height growth in 1971 was generally small, except that the July applications to Western hemlock markedly reduced height growth. Most species had virtually completed their 1971 growth by the time applications were made.

This suggests that many conifers may tolerate post-planting applications of asulam sufficiently for it to be useful for bracken control at that stage. From work elsewhere the rate to give adequate control in forestry situations should be between 2 and 5 kg/ha. During application, bracken fronds would prevent much of the spray from reaching the conifers.

III. WOODY WEED CONTROL

Ultra Low Volume (ULV) Spraying of 2,4,5-T

Results from trials laid down in 1969, 1970 and 1971 using ULV application of 2,4,5-T to woody weed foliage during the early establishment stage of coniferous crops are confirming conclusions in the *Report* for 1971, pp. 55-56.

Work Study Section has examined the machines and diluents used in these trials (see Work Study, p. 126). Results suggest that more care in calibration and choice of diluent will be necessary before the best can be got out of this technique.

Control of Heather (*Calluna vulgaris*)

The "Ulva" ultra low volume sprayer was first used for heather control in May to check the potention of this method compared with medium (knapsack) and low (mistblower) volume application. The trial indicated that ULV gave almost as good control as the other conventional methods.

Further trials in August at six sites on both mineral soil and peatland heather areas (five in Scotland and one in Wales) confirmed that 4 kg/ha of 2,4-D ester in 10 litres of non-phytotoxic oil gave satisfactory heather control, although up to 15 per cent less effective than where applied by knapsack (4 kg 2,4-D in 450 litres water/ha) or mistblower (4 kg 2,4-D in 200 litres water/ha) controls. Reducing the rate of 2,4-D to 2 kg/ha did not give satisfactory control and there was no marked advantage in raising the amount of oil to 15 litres/ha.

Damage to Sitka spruce tended to be higher with ULV spraying than with the mistblower, although on trees in the 1-2 m height class, the damage was confined to browning of the needles on the lower branches only. On smaller trees, needles on the leading shoots were sometimes discoloured. Much depends on the recovery pattern during the 1972 growing season, but it does seem that the damage level will be acceptable for spruce. Lodgepole pine is much more susceptible to damage by 2,4-D and trees less than one metre tall can be killed, both by ULV and mistblower application.

It is hoped that by increasing the droplet size of the ULV spray, damage may be reduced without losing the effectiveness of the control of heather.

R. M. BROWN

J. M. MACKENZIE

REFERENCE

HOLROYD, J., PARKER, C., and ROWLANDS, A. (1970). Asulam for the control of bracken (*Pteridium aquilinum*, (L) Kuhn). *Proc. 10th Br. Weed Conf.*, pp. 371-376.

NUTRITION OF FOREST CROPS

Experimental Design

The size of plots has been reduced in southern fertiliser experiments. This decision has been based on increased awareness of the variability of the soils and of the need for economy. Analysis of results has shown that as few as 16 trees provide an adequate sample. The use of standard fertilisers and rates of application will allow of direct comparison of results between experiments.

Experiments have been made even more compact by using a systematic design of single tree plots based on J. A. Nelder's work at the National Vegetable Research Station, Wellesbourne. By working on a very small area of ground and a small number of plants it becomes possible to minimise unwanted variation.

Table 7 shows the design for ten rates of application of P and K. The position and direction of the P and K treatments are randomised between blocks. Statistical interpretation will be by regression analysis rather than analysis of variance. The values used for the analysis will be running means of three trees ; for example, in Table 7, for a regression of P on K 320 the values for P 40 and P 60 will be the means of trees a, b, c and b, c, d respectively, and for a regression of K on P 140 the values for K 120 and

TABLE 7
ONE BLOCK OF A SYSTEMATIC DESIGN FOR A PK FERTILISER TRIAL
P RATES

	0	0	0	0	20	40	60	80	100	120	140	160	180	200	200
	0														
	0														
	0														
	40														
K R A T E S	80										w				
	120										x				
	160										y				
	200										z				
	240														
	280														
	320				a	b	c	d							
	360														
	400														
	400														

Note: Each square contains one tree (see text for explanation).

K 160 will be the means of trees w, x, y and x, y, z respectively. Three zero lines and a rate higher than the highest being tested are therefore necessary ; the outermost line is also repeated to provide an unassessed buffer.

The fertiliser dose for each tree was calculated and packed before transport to each site. Six such experiments have been established so far ; most of them are located next to conventional experiments over the same range of rates.

Foliar Analysis

Relationships between tree growth and the concentration of foliar nitrogen, phosphorus and potassium, for the most commonly used conifers, have been determined by plotting height or height increment against the concentration of a single element. Figure 2 shows one such relationship between phosphorus and the subsequent height increment. It is hoped to determine generalised relationships from the response curves for a range of species and sites ; these would then become the bases for the interpretation of foliar analysis results.

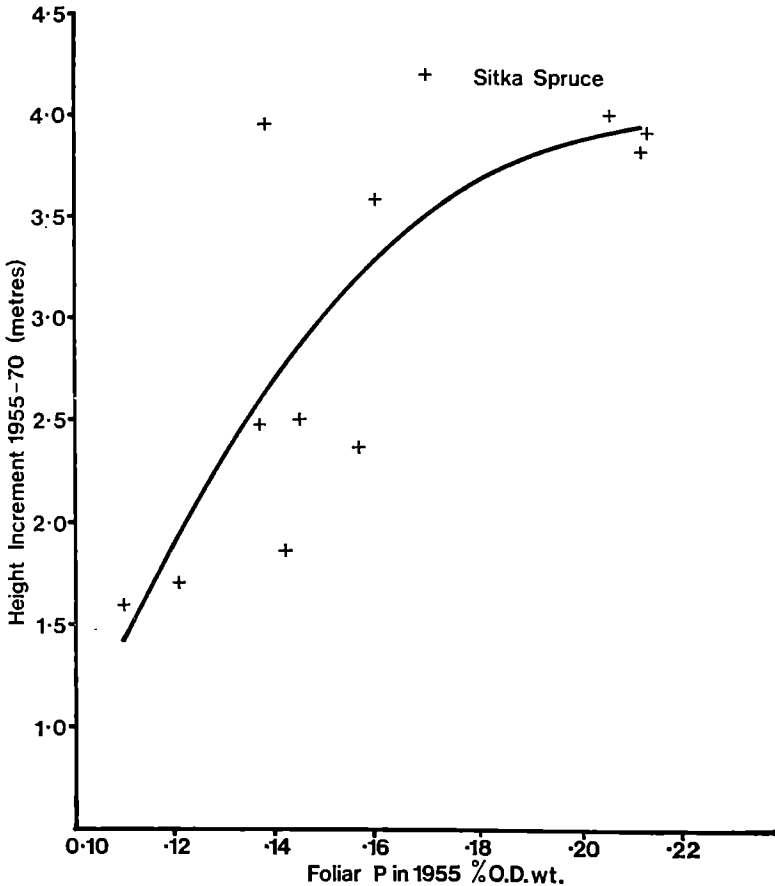


Figure 2: The relationship between foliar phosphorus and subsequent height increment for Sitka spruce, Tarenig, Ystwyth Forest, Montgomery (Experiment 2/56).

The high levels of phosphorus found in Western hemlock needles are striking; whereas 0.24 per cent of the oven-dry weight of the needles can be regarded as the optimum in Sitka spruce, such a low level can be regarded as deficient in Western hemlock (see Figures 2 and 3).

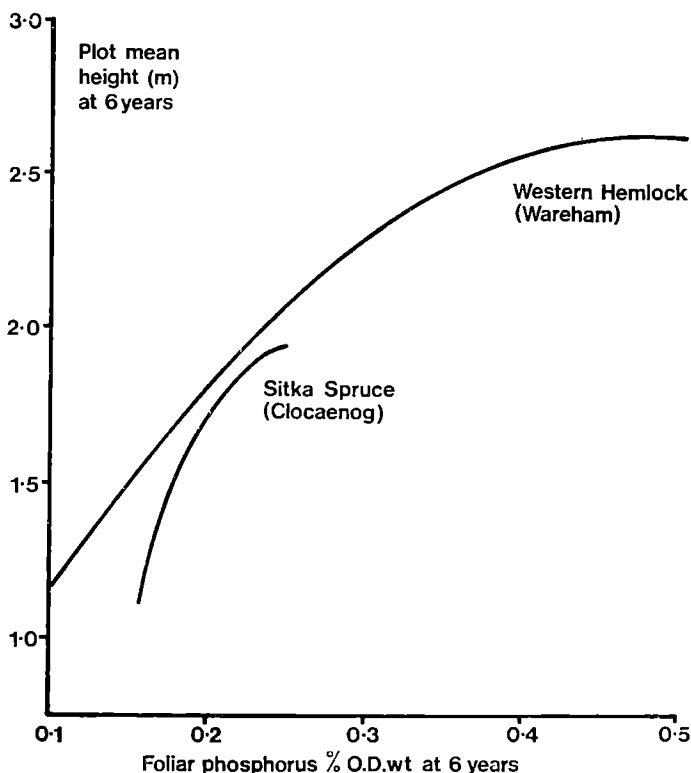


Figure 3: The relationship between foliar phosphorus and tree height for Sitka spruce, Clocaenog Forest, Denbighshire (Experiment 52/65), and Western hemlock, Wareham Forest, Dorset (Experiment 143/65).

Foliar Sampling Surveys

During 1970 and 1971, blocks of forests in which nutrient deficiencies were suspected were stratified by species and age or soil types using the working plan form WPO. Within the various strata foliar samples were collected at random. The purpose of this type of sampling was to determine the nutritional condition of the crops throughout the whole block, to help in prescribing overall fertilisation. Often in the past attention has been concentrated on those parts of the forest where tree growth has been relatively poor; in many instances these represent only a small proportion of the total area. The completed surveys for which foliar analysis results are available led to the following conclusions:

Parts of Tywi Forest (Cardiganshire), Irfon Forest and Glasfynydd Forest (Breconshire): phosphate and potash were required on most soil types except brown earth.

Mynydd Margam, Margam Forest (Glamorgan): there were no deficiencies in a range of species on a wide range of soil types.

New Forest (Hampshire), Verderers' Enclosures: There was general phosphate deficiency in Scots and Corsican pine and in Douglas fir on brown earths, podzols and gleys.

Halwill Forest (Devon), Dyfnant Forest (Montgomeryshire) and Margam Forest were also surveyed in the same way: results are not yet to hand.

These surveys provide a service for Conservancy managers; they also supplement the information on nutrient deficiencies gained in research experiments.

Phosphate and Potash Fertilisers

An extension to top-dressing on Sitka spruce planted in 1965 at Shin Forest (Sutherland) confirms that a standard application of phosphate rock (42 g per plant) only lasts 6 years on unflushed hill peat in northern areas (see *Report* for 1971, p. 47). The extension also showed that a combination of phosphate and potash fertiliser produced the best foliage nutrient levels and the greatest height increment. Phosphate alone reduced foliar levels to below optimum, but the full effect on growth is not yet determinable.

An experiment on Sitka spruce, planted in 1966 at Glengarry Forest (Inverness-shire) to observe the effects of top-dressing with phosphate, potash and nitrogen fertilisers showed that, while the most dramatic responses resulted from applied nitrogen, encouraging results also came from combinations of phosphate and potash. The soil types involved are partially flushed deep peats and peaty gleys overlying very poor Moine rocks. Phosphate and potash together markedly increased the N and P content of the foliage. To date, two seasons after application, there is no obvious advantage in increasing the rates of P and K above those currently recommended (50 kg P/ha and 100 kg K/ha).

Complete cultivation of an ironpan soil at Teindland, Laigh of Moray did not obviate or delay the need for phosphate at planting for Sitka spruce. The disturbance and mixing of soil by complete cultivation might have improved the available P supply. But foliar P levels and growth response after three years indicated that phosphate is still required at planting.

Potash Fertilisers in Wales

The use of potash in addition to phosphate when planting Welsh peat soils was recommended in last year's *Report*. Further evidence on the beneficial effect of potash comes from experiments at Tywi Forest (Cardiganshire), Tarenig Ystwyth Forest (Montgomeryshire) and Clocaenog Forest (Denbighshire). The application of phosphate alone results in unbalanced nutrition of the young plant and the harmful effects may last for at least 15 years. A mixture of 375 kg/ha of unground phosphate rock and 200 kg/ha of crude muriate of potash should therefore be applied at planting. This recommendation applies to all peaty soils where the depth of the peat is greater than 25 cm over soils of Silurian and Ordovician origins. There is at present no clear evidence for the use of potash on soils of Devonian and Carboniferous origins and phosphate alone should be applied at planting.

Nitrogen Fertilisers

Figure 4 presents foliar analysis results and height growth of the oldest experiment (planted in 1965) in the Sitka spruce/nitrogen series. At Strathy, Borgia Forest (Sutherland) on an unflushed deep peat, nitrogen has been applied as urea at 168 kg N/ha either annually for 6 years or once in the year after planting. Potash was applied overall in 1967, at 94 kg K/ha, and phosphate, in addition to the standard spot application at planting, was applied broadcast overall in 1969 at 50 kg P/ha. Herbicide to control heather was applied in 1969 to "no nitrogen" plots and to half the nitrogen treated

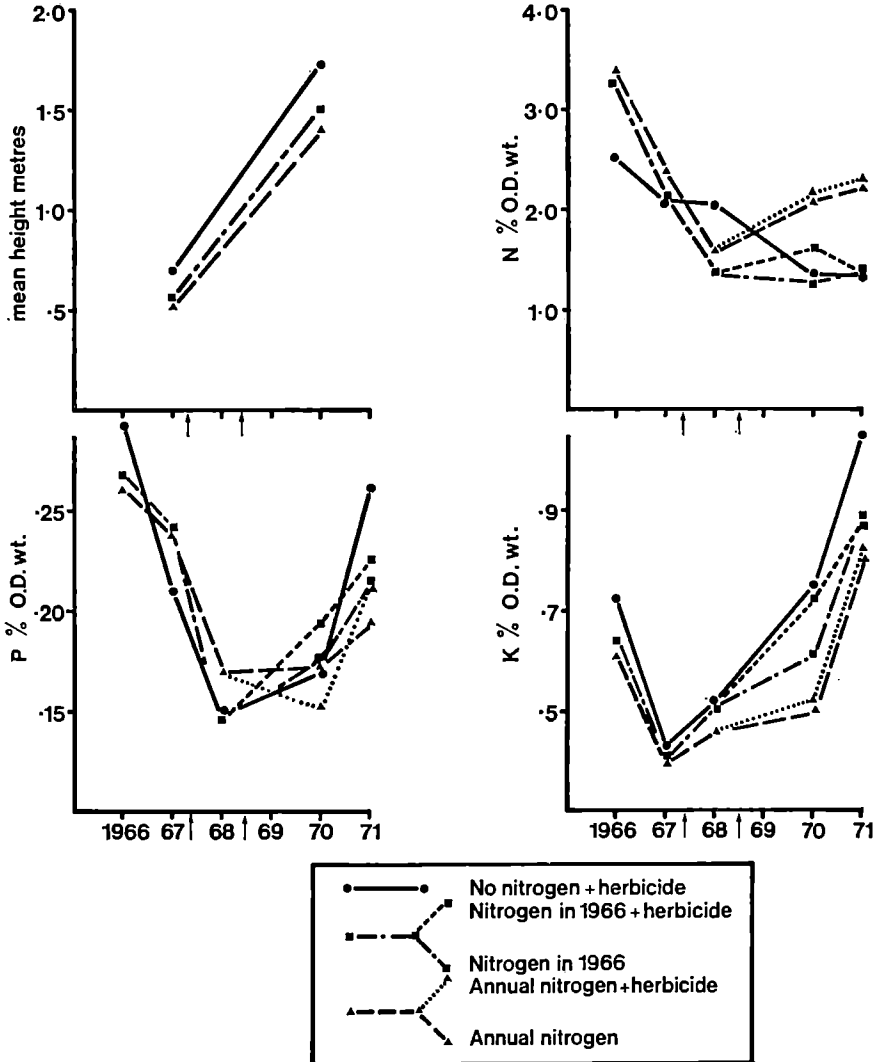


Figure 4: Height growth of Sitka spruce 1967–1970 and concentrations of N, P and K in the foliage 1966–1971, Strathy, Borgia Forest, Sutherland (Experiment 2 P.65). Arrows show dates of later treatments (1968: 95 kg K/ha. 1969: 50 kg P/ha and herbicide).

plots. In comparing the data, it appears that early growth is governed more by K and P levels than by N. The interest now is to learn how long the differential will be maintained and at what stage nitrogen will become limiting in the presence of adequate potash and phosphate.

An experiment at Durris Mearns Forest (Kincardineshire) on nitrogen deficient seven-year-old Sitka spruce on a peaty ironpan/hill peat site indicated that nitrogen (as urea) can be applied in winter with successful effects. Needle weights were substantially increased by application in November, January and March compared with the standard May application. Foliar nitrogen levels showed similar increases at all times of application. While the 1970-71 winter was unusually mild, the above indications tend to confirm results from an earlier experiment in Lodgepole pine on deep peat (see *Report for 1969 p. 63*). Applications are being repeated at Durris during the 1971-72 winter.

Fertilisers and Herbicides

First year foliar analysis of a young Sitka spruce experiment at Wark Forest (Northumberland) planted in 1966 on a heather dominated hill peat confirms results from similar experiments elsewhere, namely that phosphate/potash fertiliser and 2,4-D herbicide is the best ameliorative treatment. Previous claims that early control of heather is essential for successful growth of Sitka spruce on hill peat are also substantiated. In young crops heather control with herbicide is a much more effective way of improving foliar nutrient levels than nitrogen fertiliser, as the herbicide treatment increases phosphate and potash levels as well as nitrogen.

However, it was noted that in earlier experiments foliar nitrogen levels are falling in the PK plus herbicide treatment; the questions are again raised, what effect do sub-optimal N levels have on growth in the presence of high P and K levels, and how long can a nitrogen input be delayed?

Fertilisers in Established Crops

Table 8, on pages 54 and 55, summarises the results of some recent experiments in pole stage crops in Scotland and North England.

The assessment expressed as per cent increase in basal area increment does not indicate how worthwhile the responses are in economic terms, but it would seem probable that at least 15 per cent increase over a six-year period is required to pay for the minimum fertiliser input, and considerably more if a reasonable rate of return is required on capital invested.

Most of the experiments do not allow increases to be ascribed to N, P, or K; but in four of the trials nitrogen is clearly effective. However, the pattern is not at all clear when it comes to yield class and site type response prediction.

Scots pine gives the most consistent response but could be only marginally profitable. The most definite response from Sitka spruce has been on low yield classes on deep peat; results on most other site types have been disappointing. Norway spruce appears more promising, but again results are variable.

Analysis of Soils and Foliage

Mineral Soils

There has been little progress in developing methods for more detailed soil analysis, due to the pressure of routine work. Samples have been analysed for the Site Survey Officer with only moderate delays.

Foliage

The total number of samples in the year, 4,500, was only a little smaller than last year, due to a large number from northern Conservancies which previously had sent us few. There has been difficulty in getting results back to Conservancies as quickly as they wanted them, but a new timetable proposed for making contracts for aerial application of fertilisers will require results from foliar samples to be available in the autumn ; it will therefore be necessary to sample a year earlier than at present. While this will relieve the pressure on the laboratory to meet early deadlines, it will not reduce the total load, which is almost certain to increase.

It will therefore be necessary either to increase the speed of the analysis, which could be done either by automating the procedures or increasing the size of the laboratory, or else by putting all or part of the work out to another analyst. The problem is being studied urgently ; a solution is necessary soon.

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J. E. EVERARD
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TABLE 8
RESPONSE OF POLE STAGE CROPS TO FERTILISERS

Species	Experiment (No. of replications)	Site type	Yield class	Age at application	Nutrients applied kg/ha	Total 3-year basal area increment		Total 6-year basal area increment	
						Actual (m ² /ha)	% increase over control	Actual (m ² /ha)	% increase over control
Scots pine	Speymouth 7/64 (5)	Imperfectly drained gravel	5	48	O 134N; 56P; 112K 268N; 112P; 224K	2.89 3.92 3.92	- +36% +36%	6.63 7.77 7.77	- +17% +17%
Scots pine	Speymouth 13/67 (5)	Podzol	9/10	37	O 134N; 56P; 112K 268N; 112P; 224K	3.09 4.03 4.21	- +30% +36%	Not available Not available	Not available Not available
Scots pine	Devilla 19/65 (5)	Podzol	8/10	27	O 134N; 56P; 112K 268N; 112P; 224K	3.13 3.59 3.59	- +15% +15%	Not available	Not available
Scots pine	Strathspey 1/66 (5)	Podzol	8	85	O 134N; 56P; 112K 268N; 112P; 224K	2.98 3.74 3.30	- +26% +11%	5.65 6.32 6.29	- +21% +11%
Norway spruce	Knapdale 6/69 (3)	Ironpan, peaty ranker	13/14	30	O 168N 82P 168N; 82P	5.72 7.06 5.69 6.13	- +23% - +7%	Not available	Not available
Norway spruce	Fearnoch 1/69 (3)	Brown earth, podzol	10/12	34	O 168N 82P 168N; 82P	4.14 5.24 4.06 5.42	- +27% -2% +31%	Not available	Not available
Norway spruce	Glenbranter 11/69 (3)	Surface water gley	14/18	31	O 168N 82P 168N; 82P	7.42 6.97 6.40 6.33	- -6% -14% -15%	Not available	Not available
Douglas fir	Black Isle 2/69 (2)	Podzol, brown earth	16	40	O 168N 82P 168N; 82P	3.92 5.25 3.79 4.92	- +34% -3% +26%	Not available	Not available

Sitka spruce	Glenbranter 9/65 (5)	Podzol	14-16	33/36	O 134N; 56P; 112K 268N; 112P; 224K	3-57 3-78 4-95	- 6% + 39%	Not available	Not available (windblow)	
Sitka spruce	South Lagaan 15/67 (5)	Brown earth	16-20	36	O 231N; 48P; 92K 462N; 96P; 184K	4-84 4-35 5-08	- 10% + 5%	8-81 8-21 9-01	- 7% + 12%	
Sitka spruce	Ae 43/68 (5)	Brown earth	18	21	O 134N; 56P; 112K 268N; 112P; 224K	6-88 7-12 6-63	+ 3% - 4%	Not available	Not available	
Sitka spruce	Kershope 12/67 (3)	Deep peat	7	26	O 49P 134N; 56P; 112K 268N; 112P; 224K	3-83 5-67 7-60 7-07	+ 48% + 98% + 84%	5-08 6-91 8-55 8-20	+ 36% + 68% + 61%	4 1/2 year total incre- ment
	Kershope 12/67 (3)	Deep peat	10/11	26	O 49P 134N; 56P; 112K 268N; 112P; 224K	4-79 6-52 6-90 7-27	+ 36% + 44% + 52%	6-84 8-06 8-63 8-63	+ 18% + 26% + 26%	
Sitka spruce	Black Isle 1/69 (2)	Surface water gley	20	43	O 168N 82P 168N; 82P	4-00 4-61 4-74 4-81	- 15% + 18% + 20%	Not available	Not available	
Sitka spruce	Knapdale 7/69 (2)	Ironpan, peaty ranker	12/14	31	O 168N 82P 168N; 82P	5-05 4-97 4-93 5-16	- 2% + 2% + 2%	Not available	Not available	
Sitka spruce	Fearnoch 2/69 (2)	Brown earth, podzol	14/16	36	O 168N 82P 168N; 82P	4-63 4-46 4-88	+ 4% - 13% + 5%	Not available	Not available	

SOIL STUDIES

Physical and Mechanical Properties of Soil Types

Soils on Indurated Material

Three more soils developed in indurated material have been subjected to field testing and sampling for analysis in the laboratory, bringing the total to 11. A further five soils have been selected to complete the coverage of profile types and lithologies, and these will be dealt with in 1972. Apart from the analysis of these soil samples, further work on indurated soils will consist mainly of an attempt to measure the relative permeability of the soil horizons using boreholes of different depths. Publication of results will await the outcome of this new work.

The Effects of Cultivation Treatments on the Physical Properties of Soil

Work has begun on the assessment of soil physical conditions in cultivation experiments. The aims are (a) to devise effective methods of measuring soil properties affected by cultivation; (b) to measure the effects of past and current cultivation methods on a variety of soils; (c) to suggest how further worthwhile effects of cultivation might be obtained on particular soils.

Cultivation experiments have been studied at the following places:

Clashindarroch (Huntly) Forest (Aberdeenshire) and Teindland (Speymouth) Forest (Moray) in ironpan soils with indurated material; Rosedale (Cropton) Forest (Yorkshire) in a peaty gley on clayey material; and Inshriach Forest (Inverness-shire) in a podzol on glacio-fluvial gravel.

Soil properties have been assessed in a single excavation about 3 m × 2 m in one plot of selected treatments; approximately 15 measurements of soil properties were made within each horizon of the profile. No attempt has been made at this stage to sample throughout the treatment plot or its replications. Results are therefore provisional, but adequate for the first aim of the work.

Portable gamma-ray transmission equipment is used to measure soil bulk density *in situ*. Small samples are taken from between its probes for gravimetric determination of moisture content and weight loss on ignition (organic matter content). These assessments are made at intervals of about 10 cm depth throughout the profile. Large disturbed samples are taken from each soil horizon or 15 cm thick subdivision thereof for the gravimetric determination of stoniness percentage by weight and to provide material for other laboratory tests. Stone volumes are then determined by a water displacement method, and stone densities calculated.

The soil bulk density, moisture and organic matter content results are assembled according to the recognised soil horizons or depth subdivisions. Individual and horizon mean values for the following properties can then be

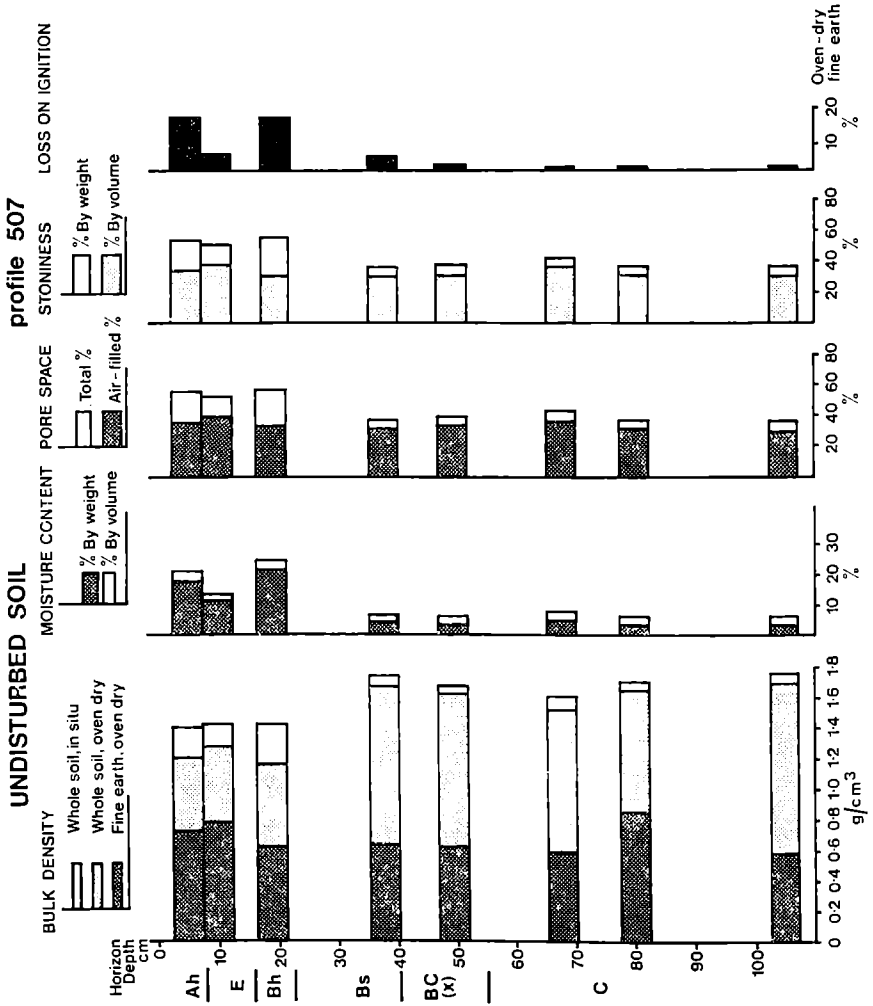
calculated: bulk density of whole soil on an oven-dry basis, stoniness percentage on a volume basis, bulk density of the stone-free soil (fine earth), moisture content on a volume basis, total pore space, air-filled pore space.

Figure 5 illustrates results for two profiles from one experiment. The undisturbed profile 507 shows the typical features of a podzol, with high organic matter and moisture contents at the surface and in the Bh horizon, with low levels in the E horizon and the deeper subsoil. Whole-soil bulk density is high throughout the profile, but this is largely due to the extremely high stoniness of this glaciofluvial deposit. Bulk density values for the fine earth component are quite low and give a quite different impression of the rootability of the soil. Total pore space is moderate but air-filled pore space is quite high due to the low moisture content. The soil was sampled in late October 1971 and the moisture contents are probably fairly typical of summer conditions. It is probable that seasonal variations are not great in this soil due to its very coarse texture.

The soil which has received "deep complete" cultivation treatment (depth of disturbance about 35 cm) is distinguished by appreciably lower bulk density in the disturbed (S) layer. The effect is most noticeable in the bulk density of fine earth values. The mean contents of organic matter and moisture have been made more uniform throughout this depth. Total pore space and air-filled pore space have increased, as would be expected from the lowering of bulk density. Profile 508 is more stony than 507 especially in the lower horizons, but this difference does not appear to have interfered with the detection of cultivation effects. It will be appreciated that when soil bulk density is reduced by cultivation, then stoniness as a percentage by weight is unaffected whereas stoniness by volume is reduced. This effect is evident in the data in spite of the difference of stoniness.

The benefit to tree growth at 6 years of age of complete cultivation at Inshriach 2 is considerable (see page 40 of the 1968 *Report*), but we cannot yet separate the effect of the temporary suppression of *Calluna* competition from the effect of the improved soil physical conditions.

Studies at the other cultivation experiments have indicated that the effects of ploughing are very long lasting, and that the slices into which the soil is cut with the plough are easily recognisable in the vertical section after 25 years, even including the large voids which may be enclosed beneath the over-turned slice. The degree of soil mixing achieved by so-called deep complete ploughing was, however, disappointing. There is clearly much scope for achieving a more intimate admixture of organic and mineral material if this could be shown to be beneficial to tree growth.



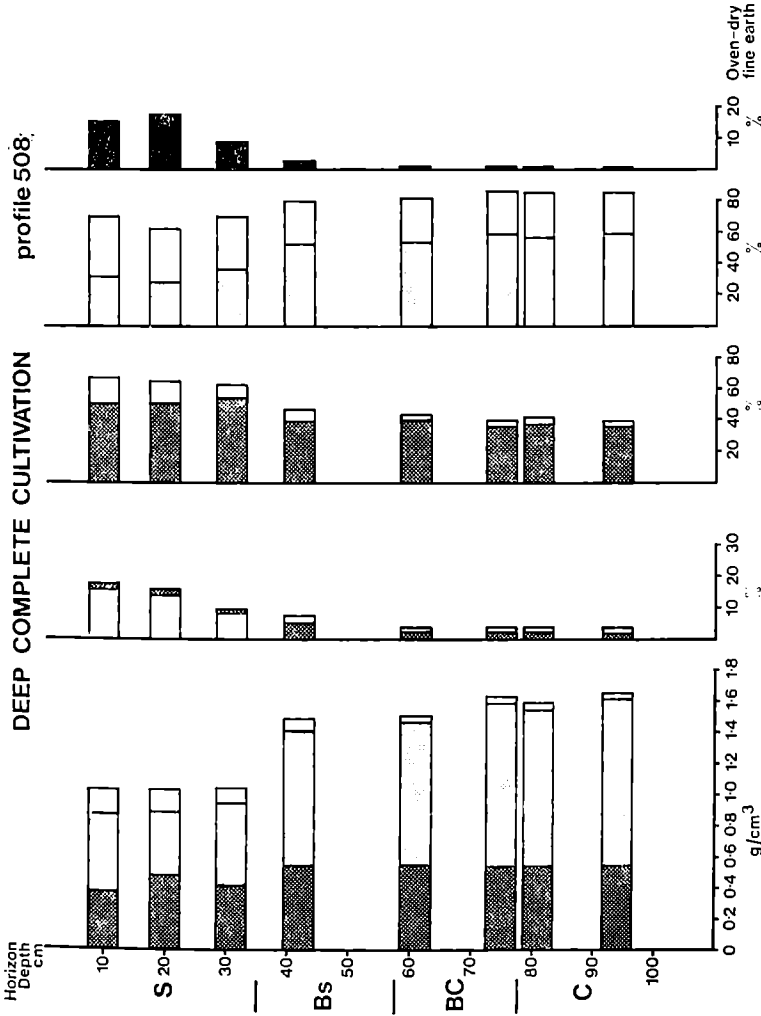


Figure 5: Physical properties of undisturbed (above) and cultivated (below) podzol profiles on glacio-fluvial gravel, Inshriach Forest, Inverness-shire (Experiment 2, P. 62). The histograms for the different measures of bulk density, moisture content, pore space, and stoniness are not cumulative, but have been superimposed.

Quality Control in Soil Physical Analysis

A recent publication of the Road Research Laboratory (Sherwood, 1970) has drawn attention to the serious "between-laboratory" variation in results for some important analytical methods in soil physics and mechanics. Particle size analysis especially seems to be liable to poor between-laboratory reproducibility. The opportunity was taken to benefit from this investigation, by obtaining quantities of the three soils which RRL had distributed to the 40 laboratories taking part in their survey. We subjected the soils to the procedure for the pipette method of analysis, which we have developed during the last two years, using four subsamples of each of the three soils. The "correct" results were not made known to our operator until afterwards. Our results revealed excellent repeatability for each of the three soils. For two of the soils our results closely matched the "correct" analysis, for the third there was a consistent departure for the sand and silt percentages while the clay percentage was correct. Overall our results were as good as the best achieved by any of the 40 laboratories previously tested. The soils will be retained for future use in the event of a change in our procedure.

D. G. PYATT

Instrumentation

Reading Water Levels in Boreholes

Equipment for automatic recording, the development of which has been mentioned in previous *Reports*, has now been installed on a drainage experiment at Crychan Forest (Breconshire). Poor performance of electrical contacts under field conditions caused some initial troubles which have been corrected; the equipment is now working well.

Soil Aeration

Both membrane covered electrodes and bare platinum microelectrodes are quite straightforward to operate in the laboratory, in our experience. However, the measurement of soil oxygen *in situ* is more difficult since it is hardly possible to place and maintain a membrane covered electrode in position without gross disturbance of the soil; the platinum microelectrode is easy to insert, at least in some soils, but the current measured at constant voltage is dependent on other soil factors besides aeration. Armstrong (1967) has shown that the plateau in the current/voltage curve shifts in a positive direction under the influence of acid peaty soil especially at the lower oxygen levels. We have been impressed by the results he has obtained on a Forestry Commission site and have therefore made equipment which will automatically draw current/voltage curves for a set of up to 24 platinum microelectrodes.

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G. P. MOFFATT

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DRAINAGE

Drainage of Deep Peat

Treatment differences in terms of water levels in boreholes and foliar nutrient levels have been recorded at the major drainage experiment at Rumster Forest (Caithness) (see *Report* for 1968, p. 42). In brief, the treatments have reduced water levels from the surface (undrained plots) down to an average of as much as 28 cm below the surface. The range between the most intensive (deep single mouldboard ploughing at 2.3 m spacing) and the least intensive drainage treatment (double mouldboard turf ploughing with cross drains at 18.3 m spacing) is approximately 13 cm.

Foliar analysis at the end of the third year has shown highly significantly increased needle weights and nitrogen contents in the most intensive drained treatments, but in part this effect is likely to be due to larger turves in these treatments. Where turf size was common and only the interval between cross-drains varied, only needle weight of Lodgepole pine was significantly correlated with drainage intensity. In the older experiment at Achray (Stirlingshire) on six-year-old trees, reduction of cross-drain spacing has also shown significantly improved needle weight and nitrogen content, but it was of interest that whereas Lodgepole pine from Port Alberni reacted significantly to drain spacing and not to drain depth, "rogues" of more inland type which form 15–20 per cent of the population reacted significantly to drain depth and not to drain spacing. Phosphorus and potassium uptake was not consistently affected by drainage treatments.

These results and the tree-pulling studies described on page 65 of this *Report* have encouraged us to change the ploughing prescription for peatland; viz. to use the deep double mouldboard drainage plough at approximately 4.2 m spacings with additional cross drainage limited to strategic interception locations.

S. A. NEUSTEIN

CULTIVATION

Cultivation of Ironpan Soils

The most recent assessment of the main experiment in this project (Teindland Experiment 81) has given results which suggest that the effect of complete cultivation which gave enhanced growth over the spaced furrow ploughed control for 15 years has now decreased; during the period between 15 and 20 years after planting, the height and basal area increment of some completely ploughed treatments is apparently lower than that of the controls. Further assessments are being made as a matter of urgency to check these findings, which reinforce the need for further long-term experiments with more intensive treatments.

New experiments have been established at Inshriach and Inchnacardoch Forests (Inverness-shire) and at Wykeham, Broxa (Yorkshire). All compare a range of cultivation intensities using various species and fertiliser regimes.

Deep complete cultivation of well-developed ironpan soils is being increasingly used in those Conservancies with a high proportion of such soils. For areas where these soils appear in smaller proportion, the highly advantageous flexibility that is a feature of the Parkgate "Universal" carriage and mouldboards, has provided the stimulus to develop both single and double-throw deep-tine mouldboards for use with the Parkgate "Humpy" carriage. The deep-tine single mouldboard body is similar to that currently in use for cultivating hard, stumpy sites. It is hoped that the new range of plough bodies mounted on the "Humpy" carriage will provide the forester with the facility to cultivate a wide range of soil types.

Cultivation of Gleys with Clay Subsoils

In last year's *Report* mention was made of the use of the Parkgate deep drainage plough to provide planting turves in an experiment at Clocaenog Forest (Denbighshire). The results of this form of ploughing were so encouraging that it has been repeated on a compartment scale on a number of wet soils in Wales and North-east England. At Coed-y-Rhaiadr Forest (Glamorgan) the double drainage mouldboard was used to produce drains aligned up and down the slope at 5 m spacing, and cross-drains collecting water from hollows were made at an interval of about 150 m, using the single mouldboard body. The large planting turves should improve early growth, particularly where heather (*Calluna vulgaris*) is dominant. The strip left unbroken by ploughing is 5 m wide, and twice that with single mouldboard turf ploughing. Such treatments should lead to greater stability. (Cf. Tree Pulling, under Crop Stability, p. 65 of this *Report*). Although two tractors are employed on this form of ploughing, as opposed to one on conventional turf production, costs of the whole ploughing and drainage operation are not markedly greater. By reducing the number of cross-drains the handwork usually associated with conventional cross-draining is greatly reduced.

Two new experiments were established on peaty gleys at Kielder (Northumberland) and Rosedale, Cropton (Yorkshire). At Kielder on a cleared area, riggs and furrs of 10 and 14 m wavelength and approximately 2 m amplitude are compared with current practice. At Rosedale, riggs and furrs of 8 m wavelength and similar amplitude are compared with a range of cultivation/drainage intensities including deep complete cultivation and spaced furrow ploughing with single and double mouldboard drainage ploughs. The riggs and furrs were constructed by means of a mechanical excavator and achieve a high degree of cultivation at a high cost, which is acceptable at present only in research. To this end the land beneath some riggs was deep cultivated before superimposing the rigg material. The object of this extreme degree of cultivation is to determine whether the treatment response curve is steep and long enough to justify continued research to determine worthwhile yet less expensive and less intensive cultivations of this type. If success is not achieved in terms of growth rate, improved rooting, reduced maintenance and easier extraction, the natural limitations of this site type may have to be accepted.

Preliminary studies of the water levels in boreholes show considerable treatment effects and further instrumental studies are being supported by bio-assays using clonal Sitka spruce.

Feasibility trials of artificially intercepting a major proportion of the rainfall are in hand, as an alternative method of achieving maximal drainage effects in clay soils. As reported last year, responses to conventional drainage practices have been small, and it is thought that to work back from an ultimate treatment would be more economical of time and effort than continuing with small steps forward in increased drainage intensification.

S. A. NEUSTEIN

J. E. EVERARD

CROP STABILITY

Distribution of Windthrow

A fourth periodic survey of windthrow was carried out at Kershope Forest (Cumberland), using vertical 35 mm aerial photography. Because there has been a consistent thinning policy since windthrow began in the late 1950's and as virtually no anticipatory felling has been carried out, the distribution of damage here is relatively unaffected by factors other than those of site and crop.

Anemograph records show that between 1958 and 1970 the number of hours with winds of gale force (37 knots or above) ranged from 0 to 32 per annum (average 12.5 hours). In the first quinquennium of this period the frequency of gale hours was twice as great as in the subsequent eight years, but proliferation of vulnerable margins in susceptible crops and increasing height growth has led to a steady increase in damage. Within the study area, it can be said that by the time crops on the higher land reach a height of 14 m, 26 per cent have been windthrown; by 17 m, 46 per cent have been windthrown. Using maps of the area from which damage, elevation, aspect, tree height, topex value and weighted topex value (Howell and Neustein, *Report* for 1965, p. 201) could be extracted, a multiple correlation analysis was attempted for 1,050 systematically spaced sample points. Although at best only 10 per cent of the damage that had occurred could be explained statistically, it must be remembered that the damage was the result of a large number of gales of different speeds and directions over a 14-year period. A more instructive conclusion comes from looking at the contributory values of the variables. The best correlation was derived from a combination of elevation plus aspect plus tree height, i.e. our commonly used combination; this confirmation is encouraging. The use of topex (weighted or unweighted) was not helpful in assessing site hazard in this context; it seems that this is too coarse a measure to characterise the complex topographical features found in the Scottish Border Forests.

S. A. NEUSTEIN

Thinning

Monitoring of windthrow has continued in the thinning experiments described in the 1971 *Report*, p. 64, and one new site at Castle O'er (Dumfriesshire) has been added to the list. Windthrow has continued to spread during the past year, negligibly in unthinned, increasing by 34 per cent in selectively thinned and by 43 per cent in line thinned plots. In total overall, the average number of trees windthrown in unthinned plots was 0.6 per ha, on normally thinned plots, 5 trees per ha were windthrown and in the line thinned area 24 trees per ha had blown. Cutting of extraction racks at an angle to line thinning increases windthrow considerably. The distribution of windthrow within the size classes varies according to treatment. In unthinned stands "larger than average" stems form 52 per cent of the small number thrown; as the crop is opened up more this figure falls progressively to 30 per cent in line thinning and the percentage of "smaller than average" increases from seven to 27.

Basal Sweep of Lodgepole Pine

Eight-year-old crops of Lodgepole pine of two provenances, one South Coastal and one Inland were measured in detail (18 parameters, both root and shoot). Correlation matrices were calculated for each provenance and the major correlations with lean are given in Table 9.

TABLE 9
BASAL SWEEP OF LODGEPOLE PINE: MAJOR CORRELATIONS WITH LEAN

	Linear correlation coefficient	
	<i>South Coastal</i>	<i>Inland</i>
Total weight (green)	0·69	0·24
Total height	0·62	0·14
Total number growing points	0·62	0·31
Shoot/root ratio	0·72	0·35
	5 per cent significance level 0·43	1 per cent significance level 0·61
Mean angle of lean	29·73°	4·13°

As the inland provenance had a very low figure for lean it was reasonable to expect no significant correlations. This study has merely highlighted the already known differences between the two provenance types; and shown that weight distribution within the tree and growth rate are factors influencing basal sweep.

Three experiments planted in 1966 at Shin and Strathy* Forests (Sutherland) and Glentool (Kirkcudbrightshire) attempting to improve the stem form of Lodgepole pine have been assessed for height, stability and stem form. Ten treatments were applied which aimed at altering the growth pattern of a South Coastal provenance; an Alaskan provenance was included for comparison. At Strathy and Shin there is good correlation between vigorous height growth and poor stability and stem form; but even the slowest growing South Coastal trees have a poorer stem form than those of the Alaskan provenance of similar height. At Glentool the treatments did not produce the same contrasts in height growth but there was still a wide range of stem form and stability with no obvious correlation with treatment. It was noted at this experiment that the crop in general is more stable now at six years than it was at three years. This improvement in stability has been confirmed recently at Dalby (Pickering, Yorkshire) where an eight-year-old crop of South Coastal origin which is now stable shows stem bends which formed in the second and third years of the growth of the trees.

Tree Pulling

Fraser and Gardiner (1967) described a hand winch, dynamometer and pulley block system to pull over trees. Recent modifications of the technique include the use of a powered winch on a crawler tractor to exert a pull through a load cell attached to a chart recorder. Formerly a pulley attached to a nearby tree was used to ensure a horizontal pull. Now a vertical metal bar is used instead.

* Now part of Borgie Forest.

To date, about 1,000 trees have been pulled over, and the data is being re-analysed. One of the objectives is to provide a revised set of wind speed—critical height curves for different sites.

The greater part of the tree pulling programme during the past year has been carried out at Inchnacardoch Forest (Inverness-shire) as the beginning of a three-year project to study Lodgepole pine rooting systems and stability. During an eight-week period approximately 100 trees were pulled on deep peat and on ironpan soils. Comparisons were obtained between provenances of Lodgepole pine on both soil types, with Sitka spruce on deep peat and Scots pine on ironpan soils.

On deep peat trees ranging between 32-44 years old and with stem weights from 87-484 kg were successfully pulled. Stem break on smaller trees made it impossible to uproot some younger trees on early Cuthbertson ploughing. An extremely good regression line for stem weight against turning moment was obtained ($R^2=0.88$). The peat under a range of ages of Lodgepole pine was drying out. Cracking of the peat was beginning in the P.46 crop and in the P.28 crop there was no free water down to 1.06 m although the adjacent ride was completely water-logged. The root systems had no tap root nor long large laterals, but consisted of an intensive system of medium sized sinkers colonizing the area adjacent to the tree stem, with no sign of dead roots down to a maximum of 1.06 metres. A large peat ball was pulled out with each root system; the ball completely enclosed all but the root tips and on older trees weighed between 3 and 4 tonnes. The adjacent crop of Sitka spruce had not dried its site to the same degree and had produced a flat plate root system with large laterals and dead "shaving brush" roots on the underside with an average depth of 0.5 m. Crops on shallow turf drains at 1.22 and 4.12 m were pulled, the latter having a turning moment $2 \times$ the former at all stem sizes, illustrating the importance of the lateral spread of the root plate on deep peat.

On ironpan soils, Lodgepole pine root systems again showed a small root plate diameter. Sinkers were restricted to weak points in the ironpan but once through the pan deep rooting was not restricted. Deep cultivation of the pan will allow better root exploitation of the site. Scots pine had a similar root pattern and turning moment. Although a good regression of stem weight on turning moment was obtained for Lodgepole pine on ironpan soils, the variation around the regression line was much greater than on deep peat ($R^2=0.77$).

Although Lodgepole pine on the two soil types had a similar maximum pull for trees of the same size the angle at which it occurred was higher on deep peat, suggesting a greater stability.

T. C. BOOTH

G. J. MAYHEAD

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REGENERATION

ARTIFICIAL REGENERATION

Gley Soils

South-west England

At Halwill Forest (Devon) second rotation crops, usually of Sitka spruce, often have low survival rates in the early years following replanting. Death of trees becomes noticeable mostly in the second year, and may occur on a range of sites irrespective of species and the previous type of crop. The method of timber extraction may be an important factor since tractor movement over the site appears to leave conditions, manifested by surface water logging, especially unfavourable to tree establishment. A start was made during the year to determine the factors that contribute to the failure of the replanted crop and their relative importance. Additionally, an experiment was laid down on a typical recently felled site to compare the survival and early growth of alternative successor species to Sitka spruce. The six species include Sitka spruce, and are sufficiently represented in the unit plots to allow the removal of trees for examination.

Because conditions on the site are such that socketing and windblow of young, vigorous, vegetatively propagated trees may be expected, a second experiment was planted to compare the behaviour of rooted cuttings of Leyland cypress in different sizes of Japanese Paperpots.

Scotland

Six-year assessments at The Bin, Huntly (Aberdeenshire and Banffshire) and Kirkhill Forest (Aberdeenshire) support previous results in Scottish Border forests, showing no benefit from single furrow ploughing or application of phosphate in replanting peaty gleys and surface water gleys.

New experiments at Kielder (Northumberland) to identify the causes of high planting losses in the first year (mentioned in the 1969 *Report*) have shown that direct notching in the slightly raised position adjacent to the old stumps gave a satisfactory survival of 82 per cent. A further twelve sites have been chosen to represent the worst possible conditions and the recommended technique has been used in planting them this year.

Freely Drained Soils

At Tentsmuir Forest (Fife) the experiment referred to in the 1971 *Report* has been established and a limited coverage of minimum thermometers placed in position to obtain data on variation in frost effects according to treatment. *Fomes annosus* is already causing deaths in Lodgepole pine, Douglas fir and Western hemlock in a similar experiment now six years old at Culbin, Laign of Moray Forest ; no deaths have yet been found in Grand fir.

Ironpan Soils

Variations in frost levels are also being measured at Speymouth Forest (Moray) in the experiment mentioned in the 1971 *Report* (now planted). There is already some evidence that the opened-up crop may not be stable and that its liability to wind damage may be correlated with the degree of opening up.

At Wykeham Forest (Yorkshire) in an experiment to compare methods of establishing Grand fir on average 95 per cent have survived, the minimum being 86 per cent. A scrutiny of old experiment records suggests that intensive cultivation may be at least part of the answer to obtaining good survival with this species.

Scottish Woodland Owners' Association Questionnaire

A questionnaire has been drafted for distribution by SWOA to ascertain regeneration problems peculiar to the private sector in Scotland which may not be covered by the current research programme.

J. JOBLING

T. C. BOOTH

SITE CLASSIFICATION

Research and Management Services Divisions are co-operating on the development of site classification methods. In a minor study in Scotland association analysis was successfully used. Data for continuous characteristics were first reduced to a range of classes, and thence to two classes adaptable to the presence-absence format required for this form of analysis. Presentation of the results of this study has underlined the major problem as to what type of classification or site information is most useful, and the management level for which it should be designed.

The intensive study of one site combined with system modelling outlined in the *Report* last year has been held in abeyance.

G. J. MAYHEAD

REMOTE SENSING

The year has seen a surge of interest in remote sensing though results have, on occasion, been disappointing. A flight at Thetford sponsored by the Natural Environment Research Council used multiband and linescan techniques ; it failed to give any more information than could be obtained from 35 mm transparencies, e.g. a ring of eight 15 m Scots pine under water stress failed to show up conspicuously ; Scots and Corsican pines were difficult to separate ; distortion on the infra-red linescan was so severe in two directions that location of the areas photographed was difficult.

A borrowed portable infra-red linescan unit demonstrated some interesting small temperature differences. For example, two young beech trees grown under contrasting water stress regimes (but watered for this experiment) were examined. In a darkened room the dry regime tree was warmer than that grown in a moist regime although both trees had appeared quite similar to the naked eye.

This type of equipment, which is relatively insensitive to wavelength, seemed best used in the dark in order to avoid confusion between emitted and reflected radiation. It appears to have potential for detection of minor temperature differences in standard large-scale observations. It is expensive to use for casual observations.

A multi-spectral aerial photo flight was commissioned for part of Leanachan Forest (Inverness-shire). This involved simultaneous exposure of 4 film/filter combinations. The objective was, to determine the relative merits of various films in reflecting irregular crop growth and its causes.

Aided by professional advice from Dr Langdale-Brown of the Department of Forestry and Natural Resources, Edinburgh University, and by Forestry Commission Management Services Crop Surveyors, the ability of each film to discriminate various crop and vegetation features was appraised. True colour for office interpretation and black and white prints (produced from these transparencies) for field use, appeared to combine best economy and effectiveness. Nutrient deficiency symptoms did not appear as clearly on the scale employed (1 : 9000) as on large-scale 35 mm photographs.

G. J. MAYHEAD
S. A. NEUSTEIN

ECOLOGY

Tree Growth in Forests of the South Wales Coalfield

In 1971 the decision was taken to carry out estimates of yield of all the main species in Ebbw Forest, Monmouthshire (*Pinus sylvestris* L., *P. nigra* Arn. var. *maritima* Melville, *Picea abies* Karst., *P. sitchensis* (Bong.) Carr. and *Larix kaempferi* Sargent; that is, Scots and Corsican pines; Norway and Sitka spruces; and Japanese larch). These were the main reasons:

- (1) The difference in climate between Ebbw Forest (somewhat drier, in the main less wind) and the West Glamorgan forests hitherto surveyed in Cwm Afon, Cwm Nedd and the hills flanking them.
- (2) It was supposed (and eventually confirmed) that soil variations would be relatively unimportant, with freely drained soils dominant. Ebbw offered, therefore, an opportunity to examine the relative performance of several trees in relation to the striking variations in relief.
- (3) Disturbing influences of local variations in air pollution were thought to be small: while mild general pollution (much of it from the burning of domestic coal, or, in the past, of colliery waste) has prevailed, there are no large centres of industrial pollution.
- (4) In 1938, W. R. Day and R. G. Sanzen Baker, with help from colleagues, prepared a comprehensive report on the terrain, the history of afforestation from 1921 and the successes and failures up to 1937. One may, therefore, appraise the often important bearing on estimates of yield class of such factors as ground preparation; planting and tending; early troubles like frost, or insect attack.

Ebbw Forest was surveyed in the late summer of 1971, and the main findings arising from the work done since 1968 in the coalfield area were included in an interim report completed early in 1972: they are likely to have a strong influence on choice of species for reforestation.

Little further field work was carried out elsewhere in S. Wales; but the results of foliage analysis for plant foods, which was done on material collected from three Sitka spruce compartments in October 1970, merit brief notice. The two 30-year-old stands in Rheola (Glyncastle) Forest, on soil largely derived from drift material, gave widespread indications of phosphate deficiency and occasional indications of some nitrogen deficiency as well. Low phosphate concentrations were mainly restricted to peat soils, or peaty gleys with impeded drainage, and showed highly significant correlations with check, or retarded growth. Foliar nitrogen concentration was also significantly related to height growth. In the 37-year-old Margam stand on Pennant Sandstone, while some values for phosphorus were near, or below, the commonly accepted threshold value for good growth, they bore no relation to the variably poor increment. The causes of this must be sought elsewhere:

e.g. in severe exposure to wind, or to air pollution; in seasonal lack of soil moisture, or recurrent defoliation by *Elatobium abietinum*; or in some combination of these.

K. BROAD

J. M. B. BROWN

Survival of Corsican Pine after Forest Planting

In the month of planting experiment on Corsican pine (*Pinus nigra* Arnold), duplicated in Wareham Forest (Dorset) and Thetford Forest (Norfolk), assessments in autumn 1971 showed mainly good survival up till then of plants set out in the preceding 12 months. The exceptions were, as expected, those set out during the period of active shoot growth (May/June). Dipping the roots in sodium alginate solution immediately after lifting in the nursery gave no better survival at either site in the conditions of this experiment. Survival at Thetford over the whole course of the trial has not been good and the data so far are somewhat inconsistent: it is premature to draw any inferences. At Wareham, the survival of plants set out from October to March (inclusive) has been consistently good in two consecutive years. For the southern counties, September planting appears a little too risky, while April is rather more so. October and February showed the best figures, both for survival and for visual appraisal, while there are indications that autumn planting results in better height growth in the following year. The full results, with relevant climatic data, will be reported in the fall of 1973.

Root Regeneration After Transplanting

An important factor in the survival of young trees after transplanting is the capacity of the damaged root system to make speedy repairs and then to exploit the soil more widely and deeply. In connection with the month-of-planting experiment mentioned above, a small array of 48 second-year Corsican pine plants was set out each month in Headley Park Nursery (Hampshire) on a sandy podzolic soil. At intervals of about one month, small samples of each month's array were carefully dug up, scored for the presence of fresh white root tips and put back again. The soil temperature at 30 cm depth was recorded on each visit: additional weather data are available at the Alice Holt Station 5 km to north.

These data have been maintained for more than three years, showing a very satisfactory consistency, with little or no growth after November, until late February or early March, after which a period of active root growth precedes bud extension (sometimes during May). Earlier observations on slightly older plants pointed to a suspension (partial or complete) of root growth during the period of active shoot growth (mid-May until near the end of June in most years). The current systematic examination shows that, while this may be so with well established plants, those set out within the preceding nine months continue active root regeneration at this season. It is well known that forest trees make insignificant height growth during their first year in the plantation and foresters are accustomed to speak of post planting check. Post planting adjustment may be a better way of describing the tree's urge to redress the balance between root and shoot.

Altogether, with other conditions the same, the recently planted pines, allowed at least a month to settle down, showed relatively much more prolific root growth than those which had been planted for a year. It is intended to recast the data in such a way that aggregate scores are plotted separately for trees set out nine months or less before the examination date. While the relationship between root growth and soil temperature is outstanding, the number of weeks since planting appears to be influential also. Regenerating roots of Corsican pine seemed remarkably insensitive to soil moisture, growing apace during the very dry early autumn periods of 1969 and 1970.

Apart from the soil environment the author believes that the atmospheric conditions during the few weeks after setting out are critical. Cloud, quiet weather, high relative humidity and moderate temperatures all contribute to the favourable environment wherein these sensitive young trees, with transpiration reduced, can resume root growth. Confirmation of the importance of wind was given by the experimental plantings in Headley Nursery, where the month by month results were in good agreement with those from Wareham. This nursery has considerable all round exposure to wind. Even if the plants set out in May and June are discounted, survival has been patchy for the earliest plantings and for the latest: for those set out between September 1969 and April 1970, within a small enclosure of Netlon netting, it was very good.

In December 1970 a feasibility trial was made of vertical glass sheets in the ground, with a small array of six conifers lined out behind them. This proved a relatively convenient way of conducting periodic examinations of undisturbed plants for fresh root growth: a more elaborate venture with twelve species of tree has now been launched. Observations during the preliminary trial suggested that the roots of Western hemlock (*Tsuga heterophylla*) are less restricted by low soil temperature and those of Douglas fir (*Pseudotsuga menziesii*) more so, as compared with Corsican pine. The other species (Scots pine, Norway and Sitka spruce) behaved much as Corsican pine, with, perhaps, less inclination towards any activity in winter.

J. M. B. BROWN

Canopy Closure Studies

Implicit in much of the research work of the Silviculture Sections is study of the maximisation (more correctly optimisation) of crop leaf area as soon as possible, but with the minimum number of stems. In the past, the criterion of success in relation to different inputs in site amelioration experiments has been height growth. By studying canopy development in young crops, it is hoped to increase the useful information of some establishment experiments at little extra cost, and also to provide information on the neglected aspect of leaf area development prior to canopy closure.

A computer model to simulate canopy development in a young crop is now being produced in co-operation with the Statistics Section. Initially, it is being based on assessments of rate of canopy closure made with high contrast black and white film.

G. J. MAYHEAD

The Weather of the Year 1971

The weather during 1971 left an impression of an unusual prevalence of high pressure systems around Britain: perhaps this is partly why regional differences in the monthly weather patterns were seldom sharply defined. Nevertheless, the average value for run of wind at Alice Holt (88 km per day, cf. accompanying Table 10) was rather above the very low 1970 value of 68 km. The year 1972 opened with some stormy weather causing local wind-throw in this forest.

Over Britain as a whole the salient features of 1971 were the very mild winter; the dull cold wet June, particularly in the south and west, where some stations experienced the wettest June on record; and the outstandingly warm sunny autumn. The summer followed a see-saw course—May warm and sunny, June dull, cold and wet, July sunny and rather dry, August bringing a good deal of cloud and rain, September and much of October warm, sunny and very dry. At Alice Holt, values for summer sunshine and potential evaporation were the same as in 1970, while rainfall was more plentiful. These conditions ensured a welcome freedom from floods and droughts and generally good weather for survival of young trees in plantations; in the warmer districts of the south, however, soil moisture deficits after the rather dry weather of April and May may have caused a critical water stress before the June rain relieved it. As compared with 1970, the past summer showed rather smaller soil moisture deficits, with less marked geographic variation.

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P. MARSH.

D. F. FOUNT.

J. M. B. BROWN.

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TABLE 10
MONTHLY WEATHER RECORDS, ALICE HOLT LODGE, HAMPSHIRE, FOR THE YEAR 1971 (ALTITUDE 115m)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Apr. to Sept.
Air temperature (°C)														
Mean daily maximum	6.9	7.5	8.2	11.7	17.1	16.8	22.7	19.7	19.8	16.1	9.6	8.4	13.7	18.0
Mean daily minimum	1.6	0.9	1.0	3.2	6.2	8.8	11.9	12.2	8.3	6.6	1.6	3.7	5.5	8.4
Monthly extreme grass minimum temperature (°C)	-13.3	-7.8	-10.9	-5.3	-6.1	-0.4	-1.4	1.4	-2.5	-6.4	-8.9	-6.4		
Soil temperature (°C) at 9 hrs														
Mean at:														
10 cm under bare soil	3.8	3.0	3.7	6.4	13.0	14.4	19.4	16.2	13.8	9.9	4.7	5.4	9.5	13.9
20 cm under bare soil	4.3	3.9	4.5	7.5	12.4	14.1	19.1	16.5	14.6	11.2	5.9	6.1	10.0	14.0
60 cm under short grass	5.2	5.3	5.7	8.4	12.6	14.6	18.5	17.6	15.9	13.4	8.8	7.4	11.1	14.6
Precipitation (mm)	115.0	22.8	64.6	69.0	42.1	135.3	17.1	81.6	11.4	57.9	67.4	23.8	708.0	356.5
Number of days with rain (2 mm or more)	21	7	12	11	13	18	7	17	5	8	13	7	139	71
Number of days with rain (1 mm or more)	17	6	7	6	10	12	5	15	3	7	10	5	103	51
Lysimeter evaporation losses (mm):														
Garnier Gauge A	-19.6	6.1	12.9	29.2	48.7	53.7	85.8	53.8	47.4	20.5	4.3	-0.2	342.6	318.6
Garnier Gauge B	6.2	6.0	31.1	31.3	46.7	70.8	79.3	48.4	52.7	18.2	19.5	1.5	411.7	329.2
Estimated evaporation (Et)*	6.3	10.2	25.4	46.7	86.4	78.4	106.7	66.0	50.0	16.5	5.8	3.8	502.2	434.2
Total hours of bright sunshine	45.6	80.7	106.9	134.4	233.4	143.3	241.6	148.3	190.6	154.8	106.5	29.2	1,615.3	1,091.6
Mean daily run of wind (km)	90.5	75.5	98.2	107	78	85.8	67.2	99.3	54.7	91	94.6	110.2	87.7	82

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

FOREST GENETICS

The 1971 cone crops of all species were generally light throughout the whole country, although moderately heavy crops occurred in the Scots pine tree bank at Newton Moray and in the important Scots pine seed orchards at Dunkeld, Ledmore (Perthshire), and Bradon Savernake (Wiltshire). Corsican pine crops were again very light in all regions ; it is now eleven years since this species cropped heavily in Britain. Larch crops were virtually a complete failure in north-east Scotland where they were heavy in 1970 ; there were reports of localised moderate crops in south-east and south-west England.

Heavy cone production was recorded on only a few Douglas fir clones in the Dunkeld, Ledmore, seed orchard. In view of the high risk of inbreeding and often consequential poor growth of the progenies (see Plate 10.) the cones were not collected.

Sitka spruce cone crops were very patchy with moderate crops in west and north-west Scotland in particular. It is interesting to note that good cone crops of Sitka spruce have occurred in some districts of western Scotland in each of the last four years, whereas the large Sitka spruce forests of south-west Scotland, the English/Scottish borders, Wales and south-west England have still to produce a really good crop.

Crops of both acorns and beech nuts were also generally poor but moderate crops of sycamore and ash were noted in central Yorkshire and the Lake District.

Register of Seed Sources

The first survey of seed sources took place during the period 1950–1961. By 1972 the trees in many of the sources had been felled or were either too old to respond to management treatments for seed production or too tall for practical seed collection purposes. On entering the European Economic Community, Britain will be obliged to provide a scheme for the marketing of silvicultural propagation materials. In this scheme it will be necessary to describe “regions of provenance” which are by definition, “for a genus, a species, a sub-species or a distinct variety, the region or regions with sufficiently uniform ecological conditions in which stands are to be found with genetical or at least morphological characteristics which are similar and of equal value for timber production.” In addition lists of seed sources will have to be established.

This new situation provided a suitable opportunity for completely revising the existing Register of Seed Sources. Some sources which in the past have been unproductive or uneconomic to collect from have now been removed from the Register and alternative younger stands which are well-suited to management for seed production are being located to provide replacements.

Pre-requisites for any new coniferous seed source are, that access should be good ; aspect should be southerly ; live crowns should generally be within

3–4 m above the ground ; the source should be capable of withstanding heavy thinnings without serious risk of windthrow in order to promote the development of long, live crowns.

Rideside trees up to 15 m tall, with a southern exposure and of good phenotype and known origin, are also seriously considered for inclusion in the new Register—providing the ride is over 200 m in length.

The new survey is in progress ; it is hoped to complete it by August 1972.

Survey of Plus Trees

In 1961 “Coastal” Lodgepole pine plantations in the Republic of Ireland were surveyed for Plus trees jointly with the Department of Lands, Forest and Wildlife Service, in order to supplement the list of Plus trees recorded in Britain. A second successful joint survey was undertaken in 1971 during which an additional 97 trees of “Coastal” type were selected ; we are greatly indebted to the Irish Forest and Wildlife Service for their co-operation.

The first stage of the Sitka spruce “candidate” Plus tree selection programme was completed by surveying the remaining areas in west and north Scotland which were planted before 1935 ; a total of 964 trees have been selected since the start of the survey in 1963. Surveys will be resumed in 1976 when stands which were planted with the aid of modern establishment techniques, for example, ploughing and fertilizing, will have reached a size at which Plus tree selections might be made.

Vegetative Propagation

The first full propagation programme was undertaken at the new main propagation centre at the Northern Research Station, Midlothian, in 1971 (for details of the facilities see *Report* for 1971). Five thousand grafts were attempted of which slightly more than half were Sitka spruce and approximately one-third Lodgepole pine ; the overall success rate was 57 per cent. Sitka spruce had an initial success rate of 51 per cent which compared favourably with results previously obtained at the propagation centre at Grizedale. This ratio dropped later to 37 per cent as a result of problems associated with the irrigation methods. The rootstocks had been raised in plastic pots and watering was carried-out using a sub-irrigation system instead of top-watering ; difficulties were experienced in maintaining the correct water-level on the benches and the potting compost created water-logging problems. Additional difficulties were experienced in promoting early root growth in pots which were free-standing on the sub-irrigation bench. These problems will be investigated during 1972. Shading and regular water-sprays to increase humidity inside the propagation houses were essential from early spring onwards and particularly during times when the automatic cooling system was inadequate during periods of high temperatures. As previously observed there were large differences in success rates between clones ; clones which are consistently difficult to graft will be eliminated from the breeding programme.

Seed Plantations

A sharp rise in the use of Lodgepole pine since 1964 has produced serious difficulties in meeting the demands for seed of the most desirable provenances; these problems had been anticipated following the visit of Mr. H. A. Maxwell and Mr. J. R. Aldhous to British Columbia in 1965. During that visit arrangements were made for special seed collections of many provenances and these collections, together with additional seed obtained through the auspices of the International Union of Forestry Research Organisations and some "home" collections, provided the basis for establishing special plantations which will be managed solely for seed production units. Ninety-four ha of these special seed plantations have been established since 1966. They consist of trees of the following main origins: Alaska 23.5 ha; North Coastal British Columbia 18.7 ha; South Coastal USA 2.0 ha; North Inland British Columbia 39.7 ha. The plantations have been established at a close spacing of 1 m × 1 m on fertile sites and they will be heavily thinned from an early age to maintain the maximum crown size on the best remaining phenotypes. The seed plantations are composed either of a single provenance or a line-mixture of six provenances from the same broad region. In the mixed seed plantations those provenances which, on the appraisal of results of concurrently planted provenance experiments, prove to be undesirable will be removed by felling.

Progeny Tests

Four nurseries are used for raising progenies by the nursery technique described by Faulkner (1967) and over 200, mainly half-sib (open pollinated), progenies are now planted annually under forest conditions. Sitka spruce has the highest priority and this species is normally tested on eight forest sites representing the principal planting areas for the species in Britain. The Lodgepole pine programme is increasing as a consequence of the greater availability of seed from the tree banks. The Scots pine programme is being curtailed following the rapid decrease in interest in this species. Table 11 provides a summary of the present situation for the more important species.

The useful information now being obtained from the forest trials is substantial and is expected to increase during the next decade before levelling out at the point where new experiments will counter-balance those which will be completed and written-up. A programme for an IBM 1130 computer has now been prepared to meet this problem; the programme will accept unprocessed routine data.

Early results from trials planted in 1966 are very promising; several progenies are growing well and demonstrating good adaptability to a variety of site conditions—a most important attribute for British conditions where forest sites are extremely varied.

Early-tests

In earlier trials hybrid larch was successfully grown under glasshouse conditions at Alice Holt and under the improved glasshouse facilities at the Northern Research Station an attempt was made to force the rate-of-growth of both Douglas fir and Lodgepole pine seedlings. As with hybrid larch it was

found that six months after sowing it was possible to produce well balanced Douglas fir seedlings up to 200 mm tall under conditions of natural day-length and with air and soil temperature of 15°C and 20°C respectively. By extending the day-length to 18 hours plants up to 400 mm tall were obtained. These plants were, however, spindly and had poorly developed branches and it was difficult to induce a state of dormancy in them—even after periods of low ambient temperatures and short, 8-hour (December) day-lengths. Lodgepole pine behaved abnormally in the glasshouse under natural and extended day-length conditions. Excessive prolepsis and lammas development occurred giving rise to bushy, stunted plants.

TABLE 11
NUMBERS OF PARENT TREES BY SPECIES REPRESENTED IN PROGENY TESTS

Species	Number of parent trees represented in progeny tests				
	Nursery-stage experiments	Forest-stage experiments			
		Half-sib	Half-sib	Full-sib	Number
Scots pine	77	396	128	63	41.6
Lodgepole pine	48	85	4	20	6.0
Corsican pine	0	48	7	11	4.7
European larch	0	57	32	} 23**	} 5.8**
Japanese larch	0	30	30		
Sitka spruce*	189*	166	7	39	47.2
Douglas fir	0	133	24	14	11.0
Western red cedar	0	14	0	3	0.2
Beech	40	19	0	2	1.3
Oak	0	17	0	1	0.4
Total	354	965	232	176	109.3

* Includes 134 trees in a special population study.

** Mainly hybrid larch.

Early-test work was again mainly concerned with Sitka spruce. Data from two-year-old glasshouse-raised plants from the Sitka spruce diallel cross (see the *Report* for 1971) were analysed; these showed a good correlation with the inheritance patterns revealed by the first-year data.

Repeatability of results is of major importance in any programme of progeny testing. In order to obtain data from which to calculate correlation coefficients for "between-year" results in a glasshouse environment, ten controlled crosses from the original Sitka spruce diallel cross, were re-sown and grown for one season under glasshouse conditions similar to those used in the previous year. The crosses were chosen on the basis of extremes in growth-rate, stem and branch form and other characters. The results are being analysed but, from visual checks, it seems fairly certain that the between-year correlations will be quite strong.

An experiment to determine the effect of seed size on the growth of individual progenies of Sitka spruce was conducted in the glasshouse. The object was to obtain data from which end-of-season height correction factors could

be calculated. Additional correction factors may be required to take into account the actual dates of germination.

Biochemical Variation

Variation in the polyphenol composition of Sitka spruce shoots is being studied by thin-layer chromatography (TLC) and gel-filtration to determine the correlations, if any, between polyphenol composition and vigour. If there is a correlation, polyphenol composition could be used as an early stage selection criterion.

Sitka spruce is rich in a variety of polyphenols, but preliminary work showed that TLC could not be used to separate provenances reliably. Within a plant, stems differed from leaves in having fewer and lower concentrations of polyphenols, and were characterised by high stilbene levels which were low or absent in leaves. In mature trees stilbenes, which may be precursors of the tannins, reached very high levels in the bark.

Separation of leuco-anthocyanins (a class of tannin precursors) by gel-filtration on Sephadex columns gave three basic peaks corresponding to polymeric, oligomeric, and monomeric components. The monomeric peak

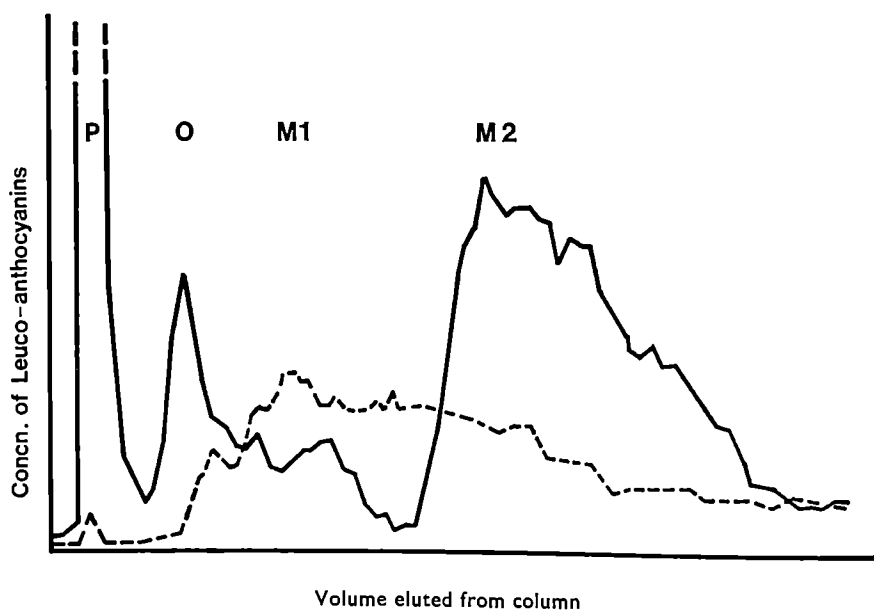


Figure 6: (Biochemical Variation). Separation of leucoanthocyanins in one-year-old leaves (—) and bursting buds (---) of Sitka spruce, using Sephadex columns. P = Polymer, O = Oligomers, M1 = Simple monomers, M2 = Complex monomers.

was composite and sub-divided into two peaks of simple and complex monomers by adsorption rather than exclusion chromatography. The method is quantitative, and showed differences between trees which were not detectable with TLC. A very marked seasonal variation in the leuco-anthocyanin pattern was shown by a gradual increase in both molecular size (polymerization) and complexity as stems and leaves developed and matured (Figure 6). There was no constant distinction between the patterns obtained from stems and

leaves, but generally stems had more polymer and less monomer than leaves ; often the current year's leaves had no polymer. During their second growing season, stems and especially leaves accumulated high levels of polymer.

This and other polyphenol assays were applied to a series of Sitka spruce grafts which had received different temperature regimes in growth-rooms. In each of two provenances it was shown that the regimes caused marked differences in polyphenol levels, but in all cases the inherent differences between the clones overrode variation due to treatments.

The analysis of current year's shoots of five Sitka spruce provenances showed as much variation within as between provenances.

Assay of Sephadex column fractions for total polyphenol by UV-absorption, rather than for leuco-anthocyanins, was found to give a series of peaks, some of which could be identified by TLC of the fractions. In stem extracts, some of the most prominent peaks were due to the stilbenes (Figure 7). There were strong indications that definite between-provenance differences existed and

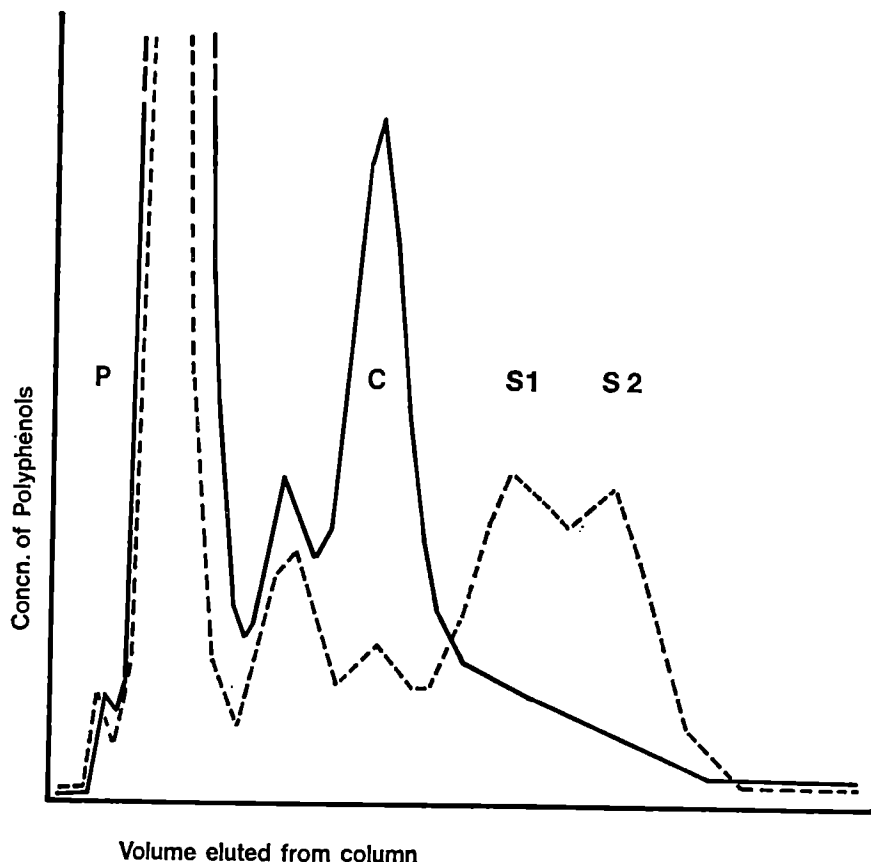


Figure 7: (Biochemical Variation). Separation of total polyphenols in one-year-old leaves (—) and one-year-old stems (---) of Sitka spruce, using Sephadex columns. P = Polymer, C = Catechin, S1 and S2 = Stilbenes.

particularly in the stilbene peaks. Analysis of shoots (leaves and stem) from different parts of a young Sitka spruce tree showed a gradual decrease in the stilbenes and an increase in the catechins from upper well-lit shoots to the lower shaded shoots which were primarily due to the increasing ratio of leaf stem material; it seemed probable that two-year-old stems would provide the best material to sample. A study of the variation in the polyphenol patterns obtained from such material collected from two 5 m tall trees showed that at a given level on a tree there was a remarkably little variation in the pattern, but in each tree there was a gradual increase in the height of the second stilbene peak towards the top of the tree. Lateral two-year-old stems produced a more constant pattern and were richer in stilbenes than the terminal two-year-old stems of a branch. From these observations it was concluded that two-year-old lateral stems taken from the upper branches of a tree provide the best sampling material.

A study of the within- and between-provenance variation in Sitka spruce on four distinct sites in different parts of Britain has recently been initiated.

Section Organisation

Since 1948 each senior member of staff has been responsible for the entire breeding programme associated with one or more species; the effort devoted to each programme being broadly related to the commercial importance of the species. In recent years a state of imbalance developed as a consequence of the greater importance attached to the Sitka spruce project. Re-organisation became necessary to correct the growing imbalance between the workloads of different members of staff and also to develop a greater degree of specialisation by individual workers in the main activities of the Section. This re-organisation was affected in August 1971, the main result of which was the delegation of responsibilities for all activities associated with Plus tree selection and propagation, seed orchard and tree bank establishment and wood investigations to Dr. A. M. Fletcher; all activities associated with crossing programmes and the progeny testing to Mr. R. C. B. Johnstone; and phenological records and bio-chemical variation investigations to Dr. G. I. Forrest. Seed stand surveys, the maintenance of the Register of Seed Sources and seed certification continue to be the responsibility of Mr. R. Faulkner. As a consequence of the re-organisation all Genetics Section staff previously based at Alice Holt have now been re-deployed either at the Northern Research Station or at other forest research centres.

R. FAULKNER
A. M. FLETCHER
R. C. B. JOHNSTONE
G. I. FORREST

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TREE PHYSIOLOGY

The Physiology Section was started in 1968, and has now completed two years work at the Northern Research Station. Its programme of research consists chiefly of "whole-plant" physiology, involving studies of the effects of external and internal factors upon tree growth and development. In comparison with other crops, little is known about the influence of specific climatic and soil factors on the production and growth of the various organs of the forest tree, or about the controlling systems inside it. It is a great deal easier to identify and examine these one by one under circumstances where the other conditions are kept constant, for example by experiments with clonal trees in controlled environments, and much of the physiological work in progress is of this nature.

One of the aims underlying this approach is to develop methods of control, such that flowering, root initiation, the timing and rate of shoot and root growth, and so on, can be governed at will. A second is to link up with field studies, providing a firmer basis for interpreting both research results and growth problems in forestry. Improvements can then be expected in the quality and growth potential of planting stock, in the treatment of the planting site, and in the matching of the two.

Vegetative Multiplication

Work on rooting of cuttings, begun in the Genetics Section (see 1970 *Report*, pp. 107-9), has been expanded, and success with Sitka spruce and Lodgepole pine has led to a good deal of interest and discussion. The aim of the research is to provide a basis for developing reliable methods of rooting clonal cuttings, firstly as a more uniform research tool which can greatly increase the precision of experiments, secondly as an alternative to grafting of selected clones, and thirdly for possible future forest use, should the advantages be as great as they appear to be, and the costs reasonable.

In Lodgepole pine, root initiation was much more rapid when the medium in which the cuttings were struck was maintained at 28° rather than 20°C (see Figure 8), while in another experiment there was no great difference between 28° and 24°C. Future studies will include changing the temperature of the bed once roots have been formed, since the optimum temperature for root elongation may well be quite different. Stimulation of root initiation by hormones was clearly shown, 0.1 per cent indolebutyric acid + 0.1 per cent naphthalene acetic acid, applied as a rapid methanolic dip, producing 95 per cent rooted plants after 8 weeks, compared with 48 per cent in the controls, and 24 per cent when the auxins were at 0.25 per cent. The best estimate so far of the optimal exogenous hormone supply is 4.5 micrograms per plant. If too much is added root growth may be inhibited, or in extreme cases the leaves may senesce and the plant die.

Perhaps the most far-reaching discovery in this field was that roots of two different types could be produced, depending upon the auxin levels. With no

hormone, the roots were all fine and branched ; at 0.25 per cent all the roots were thick and unbranched in the early stages ; both types occurred at 0.1 per cent (see Plate 7). The prospect of being able to control qualitatively the root systems of planting stock and experimental trees could influence thinking

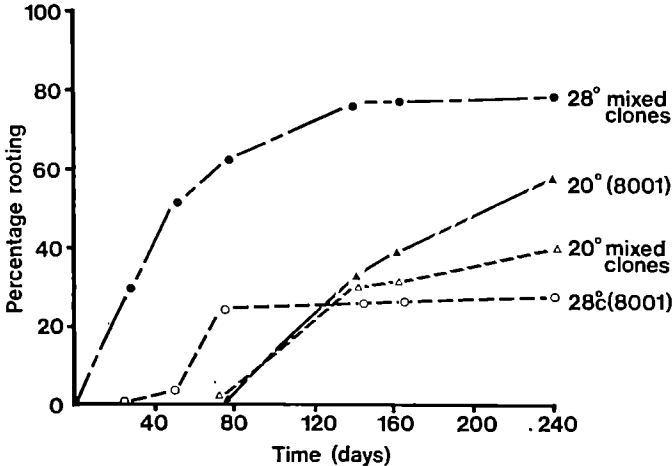


Figure 8: Rooting of Lodgepole pine cuttings showing the effect of bed temperature, in degrees Centigrade.

on both research and forest practice. A detailed study of changing hormonal levels in relation to root production will be started next year, including monthly extractions of root-promoting fractions, and the planting of Lodgepole pine cuttings in a standard rooting environment.

The prospects therefore seem good for this species, which can even be rooted when 40 years old, and also for Sitka spruce, where root initiation can sometimes occur in less than $3\frac{1}{2}$ weeks. Future studies will provide data on the best conditions for root initiation, root growth and handling of cuttings of each species, the effects of physiological condition and age of the vegetative stock-plants, and the hastening of growth and multiplication of selected clones. With a view to the possible wider use of cuttings, the necessary selection of clones, trials of "rootability", establishment of a sufficient supply of vegetative stock-plants and field clonal trials will be undertaken in due course in collaboration with the Silviculture and Genetics Sections.

Flowering and Seed Production

The background for this work was given in the 1970 *Report*, pp. 109–110. It is a very difficult subject to study in forest trees because of the large size and complex branching which has usually occurred before reproductive activity starts, and because of the irregularity of good flowering years in the field. Two techniques have been developed, however, with some of the more responsive species, which allow a measure of control over flowering. This enables other influencing factors to be studied, and from this knowledge reliable, practical flower-stimulating techniques can be developed.

In Japanese larch, removal of a complete ring of bark at the base of branches of "mature" grafts stimulated flower initiation in a good year for flower formation (1969), an average of 59 per cent of the buds being floral, compared with 33 per cent in the control branches and 48 per cent when two half-rings about one cm apart were used. Moreover, the proportion of the flower buds which were female was also increased by complete ringing, so that the total number of female cones is very much greater. In European larch the position is similar, and it was also discovered that there were highly significant effects of gravimorphic treatment, a greater proportion of female cones being formed in branches which were trained horizontally or fixed in their original position, while branches tied down had more male cones. In these experiments, there were not any notable effects of treatment upon flower opening times, as had been found with larger trees of seedling origin whose stems had been partially ringed. A combination of rapid early growth, complete ringing and horizontal treatment induced 6 female and 91 male flowers in a hybrid larch seedling, which emerged before it was three years old.

Most progress has been possible with Western red cedar, because this species has a number of favourable characteristics. While flowering tends to be rather sparse or absent except in older trees and in favourable years, the stimulation with complete ringing is remarkable, up to 1800 female cones having been formed on a single branch, with male flowering estimated at around 25,000. Even though the averages are somewhat lower, the potential seed production from a whole tree is clearly enormous, and techniques of ringing selected trees before thinning are to be investigated.

Cuttings from old trees of this species often root easily, especially with added hormone, and when rooted can be grown on without problems of bud dormancy. After about 12 months in a warm greenhouse under long-days, when the trees are about 30–50 cm high, a few mainly female cones may be produced. Thus for the first time potted clonal material with the capacity to flower was available for the testing under known conditions of factors which cause a tree to flower. There have, of course, been many reports that good seed years follow hot, dry summers, but little or no experimental indication as to whether the drought, the higher temperatures or the high insolation, or a combination of these or other factors, was involved.

A series of experiments with potted cuttings in growth rooms began with the demonstration that air temperature and day-length were involved in flower initiation and that they interacted together. (See Table 12.)

TABLE 12
FLOWERING IN *Thuja plicata* IN CONTROLLED ENVIRONMENTS

Female	Day-length (hours)			Male	Day-length (hours)		
		8.75	19.75			8.75	19.75
Temperature (°C)	15°	2.6	6.5	Temperature (°C)	15°	1.0	0.0
	25°	3.0	29.3		25°	12.0	380+

Only when the trees received both long-days and warm temperatures did they initiate substantial numbers of male and female cones. A second experiment showed that at 20°C female cones were formed at a day-length of 19½ hours, to a much greater extent than at 16½ hours or less. In the third investigation, female flower formation was much greater at 16½ hours when the temperature was a constant 20°C than when the day was at 20° and the night at 8°C. A final experiment in the series showed that complete ringing of the main stem greatly stimulated male and female flower initiation and even brought some young seedlings into flower in their second year. Temperatures of 24°C, and particularly 28°C, led to very much heavier flowering (even up to 7,000 cones per plant), than either 20° or 16°C. These effects are clearly due to temperature, since the total light intensities, day-lengths, evaporative power of the air (vapour pressure deficit), pot sizes, compost, watering, nutrient addition and fresh-air supply were the same for all four growth rooms.

Future studies will cover the stages after the original initiation, which lead up to pollination and seed formation, and will include the role of hormones. The experience gained will be used to attack the problems in other species, notably Lodgepole pine and the more difficult case of Sitka spruce.

Control of Shoot Growth and Bud Dormancy

The growth rooms, greenhouses and cold rooms have been used for a considerable number of experiments and studies of shoot growth, again aimed at understanding, and then being in a position to control, the growth in length of the shoot system. Under favourable conditions a Wych elm cutting may grow more than two metres tall in its first year, while at the other extreme a small pine fascicle bud cutting may grow only one centimetre in a similar environment. The internal factors which lead to prolonged bud dormancy are not well understood, nor the differences between the growth habits and optimal requirements of various species, and so there are unnecessary delays and losses in the production of research plants, rapid growth of vegetative stock plants, etc.

An example is work on Sitka spruce in a joint study with the Department of Forestry and Natural Resources of Edinburgh University (p. 141 of the 1971 *Report*), in which "juvenile" cuttings grew continuously at a constant rate under long-days at 20°C in the growth rooms, producing a sequence of growing laterals in the way that is found in first-year seedlings. Day-lengths of 13½ hours were sufficiently short to stop first the out-growth of laterals, and then the elongation of the main stem, while at 10½ hours elongation stopped earlier, indicating a quantitative effect of day-length. Another new feature of these controlling agencies which was discovered was that after a prolonged growth period the spruce would form terminal buds with a 20° day and 8°C night, even though the days were still long, while controls at a constant 20°C continued to grow. Thus temperature as well as day-length influences the onset of bud dormancy. This will be further studied in relation to provenance and clonal differences in bud-setting and production of a second flush under forest conditions.

The Physiology of Tree Roots

Investigations into the effects of internal and environmental factors on root growth and development of Sitka spruce and Lodgepole pine are being started, using clonal material and seedlings. Apparatus is being developed which will permit soil temperatures to be controlled independently of the temperature of the air, and in addition allow frequent inspection and measurement without the roots being disturbed. In this way, direct effects can be distinguished from root/shoot interactions, and the immediate and longer-term effects of, for example, the gaseous environment in the soil and mycorrhizal infection, can then be made in a known and "steady-state" system. These controlled environment studies will be made in conjunction with field measurement of the timing and direction of root growth.

K. A. LONGMAN

M. P. COUTTS

M. R. BOWEN

FOREST PATHOLOGY

Death and Decay Caused by *Fomes annosus*

Deaths on Alkaline Sites

Assessments of established experiments supported the conclusion that stump removal is the most efficient method of eradicating the disease. In one experiment where stumps were removed from an infested site, only three trees (0.4 per cent) have been killed by *F. annosus* in the past three years out of 720 trees at risk. In control plots where stumps were left *in situ*, 114 trees (10.9 per cent) have been killed by the fungus out of 1,045 trees during the same period; all trees were 11 years old. Liaison was maintained with the East England Conservancy who are carrying out large-scale user trials of various machines to remove stumps on areas infested with *F. annosus*. After stumps have been removed from the ground it is simple to achieve bare soil conditions, i.e., to clear the ground of vegetation. Results from experiments have shown that the survival rate and height growth of Corsican pine improved when the trees are planted on to bare soil and this condition is maintained for up to three seasons. For example, in one experiment, the mean height for plants growing on bare soil after three years was 38 cm compared to 27 cm for plants growing on land that is now covered by vegetation, mainly grass, after shallow ploughing before planting.

A study of volume production in healthy and infected Scots pine sample plots in Thetford Forest (Norfolk and Suffolk) was made during the year in order to estimate volume losses which might occur in severely infected Scots pine stands. In one set of sample plots there were four thinning grades: B, L/C, C/D and D grades. The B grade thinning involved the removal of a small volume of timber in the first three thinnings. Those trees which were removed were small and many dead through suppression. The stumps of these trees were therefore unlikely to become infected by *F. annosus* and the B grade plot approximated to a control treatment from the disease point of view. Very few trees in this plot were killed by *F. annosus*. On the other hand, in the C/D grade plot, which is similar to the thinning practice usually employed in Thetford Forest, many more live and vigorous trees were removed in the first three thinnings and severe losses due to *F. annosus* occurred. This plot was on an alkaline strip of soil running through the sample plot area giving ideal conditions for *F. annosus* to cause mortality. Losses from L/C grade and D grade thinning were intermediate and influenced by differing soil pH. No treatment was applied to the stumps created during the first three thinnings to prevent infection.

The total volume produced by two of the plots after 41 years is given below:

B grade plot 401 m³/ha

C/D grade plot 339 m³/ha (including volume of trees killed by *F. annosus*)

C/D grade plot 295 m³/ha (excluding volume of trees killed by *F. annosus*).

As these figures are taken from unreplicated plots, they should be interpreted with caution.

In another set of sample plots in Thetford Forest which were free from *F. annosus*, total volume production after 41 years was 377 m³ per ha in the A/B grade plot and 360 m³ per ha in the D grade plot. It is not considered that the thinning regimes in these plots would, on their own, have any marked effect on total volume production.

It appears that the total volume production of the infected C/D plot (including the volume of trees killed by *F. annosus*) is less than that of any of the uninfected plots. This suggests that *F. annosus* may cause a reduction in volume in addition to that caused by mortality. The root systems of some of the apparently healthy trees may have been severely attacked by *F. annosus*, thus causing a marked reduction in growth.

D. A. BURDEKIN.

B. J. W. GREIG.

Phytophthora Diseases

The Trichoderma Effect

The effect of the common soil fungus, *Trichoderma viride*, in stimulating oospore formation in normally sterile isolates of *P. cambivora* and *P. cinnamomi*, (Plate 4A and 4B) has been the subject of further cultural studies (see *Report* for 1971 and Brasier, 1971).

The testing of isolates of the A¹ and A² compatibility types of *P. cambivora* and *P. cinnamomi* for response to *T. viride* has continued. Of a total of 11 A¹ and 41 A² isolates of these species tested, all 41 A² isolates have responded whereas none of the A¹ isolates have done so. The possibility exists that A¹ isolates may yet be found to respond, if not to *Trichoderma* then to other soil organisms including bacteria and actinomycetes.

As the genus *Trichoderma* contains many soil inhabiting species, experiments were carried out to investigate the ability of different *Trichoderma* species to stimulate oospore formation. All *T. viride* isolates tested were stimulatory, and some isolates of *T. koningii*, *T. polysporum*, and *T. piluliferum* were also active. Isolates of *T. harzianum* and other species were inactive.

The viability and genetic status of oospores formed in response to *Trichoderma* volatiles is of considerable importance. Cytological aspects are being investigated in close collaboration with Dr. Eva Sansome. Nuclear behaviour in the gametangia of selfed A² isolates of *P. cinnamomi* and *P. drechsleri* was strictly comparable to that in gametangia formed in A¹ x A² pairings of these species. Prior to oospore formation, the nuclei underwent two successive divisions, including meiotic prophase and metaphase stages with multiple associations, and the resulting nuclei were roughly half the size of the vegetative nuclei. Stages in fertilisation have been observed. These observations are consistent with the concept of diploidy in these organisms (Sansome, 1965).

A very few oospores from selfed A² *P. cambivora* and *P. cinnamomi* cultures have been germinated and have yielded A² progeny cultures resembling the parent isolates in morphology. In contrast, many progeny cultures from a selfed A² isolate of *P. drechsleri* were morphologically and physiologically variable, though again all were of the A² compatibility type. Variation in the progeny of a selfed isolate is again consistent with gametangial meiosis and diploidy or polyploidy in the vegetative state.

Whether the *Trichoderma* phenomenon occurs in nature, so that oospores are formed without mycelium of both compatibility types present, is of particular interest, as the thick walled oospores would probably provide both a means of survival and a potential source of genetic variation. Mircetich and Zentmyer (1966) obtained oospores and chlamydospores when they buried mycelial mats of *P. cinnamomi* in soil. We have repeated their work (Plate 4.) and have confirmed their results in every detail. We have also recently observed both A¹ and A² isolates of *P. cambivora* producing oospores in abundance when freshly isolated from soil, though the ability was lost on transfer. It is therefore apparent that a *Trichoderma* type of effect does occur in soil, though other soil organisms may also be involved.

Trichoderma viride has long been known as an antagonist of *Phytophthora* and other fungi. We regularly observe antagonism of *Phytophthora* by volatiles of *T. viride*, including inhibition of growth (Plate 4.), vacuolation of cell contents, and lysis of hyphal tips. The formation of resistant oospores by *Phytophthora* at the approach of the mycelium of such an antagonistic fungus might clearly be of importance in its survival. *T. viride* is common in soil and on root surfaces, and has often been noted as replacing primary pathogens in woody material. It is therefore likely to be an early invader of root tissues recently damaged by *Phytophthora* attack.

We have carried out a brief survey of the frequency of the compatibility types among isolates of *P. cambivora* and *P. cinnamomi* from trees and shrubs in this country. At present, the A² appears to be predominant over the A¹ in *P. cambivora* (12 A² and 3 A¹ isolates) and in *P. cinnamomi* this predominance appears to be complete (26 A² and no A¹ isolates). It is possible that this predominance reflects a selective advantage to A² isolates over A¹ isolates in nature. It appears that the chances of oospores being formed by the pairing of A¹ and A² isolates in nature may be fairly small, and that the formation of oospores by selfing of single isolates in response to *Trichoderma* or other organisms may be of greater importance.

C. M. BRASIER.

Dutch Elm Disease (see also p. 101)

During the summer of 1971 Dutch elm disease again caused great concern and reliable information was urgently needed on the size of the elm population and the proportion affected with disease. To this end the Pathology and Statistics Sections of the Research Division collaborated with the Field Survey Branch of the Management Services Division to conduct a ground survey of the elms of Southern England. The survey was carried out between mid August and mid September and covered five hundred and sixty-six 10 km

squares. In each 10 km square three random 10 ha strips were selected and the number of elms over 6 m high recorded. These trees were classified accordingly to site, species and size. They were also assigned to six disease categories ranging from healthy to long-dead.

The main results can be summarised as follows. The estimated elm population in the survey area was 18 million trees of which 56 per cent were English, 29 per cent Smooth-leaved and 15 per cent Wych elm. Eleven per cent of all the trees were in non-rural sites, 49 per cent in rural, non-woodland sites, and 41 per cent in woodland.

Of the 18 million trees it was estimated that 1,650,000 (9 per cent) had disease symptoms affecting up to half the crown, 376,000 (2 per cent) had symptoms affecting more than half the crown and 204,000 (1 per cent) were recently dead. There was also 205,000 long-dead trees.

There were pronounced regional differences, the disease being most severe in the West Midlands, in some of the eastern counties and along part of the South coast. Where comparisons could be made, English elm was more affected than Wych elm. Trees in rural sites were the most affected and woodland trees the least. More detailed results may be found in Forest Record 82 (Gibbs and Howell, 1972).

During 1971 research was also conducted on a variety of projects related to Dutch elm disease. In particular, variation in the pathogenicity of the causal fungus *Ceratocystis ulmi* was examined in a series of inoculation experiments carried out at Alice Holt and at Wageningen in Holland; the latter in conjunction with H. M. Heybroek. The results of these experiments have been published in a letter to *Nature* (Gibbs, Heybroek and Holmes, 1972). From this work it appears that an unusually aggressive strain of *C. ulmi* exists in Britain at present and that this is responsible, at least in part, for the current severity of the disease. It also appears that some of the clones bred in Holland for resistance to the disease are susceptible to this strain. Work is in progress to examine the aggressive isolates further and to study their performance against a full range of elm material.

J. N. GIBBS

Advice on Dutch Elm Disease Control

More than 200 enquiries were received in relation to the current outbreak of Dutch elm disease. These enquiries came from a variety of sources including members of the general public, television, press and other news media, and local authorities. Two Forestry Commission publications, *The Dying Elms* (Research and Development Paper 78) and *Dutch Elm Disease* (Leaflet 19, HMSO 8p), provided a useful means of informing members of the general public about the cause of the disease and about measures necessary for control, i.e. a programme of sanitation felling and burning of severely infected trees. Felled diseased elms are shown in Plate 5 (see central inset).

Several members of the Pathology Section appeared on television and radio to give nationwide publicity to the problem. Additionally, press reports gave further information to the general public about the disease.

Following the introduction of the Dutch Elm Disease (Local Authorities) Order 1971 and subsequent Orders, there was increased liaison with local authorities.

In October, a series of three conferences was held with representatives from local authorities in the affected areas to discuss future strategy for the control of the disease. It was clear that not all dead and dying trees which might act as a source of beetles and hence infection for the following season could be felled, and it was suggested that highest priority should be given to those trees on the fringes of severe outbreak areas and those present in scattered foci of infection. As the disease does not cause deterioration of the wood, the marketing of utilizable timber could help offset the costs of control.

D. A. BURDEKIN

Beech Bark Disease

The *Nectria* sp. associated with bark necrosis following infestations of the Beech scale *Cryptococcus fagi* has been studied in culture. Typical asexual spores of the imperfect genus *Cylindrocarpon* are formed on 2 per cent malt agar within three weeks at 22°C. Sporulation is enhanced by the use of a near ultra-violet light bench. Macroconidia are cylindrical, slightly curved, with rounded ends, 0-8 septate, and generally agree in size with those of *C. candidum*, the conidial state of *Nectria coccinea*. Fertile perithecia have developed within three months when fresh single ascospore isolates of opposite mating types were crossed on 1 per cent malt agar, and placed under near ultra-violet light. This observation on the heterothallic nature of *N. coccinea* agrees with that of Booth (1966).

TABLE 12
RESULTS OF INOCULATIONS ON BEECH

Inoculum	Number of trees	Method of inoculation	Number of cankers formed
None (Control)	12	No wound	0
		Knife wound	2
		Perforations	1
Branch isolate	12	No wound	0
		Knife wound	11
		Perforations	11
Trunk isolate	12	No wound	0
		Knife wound	8
		Perforations	8

Date of inoculation: 12th November, 1970.

Date of sampling: 11th January, 1972.

In a field experiment, 26 year-old beech trees were inoculated with single ascospore isolates obtained from *Nectria perithecia* found on a branch and trunk of beech. Trees were inoculated without wounding, through knife wounds, and through perforations made in the bark. Inoculation points were at heights of 0.6, 1.2 and 1.8 m on the main trunk.

The results of these inoculations can be seen in Table 13. No cankers were formed without wounding and the three infections which occurred in the uninoculated control treatments were probably the result of natural infection. Pathogenicity was confirmed by the successful re-isolation of the *Nectria* sp. after 14 months from cankers surrounding the points of inoculation.

In a forest affected by Beech bark disease, regular observations on selected trees over a two-year period have provided evidence on symptom progression, and showed an average mortality rate of about 5 per cent per annum.

E. J. PARKER

Dieback of London Plane

As described in the *Report of 1970* (pp. 117–118) there is an apparent association between this disorder and the over-rapid thawing of twigs and small branches in unusually cold and sunny winter periods. The London plane population of Central London consists of genetically varied individuals and clones, some of which appear resistant to dieback.

In the winter of 1970–71 a collection of twigs was made from two apparently resistant trees, V59 and M15, and from three susceptible trees, GP5, GP6 and M9. The two seemingly resistant trees had remained healthy in situations where dieback was generally severe in 1969, and the three susceptible had suffered moderate damage that year.

Ten twigs from each tree were subjected daily to a slow thaw for ten days, and equal numbers were similarly subjected to a rapid thaw. In the two automatically controlled chambers used for the treatments, the daily air temperature regimes started with a three-hour descent from 14°C to -6°C, which was then maintained for 9 hours. Thereafter the slow thaw chamber rose to -1°C in two hours, to 3°C in a further 7 hours, and to 14°C in the remaining 3 hours, while the rapid thaw chamber rose to 14°C in two hours, and maintained that temperature for the remaining 10 hours. The twigs stood separate and upright, with their lower ends in seed trays filled with a moistened sterile rooting medium and covered with expanded polystyrene through which the twigs passed. After the treatments, the trays with their twigs were placed under mist in a greenhouse. Bud development was assessed at intervals, the buds being scored as follows: 0, unopened; 1, opening; 2, leaf or flower emerging; 3, two leaves emerged; 4, three leaves emerged, and so on. The results of the final assessment on May 19 1971, some six weeks after the treatments ended, are summarised in Table 14.

TABLE 14
HEALTH RATING OF LONDON PLANE CLONES SIX WEEKS AFTER SUBJECTION TO
SLOW AND RAPID THAWS

(1) Clone	(2) Thaw	(3) Buds with live growth per cent	(4) Mean score of live growth	(5) Health score (3) × (4)
V59 (r)	S	39	3.5	137
	R	56	3.1	174
M15 (r)	S	25	3.9	98
	R	25	3.9	98
GP5 (s)	S	14	2.7	38
	R	7	2.4	17
GP6 (s)	S	27	2.2	59
	R	13	2.4	31
M9 (s)	S	19	1.8	34
	R	2	1.5	3

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

Col. (2): S = slow; R = rapid.

Survival of buds or of growth from buds was generally low and was highest on the rapidly thawed apparently resistant V59 twigs. The other apparently resistant clone, M15, showed no difference between treatments. In marked contrast, the three susceptible clones showed much lower survival in the rapid thaw treatment than in the slow.

C. W. T. YOUNG

Dieback of Corsican Pine

An experiment in which new unwounded shoots of Corsican pine were sprayed in May and June with a suspension of *Brunchorstia pinea* conidia in water gave results similar to those obtained by Gremmen (1968) with both conidia and ascospores. The earliest symptoms of the disease, fresh resin exudation from buds, appeared in December on nine out of ten plants sprayed in May, and on five out of ten sprayed in July. In late March complete death of some shoots was apparent, and pycnidia were developing on dead buds. Control plants sprayed with water alone remained healthy.

Two likely prerequisites for epidemic outbreaks are the perfect state of the fungus, *Scleroderris lagerbergii*, to provide windborne ascospores for widespread infection, and wet conditions in the growing season to favour discharge of ascospores (Skilling, 1969). In Thetford Chase (Norfolk and Suffolk), where outbreaks appeared in young crops early in 1969 and 1970, a search for apothecia of *S. lagerbergii* was made at intervals during 1971. While pycnidia were abundant on dead shoots, only one apothecium was found. It appears that some as yet undetermined factor may restrict development of apothecia in certain years.

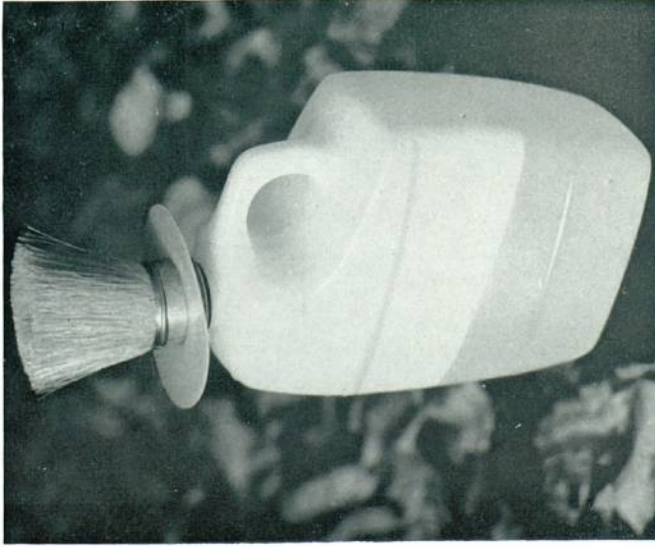


PLATE 1. Work Study (p. 127).
A cheap stump treatment bottle developed jointly by Pathology
Section and Work Study Branch for the control of *Fomes*
annosus.

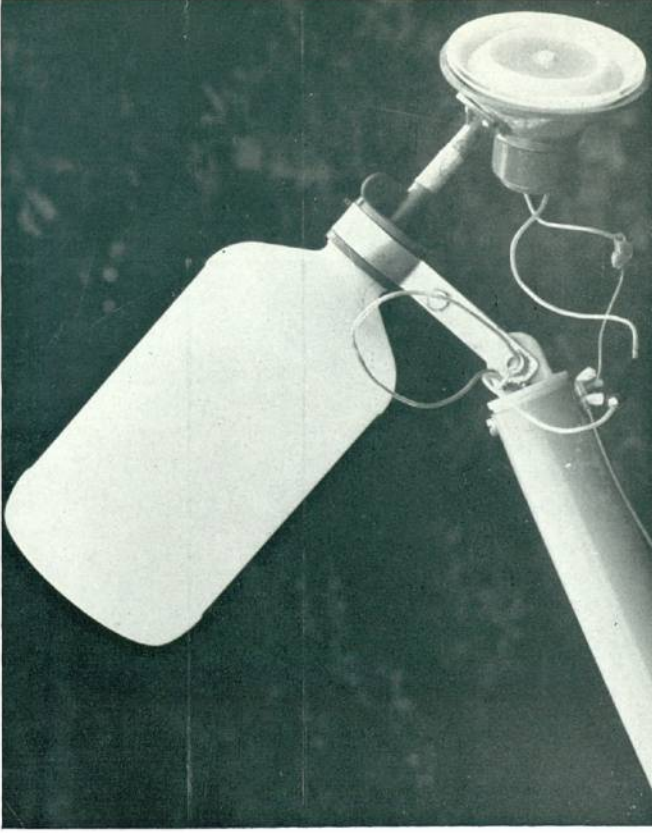


PLATE 2. Work Study (p. 126).
Ultra low volume (ULV) portable battery-operated sprayer.

PLATE 3. Timber Utilisation
(p. 132).

Bark used for mushroom culture. Experiments have shown that pulverised pine bark can be used in place of peat for the casing, which covers the compost in mushroom growing.

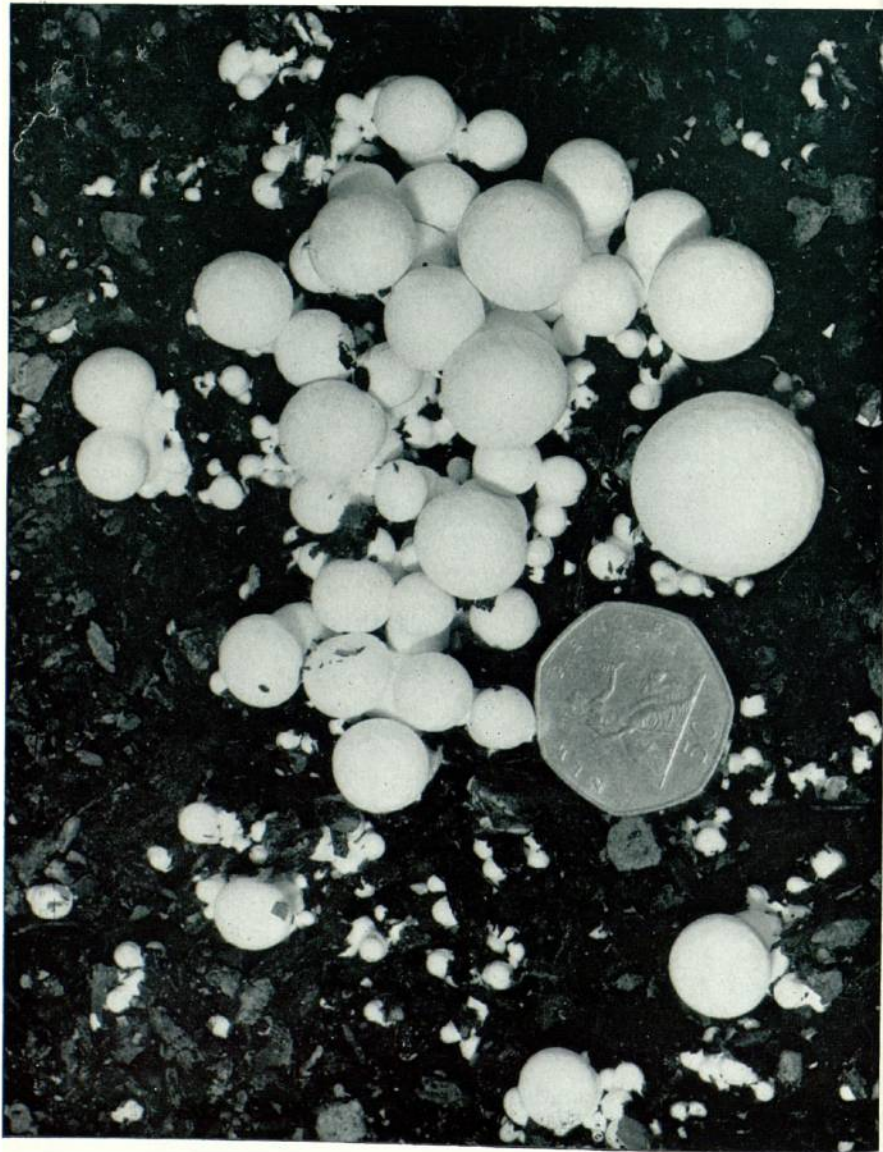


PLATE 4. Forest Pathology (p. 89).

A. *Phytophthora dis-eases*—The *Trichoderma* effect. Oospores of *Phytophthora cinnivora* formed on agar in response to volatiles of *Trichoderma viride*.

B. As above, enlarged to show thick-walled coospores.

C. Germinating chlamydospore of *P. cinnivora*, formed on mycelium buried in soil.

D. Inhibition of growth of *P. cinnivora* by volatiles of *T. viride*. The right hand culture was exposed to *T. viride* after four days growth (arrowed). The left hand culture is a control.

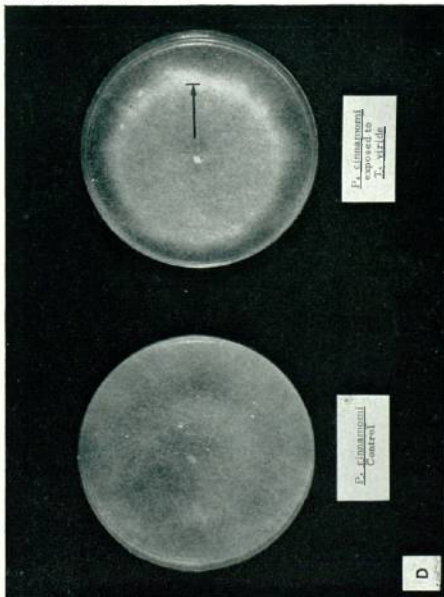
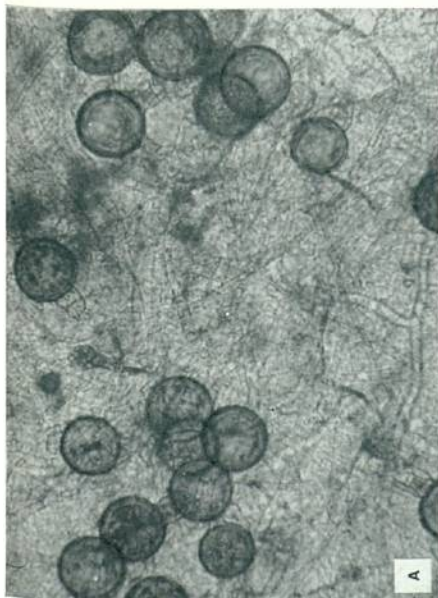


PLATE 5. Forest Pathology
(p. 91).

Aerial photograph of felled
trees suffering from Dutch
elm disease.





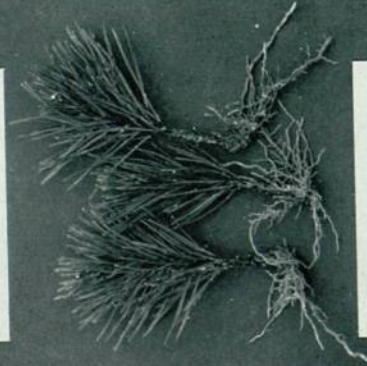
PLATE 6. Planning and Economics (p. 119).

Planning and Economics Branch have been testing the use of 35 mm oblique aerial photographs in estimating recreational use of the New Forest. This photograph of Ober Heath shows people's preference for camping at the edge of open areas. A. 4827

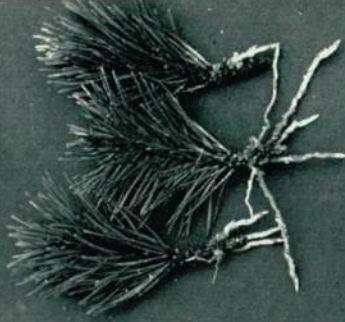
LP (Hybrid)
cuttings
clone 8021
7 weeks



0.1% IBA
+
0.1% NAA
in Me oh



Control
Me oh



0.25% IBA
+
0.25% NAA
in Me oh

PLATE 7. Tree Physiology (p. 84).

Cuttings of selected Lodgepole pine clones from inter-provenance hybrids (LP 8021 Q C 1 x Olympos) showing the effect of hormone concentrations on the type of root formed.



PLATE 8. Production and Use of Planting Stock (p. 29).

Part of a plot at Naver, Borgie Forest (Sutherland) planted with 8-week-old Lodgepole pine tubed seedlings in early September 1967 and photographed at the end of the 1970 growing season. Poorly flushed hill peat site, with single mouldboard plough ridges stepped prior to planting. A. 3853.



PLATE 9. Production and Use of Planting Stock (p. 29).

Close-up view of a representative Lodgepole pine plant in the plot shown in PLATE 8. Note vigorous current growth and well balanced crown, with little sign of basal bowing. A. 3855.

PLATE 10. Forest Genetics
(p. 76).

On the right, inbred Douglas fir progenies growing at Alice Holt derived from self-pollinated flowers on a single mother tree. On the left, outcrossed progenies of the same age derived from the same mother tree but from controlled pollinations using a mixture of pollens from an unrelated population.



A marked decline in the disease was observed in the Thetford outbreak areas in 1971. Whether apothecia were numerous or not in 1970 is unknown, but the exceptionally dry summer would not have favoured infection of developing shoots.

C. W. T. YOUNG

R. G. STROUTS

Disease Survey in Scotland

This survey is now complete and results for the last Scottish Conservancy (South) are given in Table 15. The methods used were briefly described in the 1970 *Report*, in which results for West and East Scotland Conservancies are also given. The results for North Scotland Conservancy appear in the 1971 *Report*.

TABLE 15
INCIDENCE OF UNHEALTHY CROPS IN SOUTH SCOTLAND CONSERVANCY

	Scots pine	Lodgepole pine	Japanese larch	Norway spruce	Sitka spruce	Total
Number of crops sampled	19	5	14	41	52	131
Per cent affected	11	60	7	37	21	24

Although nearly 25 per cent of crops sampled are recorded as affected, a large proportion of these records only signify the presence, frequently on less than 5 per cent of crop trees, of such relatively minor disorders as lightning damage and drought crack or of such minor diseases as that caused by *Chrysomyxa abietis* on Norway spruce.

While there were one or two cases each of bent top (Sitka spruce), check (Norway and Sitka spruces), *Armillaria mellea* (Norway spruce and Scots pine), *Cucurbitaria piceae* (Norway spruce), shoot die-back (Scots and Lodgepole pine) and *Chrysomyxa abietis* (Norway spruce), the major "disorders" were stem damage by deer on Norway spruce (two crops) and Lodgepole pine (three crops), and extraction damage in Sitka spruce (six crops) and Norway spruce (seven crops). In one Norway spruce crop some of the extraction wounds were infected by *Fomes annosus*.

Comparison of results for the four Scottish Conservancies shows that the proportion of crops with at least one disorder varied from 18–39 per cent with a mean of 30 per cent. Lodgepole pine, Norway spruce, Sitka spruce and Japanese larch kept the same relative positions in each Conservancy when ranked in order of decreasing incidence of disorder. In Scotland as a whole 63 per cent of all Lodgepole pine crops examined had at least one disorder whereas the figures for Norway spruce, Sitka spruce and Japanese larch are 42 per cent, 27 per cent and 3 per cent respectively.

D. B. REDFERN

Advisory Service (Alice Holt)

Excluding the numerous enquiries on all aspects of Dutch elm disease, 367 enquiries were received. Of these, 104 concerned disorders in woodlands and plantations, 47 in nurseries and 211 in parks and other ornamental plantings. There were 61 enquiries from Forestry Commission staff. Visits were made in the course of 75 investigations. In 30 cases of damage the cause was not determined on investigation and in 36 cases the specimens and information supplied were inadequate for diagnosis. A further 29 are still under investigation. Damage was attributed to parasites in 133 cases and to non-living agencies in 44.

Apart from Dutch elm disease, the most frequently recorded diseases were those caused by *Armillaria mellea* (33 cases) and *Verticillium dahliae* (eight cases). There were six confirmed and seven probable cases of *Phytophthora* root rots and stem cankers, and six cases each of *Nectria* cankers, *Marssonina salicicola*, *Melampsora pinirotqua* and *Botrytis cinerea*.

Most damage attributed to non-living agencies was the result of cultural malpractice.

Notable cases

Large numbers of 2 to 3 m high standard ornamental *Acer*, *Ulmus* and *Sorbus* species in three widely separated nursery fields in south Hampshire were badly damaged by *Phytophthora* root rot. *P. cambivora* and *P. megasperma* were isolated from dying roots of some *Acer* species and from soil around affected trees of all genera. Infection apparently occurred between the 1970 and 1971 growing seasons, but foliar symptoms were not severe until June 1971.

During August and September 1971, reports were received from seven widely scattered sites in southern England of wilting of Indian bean trees (*Catalpa bignonioides*). Isolations made from brown streaks immediately beneath the bark of wilted branches from three sites yielded *Verticillium dahliae*. *Catalpa* is well known to be susceptible to the disease in the USA, but these appear to be the first records on this host from elsewhere.

Numerous reports were received in late summer from the southern half of Britain of damage to sycamore (*Acer pseudoplatanus*) "resembling Dutch elm disease" in the sudden wilting of parts of the crown. The cause was commonly bark-stripping by squirrels.

In September 1971, following the discovery of a woman's dismembered body in three shallow graves in woodland near Leatherhead, Surrey, we were asked to examine graveside trees for damage that would show when the graves were dug. The damage appeared to have been done at some time during the 1968/69 dormant season. It later transpired that a newspaper used for packaging the contents of one grave was dated December 5, 1968.

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

Advisory Service (Northern Research Station)

One hundred and sixteen enquiries were received during the year, 52 of them from the Forestry Commission. Sixty-three concerned disorders occurring in woods and plantations, 28 concerned disorders in nurseries and 25 disorders in parks, roadside trees and other ornamental plantings. Twenty-five visits were made in the course of investigations. Fourteen enquiries remain unsolved and 15 are still under investigation. Sixty of the disorders investigated were caused by parasites and 27 by non-living agencies.

The most frequently recorded diseases were those caused by *Armillaria mellea*, *Fomes annosus* and *Pythium* species. Damage due to non-living agencies was mainly caused by misuse of herbicides and by frost.

The disease most frequently recorded in nurseries was damping-off and root rot of first-year Lodgepole pine and Sitka spruce seedlings caused by *Pythium* species. Another root disease, caused by *Helicobasidium purpureum*, killed patches of Sitka spruce transplants in one private nursery established in a walled garden.

Dieback of two-year-old Lodgepole pine seedlings was observed in a nursery in North Scotland. This disease was last reported more than 20 years ago (see *Report* for 1959) from six nurseries in the same area. It was ascribed to *Ascochyta piniperda*, a fungus which is more usually associated with dieback of Sitka spruce transplants. However, the fungus associated with the present occurrence on Lodgepole pine was identified as *Sirococcus strobilinus* (IMI 163501) by Dr. B. C. Sutton, Commonwealth Mycological Institute. In addition, inoculation experiments, which were carried out during the first outbreak (see *Report* for 1960) with the fungus isolated from diseased Lodgepole pine, caused infection in that species but not in Norway spruce. Thus it is uncertain whether dieback of Lodgepole pine seedlings and Sitka spruce transplants is caused by two different fungi or by two strains of the same fungus.

Unusual needle damage on Sitka spruce transplants in nurseries and on trees up to seven years old in the forest was associated with widespread and severe early frosts (October 13-15) during which grass minima between -5°C and -8°C were recorded in several nurseries. These frosts were preceded by approximately 14 days of mild weather with maximum day temperatures between 10°C and 20°C and minimum (screen) night temperatures between 5°C and 15°C . Damage mainly occurred in South and East Scotland. Symptoms were very distinctive; damage was confined to 1971 (i.e. current year) needles, and buds were not affected. All needles on affected shoots, except those at the shoot tips which typically remained green, presented a uniform appearance and were either completely reddish-brown or reddish-brown in the middle and green at the base and tip. Occasionally the brown centre patch extended to the needle base. Strong circumstantial evidence based on the distribution of damage in nurseries and forest nutrition experiments suggests that plants of low nutrient status and those of southern provenances were particularly susceptible. Normal frost damage to the succulent tips of seedlings was also common at this time but damage was far less severe on Queen Charlotte Island Sitka spruce than on Washington Sitka spruce.

Several enquiries were received concerning Dutch elm disease but only two cases were confirmed, one in Peeblesshire and the other in Northumberland.

D. B. REDFERN

J. D. LOW

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FOREST ENTOMOLOGY

Pine Looper Moth, *Bupalus piniarius*

Pupal Survey

As a result of the amalgamation of many Commission units in recent years, the number of forest names covered by the annual survey has fallen from 47 to 22 but the number of sample areas is in fact unchanged. The total number of units therefore remains at 51, of which four are private estates in Scotland. In general pupal numbers have decreased, or remained at the same level. This includes Wykeham and the nearby forests at Langdale, Cropton, Dalby (Allerston) and Ampleforth where there was an epidemic population in 1970. Fourteen units have failed to find any *Bupalus* pupae, while the most notable reduction occurred at Montreathmont. Last year the *forest average* for this unit was the second highest in the country at 5.01 pupae per m² (with a highest *compartment average* of 10.8 pupae per m²), whereas this year it has dropped to 1.81 per m² (4.4 per m²).

There has been some increase in certain places. Cannock Chase deserves mention since it jumped from a *forest average* last year of 0.90 per m² to 4.73 per m² (or highest *compartment average* of 2.8 per m² to 11.2 per m²) this year. However, it is at Sherwood (Clipstone) that the pupal figures are dangerously high, though certainly not anywhere near the epidemic proportion that necessitated control measures at Cannock in 1963, and at Wykeham in 1970. The *forest average* at Sherwood has been rising steadily over the last four years, and has now reached 11.47 per m². Six compartments have an average of more than 20 pupae per m², the highest being 49.2 per m². It was in these same areas in 1959 that high pupal counts caused concern though they subsequently collapsed naturally (*Report* for 1960) and indeed may do so again.

Green Spruce Aphid, *Elatobium abietinum*

The mild early months of 1971 appeared to favour the build-up of large colonies of this aphid in many parts of Britain, particularly at lower elevation forests in the west. In general there were no prolonged or severe frosty periods of weather which could bring about much winter mortality (*Report* for 1971, p. 87).

One noticeable feature in certain areas of west Scotland was a considerable loss of needles on many of the older Sitka spruce trees which had apparently been unaffected for several years. Completely defoliated young Sitka spruce was common in the western half of Britain. The reduction of leader growth in the following season was as much as 50 per cent compared with unaffected trees. Norway spruce was also badly affected and leader growth on some forest areas was reduced by 40 per cent.

A questionnaire was sent to all Commission foresters to gather information on attacks this year. The distribution and nature of attacks is

TABLE 16
AREAS OF SITKA SPRUCE SEVERELY DEFOLIATED

Conservancy	South-west England	South Wales	West Scotland	South Scotland	North Wales	North-west England	East Scotland	North Scotland	East England	North-east England	South-east England	Overall
Hectares severely defoliated	1,585	5,782	8,529	8,333	5,506	1,823	2,528	2,364	8	1,221	0	37,679
Per cent of total area	34.6	25.3	19.4	18.2	17.6	16.7	14.2	8.5	5.3	4.3	0	14.9

currently being analysed. In Table 16, the areas of Sitka spruce that were severely attacked in each Conservancy are given in hectares and also expressed as a percentage of the total conservancy area under Sitka spruce.

Adelgids forming Pineapple Galls

During the past season more enquiries than usual have been received concerning acute gall formation on Christmas tree crops in the south of England. Trees had been sprayed in early April but this treatment had not always brought about an effective control. Since adelgid development in the early spring appears to commence at the same time as the sap starts to run it seems very likely that this year because of the mild weather the insects had advanced beyond the stage when they are easily controlled. Following previous work on development and dispersal of the adelgid concerned (Carter, 1971) trials with various insecticides applied in November and April are being carried out to improve the available means of control.

The Spruce Sawfly, *Gilpinia hercyniae*

Work continues on the infestations of this sawfly in the forests of mid-Wales at Hafren and Ystwyth (Tarenig, Myherin). The area affected has increased as also has the degree of defoliation. Despite severe damage on some trees for over three seasons, no deaths have so far occurred.

In cooperation with the Natural Environment Research Council's Unit of Invertebrate Virology at Oxford, a study has been started in order to find a specific virus to control this insect. There is a natural virus in the outbreak area, and this together with another unidentified larval disease is beginning to spread and reduce populations.

The Elgin Shoot Moth, *Rhyacionia logaea*

This moth was found mining in current year shoots of *Pinus contorta* in five forests in Scotland. At present little is known about it, though there is more information on the European species *Rhyacionia duplana* Hübn., of which *R. logaea* Durr. may be a subspecies. The taxonomy and biology of the insect is being studied.

Moritziella corticalis

Specimens of the phylloxerid *Moritziella corticalis* (Kalt.), which is new to Britain, have recently been found in large numbers in Sussex and Berkshire. The insect appears only to attack the stems and leading shoots of young planted oaks up to the age of 20 years, and is closely connected with a reduction in shoot growth or even die-back. Its life history, dispersal and overwintering behaviour are being investigated.

Dutch Elm Disease (see also p. 90)

This disease has over the past four years killed many of the elms in the southern half of England. In certain parts of Essex and the West of England, up to 75 per cent of the trees have succumbed and there are as yet no signs of a decrease in the ravages of the disease.

In September 1970 it was decided to initiate investigations into certain aspects of the biology of the two scolytids, *Scolytus scolytus* (F) and *Scolytus multistriatus* (Marsh.), the vectors of the disease. The studies were carried out during 1971, using infested logs from two major outbreak areas supplemented by a small quantity from other less affected places. Preliminary analysis of data on parasitism seems to agree with the results obtained by Beaver (1967, a, b) in studies at Wytham Wood, Berkshire. The proportion of parasitised beetles was nowhere greater than 12 per cent, the mean was around six per cent, and in some cases was negligible. Five species of chalcid parasites were found and identified. Four species of braconids were found, but only *Coeloides scolyticida* Wesm. has so far been named. However, the chalcid *Entendon urgias* Walk, and *C. scolyticida* seem to be the most numerous parasites in the present outbreak. Time permitted no investigation into the influence of predatory animals or fungal infection. Some work on nematodes is being done in conjunction with Reading University. It is hoped to set up a small network of window traps to obtain information on adult flight periods. The work on the biology and populations of beetles will be continued during 1972.

Much work is being done to find a control of the disease through insecticidal control of the beetles. This work is aimed at killing the beetles during maturation feeding and at their breeding time. Prophylactic spraying of the crowns of large elms will be carried out during April 1972 to test several insecticides and methods of application. The latter include ultra low volume, low volume and high volume spraying from the ground and low volume spraying from helicopters. In the United States the organochlorine insecticide methoxychlor has given good protection and is now a standard treatment there. This material is being tested here together with two promising organophosphorus insecticides, tetrachlorvinphos and dursban as possible alternatives. In addition, screening trials of a large number of insecticides is currently being undertaken using small plants and branches. Infested logs will also be sprayed using BHC with a number of different oil carriers at two concentrations, 0.5 and 0.25 per cent.

British Forest Entomology Group

This newly-formed group held its first meeting in the Allerston group of forests near Scarborough in Yorkshire, on 13-15th October. Like the Forest Pathology Group, which has now been meeting for some seven years, it aims mainly to provide an opportunity for research workers from different organisations to meet and discuss their subject once a year. It was evident from the first meeting that a small group such as this can quickly establish a useful rapport and become a fertile ground for the exchange of ideas and for the voicing of constructive criticism.

Enquiries

During the year Forestry Commission staff sent 102 written enquiries to Alice Holt and 36 to the Northern Research Station. One hundred and

seventeen enquiries from outside the Commission were sent to Alice Holt and 23 to the Northern Research Station.

D. BEVAN

JOAN M. DAVIES

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WILDLIFE

Grey Squirrel

A summary of the results of the 1968–1971 field trials of Warfarin poison for grey squirrel control was submitted to the Ministry of Agriculture. The detailed results are being prepared for publication. The trials showed that Warfarin could be used to reduce grey squirrel numbers at least as effectively as cage-trapping during May, June and July. The strategy of use is similar to that for cage-trapping. The number of bait hoppers required varies considerably with the size and shape of the crop to be protected and with the use made of adjoining land. Investigations of bait suitability confirmed that whole wheat was acceptable and easily treated with poison at a concentration of 0.02 per cent Warfarin, using a powder formulation applied either with an oil or dispersed in a latex solution as a sticker. The taking of bait by birds and mammals other than squirrels, rats, mice and voles can be largely prevented by ensuring that the only access to the bait is via a tunnel at least 225 mm (9 in) long and no more than 100 mm (4 in) in diameter or square. It did not prove possible to design a simple system of presenting the poison bait to exclude mice and voles without also reducing the efficiency of squirrel control. It is unlikely that *Apodemus* species in particular could be excluded by any inexpensive method. When ground hoppers with tunnel entrances were used a relatively small proportion of the mice and voles around a poison site were affected. No animals other than *Apodemus* species, *Clethrionomys glareolus* and squirrels were found dead despite intensive searches. Birds were occasionally seen to feed on spilled poison bait but this was an infrequent occurrence and no evidence of any deaths was found.

In 1971, squirrels were responsible for more damage than in any year since their 1961 peak. Beech and sycamore were most frequently attacked among a variety of species including oak, red oak, larch, Western hemlock and maples.

Contributions from the Forestry Commission to the Ministry of Agriculture 10 km Grid survey of red and grey squirrels in England and Wales showed that the grey squirrel had extended its range in England and Wales. The annual Forestry Commission Squirrel Questionnaire also suggested some extension of the range of the grey squirrel in Scotland.

Red Squirrel

The contraction in range of the red squirrel is also showing clearly in both Ministry of Agriculture and Forestry Commission surveys. It seems possible that the key to the survival of the red squirrel in Britain is the maintenance of extensive pine plantations with a high proportion of trees of cone-bearing size rather than attempts at grey squirrel control. Investigations of the silvicultural and biological problems involved in conserving red squirrels are being initiated as is a study of the sub-specific status of British populations in conjunction with the Nature Conservancy.

Deer

The use of bait to attract roe deer to traps was frustrated by the mild winter. Limited success was achieved with the use of self-attaching collars to mark both roe and woodland red deer. Freeze-marking results suggest that the technique could be useful for permanent individual identification but the stage of the hair growth cycle at the time of marking may be important for consistent results. Histological investigations of this aspect have begun. Two methods of assessing the proportion of fat in bone marrow of the long bones as a guide to deer condition have been developed. Catching-up and marking of roe deer in Powerstock Forest (Dorset) continued for the tenth year. At present, two Ph.D. students are working in the wood, on food and on social behaviour of these individually marked deer. A roe enclosure of some five hectares was established in Alice Holt Forest (Hampshire). It is hoped this will provide information on methods of protection from roe deer to complement the results obtained for fallow deer in the New Forest enclosure.

Chemical Repellants

Two chemical repellants were tested during the 1971-72 season. The first was a new formulation of Curb which did not prove any more successful than the original formulation tested in 1967-68. The second, Dendrocol 17, was not received in time for adequate over-winter tests. However, it completely clogged the sprayer during trials and, if successful as a repellant, would probably have to be applied as a smear.

Fencing

A new weldmesh netting is undergoing trials. This is cheaper and easier to erect than woven field netting or hexagonal mesh netting in stock and deer fences. There is no satisfactory alternative at present to hexagonal mesh rabbit netting. Twin strand high tensile barb wire has proved satisfactory and easier to handle than single strand high tensile barb wire in combination with spring steel fencing and may be recommended in the relatively few instances where forest fences require this additional component.

Damage

The most important introduction in this field is the development, in conjunction with Statistics Section, of two methods of sampling damage with an accuracy of at least ± 5 per cent. These techniques can be used to measure the occurrence of scattered sporadic damage in a whole compartment (10-15 ha) or smaller area and to identify and to measure the occurrence of patches of less evenly distributed damage. A method of measuring the percentage loss of seed and seedlings with a pre-determined probability of error not more than ± 10 per cent of the true mean has also been developed for use in surveys of bird and mammal damage in extensive nursery sowings.

Forestry and Pheasants

The investigation of the problems of managing pheasants in extensive upland spruce forests has shown that the limiting factor is the distribution

of ground cover from which the birds may be presented to guns during shoots.

Dissemination of Information

Conservation Foresters and Head Rangers from all Conservancies attended a course on wildlife management research held at Alice Holt in conjunction with Forest Management Division and Education and Training Branch. Current recommendations on grey squirrel control occupied about a third of the time. Developments in damage appraisal (both sampling and evaluation), in red squirrel conservation, nursery protection, rabbit and vole control were also covered as were techniques associated with shooting, stalking under licence, and the development of the potential for fish and wildfowl in forests and the interpretation of wildlife to the public.

JUDITH J. ROWE

STATISTICS AND COMPUTING

General

Organisation

At Alice Holt the Statistics and Computing Section has been more formally organised into four groups; viz. statisticians, data analysts, programmers and operators. Though no sudden changes in methods of working were possible or desired, there is now some evidence that the changes are more than nominal. At the Northern Research Station one Machine Operator post has been regraded to Assistant Scientific Officer. Eight members of the Section are currently allowed special leave while pursuing part-time courses of study for further qualification in statistics or computing science.

Computing Facilities

The year under review started with the acceptance trials of the IBM 1130 computer (described in last year's *Report*) which was delivered in March 1971. These tests were generally passed without trouble and the Calcomp 565 graph plotter was found to be easily interchangeable between the ICL Sirius machine and the IBM 1130. Only with the 1134 paper tape reader was any difficulty encountered.

Rather more difficulty was met a few months later in connecting the IBM 1130 to the UNIVAC 1108 at the University Computing Company's Centre in London. This was mainly because there was at the time little or no experience in this country of linking these two machines over a distance of 50 miles or so. Currently we find that the quality of transmission is only satisfactory at 2400 bauds although the terminal equipment is capable of working at twice this speed. With the initial low level of use of the facilities of the UCC system no inconvenience is felt by this restriction.

All the personnel of Research and Management Services Divisions whose work requires some knowledge of computing have attended IBM courses in Fortran and the 1130 monitor system. The interchangeable disk storage facility has been found to bring the most revolutionary freedom from the constraint imposed by the absence of backing storage on the ICL Sirius. The change of method of handling input data from that of free format paper tape to fixed format card and tape has meant that the Sirius machines are still kept busy running jobs under old programmes. Much of their time is however now spent in converting paper tapes to a form which can be read by 1130 Fortran programmes.

The system under which the 1130 is operated has changed during the year. Initially much of its time was spent in "hands-on" mode by programmers gaining familiarity with its functional characteristics. It was however soon found necessary to designate four periods during the day for queues of quick jobs handled by a duty operator. Most of the rest of the time is now spent on a slower moving queue of longer jobs. "Hands-on" sessions are

now restricted to development runs of more complex programmes and more truly interactive computations.

Off-line data preparation equipment has been augmented by the hire of one IBM 029 and two ICL 72/1 card punches, two ICL 171/1 verifiers at Alice Holt and one IBM 059 verifier at the Northern Research Station. Machine operating staff were trained to use the new equipment by means of the KATE course of audio-tape instruction. Two Wright-line card punches were purchased to allow the computer operator and programmers to punch occasional cards without interrupting machine operators.

M. H. WEBB

Service Work

Statistical

The main advisory work of the Section has continued to be in relation to the design of experiments for Research Division and the design of time studies for Work Study Branch.

A statistics course lasting one week was given by C. J. A. Samuel and I. D. Mobbs to Work Study field staff. Attention was concentrated on basic concepts but particular emphasis was put on regression analysis since this is the technique which Work Study staff need most to use in one form or another.

For Recreation Branch a survey concerned with the recreational use of the New Forest was designed. The design chosen was a double two-stage sampling procedure of Vos (1964) and this has given satisfactory results. A preliminary analysis was done with the help of the BMD General Linear Hypothesis Program using the remote link to the UNIVAC 1108.

For the Pathology Section a survey on the distribution of Dutch elm disease was designed. One of the main constraints on this survey was that it had to be rapidly carried through and analysed. The structure of the sample was therefore kept as simple as possible. A full description of methods and results has been published (Gibbs and Howell, 1972).

For the Genetics Section analysis is in progress on results from the extension of the diallel cross reported last year (*Report* for 1971, p. 74).

Data Analysis

As a result of the reorganisation of the Section at Alice Holt much of the load of data analysis has been removed from the statisticians. The main function of the data analysts group is to aid research workers to get their data processed quickly with programmes already available. Some problems of form design are also dealt with by this group. The group has also been concerned together with the Silviculture (South) Section in the early stages of a study of paths and rates of data flow.

C. A. THORNE

Programming

Sixty-eight programmes and routines for the new computing system have now been written and catalogued. Only a few of these can be mentioned here; viz. a multiple regression programme which is used particularly for Work Study data, a Sample Plot programme converted from that used on the Sirius machine, a programme for analysing progeny trials, a set of programmes which produce personal sets of reference cards to the Alice Holt Library and a keyword index. A start has also been made on the storage on magnetic tape of the Census of Woodlands data.

G. J. HALL

Students

The Section has been helped by two sandwich students, F. Rogers (at Alice Holt) from Sheffield Technical College and A. Sangha (at the Northern Research Station) from Aston University. Mr. Rogers worked principally on a study of the relationship between the tatter of unhemmed flags (used to estimate windiness) and the local topography of their sites, and on a programme to summarise the working characteristics of heavy machines in the Commission's forests. Mr. Sangha developed an improved analysis for single classification data which has since been adopted by the Systemshare computer bureau. He also co-operated with Dr. W. J. Bloomberg, a visiting forest pathologist, on programmes which applied Pielou's (1959, 1964) methods of pattern analysis to disease distributions in forest nurseries. These programmes when generalised will be available to ecologists and others interested in testing mapped dichotomous distributions for randomness, clustering etc.

Data Capture Developments

J. Baird prepared a sweeping "state-of-the-art" review for a meeting in June which attempted to guide further work.

A feasibility trial of optical character recognition has been started with the help of the Silviculture (North) Section using the bureau services of the National Coal Board. A report should be concluded soon.

D. H. STEWART.

R. S. HOWELL.

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ENGINEERING SERVICES

Three regional engraving centres have been set up, at Brechfa (South Wales), Thetford (East England) and Fochabers, Speymouth Forest, (East Scotland), to manufacture standard wooden signs for use on Commission properties. The workshop has provided each centre with machines, tools, master templates etc, and given the operators a short course of instruction at Alice Holt. Additional equipment has been supplied to Brechfa to enable plastic notices to be engraved.

Work has continued with the design of equipment to aid the experimental work on container grown plants. A new sanding unit, to cover container-sown seed with sand, based on a commercially available unit, has been made and tried. Two variable speed units will shortly be built.

A breeding chamber for bark beetles was designed and made for use by the Entomology Section. Seventy-five production units were then built, mainly by Entomology staff, with assistance from the workshop.

In connection with work on Dutch elm disease the Entomology Section needs to spray trees up to 30 metres (100 ft) high. Equipment has been purchased and modified to give two types of portable units to apply high volume insecticidal sprays to trees:

(a) *for trees up to 15 metres (50 ft) high*

The tractor-mounted tower used earlier at Wykeham (*Report for 1971*) was modified so that a man could be strapped to it approximately six metres (20 ft) above ground level. A Cooper Pegler pump with an output of approximately eight gallons/minute at 40 kg/sq cm (560 lb/sq in) was attached to a 200 gallon trailer tank.

An extension mast was made for the tower to enable an ultra low volume (ULV) sprayer to operate approximately 12 metres (40 ft) above ground level.

(b) *for trees 15 metres to 30 metres (50 ft to 100 ft) high*

Power was provided by a Coventry Climax fire pump with outlets varying in size from $\frac{1}{4}$ in diameter to $\frac{3}{4}$ in diameter operating at 100 lb/sq in to 150 lb/sq in. The suction line was adapted to fit the same 200 gallon tank. This apparatus was operated from the ground.

The equipment will be used early in 1972.

Also for use in work on Dutch elm disease, several gravity-fed tree injection units were made for the Pathology Section. Two pressurised units have now been made.

Again more than 8,000 engraved labels have been produced, but with the setting up of the area centre at Brechfa (referred to above), this load should be reduced in future.

R. E. STICKLAND

PHOTOGRAPHY

General

The Section was able to provide less territorial coverage than it would have wished, but a limited programme produced some new material from West Scotland Conservancy, and those of North-east, North-west and South-west England, and South Wales. The increased co-operation of Conservancies and Divisions in giving early warning of their photographic needs helped considerably in programme planning. Conservancies are also making more use of the Section as an agent for services, material and equipment.

Photographic Collection

The re-organisation and cataloguing of the Photographic Collection took longer than anticipated. This was mainly because, particularly during the summer months, work was frequently interrupted by more pressing items. Lack of adequate descriptive notes also caused delays in key-wording. The latter difficulty is due, in part, to our present low printing capability. We cannot attach key-words to photographs until we get the descriptions from the Conservancies and others, who in turn cannot let us have full descriptions until they have seen the prints or transparencies. This produces a vicious circle, and a new procedure will have to be evolved for future use. Stabilisation equipment has been bought and the early indications are that the results, whilst not entirely up to conventional processing standards, are adequate for most purposes. This should help to reduce printing delays. The slide collection at the Northern Research Station is now being duplicated and will be stored using a suspended system similar to that of the Central Collection.

Sound Library

Two more slide/tape sets—*The Border* and *Glentroot*—were started during the year but the retirement on 31 December 1971 of R. W. Genever, who had been responsible for this work, has delayed their completion. Since December the Sound Library has, of necessity, closed down, and cannot be reopened until the appointment of further staff.

Aerial Photography

The need for aerial photographs for short-term management use is now accepted. Whilst it may sometimes be possible for field staff to undertake a limited amount of oblique photography it is clear that the Photographic Section must provide a service for the taking of vertical photographs. The necessary equipment has been purchased and tested satisfactorily. There only remains the question of a camera mounting. This has been examined in collaboration with the Research Workshop and a preliminary design agreed. We are at present awaiting delivery of an aircraft part for modification before we proceed with construction and certification.

Photo-lettering

Photo-lettering equipment has now been bought jointly with Management Services Division. The machine is at Alice Holt and, initially, it will be used by the Illustrator for work for Publications Section and the Central Drawing Office. It is hoped that, eventually, a more general service will be offered—though this will largely depend on the availability of staff—to Forest Information Centres, the Commission Show Units etc. This should ensure a more uniform and professional standard of captioning than that obtaining at present.

Illustrator

A considerable amount of the Illustrator's time was taken up with publications, particularly with the design of modules for the front covers of the standard series of Forestry Commission publications which are printed by HMSO. He has also been involved—in conjunction with Conservation and Recreation Branch and the Central Drawing Office—in the design, layout, and art work of local guides, maps, and symbols.

I. A. ANDERSON.

PUBLICATIONS

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

Reports

Fifty-first Annual Report of the Forestry Commissioners, 1970/71 (HC 70, Session 1971/72) (75p).

Report on Forest Research for the year ended March 1971 (£1.60).

Bulletins

No. 42. Conifer Woolly Aphids (Adelgidae) in Britain, by C. I. Carter (75p).

No. 45. Windblow of Scottish Forests in January 1968, edited by B. W. Holtam (45p).

Forest Records

No. 74. Development of Glasshouse Techniques for Early Progeny Test Procedures in Forest Tree Breeding, by R. B. Herbert (20p).

No. 78. Loading and Unloading Timber Lorries, by A. Sutton and T. R. Sawyer (30p).

No. 79. Nothofagus Plantations in Great Britain, by M. Nimmo (17½p).

No. 80. Forest Fencing, by H. W. Pepper and L. A. Tee (35p).

No. 81. Protection of Small Steel Structures from Corrosion, by E. F. Granfield (17½p).

Booklets

No. 28. Gwydyr Forest in Snowdonia. A History, by D. L. Shaw (40p).

No. 29. Wildlife Conservation in Woodlands, by R. C. Steele (40p).

No. 30. Metric Conversion Tables and Factors for Forestry, by J. E. Everard (50p).

No. 34. Forest Management Tables (Metric), revised by G. J. Hamilton and J. M. Christie (£1.60).

No. 35. The Plan of Operations (Metric) (25p).

In addition eleven 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, *Horticultural Uses for Bark*, and eleven others were revised and reprinted.

Research and Development Papers. Five of these unpriced papers were produced, mainly for internal use. Their titles are:

No. 81. Forest Management for Conservation, Landscaping, Access and Sport, by P. F. Garthwaite.

No. 82. Fume Damage to Forests.

No. 83. Trees are for People, by W. Grant.

No. 84. Report on the Beetle *Hylastes Angustatus* in Pine Plantations of Swaziland and Adjacent Areas of the Republic of South Africa, by D. Bevan and Tecwyn Jones.

No. 85. A Plan for the Improvement of Sitka spruce by Selection and Breeding, by A. M. Fletcher and R. Faulkner.

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

H. L. EDLIN.

RESEARCH INFORMATION

Visitors

The number of visitors continues to rise. Visits by parties with a general interest disrupt research work because of our very limited facilities for their reception, and visits by such parties have usually had to be refused. To provide for local schools and members of the public, consideration is therefore being given to the holding of an open day at Alice Holt for those living close to the research station.

Market Research

A survey was carried out among District and Forest Officers of one Scottish Conservancy which had asked for help in handling information. The survey revealed that 76 per cent received sufficient literature but 91 per cent had difficulty in finding it again. Seventy-nine per cent said that subject indexes to readily available literature, Forestry Commission instructions etc., would go far to solve their problems, and work has subsequently been carried out to write a computer program to produce such indexes. The first index will cover all Forestry Commission publications and should be available early in the new year.

Computer Working

The arrival of the new IBM 1130 computer necessitated the re-writing of all the programs used for library and information work. With the need to learn and use the more complicated language, Fortran (instead of Sirius Autocode), this has been a major undertaking. However, with the much greater facilities available and the assistance of Statistics Section staff, the new programs are far more efficient and extensive.

Library

Book acquisitions totalled 242, a further eight periodicals were taken and 24 translations commissioned. The number of loans has risen to a new record of 4,065, almost treble the number five years ago. This is satisfying evidence of the success of the various information services now provided by the Section, and the readiness of the library staff to give an immediate and personal service to all library users.

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

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

D. R. JOHNSTON

PLANNING AND ECONOMICS

POLICY

Government Review of Forestry Policy

In December 1970, it was announced that Forestry Ministers had decided to review various aspects of forestry policy. A subsequent announcement noted that the review would cover both public and private sectors and that cost-benefit studies would be made in support of the review. The Branch has been engaged in work for this review which has now been published.* Arising out of the work done on the evaluation of recreation benefits in forestry, a paper was prepared by A. J. Grayson, R. M. Sidaway and F. P. Thompson (then at HM Treasury and leader of the cost-benefit study team) for a Symposium on Recreational Economics organised by the Department of the Environment in January 1972.

Financing of the Forestry Commission

The Branch has been engaged with the Director of Management Services Division and the Controller of Finance in working out the methods of calculation and of accounting needed to implement decisions on the future financing of the State Forestry Enterprise. Two sorts of valuation are involved. One is the valuation of plantations, in terms of expectation value calculated with a discount rate of 3 per cent, and of other assets which together form the existing estate ; the other is the expected net discounted revenue, again calculated at 3 per cent, expected from new planting and restocking by major site types. The calculations for both these assessments are being made within each Conservancy. This work has involved a reduction of the continuing effort devoted to Conservancy planning. It is expected that the results of the valuations will be announced in the Forestry Commission's Annual Report for the year ending 31st March 1973.

A. J. GRAYSON

R. J. N. BUSBY

* *Forestry Policy*, HMSO London, June 1972, 18p, and *Forestry in Great Britain, An Interdepartmental Cost/Benefit Study*, HM Treasury, HMSO London, £1.25.

AIDS TO MANAGEMENT AND PLANNING

Production Forecasting

A new system of producing medium and long-term forecasts of wood production has been developed. The old system used a program written for the Sirius computer. The withdrawal of Sirius led to the need to redesign the forecasting system to suit the IBM 1130 computer now in service. This change has afforded an opportunity of incorporating amendments which make the new system more useful to management.

The new system, like the old, uses standardised growing stock descriptions and standard cutting regimes, a cutting regime being defined as a statement of age of first thinning, thinning intensity and felling age applicable to some given part of the growing stock. The new system is however much more flexible than the old. If one of the standard cutting regimes is considered inappropriate in the particular circumstances, then a new cutting regime may be defined together with a statement of the growing stock to which it applies. A user of the new forecasting program may also change one or more of the standard growing stock descriptions, though the need for this should rarely arise.

The new system should help management by facilitating the rapid production of more realistic production forecasts. It will also offer management the opportunity of testing the effect of a number of different cutting regimes before finally adopting one of them.

J. F. MORGAN

RECREATION

1970 Day Visitor Survey

Analysis of the results of this survey has continued and estimates of seasonal use have been produced for 14 of the 15 areas studied. The estimates given in Table 17 are based on observation of arriving and departing vehicles from 0930 to 1830 hours on a random sample of five days within each day type (Saturdays, Sundays, weekdays) from the period 1st June to 30th September. Observations were also made of weather and the number of parked cars at hourly intervals on each survey day. Three measures of recreational use are obtained, each of which may be relevant in planning and management. Estimates of the number of visits may be useful in gauging potential revenue, visits being the number of people entering the area over a given period. Individuals are not distinguished in the measure, so that repeated visits by the same person on the same or subsequent occasions will be included. Visits are combined with length of stay observations to produce estimates of visitor hours. This measurement is more valuable when estimating recreation benefits and when comparing the use of different areas. The other

measurement which will be of value, particularly in site management, is the number of cars parked on the area at a point of time (stock count). The stock count at peak times during the day recorded on a large number of occasions gives a measure of site occupancy and is likely to be useful in deciding the desirable size of facilities to cope with existing use. The general pattern of day visitor attendance that emerges from the survey is one of marked peaking, particularly on fine Sunday afternoons. There are exceptions: use of the Fyfi site, for example, peaks on Saturday lunch times, probably as the site adjoins a holiday traffic route. Average length of stay varies markedly from site to site being markedly shorter at viewpoints.

One implication of these findings concerns future extensive surveys. The number of cars parked at the peak time in the afternoon has previously been used to estimate total seasonal visits. The magnitudes of the maximum parking figure (Col. 8 Table 17) compared to the total visits (Col. 5) suggests that this measure alone is unlikely to provide a reliable general estimator of visits.

As parking fees are collected at Newborough Beach car park, it was possible to compare the survey results with an independent method of estimating visits. Corrections were made for the length of survey day and the length of season to ensure comparability and assumptions made about the fee data to allow for season ticket holders and number of persons per car. The estimate of use based on ticket sales was 67,000 visits compared to 51,000 \pm 15,000 visits estimated from the sample survey. The survey results appear conservative but of the right order. Further work is clearly needed before sample surveys can be shown to give dependable estimates of use.

Estimation of Day Visitor Use of the New Forest

A survey was designed to assess peak usage of day visitor parking in the New Forest during the summer of 1971. Three counts on Sundays covered all the areas used by day visitors. Only two attempts had been made previously to cover the entire forest, in 1965 and 1969. Detailed organisation of this exercise ("Operation Countdown") was carried out by Conservancy staff and each count required 60-70 volunteers. The highest count was recorded on 1st August 1971 when 6,000 cars were parked in the forest at about 1600 hours. The forest had been subdivided into 42 survey tracts each containing up to 18 units so a detailed picture of the location of parking has been obtained. This will provide a valuable record as the spatial pattern changes with the implementation of the proposals for car-free zones, car parks and restrictions on camping recommended by the New Forest Study.

These extensive counts were backed by similar counts on 13 of the most popular survey tracts which attract nearly 60 per cent of the parking. Peak use occurs on Sundays and 4 of the 13 tracts were counted on each of 13 Sundays randomly selected from the period between 1st June and 30th September. (Further details of the sample design are given in the report of the Statistical Section (p. 108.) Together with weather data, these observations enable estimates to be made of usage on each Sunday throughout the summer.

Use of Aerial Photography

Both the surveys mentioned above required a large number of observers and these may not always be available. On 31st May and 1st August 1971 two flights were made to see how useful 35 mm hand-held oblique aerial photographs could be as an alternative method of counting cars. About 60 per cent of the survey tracts in the New Forest appear to be sufficiently open to make the technique worthwhile. Comparison was made between ground counts made at approximately the same time and counts made from panchromatic prints. Despite some problems in obtaining complete coverage and masking of vehicles by vegetation, the estimates from photo counts range from 85 to 95 per cent of the ground counts. Most of the suitable open areas can be photographed from the air within two hours by a three-man team and the technique appears to be a suitable alternative for the open areas of the New Forest (See Plate 6). Exact comparison of cost between the two methods is difficult. When the cost of photo interpretation is included the photographic method may not be much cheaper with current labour costs but the photographs provide a valuable permanent record and can also be used to obtain camping and other data.

Other Activities

The implications of day visitor demand surveys for recreation planning are reported in Forestry Commission Bulletin 46, *Forest of Dean Day Visitor Survey* by R. J. Colenutt and R. M. Sidaway published by HMSO (in the press).

Liaison was maintained with other government agencies concerned with recreation research principally via the Countryside Recreation Research Advisory Group. This included membership of working groups concerned with identifying recreation research needs and priorities and developing programmes of research. This work is reported in *Research Priorities*, Countryside Recreation Research Advisory Group, 1971, available free of charge from the Countryside Commission, London.

R. M. SIDAWAY.

R. Q. OAKES.

TABLE 17
ESTIMATES OF SEASONAL USE OF DAY VISITOR RECREATION AREAS
(1.6.70—30.9.70)

Conservancy (1)	Name of site (2)	Forest (3)	Type of site (4)	Estimated no. of visits (5)	Estimated no. of visitor hours (6)	Estimated mean length of stay (hours) (7)	Maximum no. of cars parked at any one time (1330 hrs, 2.8.70) (8)
North West England	Grizedale Hall	GRIZEDALE DELAMERE	Car park (a) Roadside parking	31,000 ± 5,000 100,000 ± (b)	33,000 ± 7,000 78,000 ± (b)	1.1 0.8	33 340
North East England		HAMSTERLEY	Forest drive	24,000 ± 7,000	38,000 ± 13,000	1.6	151 (c)
East England	Lyndford	THETFORD	Picnic place	24,000 ± 3,000	28,000 ± 5,000	1.2	130 (d)
New/South East England	Rhinefield Drive	NEW SLINDON	Road verge and car parks Car park	67,000 ± 12,000 10,000 ± 2,000	45,000 ± (f) 13,000 ± 3,000	0.7 1.3	170 61 (d)
South West England/ Dean	Symonds Yat Rock Edge End	DEAN	Viewpoint car parks Picnic place	120,000 ± 22,000 16,000 ± 2,000	102,000 ± 30,000 11,000 ± 3,000	0.8 0.7	131 32 (e)
North Scotland	Loch Benavean Loch Morlich	AFFRIC QUEEN'S	Informal car park Lakeside car park (f)	21,000 ± 4,000 42,000 ± 12,000	25,000 ± 9,000 56,000 ± 26,000	1.2 1.3	34 185
East Scotland	Queen's View	TENTSMUIR TUMMEL	Beach car park Viewpoint car park	7,000 ± 2,000 128,000 ± 24,000	12,000 ± 4,000 48,000 ± 10,000	1.8 0.4	53 60
North Wales	Cwmcaidian	DYFI NEWBOROUGH	Car park Beach car park	19,000 ± 4,000 51,000 ± 15,000	16,000 ± 3,000 140,000 ± 60,000	0.9 2.8	20 (g) 428

Notes:

(a) Also used by campers.

(b) Error term not calculated.

(c) Estimate for Bedburn car park and not forest drive.

(d) 1630 hrs, 2.8.70.

(e) 1730 hrs, 2.8.70.

(f) Eastern car park only.

(g) 1330 hrs, 6.6.70.

FIELD SURVEYS

Topographic Surveys and Assessments

A major project during the year was the Dutch elm disease survey covering 56,600 square kilometres of southern England. This was undertaken to assess the extent and distribution of the disease. Twenty-two courses were given to local authority officials on winter identification and control of the disease.

A pilot survey was set up in Scotland with the object of developing a site classification related to planning and investment decisions at the various levels of management.

A project to improve the techniques of crop assessment in crops with patchy check was completed.

In connection with the Financial Reconstruction and Conservancy Valuation 1972, field checks on the accuracy of basic data are being carried out on forests where areas of uncertainty have been identified by local staff. Courses for Conservancy staff on the updating of the basic data, a necessary prerequisite for the valuation, had been completed for over half the Conservancies by the end of the year.

Routine topographic survey work completed is summarised in Table 18.

TABLE 18
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	28,800	9	14,000	2	42,800	11
England and Wales	19,800	13	22,100	5	41,900	18
Total, Great Britain	48,600	22	36,100	7	84,700	29

Plot data from fertilising operations in West Scotland Conservancy were analysed and the broad conclusions following two years' growth after the application of fertiliser (mainly unground rock phosphate) are:

- (a) In crops where height growth is following a normal yield class pattern an increase in volume production equivalent to an increase in growth of approximately half a yield class can be expected.
- (b) In crops where height growth has been decelerating the response is likely to be above half a yield class and at very low yield classes (6 and below) considerably above it.

- (c) The response is better on peat soils than on mineral soils.
- (d) The response is better on ploughed than on turfed sites.

L. M. SIMPSON.

Site Survey

Soil surveys were completed on 32,524 ha in five Conservancies the location of teams remaining as in 1970/71. Survey efforts have been directed towards sites proposed for afforestation. Now that three site survey teams are fully trained in the use of panchromatic photographs as an aid to surveys of this type, the capacity of the Section to provide this service on request has increased.

The educational programme continued with courses at Llandovery and Lochgilphead for Conservancy and District Managers in the uses of site survey information. One course on lowland soils covering Hampshire and Dorset was held for southern Research Foresters.

As part of the valuation and financial reconstruction exercise the Section is collaborating with Research and Conservancy staff in classifying plantable land into broad site groups. Guides are being prepared to assist Conservancy staff in estimating likely growth patterns on the various sites. The guides are based upon data from sample plots, research experiments, routine site surveys and local knowledge. This project will be completed towards the end of 1972.

D. B. PATERSON.

Mensuration

Problems associated with the measurement of standing timber have been the subject of some attention during the year. In particular the implications of using the familiar tariff system of measurement in older and more variable crops have been examined. Whilst some modification is required in the measurement procedure in these cases, the system basically retains most of its inherent advantages. A revised booklet* will be published shortly describing the procedures for measuring standing timber, primarily in connection with sales.

During the year under review 51 new permanent sample plots were established, 24 of these comprising a replicated line thinning experiment in Sitka spruce at Elwy (North Wales). In order to examine the effects of "respacing"—an early non-commercial "thinning", normally carried out at about the time of canopy closure—two replicated respacing experiments were also laid down, one in Lodgepole pine and another in Sitka spruce. In each experiment there are four treatments replicated four times, ranging from fully stocked controls to stem number stockings equivalent to about 30 per cent of the original stocking. Further respacing experiments are being planned.

Much of the effort on development has been devoted to an analysis of spacing experiments. The subjects for the analysis consist largely of the 1935/36 series of experiments which were laid down by the then Territorial Divisions. The experiments managed by Silviculturist (North) as well as those

* Forestry Commission Booklet No. 36. *Timber Measurement for Standing Sales using tariff tables*. H.M.S.O. (in the press).

in the south which are the Mensuration Section's responsibility have been used as a source of data. The aspects being examined are the effect of spacing on survival, mortality, height growth, basal area production, volume production, diameter growth and form. The results are expected to be available and published in the next year.

As the practice of top-dressing younger crops has increased, a need has arisen for an objective system of identifying crops which can be regarded as unsatisfactory and which merit closer scrutiny as possible subjects for crop improvement treatments. To meet this need a system of classifying current growth in Sitka spruce has been designed which identifies not only crops where growth has been unsatisfactory from planting but also cases where growth has declined after an initial satisfactory phase. Essentially the system depends on measurement of the last two years' leading shoots on sample trees, comparing these with normally "expected" leader lengths for the given height and age of the tree, and classifying its performance accordingly. The system, which can also be used to identify emergence from a period of depressed growth, has proved satisfactory in field trials.

Work on the development of a comprehensive computer program to construct yield models has continued. The program has already been extensively used in producing models of varied cutting regimes required for general management and for Conservancy planning.

G. J. HAMILTON.

WORK STUDY

I. FOREST MANAGEMENT STUDIES

General

A number of new projects were undertaken together with continuing work on studies initiated in previous years. New major projects included the study of the range of problems associated with the drainage of reforestation areas, large-scale control of heather in checked plantations and development of the latest spraying techniques. The search continues for equipment suitable for the extension of mechanical weeding to more difficult conditions of vegetation and terrain, such as narrower gauge tractors for plantation work and more powerful brushcutters for heavy scrub. Considerable progress was made on the application of granular fertilisers, the handling and planting of tubed seedlings and in plough modifications such as the hydraulic control of board and discs and step cutting devices.

PLANTING

Tubed Seedlings

During this year in which tubed seedlings were first used on any scale a better output guide was produced including a site classification. Planting and carrying frames were redesigned, studies were made of the logistics of tubed seedlings supply and some work was done on greenhouse methods including the production of a prototype tube filler.

Planting Bags

Following a study of the available types of planting bags the use of polythene coated bags of the type made by Godfreys of Dundee was recommended.

Planting Machines

The Finn Forester tree planter continues to give good results on suitable unploughed ground or complete ploughing but there are still problems to be overcome on spaced furrow ploughing before the machine becomes fully competitive with hand planting. Mechanical and economic appraisals continue, particularly with a view to combining ploughing and planting operations.

PLOUGHING AND DRAINAGE

Outputs of Ploughing Outfits

Work on the production of output guides for ploughing equipment has met with considerable difficulties. Further studies have confirmed that the statistical relationships obtained do not adequately explain the variations and it is now proposed to study gross data in order to obtain broad output guides.

Step Cutters

The use of the prototype step cutter which was developed as a result of the need to provide shelter for tubed seedlings has been extended to provide a step in the furrow slice for notch planting of bare rooted stock and has operated quite satisfactorily. It is proposed to develop a step cutter for a double mouldboard plough.

New Drains—Afforestation Areas

Hydraulic control of mouldboard depth on the Parkgate Deep Drainer has been developed and successfully tested and similar control of cutting discs will be introduced shortly.

New Drains—Reafforestation Areas

The principal method available at present of preparing drains in clear-fall areas is the use of backacting diggers or hydraulic excavators at a cost of at least 10p per metre. Trials have shown that under certain conditions it may be possible to plough out drains at a significant cost saving. The BTD 20/Lokomo plough outfit was tried at Kielder but results were unsatisfactory owing to high stump and brash densities and soft soil conditions. This was followed up with the Parkgate Deep Drainer towed by two TM 55 W tractors. An acceptable drain can be ploughed on areas where stumps are relatively small and where the heaviest lop and top has been cleared from the drain line. The problem lies in the development of equipment to clear a drain line of brash cheaply and a snow-plough-type front mounted blade is being tried for this. The use of crawler tractors over stumps is an additional problem because of track wear and it is proposed to test suitable wheeled tractors. Where normal clearfall areas with larger stump sizes have to be drained, hydraulic excavators of higher capacity than existing backacter diggers will be required, but studies indicate that their cost will not be less than for equipment currently used.

Maintenance of Drains

There have been two approaches to the mechanisation of this work:

- (a) *By Ploughs.* Where all drains have to be deepened and widened it is common practice to replough them using the Parkgate Deep Drainer drawn by two crawler tractors. In an attempt to carry out normal maintenance by ploughing, a mouldboard was mounted via an Ede linkage on a "long-wide" County crawler tractor. The results were not encouraging as the spoil tended to be pushed in front of the mouldboard. To work satisfactorily it appears that the sock of the plough must bite into new material to fill the mouldboard effectively. The possibilities of a differently shaped mouldboard are under consideration, but for maintenance only the emphasis is thrown back onto the rotary principle.
- (b) *By Rotary Ditchers.* Trials with the Oja Viska on a Roadless 115 tractor have not been encouraging but it is hoped that better results will be achieved following the fitting of a reduction gearbox to the tractor. In Finland a number of rotary ditchers are being developed specifically for drain maintenance and the suitability of these machines for our conditions will be examined.

FERTILISING

Studies were carried out to check the distribution pattern of fertilisers applied to afforestation areas or established plantations by helicopter or fixed-wing aircraft. Initial results have revealed a wide range of distribution patterns and work is continuing in order to determine the major factors controlling distribution.

WEED CONTROL

Chlorthiamid Application

The Horstine portable motorised knapsack granule applicator was found to be suitable for the application of granular herbicides such as Chlorthiamid which is a useful herbicide toxic to a wide range of grasses and broadleaved forest weeds but safe to use. The chemical can be applied in band or spot treatments.

Atrazine

Trials have been carried out with this powder herbicide which can be applied either dispersed in water from a simple sprayer or in granular form from a distributor. Guidance has been given on methods and outputs. This is a much more specific chemical than Chlorthiamid, covering only a limited range of grasses and some soft herbs.

Heather Control

As a joint project with Silviculturist (North) studies are being made to determine the most practical methods of large-scale control of heather in plantations showing checked growth. Trials have been carried out using knapsack sprayers, mistblowers and ultra low volume applicators and interim recommendations have been made. Work is continuing on new methods of application and on the logistics of chemical and diluent supply.

Ultra Low Volume Spraying (Plate 2)

A considerable amount of study has been done on the methods and equipment involved in ULV spraying which because of the control of droplet size and the very low volume of chemical and diluent required is an attractive technique. Work has been in progress with the Pathology Section to produce a hydraulic powered ULV sprayer for the control of Dutch elm disease. The machine can be powered either from a tractor's external hydraulic supply or from a small portable power pack.

Weed Control on Early Ploughing

A survey was made of the weed problems on areas ploughed one or two years in advance of planting. As a result modifications were made to a Stihl mistblower so that it could be used for the dual purpose of spot application of Prefix in winter and heather spraying with 2,4-D in summer.

Mechanical Weeding

Assessments were made of a number of narrow gauge tractors for weeding in plantations but none proved to be really suitable. The tractor-

powered front-mounted brushcutter with a hydraulic drive system to the cutters has proved very successful. Further extensive field trials have shown, however, that where heavy weeding/cleaning or scrub cutting for ground preparation is required, rather than post-planting weeding, the brushcutter should be mounted on a four-wheel-drive 75 BHP tractor.

Protection against *Fomes annosus*

Ways of applying stump treatment liquid have been studied jointly with Pathology Section. As a result, an inexpensive plastic bottle fitted with a brush has been designed (see Plate 1). It should be available commercially shortly.

II. HARVESTING STUDIES

General

The programme of the Research and Development Workshop continued to give priority to the design and development of the 45 BHP hydrostatic tractor and to timber handling equipment. On cable cranes the major development has been the study of capstan-controlled winches while further progress has been made on the problem of stacking space arising from the increasing length of skylines. Work measurement was concentrated on keeping up-to-date standard time tables for thinning, felling, extraction and cross-cutting.

Forty-five Brake-horse-power Hydrostatic Tractor

During the year the Mark I tractor was field tested and the Mark II machine was built to a similar specification. A number of modifications have been made in the light of user experience and both machines are now engaged on long-term trials under varying site conditions in Scotland and in Wales. Reports on the field performance of these machines have been encouraging. A third prototype which is now being assembled will have more power and larger winches and should be on trial by June 1972.

Hydratongs

These have now been fully evaluated, and improved Mark III versions are now in production and in service use. Other work is being done to incorporate a low powered hydraulic winch for use in more difficult terrain so that logs can be pulled within reach of the tongs.

Mechanical Handling Equipment

A number of mechanical handling devices have been developed. A rotating clamshell grapple has been designed and manufactured for use with the Volvo LM 640 so that the machine can handle shortwood ranging from small woodwool to 3 metre pulpwood. An end tamping device has been produced for squaring 1 metre pulpwood when loading lorries with a grapple crane. Front mounted hydraulic stackers were built and fitted to a Hough paylogger and a County 754 but some modifications have proved necessary and these are being tested. A new type of tong grapple and mounting has been developed and is being tested on a Massey Ferguson 165 tractor.

Ground Skidding Trailer

A prototype trailer was built to enable tree lengths to be loaded onto the trailer by a skidder and moved away by a separate towing unit. A second trailer was built and both trailers and towing unit will be evaluated in East Scotland.

Larger Tractor Tyres

Larger tyres (23 x 26) were fitted to a Hough tractor and trafficability trials were carried out. Results indicated that under certain site conditions a greater number of traverses could be made than when standard tyres were fitted.

Cable Cranes

The main project in this field has been the study of capstan-controlled winches developed by the Engineering Division. Initial experiments with cast iron capstans of various profiles met with little success mainly because of rope slip and excessive capstan wear. An improved version of capstan, hardened and correctly profiled, is now under extended field tests. The main advantage of capstan control are the reduced haul-back brake effort and the smoother running of the winch. It also gives the equivalent of a locking carriage but with the capability of dropping the load gently in the event of line failure. Troubles to be overcome include the difficulty experienced by the chokermen in pulling off rope, the instability of the tower when moving between set-ups due to the heavy top weight, accelerated rope wear and the likelihood of extensive rope damage if a crossover occurs on the capstan. The approach angle of the carriage to a support when loads are completely suspended also indicates the need for some redesign.

Other cable crane studies included :

- (a) *Line Pay-off System*. A method of line pay-off was evolved to help the chokermen, using two extra blocks and a suitable length of hoist line. In principle this was satisfactory except for some power loss on side haul and a tendency to over-shoot at the stack. A system using spring motors to pay off the line has yet to be tested.
- (b) *Line Diversion System*. In order to turn loads along roadsides a system devised using only extra pulley blocks has had a fair degree of success; the use of a third drum in the system may help cut load diversion time.
- (c) *Duplicate Skyline*. This system of using one tractor to two skylines has been further tested and has so far proved to be one of the most economic methods of dealing with stacking problems at roadside.
- (d) *Extraction of Line Thinnings*. A comparison of high lead extraction times for produce from a selective thinning and herringbone line thinning in unbrushed Sitka spruce showed no difference attributable to thinning methods.

A system of line thinning was evolved to produce sufficient volume per set-up to justify the use of a skyline. It is basically a parallel row system

with accesses cut at predetermined intervals to allow produce to be moved from the felled rows to the rack. When the rows are parallel to the extraction direction it is simple to apply and needs little supervision. When the rows are at an angle to the rack direction the system can still be applied once the fellers have been trained. This system is currently being evaluated.

Splitting Pitprops

Studies have been carried out on the Cundey splitter to determine optimum working method data on production costs and output guidance times. Study on larger pitwood sizes is necessary to complete this project but the major advantage of the system lies in the automatic feed which reduces the physical effort required by the man feeding the machine.

Multilift Detachable Lorry Body

Trials were carried out on 1.1 metre pulpwood resulting from the cross-cutting of tree length poles extracted by skidder and also on the loading of 2.3 metres pulpwood prepared in the wood and loaded direct onto the body from a skyline double drum winch. The system provides a cost benefit on the loading of the body, which is at ground level and allows quick turn-round of the lorry, which picks up a full body in approximately ten minutes.

The main disadvantage in the conditions tested were the lack of means of moving a full body. This caused obstruction on narrow roads to subsequent working and ideally the body should be moved when full to a larger turn-round to await the collecting lorry. A trailer has been designed to cope with this but a further vehicle such as a tractor would be involved in this operation. It is considered that the system would fit in well to a forwarder system of extraction where unloading direct onto a multilift body would be possible. Combination of the body with a forwarder unit is a logical follow-up to this, the problem being the determination of a load size unit suitable for both the forwarder and the lorry.

Lorry Loading and Transport of Timber

Studies of loading and transport were completed during the year in Southern England but studies of lorry loading in other areas have met with considerable difficulties due to the complexity of product mix.

Tree Processor

Trials were started at Thetford in March using the Can Car processor in order to determine and analyse the factors associated with a full tree processor unit and the problems which arise, for example, in felling and extraction methods, optimum size of felling coupe and the organisation of work at the processing site, including presentation to the machine, movement of output and the disposal of branch wood.

Production Operations

During the year work has continued with a series of projects on production operations including a major study of pitwood production in Wales and the preparation of standard time tables and output guides for thinning,

felling and cross-cutting (including the use of measuring bars) on several of the main species over a wide range of terrain conditions. Standard time tables have been produced for extraction equipment, including the Massey Ferguson 135 tractor equipped with hydratongs, and for high lead cable cranes. A study was also made of harvesting systems using the County 574 tractor.

III. OTHER WORK

Safety

Development work was carried out on personal protection of sight and hearing, on codes of practice for safe working techniques and methods, on the safe use of chemicals and guns and on safe working in the operations involving aircraft.

Vibration research has continued in cooperation with the University of Dundee and the National Institute of Agricultural Engineering. The phasing out of chainsaws not fitted with anti-vibration handles was completed in December 1971.

I. A. D. GRANT

SYSTEMS DESIGN

The work of the Financial Control Project Team, led by the Director of Management Services, came to an end in June 1971, at the end of the first year's full operation of the new budgeting and control system. A new Systems Design Section of Organisation and Methods Branch, headed by a former member of the Project Team, became responsible for the continuing development and refinement of the financial control system, and in a general review of the working of the system has identified certain aspects which require further development.

Design work on the system for control of jobs within the Forest Budget, including harvesting work, is currently being undertaken. Particular attention has been paid to the provision of local job control data which will be required when the computer system for central processing of management reports and payroll is in operation, and when certain data currently used by local managers are no longer available in their present form.

A review of the planning and control systems for road work has indicated the need to improve the link between the investment planning and operational budgeting systems for road construction and road improvement projects, and to clarify the responsibilities of the various managers involved in planning and budgeting for such projects. Development work on these aspects is in hand at present.

The Systems Design Section has also participated in a number of courses designed to increase managers' awareness of the significance of the information provided by the new system of financial control, and to improve their understanding of the roles of the various management levels upon which the system is based.

P. A. MERKER

HARVESTING AND MARKETING DIVISION

TIMBER UTILISATION

The Use of Bark in Horticulture

Most of the trials undertaken during the year involved the use of pulverised bark in bulb forcing and in mushroom culture. For both of these purposes the pH of the bark at 5.5 is too low, and it was found that about 7 gm per kg (12 oz per cwt) of slaked lime should be added to give the required neutrality.

While the addition of lime in bulb forcing might be considered a disadvantage, the lower density of the bark means that the weight of the filled forcing boxes using a bark/soil mixture is only 11½ kg compared with 14 kg when the normal practice of filling with silty soil is followed.

A number of experiments have been carried out using bark as a substitute for peat as casing in the cultivation of mushrooms (See Plate 3, central inset.). Casing, the uppermost layer in the mushroom tray through which the sporophores penetrate, usually covers the compost in which the mycelia develop to a depth of 4-7 cm. Yields in the Commission's experiments, which were undertaken at three different sites, were mostly below those given by peat casing; on the other hand yields obtained from trials by some commercial growers were sometimes better than, or at least equal to, those given by peat. Although bark has a price advantage over peat in many areas of Britain, bark casing needs to be watered more frequently than peat and consequently labour costs could be higher.

While promising results were given by a mixture of the bark of Scots and Corsican pine, mixed conifer bark (containing spruce, larch, pine and Douglas fir bark) was found to be unsatisfactory in that the sporophores failed to grow through the casing. This is thought to be due to the presence of toxic extractives, and efforts are being made to identify the less suitable species.

At the Glasshouse Crops Research Institute bark is being tried as a constituent of a compost for mushroom growing. The bark is used as an alternative to peat, which is required for its water-holding capacity, in the composting of hay and straw mixtures. The process takes place in a controlled environment at a temperature of 50°C. Further trials using bark as a main ingredient, with suitable activators, may indicate that thermophilic bacteria decompose the bark in this composting system.

Other trials have included the use of bark in ornamental mulches at Bedgebury Pinetum, the Royal Horticultural Society's gardens at Wisley, and at Bath University.

During the year two companies started to market pulverised bark to growers; and an exhibition contractor made effective use of it for display purposes, finding it cleaner to handle than peat.

The use of bark for potting composts and plunge beds was again featured at the Chelsea Flower Show of the Royal Horticultural Society.

Reduction of Needle Fall in Christmas Trees

Although no further experiments were undertaken in the dip treatment of Christmas trees to reduce needle fall, there was follow-up activity to check the efficiency of alginate dipping which is now widely practised by some Conservancies. It was noticed that poor results were obtained when the concentration was allowed to fall much below one half per cent, if no mechanical agitation was used, or if no water-softeners were used in hard-water areas.

Fence Post Trials

Results of experiments at eight sites in Scotland after 14 years' service are given in Table 19.

TABLE 19
FENCE POST TRIALS IN SCOTLAND
PERCENTAGE OF POSTS REMAINING

Species	Treatment		
	Untreated	Waterborne preservative*	Creosote
Sitka spruce	22	62.5†	100
Birch	Nil	59.3	99.3

Notes:

* The proprietary preservative tested 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 11 sites in England and Wales after 13 years' service are given in Table 20.

TABLE 20
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	0.7	84	99.4	—
European larch	1	75	93	100	—
Japanese larch	1	44	81	100	—
Ash	3	Nil	19	73	Nil
Birch	5	10	38	97.5	—
Elm	2	Nil	6.2	93	—
Oak	1	Nil	50	93	—
Sweet chestnut	1	69	50	100	44
Sycamore	2	Nil	65	93	—

J. R. AARON

F

THE JOINT PROGRAMME ON HOME-GROWN TIMBER :
PRINCES RISBOROUGH LABORATORY AND FORESTRY
COMMISSION

Since publication of last year's *Report*, the former Forest Products Research Laboratory has become part of the Department of the Environment's Building Research Establishment, and is now known as the Princes Risborough Laboratory of that Establishment.

The Joint Programme of Work on home-grown timber, carried out by the Princes Risborough Laboratory and by the Forestry Commission, has continued and has yielded further useful information on home-grown wood.

The following is a brief account of the past year's work under the Joint Programme.

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

Stress grading provides for the division of timber into grades such that the pieces which qualify for the better grades can be assigned higher stresses. This enables the stronger pieces to be used in smaller sections or over longer spans, so leading to the more effective use of timber and helping to keep it competitive with other structural materials.

The traditional method of stress grading had as its basis a visual inspection of all four surfaces of a piece of timber to identify the defect which would cause the greatest reduction in strength. In recent years, machine stress grading techniques have been developed which provide a better assessment of the strength of timber than is possible by visual inspection and which can carry out the operation quite quickly.

Experience in the machine grading of imported European redwood and whitewood and Canadian western hemlock has shown that selection to the 50 and 75 grades specified in CP 112:Part 2:1971 enables higher values of modulus of elasticity to be used and, equally important, that much better yields, especially of the higher grade material, are obtained.

To explore the advantages of applying machine grading techniques to home-grown timber the Forestry Commission, in co-operation with the Princes Risborough Laboratory, initiated an investigation of the grading of the four home-grown species, Scots pine, Sitka spruce, Douglas fir and Corsican pine in the Computermatic machine. The results of the investigation on Scots pine were given in last year's *Report*. During the year, bending tests on Sitka spruce were completed and those on Douglas fir are well advanced.

These tests showed that the basic relations between bending strength and modulus of elasticity were highly significant for both Scots pine and Sitka spruce and suitable for the calibration of grading machines. They provided the information needed to prepare programme cards for the Computermatic machine to stress grade each species, 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 were also determined, following the procedures that have been fully developed for the machine grades of European redwood and whitewood and Canadian western hemlock.

The M75 and M50 grades have been recommended for machine selected timber as an interim measure until the present work on the whole question of grade boundaries is completed. They have the same stresses in bending as for the corresponding visual grades with appropriate adjustments to the stress values for the other properties. They differ from the visual grades, where the same value of modulus of elasticity applies to a species irrespective of the grade, in having higher values of modulus of elasticity for the better grades.

The investigation showed that Sitka spruce could be machine graded satisfactorily and that considerably improved yields of the better grades could thereby be achieved. For example, some 80 per cent of the pieces of Sitka spruce tested were rated by the machine as M75 grade compared with less than 10 per cent by visual inspection. The investigation also showed that M75 Sitka spruce would have the same grade stress values in bending, compression parallel to the grain, and mean and minimum modulus of elasticity as European redwood and whitewood of M50 grade. It also indicated that roughly 25 per cent of the pieces had comparable strength properties to those of the M75 grade of European redwood and whitewood. The effectiveness of the machine selection was examined by comparing the value of ultimate bending strength of each piece obtained from a destructive test with the minimum value of ultimate strength required for the grade to which each piece was assigned. Machine selection was found to be better than visual selection provided that a realistic allowance for shrinkage was made and that dimensional tolerances comparable with those specified in BS 4471 *Specification for Dimensions for Softwood, Part I, Basic Sections* were attained in the sawing of the wood.

Some Observations on the Wood of Young Sitka Spruce of Different Provenances Grown at Bush (Midlothian) and Wykeham (Yorkshire)

The Bush and Wykeham plots were two of four demonstrations set up in 1959 to illustrate phenological differences between provenances of Sitka spruce. Six trees of each of twelve provenances covering the range of natural distribution of Sitka spruce from Alaska to Oregon were established in rows on each plot. Observations carried out in 1960 and 1961 (See *Report for 1965*, pp. 173–184) demonstrated differences in the pattern of growth between provenances, most notably in the date of cessation of height growth. This varied from July for some of the trees of Alaskan origin to late September or early October for most southerly provenances.

The pattern of shoot and leaf elongation largely determines the character of the wood laid down in the tree. Expressed simply, during the period of shoot and leaf development, thin walled early wood is laid down; with cessation of shoot elongation, late wood production occurs. Thus provenances having differences in duration of extension growth might be expected to produce different amounts of early and late wood with a consequent effect on the yield and density of their timber.

Therefore, as a further contribution to the study of the interaction between growth, wood yield and wood density in Sitka spruce, the Bush and Wykeham provenance plot trees were used to examine:

- (1) The comparative yields and density of the wood laid down by each provenance.
- (2) The pattern of within-ring structure for the timber of each provenance, in particular the amounts of early and late wood and their influence on overall wood density.

Provenances tended to show an increase in average tree volume and weight of wood substance from north (Alaska) to south (Oregon); this was seen more clearly at Wykeham than at Bush where there were some outstanding exceptions to this trend, notably the Alaskan provenances of Lawing and Juneau which had been remarkably successful. There was a remarkable difference between the success of the Lawing trees at Bush and Wykeham, as on the Yorkshire site they had given the poorest performance of all the provenances. At Wykeham, the Juneau trees had produced neither the volume nor weight of wood of the trees at Bush but had been very successful in comparison with the other Alaskan provenances on this site.

The within-ring study again demonstrated that high wood density is a function of high percentage late wood and that this increases as ring width decreases. Ring width showed no apparent relationship to latitude of provenance and so there is no evidence for a relationship between density and provenance, on the basis of the single ring study; however the whole tree study showed some tendency for density to fall in the more southerly provenances, particularly at Wykeham. Reference to the data given by Lines and Mitchell (See *Report* for 1965, pp. 173–184) indicates that the dates of cessation of height growth tend to be earlier for three Alaskan provenances, Cordova, Lawing and Sitka and the British Columbian provenance of Terrace. Except for Lawing at Bush, these provenances produce narrow rings with wood having a high percentage late wood and high or fairly high density. The fourth Alaskan provenance, Juneau, continued growth for some while after the rest, a point of some interest in view of its success also in terms of both volume and weight of wood production and in its somewhat lower wood density.

These observations could be explained in terms of late wood formation on cessation of height growth—the provenances ceasing height growth early, although typically of slow growth, having a longer period for late wood production to give a higher proportion of late wood. The outstanding exception was the performance of the Lawing provenance at Bush. As might be expected for its probable early cessation of height growth it produced a high proportion of late wood; however radial growth was vigorous, even after late wood formation, and was possibly favoured by reduced competition as only four trees survived in the row. A wide band of late wood was formed but it was of low density and thus whole ring density was low relative to the percentage late wood present.

Properties of the More Important Minor Species

Work has continued on the programme to examine the timber properties of Western hemlock, Grand fir, Noble fir and Western red cedar. The main

objective 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 are also being compared.

The tests on Grand fir have been completed and the results analysed. The logs were converted without difficulty on wide bandsaws in commercial sawmills, but some loss of sawn out-turn resulted from drought cracks. The sawn timber was graded to BS 3819: 1964 *Grading rules for sawn home-grown softwood*. No Grade I Clear or Grade I material was produced, due primarily to the fast rate of growth—between 2 and 6 rings per 25 mm—and the frequency of knots, many with bark included. The timber air-dried well to a moisture content of 18 per cent but suffered some distortion and checking when kiln-dried to 12 per cent mc. In the machining trials, carried out on kiln-dried material, a poor finish was obtained due to the predominance of soft springwood which tended to crumble. During planing operations, tearing of the grain was common around knots and where spiral growth was pronounced. The material nailed satisfactorily.

Tests on the other three species have been completed and the data are being processed.

Wood Residue Survey

A survey has been carried out of wood residues produced during the harvesting and primary sawmilling of home-grown softwoods and hardwoods. The objectives of the survey were:

- (a) To quantify the wood residues currently produced and to forecast the amount which will become available, taking account of new harvesting techniques.
- (b) To determine the present and potential use of this material.
- (c) To assess the implications of the concept of whole tree utilisation in the context of residue utilisation.

During the survey, visits were made to a number of Forestry Commission and privately-owned forests, to sawmills and most of the pulp, chipboard and fibre-board mills, and consultations were held with representatives from the Forestry Commission and the private sector.

Current harvesting systems leave over one million cubic metres (about 800,000 tons) of green wood substance in British forests every year. With more forests reaching maturity, this is likely to increase to over 2½ million cubic metres by the turn of the century. Harvesting techniques appear unlikely to change enough to affect this estimate to any great extent. Harvesting residues are generally left on the forest floor, although some hardwood residue is cleared by burning. Some is removed for firewood and some may find use in forestry activities, for example in helping to support vehicles over soft ground. Possible uses for tops and branches are for pulping, board production, animal bedding and vitamin-rich feed supplements from the foliage if these are economic to produce.

A conservative estimate is that residues arising from the processing of home-grown timber in 1970 amounted to 80,000 tons of bark, 200,000 tons

of sawdust, well over 300,000 tons of slab material and small amounts of off-cuts and trim. These figures will increase considerably over the next thirty years, by which time it is estimated that consumption of softwood will have trebled. Of the processing residues, about 70,000 tons of slabwood go for pulping and a further 40,000 tons for chipboard. Both of these industries appear capable of absorbing more slab-wood or chips from profile chippers in the future. The current major uses for sawdust are as poultry litter, cattle bedding and in building products eg sawdust/cement blocks, but again the pulp and chipboard manufacturing industries are likely to use more sawdust in their products. Small quantities of bark find uses such as in horticulture, but the bulk of it is either dumped or burned, so that further outlets could well prove profitable.

Sawlog Conversion Model

A sawlog conversion model is being developed to establish the yields of sawn timber that can be obtained from a given input of logs taking into account the size, taper and other characteristics such as sweep. Preceding the development of the model to be used, it has been necessary to consider not only the mathematical techniques available, but also their relevance in the context of the current and future sawlog supply and the demands of the various markets for home-grown timber.

Other Work in Progress

A number of other projects are currently in progress and it is expected that some of the results will be available for next year's *Report*. These include such topics as breast height boring/whole tree density relationships for Sitka spruce ; the splitting of timber on nailing, with particular reference to larch and Douglas fir ; the effect of fertiliser application on growth increments and wood density in Sitka spruce ; sawmilling studies on Douglas fir from a well documented pruning experiment, to assess the effect of several pruning regimes on the out-turn of graded sawlogs and on the sawn output of graded material.

T. HARDING

*Building Research Establishment
Princes Risborough Laboratory
Bucks*

PART II

Research Undertaken for the Forestry Commission at Universities and Other Institutions

NUTRITION AND FOREST SOILS

COMPARISONS OF CROP ROTATIONS, AND OF FERTILISERS WITH COMPOSTS, IN FIFTEEN-YEAR EXPERIMENTS WITH SITKA SPRUCE

By BLANCHE BENZIAN, S. C. R. FREEMAN and H. D. PATTERSON

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Extract from *Rothamsted Report* for 1971

In 1945, composts and green manuring were used in Forestry Commission nurseries to maintain their fertility. As a result of experiments between 1945 and 1950, safe methods of using soluble fertilisers were developed for all seedlings and most transplants of common conifers. To test whether continued cropping with conifers and repeated dressings of fertilisers had any ill-effects, experiments with Sitka spruce (*Picea sitchensis*) were begun at Kennington and Wareham in 1951 and continued to 1965. Kennington was an acid sandy loam (pH 4.5 in CaCl₂-solution) used for farming until 1950, Wareham a very acid sand on heathland. Growing conifer seedlings continuously was compared with rotations of crops, including one year in three of fallow or green crops (rye, rye-grass or yellow lupins), and of one or two years in three of conifer transplants. Composts made from young green bracken (*Pteridium aquilinum*) and hop-waste were compared with fertilisers ("Nitro-Chalk", superphosphate, potassium chloride and magnesium sulphate). The nutrients supplied to seedbeds are given below; fertilisers supplied more inorganic N, P and Ca, the composts more K:

Average amounts per year (1954-65) in g element per m²

Fertiliser	Total N	Inorg. N	P	K	Mg	Ca
Kennington and Wareham	—	14	10	11	4	36
Compost*						
Kennington	43.7	3.3	8.1	24.9	3.8	19.1
Wareham	50.0	3.5	5.8	22.4	3.7	13.1

Note:

* *Fresh produce p.a.*—Kennington: 5.4 kg. Wareham: 1954-57, 5.4; 1958-61, 6.7; 1962-65, 8.2.

No benefit was derived from interrupting the growing of conifers. At both sites, seedlings were often smaller and fewer after green crops than with continuous conifers. There was often a small benefit from growing transplants before seedlings, but not the converse.

Responses to manuring were much larger than any effects from cropping treatments.

Kennington

Seedlings were consistently taller with fertilisers than with compost, especially in the wetter seasons:

	<i>Average height (cm)</i>	
	<i>Dry Years</i>	<i>Wet Years</i>
Fertiliser	4.9	6.5
Compost	4.0	4.3

Giving compost (about 50 t/ha annually) to fertilised plots did not increase seedling height. The lack of response of seedlings to good compost at Kennington remains unexplained, though in 1959 damage from fungal attack was suspected.

Wareham

During the earlier years seedlings with fertiliser were as superior to those with compost as at Kennington, but in the last years of the experiment fertilisers gave seedlings that were only a little larger, if at all. Compost and fertilisers used together were better than either alone, especially towards the end.

Fertilisers and composts are compared in the table below which shows the usable seedlings (exceeding 3.8 cm high), large enough to transplant:

	<i>Number of usable seedlings/m²</i>					
	<i>Kennington</i>			<i>Wareham*</i>		
	1954-57	1958-61	1962-65	1954-57	1958-61	1962-65
Unmanured	348	370	108	0	16	7
Fertiliser	566	961	1,085	887	622	588
Compost	357	578	729	520	462	583
Both	440	858	1,028	953	864	1,022

* Limed plots only.

Without fertiliser or compost, usable seedlings became fewer during the experiment at Kennington; at Wareham there were none or few fit to use at any time.

Nutrient concentrations in seedlings (Table 21) at Kennington were similar with compost or fertiliser. At Wareham the only considerable difference was in % K (nearly doubled by compost) and % Mn; % K in seedlings with fertiliser also declined during the experiment from 0.8-0.6; in wet years, the fertilised plants showed severe signs of K-deficiency (similar deficiencies were cured elsewhere in the nursery by top-dressing with KNO₃).

TABLE 21
 DRY MATTER (DM) AND NUTRIENT CONCENTRATIONS OF SEEDLINGS (TOPS + ROOTS)
 Means of 12 years

	DM mg/plant	%in DM					ppm Mn
		N	P	K	Ca	Mg	
Kennington							
Unmanured	137	1.79	0.28	0.78	0.68	0.15	599
Fertiliser	315	1.94	0.30	1.24	0.61	0.13	878
Compost	281	2.14	0.30	1.55	0.57	0.13	1,065
Both	337	2.09	0.31	1.51	0.66	0.14	1,243
Wareham*							
Fertiliser	240	1.58	0.24	0.68	0.60	0.13	65
Compost	234	1.71	0.29	1.29	0.51	0.13	346
Both	338	1.70	0.26	0.96	0.57	0.14	317

* Unmanured plots not sampled.

Transplants responded well to manuring (Table 22); at Kennington they were 20–60 per cent taller, at Wareham 200–300 per cent. At both nurseries differences between composts and fertilisers were relatively small, but fertiliser was usually better in early years, composts later; the two together were a little better than either alone. Quality in seedlings is measured by their ability to grow after transplanting; the lower part of Table 22 shows that, at Kennington, seedlings grown with fertiliser grew slightly better as transplants in the early periods; at Wareham, the compost-grown seedlings were slightly better later.

TABLE 22
 HEIGHT (CM) OF TRANSPLANTS

	Kennington			Wareham		
	1954–57	1958–61	1962–65	1954–57	1958–61	1962–65
(a) Unmanured	21.7	22.0	20.5	8.9	10.2	9.9
Fertiliser	27.6	31.5	27.1	23.0	22.6	19.1
Compost	26.8	33.8	28.4	20.9	24.1	20.6
Both	27.9	36.1	29.7	25.3	24.1	21.6
SE±	0.25	0.45	0.31	0.33	0.35	0.25
(b) Ex-fertiliser	27.0	31.3	26.6	19.5	19.3	17.6
Ex-compost	25.1	30.4	26.3	19.6	21.2	18.0
SE±	0.18	0.32	0.22	0.33	0.35	0.25
cv %	2.7	4.1	3.3	4.9	5.0	4.1

Changes in soil organic matter and nutrients

The analyses of the two soils before cropping were:

	pH in 0.01M CaCl ₂	% org. C	Total elements					Exchangeable			CEC me/ 100 g	
			% N	ppm					ppm			
				P	K	Ca	Mg	Mn	K	Ca		Mg
Kennington	5.1	1.2	0.118	350	4,800	1,450	1,030	208	74	1,400	51	7.7
Wareham	3.4	2.4	0.082	58	700	200	152	26	19	140	33	3.0

Tables 23 and 24 show analyses of the soils after cropping. Although all the produce of green crops was dug in (except that some ryegrass cuts were removed), differences in soil composition from the contrasted cropping were small. Compost-treated soils had twice as much organic carbon as fertiliser-treated at Kennington and 70 per cent more at Wareham (without allowing for a possible decrease in bulk density). Except for P at Kennington and Ca at both places, compost-treated soils contained more nutrients.

TABLE 23
ORGANIC CARBON IN SOILS OF ROTATION EXPERIMENTS AFTER CROPPING, 1965

	% C in air dry soil (to 15 cm)	
	Kennington	Wareham
Averaging manuring treatments		
Fallow	1.23	2.69
Lupins	1.24	3.06
Rye	1.24	3.02
Ryegrass	1.28	3.16
Sitka spruce		
Seedlings	1.18	2.84
Transplants	1.26	3.17
Averaging cropping treatments		
Fertiliser	0.87	2.23
Compost	1.60	3.76

TABLE 24
NUTRIENTS IN SOILS OF ROTATION EXPERIMENTS AFTER CROPPING, 1965
In air-dry soil (to 15 cm.)

	Total (%) N	Total (ppm) P	Exchangeable (ppm)		
			K	Mg	Ca
Kennington					
Fertiliser	0.092	814	135	86	1,017
Compost	0.166	738	258	96	829
Wareham					
Fertiliser	0.076	108	12	14	492
Compost	0.220	140	39	64	482

These experiments are important because, although the Forestry Commission stopped using compost in most nurseries by about 1955, they were the only long-continued test of the fertiliser regime now commonly used. Compost made *Kennington* soil richer in organic matter and total nutrients than did fertilisers, but these apparent "improvements" did not produce better seedlings; indeed, seedlings with fertiliser were larger throughout. Neither fertiliser nor compost alone released enough nutrients at *Wareham* for Sitka to grow well during the 15 years, but tests associated with these long-term experiments showed that the decline in growth on fertilised plots could have been stopped by using slow-release fertilisers or by additional top-dressings of N and K. We have no evidence that any factor other than shortage of nutrients interfered with growth at Wareham. (Benzian and Freeman, with Patterson, Statistics Department.)

RESEARCH ON FOREST SOILS AND TREE NUTRITION

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

The Macaulay Institute for Soil Research, Aberdeen

Nutrition of Sitka Spruce

The emphasis in nutrition studies is now moving from pine to Sitka spruce, reflecting the predominant role that this species has attained in British forestry. An initial field investigation has been made of the distribution of dry weight and nutrients in a 21-year-old stand at Fetteresso Forest (Kincardineshire), and in the glasshouse the response of seedlings of this species to different rates and forms of nitrogen has been tested using hydroponics. These seedlings showed maximum total growth, and exhibited minimum root : shoot ratio, when the concentration of nitrogen in the needles was maintained at about 2.5 per cent of oven-dry weight. This optimum nitrogen level is much the same as that found for seedlings of Corsican pine, but the associated levels of phosphorus and potassium in the spruce—about 0.30 and 1.25 per cent, respectively—are much higher than those in the pine.

The large growth variation that can occur in pot experiments between trees in the same treatment has stimulated interest in the production of clonal Sitka spruce for future experimentation. Early in 1971 some 100 to 150 cuttings were taken from each of seven different source trees and, by using soil heating and intermittent misting, it has been possible to root a number of these, the success rate varying from 7 to 80 per cent according to clone. Cuttings from a further six source trees were taken in early 1972 and eventually it is planned to establish, within the Institute grounds, banks of the more successful clones to act as a sufficiently large source of cuttings for envisaged nutrition experiments.

Preliminary tests of the methods of handling vegetatively reproduced material, and of the advantages to be gained from its use, have been carried out with cuttings supplied by the Physiology Section of the Forestry Commission from a clone of Western red cedar known to root profusely. Propagation was successful and 198 of the rooted cuttings were experimentally subjected to the same range of rates and forms of nitrogen treatments as had previously been used in experiments with seedlings of Corsican pine and Sitka spruce (*Reports* for 1966, 1967 and 1971). Survival has been high and the pattern of growth response is similar to that obtained with seedlings of the other two species.

During the coming year it is proposed to lay out a new series of field experiments in pole-stage stands of Sitka spruce, the object being to investigate the relationship between tree growth and nutrient uptake in this species. Fertilisers are to be used to introduce a degree of controlled variation in nutrient uptake. Thus, the search for experimental sites has been limited to areas carrying an approximately 25-year-old stand of slow growing

Sitka spruce that field-management staff feel may respond to added fertilisers, there being no obvious soil physical factor limiting growth. With the assistance of the four Scottish Conservators it has been possible to locate and visit such stands in 24 forests across Scotland, the nominal Yield Class of most being about 12 and ages usually ranging from 23 to 29 years (exceptionally 22 to 31 years). Eighteen of these stands were sampled, foliage being taken from a total of 185 trees, and the analytical results for these are summarized in Figure 9. There was a surprisingly wide spread in the values for nitrogen, phosphorus and potassium and furthermore a persistent tendency for the results to group on a somewhat geographical basis. Thus, stands from the group designated A (Border forests) showed low N and K and only moderate P values; stands from forests in Group C (mid-northern) had moderate P and K levels but low N; for stands in Group B (western) N and P levels were moderate but K levels low; stands in Group D (north-east) had high P and K levels with moderate N levels and stands in Group E (extreme west) had high P and N levels with moderate K levels. This left a group of forests, designated F, that had no common geographical location but showed low N and P levels and only moderate K. The soils at all sites were fairly similar being podzols or podzolized brown earths, usually of Foudland or Strichen associations, with no evidence of an iron pan. At Ae (Group A), however, there was a cover of 15 to 30 cm peat and in the western and extreme western forests (Groups B and E) and at Rosarie, Speymouth (Group D) there were varying degrees of gleying.

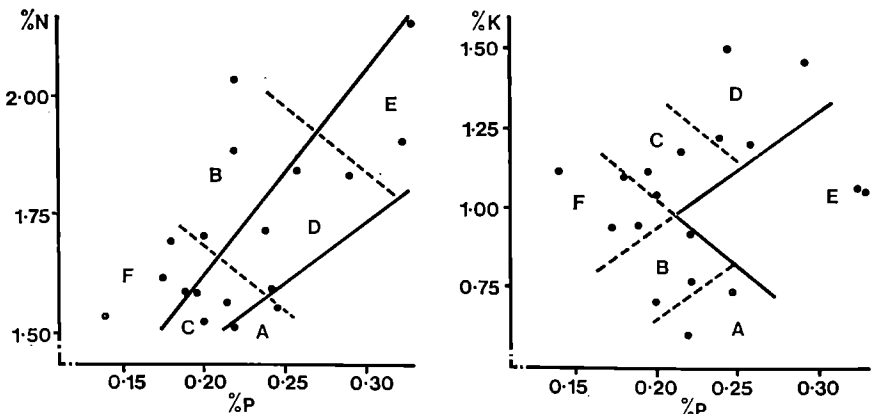


Figure 9: Foliar levels of nitrogen (N, left-hand graph) and potassium (K, right-hand graph) both plotted against levels of phosphorus (P): All expressed as percentage of oven-dry weight in top-whorl foliage.

Points congregate into groups comprising stands in the following forests:

- A. Border forests of Ae (Dumfriesshire) and Newcastleton (Roxburghshire).
- B. Western forests of Lochgoil (Ardgartan), Glenfinart (both Argyll) and Laurieston (Fleet) (Kirkcudbrightshire).
- C. Mid-northern forests of Glen Garry (Inverness-shire), Torrachilty (Ross-shire) and Leanachan (Inverness-shire).
- D. North-eastern forests of Deer, The Bin (Huntly), Bennachie (all Aberdeenshire) and Rosarie (Banffshire).
- E. Extreme west coast forests of Carradale (Argyll) and Ratagan (Ross-shire).
- F. Miscellaneous group comprising Whitehaugh (Tornashean) (Aberdeenshire), Fetteresso (Mearns) (Kincardineshire), Strathyre (Perthshire), and Elibank (Selkirkshire).

It would seem that if one were to exclude the wetter forests of Groups A, B and E the stands examined show linear increases in both nitrogen and potassium levels with increases in the phosphorus levels, but although the levels of these three nutrients in top-whorl foliage cover quite a wide range there was no accompanying change in growth. It should be remembered, however, that the stands examined were selected for a very specific reason, a particular criterion being slow growth, and are not necessarily representative of either the forest or region in which they were located.

Nutrition of Pines

The pole-stage fertiliser experiments on Scots pine and Corsican pine at Culbin, Laigh of Moray (*Reports* 1965 to 1970) have continued to be sampled and assessed. A careful examination has been made of the changes in the pattern of stem wood production, both within a single tree and between trees, in the Corsican pine experiment. These trees had been treated with fertiliser nitrogen at rates which were to supply as much as 1,510 kg N per ha over three years (*Report* for 1969). A marked increase in tree growth resulted, although the pattern of response with increasing treatment rate differed between height and basal area. Growth in sectional area at intervals up the stem responded very similarly to that at breast height (basal area) and although taper was to alter marginally over the seven year period of the experiment there was no significant change in form factor. By using radiographs of stem discs it has been possible to make a careful examination of the distribution of growth between tree sizes before and after fertiliser application. This has revealed that within any one treatment there is no significant difference between tree sizes in the *proportional* increase in relative growth brought about by the fertiliser. As growth had been much increased, however, and as the large trees were showing a greater relative growth than the smaller trees prior to application of the treatments, one effect of fertiliser treatment has been to widen the range of tree sizes and consequently an earlier suppression of the smaller trees can be expected.

Effect of Shade on Nutrient Uptake

During 1970, needle samples have been taken at monthly intervals from young Western hemlock, Grand fir, Douglas fir, Sitka spruce and Lodgepole pine planted beneath an over-canopy of larch thinned to densities of 100, 200, 300 and 500 stems per hectare and also planted in areas from which the larch had been entirely removed. These have now been analysed for chlorophyll (on fresh samples) and nutrients, while material frozen at the time of sampling has been used for determination of free amino-nitrogen and, in collaboration with the Biochemistry Department, of soluble sugars, both total and reducing.

In all species the amounts of chlorophyll per unit dry weight of foliage varied both with season of the year and with shade—the pattern of response to shade, however, differing between species. Of the nutrients examined, only nitrogen levels changed in all species in response to shade, the trend being an increase with increasing shade density. Since maximum change on shading was typically of the order of 0.3 per cent nitrogen, it is sufficiently

large to be of concern should foliar analysis be used as a diagnostic technique for underplanted trees. Phosphorus, potassium, calcium and magnesium levels, on the other hand, were with few exceptions relatively unaffected by shade and showed a similar pattern of variation with season for all species—i.e. levels of nitrogen, phosphorus, potassium and magnesium were at a minimum in July whereas calcium showed less variation.

Both amino-nitrogen and soluble sugars, when expressed as per cent of oven-dry weight, showed some response to density of shade, the nature and extent differing with species. Seasonal variations followed similar patterns irrespective of species or shade density: thus, amino-nitrogen exhibited two maxima, in March and May, with a small secondary peak in October, whereas soluble sugars yielded two main peaks in February-April and November, with a small secondary peak in August. Levels of amino-nitrogen ranged, according to species, from maximum values of 0.014 to 0.022 per cent of oven-dry weight to minimum values of 0.004 to 0.008 per cent; for soluble sugars maximum values were 9 to 10 per cent and minimum values 6 to 7 per cent.

Nitrogen Mineralisation in Peat and Humus

Incubation techniques continue to be used to study the rate of nitrogen mineralisation in samples of peat and mor humus taken from field experiments. Determination of ammonium extracted from these samples has been improved, and the rate of sample through-put much increased, by adopting an automated colorimetric procedure (Crooke and Simpson, 1971).

The stimulatory effect of treatment with a fertiliser containing both phosphorus and potassium on mineral nitrogen production in peat (*Report for 1971*) is still under investigation. Samples were taken, on a volume basis, in November 1971 from a range of fertiliser treatments in a Commission field experiment (Durriss 8/69) at Durriss Banchory Forest (Kincardineshire). These have been analysed and then incubated at 15° and 30°C under both anaerobic (waterlogged) and aerobic (wet) conditions. This experiment is still in progress but after 64 days incubation under aerobic conditions there was a response at both temperatures, in terms of mineral nitrogen production, to the application of PK fertiliser in samples taken from two of the four blocks of the field experiment. These two blocks are located on deep peat whereas the other two blocks, in which this effect was absent, are located on shallow hill peat. No effect of fertiliser treatment was observed for samples incubated under anaerobic conditions, irrespective of the block from which they came. The absence of a response in the samples from the shallow peat may reflect the higher ash and total phosphorus content of this material—10.20 per cent and 0.1 per cent, respectively, compared with values of <4 per cent and 0.05 per cent for the deeper peat. More recently untreated peat from the same area has been used to study the separate effects of P and K additions in the laboratory on samples incubated at 2°, 15° and 30°C.

In conjunction with the Microbiology Department an attempt is being made to relate the rate of production of mineral nitrogen on incubation to different measures of microbial activity.

In June, 1971, samples of humus were collected from the fertiliser experiment in pole-stage Scots pine at Culbin, Laigh of Moray (*Reports*, 1969, 1970). By this time, which was two years after the last application of fertiliser nitrogen and three years after treatment with lime and phosphate, only humus from the urea-treated plots showed a significantly increased ($P < 0.05$) total nitrogen content—1.54 per cent compared with 1.40 per cent for untreated humus. Mineral nitrogen in fresh humus accounted for less than 1 per cent of the total nitrogen present in all treatments and only in humus from plots treated with ammonium sulphate was there a significant increase ($P < 0.05$) in this parameter. On incubation of the humus samples at 30°C for 64 days there was a significantly greater ($P < 0.05$) rate of mineralisation of nitrogen in samples from plots given urea and ammonium sulphate but nitrogen applied as sodium nitrate had no effect on mineral nitrogen production. The decrease in acidity of the humus from the limed plots was highly significant ($P < 0.01$), a change that was accompanied by an increase in the proportion of the mineral nitrogen present as nitrate ions and by a significantly higher ($P < 0.05$) rate of evolution of carbon dioxide on incubation.

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THE EFFECT OF SOIL PREPARATION ON WATER POTENTIAL AND OXYGEN STATUS OF A WET HEATHLAND SOIL IN RELATION TO AFFORESTATION

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Traditional cultivation techniques have failed to produce good coniferous crops in many upland areas of the British Isles. The problems are particularly marked where combinations of exposure, high rainfall and high water holding capacity make adequate soil amelioration extremely difficult. One such difficult area is found in North Yorkshire where extensive afforestation has occurred on soils derived from Estuarine Clays of the Middle Jurassic period. As a result of the failure on these soils of single furrow ploughing an experiment was established at Rosedale* (Weatherell, 1967) to compare single furrow and complete ploughing with a different soil treatment involving the construction of cambered beds or "riggs" and "furrs". Riggs have been successfully used in wet agricultural areas in the past and are still employed in afforestation programmes in Northern Europe (Barelmann, 1963). The treatment has a configuration designed to increase runoff, improve surface drainage, and also, since the top of the rigg is elevated above the original surface, to increase the potential rooting depth above the water saturated zones. If these objectives are met successful establishment should be followed by greater stability of the mature crop.

The purpose of the present investigation has been to obtain a preliminary comparative assessment of the early effects of different cultivation treatments on some important soil characteristics. Measurements of soil water potential and soil aeration have been made since these represent the soil physical parameters most likely to be of importance both for tree establishment and for subsequent crop stability. While the success or failure of any treatment must ultimately be judged in terms of the performance of the trees such studies are intended to provide information upon which some prediction of treatment effects can be made.

Initial unreplicated observations made through the growing seasons of 1966 and 1967 revealed that water potentials in the experiment are consistently high, apparently as a result of high soil water holding capacity and a regular rainfall in excess of 40 inches a year. Within this moisture potential range, however differences between treatments could be detected. Subsequent measurements of soil water potential were made through the growing seasons of 1968 and 1969. Soil moisture tensiometers were installed to obtain replicated measurements of water potential at 30 and 60 cm depths throughout the experiment. These measurements confirm that while soil moisture potentials are high in the experiment throughout the growing season, distinct differences between the treatments are detectable.

* Now Cropton Forest, Yorkshire.

The most obvious difference between treatments is that both in the drained and undrained plots water potentials are lower in the riggs at both depths. Drains appear to have a marked effect on water potential at 60 cm depth.

The rigg is primarily designed to increase aeration by means of improved drainage and since the latter objective appeared to have been achieved it now seemed pertinent to examine the treatments for any associated differences in soil aeration. A meaningful indication of the oxygen status and, therefore, of the aeration of soil is provided by estimating the oxygen diffusion rate (ODR) at various depths. The soil ODR was measured in representative plots of each treatment by means of a polarographic technique. Measurements were made in September 1970, March 1971 and July 1971 at 30 cm and 50 cm depth. These times were selected to give soil conditions representative of late, very early and mid-growing season respectively and the depths were considered to be those most likely to be exploited by roots. It was found to be impracticable to measure ODR at depths greater than 50 cm under the conditions of the experiment. Soil moisture potentials were read in close proximity to the oxygen electrode sites. At 50 cm depth riggs were better aerated than the other treatments in all three seasons. Significant improvement of the aeration appears to be produced at 50 cm in the riggs by means of drains. The drained riggs show considerably higher ODRs than those found in any other treatment. At the same time the tensiometer measurements indicate that a close relationship exists between drainage, water potential and aeration in all treatments.

These characteristics suggest that the riggs are achieving the major physical objectives for which they were designed. Under the domed surface of the rigg an environment is produced that should be considerably more conducive to tree growth and stability than that found in a single furrow or complete ploughing. Early response of the trees on the riggs is encouraging and confirms the belief that the improved physical conditions of the rigg soils may lead to the enhancement of growth, stability and yield.

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FOREST PATHOLOGY

CONIFER SEEDLING PATHOLOGY

By G. A. SALT

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Effect of Formalin and Lime on Growth of Sitka Spruce at Wareham

The growth of two provenances of Sitka spruce, Wash. 70(7972)5 from Washington State and QCI 66(7111)3 from Queen Charlotte Island, sown on acid heathland soil at Wareham in March 1971, was much decreased by liming but increased by treating the soil with formaldehyde. Ground limestone was applied at 4 rates when the experiment started in 1969, and by October 1971 soil pH ranged from 3.4 to 6.1. Formaldehyde was applied to the same plots in autumn 1968, 1969 and 1970.

TABLE 25
HEIGHTS (CM) IN OCTOBER 1971 OF SEEDLINGS SOWN AT WAREHAM IN MARCH 1971

Lime (tonnes/ha)	0	1.5	3.0	6.0	12.0
Soil pH	3.4	3.7	4.2	5.3	6.1
No formalin					
Washington	6.61	7.63	7.08	4.62	2.34
Queen Charlotte Islands	6.65	7.60	7.38	4.78	2.82
Mean	6.63	7.62	7.23	4.70	2.58
Formalin					
Washington	7.50	7.58	7.87	6.98	6.59
Queen Charlotte Islands	7.10	7.55	7.92	7.55	6.92
Mean	7.30	7.56	7.90	7.26	6.76

Seedlings of both provenances responded similarly to soil pH and formalin. (Table 25). Without formalin seedlings grew well between pH 3.4 and 4.2. were partially stunted at 5.3 and very stunted at 6.1. With formalin seedlings grew well throughout the pH range, so the responses were small at low pH and large at the highest pH.

Neither soil pH nor formalin affected seedling emergence but provenance "QCI" had on average 5 per cent more seedlings than "Wash.". (Table 26). Between June and October, counts showed that some emerged seedlings were lost in all treatments whether formalin was used or not. The losses averaged 13 per cent for both provenances, but were greater among well grown plants in unlimed plots (20 per cent) than among very stunted seedlings grown on heavily limed soil (9 per cent). Usually seedlings died soon after emergence, and in patches where the soil may have been over-consolidated. At the end of May we noticed small patches where young

radicles had apparently been unable to penetrate the soil, and elongation of the hypocotyl had caused the seedlings to fall and dry out. In these patches the soil resisted penetration by a soft aluminium wire, whereas elsewhere the wire penetrated easily without buckling. Unrooted seedlings were more abundant in block I (seedbed 15) than in block IV (seedbed 18), and counts showed that 20, 12, 16 and 8 per cent of seedlings were lost in beds 15 to 18 respectively. This damage could easily be mistaken for damping-off, but plating-out affected seedlings and microscopic examination of stained preparations gave no evidence of damping-off or attack by other pathogens.

TABLE 26
NUMBERS OF LIVING SEEDLINGS PER SQUARE METRE
7th June, 1971

Soil pH	3.4	3.7	4.2	5.3	6.1
No formalin					
Washington	1,123	1,054	1,063	1,236	1,080
Queen Charlotte Islands	1,132	1,158	1,193	1,123	1,140
Mean	1,128	1,106	1,128	1,180	1,110
Formalin					
Washington	1,175	1,028	1,158	1,045	1,158
Queen Charlotte Islands	1,236	1,123	1,270	1,183	1,123
Mean	1,206	1,076	1,214	1,114	1,140

15th October 1971

No formalin					
Washington	881	934	977	1,080	942
Queen Charlotte Islands	934	994	1,106	1,115	1,054
Mean	908	964	1,042	1,098	998
Formalin					
Washington	881	959	1,002	838	1,080
Queen Charlotte Islands	1,020	967	1,089	977	1,020
Mean	950	962	1,046	908	1,050

%SEEDLINGS LOST, JUNE-OCTOBER

No formalin	19	13	8	8	10
Formalin	21	10	14	17	8

The distribution of different species of fungi isolated on water agar from roots sampled in October was the same as in 1970 (Salt, 1971), and again was not associated with effects of formalin on growth. *Cylindrocarpon* spp. were isolated from 90 per cent of root pieces from both untreated and formalin-treated soil. *Fusarium* spp. were uncommon and *Pythium* spp. and *Rhizoctonia solani* were not found. Roots that had been cleared and stained (Phillips and Hayman, 1970), and examined microscopically appeared free from the Chytrid-like fungi seen in roots from pot experiments. Most roots were free of fungal mycelium, except for a superficial network of septate mycelium which might have been *Cylindrocarpon* spp. or mycorrhizal fungi.

Samples of Sitka spruce seedlings from the Wareham nursery pH range trial, cropped annually with Sitka spruce since 1948, supported a similar fungus flora on their roots, so there was no evidence that, even here, stunting at high pH resulted from fungal attack.

Soil Fungicides and Seed Dressings

The effect of soil fungicides and a thiram seed dressing on the survival of Sitka spruce seedlings in the presence and absence of *Rhizoctonia solani* was studied at Wareham nursery. The culture of *R. solani* was isolated from ungerminated Sitka spruce seed recovered from Wareham soil in 1969 and was inoculated into autoclaved Sitka spruce seed in test-tubes. These seeds were stuck with araldite 2.5 cm apart on narrow paper tapes one metre long. One tape was placed across the centre of each plot, which was sown and covered normally. Seedlings were counted in one 5×46 cm grid placed lengthwise over the inoculum and in 4 similar grids on uninoculated parts of the same plot. Counts were repeated at different times on the same areas.

TABLE 27

EFFECT OF FUNGICIDES ON NUMBERS AND HEIGHTS OF SEEDLINGS IN OCTOBER 1971

	Soil Treatments				Seed Treatments	
	—	Busan 72*	Formalin	Benomyl	—	Thiram
Numbers/m ²						
Control	1,104	1,158	1,150	1,199	1,175	1,131
Inoculated	907	1,069	902	1,193	940	1,096
Height in cm	7.31	7.62	8.76	6.66	7.72	7.46

* Busan 72. Buckman Laboratories Inc., Memphis, Tenn.

Although differences in seedling numbers could not be distinguished visually, counts (Table 27) shows that inoculation decreased numbers in all plots except those treated with benomyl (22 kg/ha a.i.) and where a 50 per cent thiram seed dressing was applied at about 1 part of active ingredient per 100 parts of seed. Busan 72, 2-(thiocyanomethylthio)-benzothiazole, applied in water at 11 kg/ha a.i., decreased the losses to 8 per cent compared with 18 and 22 per cent in untreated soil and where formalin had been applied three months before inoculation and sowing. The growth of seedlings was slightly increased by formalin and decreased by benomyl treatments.

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VIRUS DISEASES OF FOREST TREES

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The attempts to transmit the suspected viruses of conifers by grafting and insects have not yet produced any positive results. These tests were made on transplants of Norway and Sitka spruce and Scots pine in the glasshouse. The trees were planted into the Forest of Dean after the grafting and insect transmissions had been completed. They have been inspected during the last year, but no evidence of suspected virus-type symptoms have been noted. In an attempt to stimulate symptom expression, some of the plants were covered with small polythene tents, but this temperature stressing was also unsuccessful. Inspection of these plants will be continued during the ensuing seasons. Additional graft and insect transmissions have been made to extend the number of suspected virus-infected donor specimens and to vary the conditions of insect feeding.

The populations of *Elatobium abietinum* on Norway spruce have been studied in a Forestry Commission nursery during the year. It is clear from this study, in conjunction with laboratory experiments on the defoliation caused by their feeding, that the aphid is not responsible for the defoliation occurring in this nursery. However, the degree of defoliation and the appearance of other suspected virus symptoms was less during the season than during preceding seasons, and so the relationship of this aphid, and of *Cinara pilicornis*, to the appearance of these symptoms is still in doubt. Virus infection remains a likely explanation, but confirmation of this must await positive results from the controlled insect feeding experiments and graft transmissions.

FOREST ENTOMOLOGY AND ZOOLOGY

RESEARCH ON THE GREEN SPRUCE APHID *ELATOBIMUM ABIETINUM*

By W. H. PARRY and W. POWELL

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Following the mild winter of 1970/71 the spring and summer of 1971 proved particularly favourable for *Elatobium abietinum* (Walk.) in North East Scotland. Extensive population sampling was carried out at Countesswells, Banchory Forest, Aberdeenshire and also at Kirkhill Forest, Aberdeenshire. Owing to the presence of an extremely high overwintering population the aphids attained their maximum intensity at the end of May, in comparison with the more usual peak attained in late June or early July (Parry, 1969). Correlated with this rapid build-up in aphid density alate aphid production was correspondingly brought forward in time. Large numbers of winged aphids were caught from mid-May onwards in comparison with the more usual time of mid-June. (*Report for 1970, and Parry, in preparation*).

It was noticeable at Countesswells that the familiar rapid decrease in aphid numbers following the attainment of the peak was not evident in 1971. The early attainment of the peak number was followed by a slow falling off of aphid numbers leading to a final complete collapse of the population in July. This was presumably caused by (a) increased needle loss, and (b) the gradual decrease in the soluble nitrogen levels in the needles reaching a critical level in July (see *Report for 1971*). From mid-June to mid-July large numbers of aphids were found congregating on current year needles but did not survive there for any considerable length of time. This observation has led to an investigation into the effect of needle age on sap uptake by the aphid.

Following the report of Parry (1971) that the probing behaviour of *E. abietinum* differed between Sitka and Norway spruces the development of the toxic symptoms has been followed in both species. Symptoms appear to take slightly longer to appear on Norway spruce. Also, of those needles which do exhibit symptoms a smaller proportion of these is lost on Norway spruce. Work is progressing on the toxic mechanisms operating during the aphid feeding processes. In addition, the effect of the seemingly more tolerant Norway spruce on aphid populations in the field is being investigated.

Research is continuing on the ecology of overwintering populations of *E. abietinum* with a view to determining the environmental factors governing the size of such populations. Aphids collected from Sitka spruce trees

at Countesswells Forest, near Aberdeen, were tested for supercooling ability throughout the winter of 1971/72. Supercooling points of individual aphids were determined by means of a copper-constantan thermocouple connected to a potentiometric recorder. A cooling rate of 1°C per minute, as proposed by Salt (1966), was used in all supercooling point determinations. Aphids older than first instar nymphs supercooled to temperatures which averaged between -16°C and -19°C before they froze. First instar nymphs showed a much greater variation in supercooling ability between individuals and aphids supercooling down to -28°C were recorded. There were differences significant at the 1 per cent level between the mean supercooling points of samples of first instar nymphs and all older stages. The reasons for this are being investigated.

The supercooling ability of monthly samples of aphids in conjunction with climatic records from the field indicates that, after a drop in temperature, the aphid population undergoes a certain degree of acclimation. In view of the fact that *E. abietinum* was originally adapted to survive the winter in the diapausing egg stage, it is considered unlikely that this acclimation is a *direct* physiological response by the aphid but is more probably a result of changes in the immediate environment caused by low temperatures, which in turn produce increased supercooling ability in the aphid. For example, changes in the chemical composition of the sap of the host plant in response to temperature changes could affect the cold-hardiness of the aphid. Work on this is currently in progress, and preliminary experiments on the supercooling of Sitka spruce needles yielded supercooling points ranging from -8°C to -13°C.

Work is also under way on the effects of low temperature on reproduction and development rates. In order to obtain accurate measurements of developmental rates (i.e. the length of nymphal instars expressed to the nearest hour) a "honeydew-collecting machine" has been devised based on the system used by Banks and Macaulay (1964), and modified for use with *E. abietinum* on potted Sitka spruce trees.

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TIT POPULATION STUDIES AT CULBIN FOREST

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As stated in the Report for 1971, the large-scale winter tit-ringing programmes of 1969/70 and 1970/71 have provided a good basis for the continuance of the population study. In addition, during the breeding season, breeding pairs from 92 nests were caught and individually colour-ringed and each brood was given an individual colour code. By ringing the birds it has been possible to follow the movements of both adults and juveniles during the subsequent autumn and winter without having to recapture the birds.

The work on family party movement commenced in 1970 was expanded and intensified in 1971. The parties show no hesitation in moving into other territories, and if two family parties come together there appears to be mutual avoidance, as Royama (1962) found for the Great Tit, (*Parus major* L.). Adults will not feed members of other broods and family parties gradually move apart with little or no display of aggression. At the end of the family party period (10-14 days) progressively more independent feeding on the part of the brood, and increasing aggression shown towards the young by the parents, acts to produce dispersal of the brood. The juveniles move immediately away from the territory, leaving a vacuum filled by other juveniles moving in. Sightings of colour-ringed individuals in September after dispersal from the nest show a range of movement of from 70 to 5,602 metres from the nest, indicating that a few individuals eventually settle a relatively short distance from the nest. Having arrived in the area, the juvenile birds tend to stay there, if they survive, for the rest of the winter, and, as Perrins (1963) found for the Great Tit, juvenile dispersal is random in that there is no tendency for members of the same brood to disperse to the same area. One interesting point is the occurrence of a number of marked juveniles at a winter feeding table outside the main forest block, providing some evidence of emigration from the forest. However, the birds may have subsequently returned to the forest and not been recaptured or sighted.

Once dispersed (during late June/July) juveniles quickly form into flocks, and indeed the largest flocks occur at this time of year as Odum (1941) found for the Black-Capped Chickadee (*Parus atricapillus*) in America.

Meanwhile the adults have remained in, or in the near vicinity of, their former territories, although little or no territorial behaviour is evident. However, adults do join local flocks of juveniles, and so each flock is composed of juveniles and the adults from the immediate area. Adults will, however, move back towards their former territorial area if the flock moves too far from it. Recaptures and sightings of marked individuals during the winter have shown that the adult does not range further than a mean of 226 metres (range 163-300 metres) from the centre of its winter "domicile"

Note: Culbin is now part of Laigh of Moray Forest.

—a term coined by Kluijver (1951) to define the area the bird occupies out of the breeding season, and which includes the former breeding territory. The pair-bond during the autumn and winter is fairly loose; a situation repeated in the Black-Capped Chickadee and the Willow Tit (*Parus montanus*) (Foster and Godfrey 1950)

We originally worked on the hypothesis that the winter flock was a cohesive unit, which had a set range in a particular area, and was composed of the same individuals when observed on consecutive occasions. A number of pieces of evidence have shown that this is not the case. Analysis of the data from fifteen colour-ringed individuals, for which there are two or more observations, shows that birds are not consistently found associated with the same individuals when sighted on different occasions. The fifteen birds were found, at various times, to be associated with a total of 206 individuals but only 30 of these were found associated with any particular individual on more than one occasion. So a flock in a particular area is not a cohesive unit in the sense of being composed of the same individuals, and associations are probably by chance.

Study of the ringing data shows that during the 1970/71 winter 81 per cent (148) of recaptures were of birds which had moved less than 550 metres. During 1971/72 winter 88 per cent of individuals had moved less than 550 metres. The remainder (19 and 12 per cent respectively) accounted for the long distance recaptures shown in the range below and may well indicate a pool of unsettled first-winter birds. So it appears that most individuals have a set area within which they move during the winter period. The range of movements for adults, using both recapture and sighting data, has been given above, and a similar estimate was made for first-winter birds. It was found that first-winter birds moved within an area with a mean diameter of 780 metres (range 270-2195 metres) which ties in well with the data from recapture alone.

Thus it is clear that individuals, both first-winter birds and adults, move within a restricted area in winter and will associate with other individuals in various parts of that range to form a flock, which will not necessarily consist of the same individuals on consecutive days.

During 1972, further work will be carried out during the territorial period, in which an assessment will be made of the amount of total territory utilised by the pairs during nest-building, incubation and brood-feeding stages. Further work on the family party period is also planned.

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HYDROLOGY

HYDROLOGICAL RELATIONS OF FORESTS

By L. LEYTON, E. R. C. REYNOLDS, and F. B. THOMPSON

Department of Forestry, University of Oxford

Rooting and Soil Moisture

During dry weather an important factor determining the water consumption of crops is the ability of the roots to absorb moisture from the soil. This in turn is related to the influence of soil moisture on the pattern of root growth. In the previous report (*Report* for 1971) mention was made of an investigation that had begun into the longevity and distribution of roots below a Douglas fir stand of Planting Year 1929 under four different soil moisture regimes: (1) control; soil receiving normal throughfall, (2) soil surface covered; no water applied, (3 and 4) soil surface covered, but irrigated weekly at rates corresponding respectively to 0.5 and 1.5 times the mean potential transpiration. Each treatment was replicated four times.

In the late spring and autumn of 1971, more than one year after the treatments had been imposed, soil cores were taken at random down to a depth of 1.22 m with the object of determining moisture and root contents of successive 15 cm layers. In all several hundred samples were taken.

To date only the moisture contents at the time of the first sampling (June) have been evaluated. Confirming the effectiveness of the treatments, the level of soil moisture throughout the profile (dry weight basis) was lowest in the covered plots and highest in the heavily irrigated plots, though that in the control plots was only slightly below the latter. In all treatments, soil moisture decreased with depth.

The technique of root extraction from soil has been described elsewhere (Reynolds, 1970). Although few quantitative data are as yet available a notable feature of the dry treatment was the concentration of roots at the top of the profile.

Concurrent with the above, measurements have been made of throughfall in the control plots using a single "5-inch" gauge randomly placed in each plot and moved to a new position usually within two or three days after rain.

REFERENCE

- REYNOLDS, E. R. C. (1970). Root distribution and the cause of its spatial variability in *Pseudotsuga taxifolia* (Poir.) Britt. *Plant and Soil* **32**, 501-517.

RECREATION

THE RECREATIONAL POTENTIAL OF FORESTRY COMMISSION HOLDINGS

By BRIAN GOODALL and JOHN B. WHITTOW

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Introduction

The Forestry Commission, because of the size, character and location of its landholdings, can make a significant contribution towards meeting the increasing demand for recreational facilities which is accompanying rising GNP per capita and increased leisure time. The recreational supply capability of forests needs to be assessed. A major objective of this investigation is, therefore, to establish the suitability of forest environments for recreational activity by means of a quantitative and qualitative evaluation of forest attributes in relation to recreational user requirements. It must be emphasized that, at this stage, the research is concerned with identifying recreational activity particularly suited to forest environments and with establishing degrees of compatibility between those activities in both spatial and temporal dimensions. It is not presently concerned with analysing levels of demand in any forest, nor with costing the supply of various recreational facilities, hence the emphasis on supply capability.

Forest attributes relevant to recreational potential are sub-divided into terrain and mantle characteristics and the data are obtained from map analysis and field investigations. These characteristics may be positively or negatively related to user requirement parameters so recognising, in terms of complementarity, incompatibility or competitiveness, the differential needs of various recreational activities.

The basic hypothesis is that substantial unrealised recreational potential exists for Forestry Commission holdings, especially where an extensive range of recreational pursuits is considered. This idea is illustrated in Fig. 10 where the level of present and potential recreational activity is related to a continuum of forest environments, ranging from single purpose commercial timber production at one extreme, through predominantly recreational forests to amenity, conservation and wilderness forests at the other extreme. It is important to realise that it is the relative (not the absolute) levels of activity showing in Fig. 10 that are important.

At one end of the continuum, timber production could remain the primary function of forests whose attributes do not lend themselves to large-scale recreational development. However, in some such holdings recreational activity need not be totally excluded—depending on the type of timber product—hence, an increasing potential level of recreational activity is shown as being con-

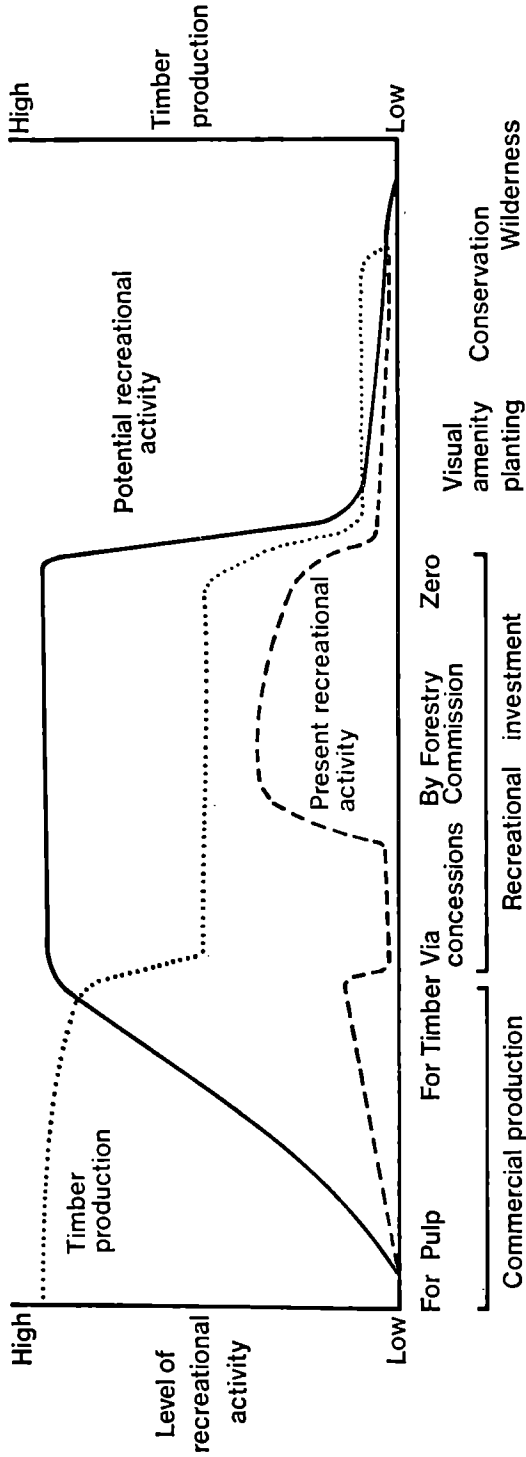


Figure 10: Hypothetical relationship of recreational activity and timber production to a forest continuum.

sistent with high timber output. At the other end some forests may make a major contribution to the conservation/wilderness sphere. Their direct recreational value is severely restricted because of access constraints in respect of general recreational pursuits. Forests in the middle range are seen as having recreation as their prime function and this potential can be tapped without necessarily sacrificing completely timber production. The position of any particular forest in this continuum is not fixed over time. A classification of Forestry Commission holdings to reflect this continuum and to serve as a basis for sampling was therefore desirable.

Classification of Forests

Limitations of centrally available data on each of the 370 Forestry Commission forests (1969/70) restricted consideration of forest attributes of possible recreational importance to scale of forest (measured in hectares) and structure (measured in hectares of planted land, of broadleaves, and of "other land" i.e. non-planted land). The forests were therefore classified on the basis of these characteristics. Regression analysis was used to test the strength and form of the relationship between forest size and the structural attributes. The relationship between forest size and broadleaf hectareage was statistically insignificant, except in the South-east England Conservancy. The other relationships were significant—for planted hectareage and forest size $r = +0.69$ and for forest size and "other land" $r = +0.88$. In each of these cases positive and negative residuals were mapped and the North and West Scotland Conservancies emerged as areas with high percentages of "other land" and low percentages of area planted.

A grouping technique based on nearest neighbour propinquity in a ranked frequency was used to identify significant size classes of forest. Eight initial classes were reduced to four final classes, namely 0–1,000 ha, 1–2,000 ha, 2–4,000 ha, > 4,000 ha, to give as even a distribution of forests between classes as possible. Applying the same technique to broadleaf hectareages of forests revealed two classes, above and below 25 per cent broadleaf hectareage. This grouping technique showed planted and "other land" hectareages to be positively correlated, hence only "other land" was used in classifying forests. Again two classes were deduced, above and below a 33 per cent "other land" hectareage. Sixteen categories would emerge from the multi-factor classification but since broadleaf hectareage is significant only in the South-east England Conservancy and "other land" hectareage in the North the West Scotland Conservancies the four size categories are adequate elsewhere.

Selection of the Sample Forests

Terrain characteristics were now introduced at a macro-level by grouping the Conservancies into lowland, intermediate and highland areas. The highland area was further subdivided into three groups: Wales, those Scottish Conservancies established from mapping residuals of "other land", and the rest of Scotland. Five Conservancies were selected randomly, one from each of five groups, subject to the constraint that three spatially contiguous Conservancies would not be allowed in order to achieve maximum contrast. South-

east England, North-east England, South Wales, East Scotland and North Scotland were the Conservancies selected.

Individual forests were then selected on a stratified (size) basis within each of those conservancies, and, in addition, reflecting broadleaf hectareage in South-east England and "other land" hectareage in North Scotland. Twenty forests were chosen so as to give at least a 10 per cent sample of forests in each Conservancy and a sample hectareage for the five Conservancies of approximately 10 per cent. A spatial contiguity restraint was also built in so that chosen forests would not be first or second nearest neighbours, again, to achieve maximum contrasts. The distribution of the sample forests is shown in Fig. 11. The resultant spatial distribution of sample forests provides a wide range of conditions and locational characteristics in the sense that Mynydd Ddu and Rievaulx are in National Parks, Shipbourne is in an Area of Outstanding Natural Beauty, Culbin is coastal, Mull is insular whilst Micheldever contains no surface water. In access terms some forests are virtually urban, e.g. St. Gwynno and Shipbourne, others are within day-trip distance of major industrial areas, e.g. Edensmuir and Hamsterley, and others relatively inaccessible, e.g. Mull and Naver. Port Clair and Inshriach are in major tourist areas whilst certain Conservancies in the sample—South Wales, East Scotland, and North-east England—are relatively underdeveloped as regards recreational potential. (See *Note*, p. 165.)

Map Analysis of the Sample Forests

Analysis of terrain and forest characteristics from Ordnance Survey maps allows each sample forest to be placed in its sub-regional setting. In the case of terrain features a sub-regional standard is obtained against which terrain character of the individual forest sections are compared. For example, the various sections of Micheldever Forest (Hampshire) are spatially spread through 780 km² of chalk downland for which major regional terrain parameters can be established as follows—amplitude of relief 76 m, average elevation 152 m, average slope 3° 24', slope direction changes/ km 1.65. Contrasting parts of the forest can then be identified separately. For example, the relatively subdued relief of the Basing Wood section of Micheldever where the local terrain parameters gave amplitude of relief 46 m, average elevation 81 m, average slope 1° 48', and slope direction changes/ km 0.93; or the more greatly dissected relief of Bushy Leaze and Chawton Park Woods which gives an amplitude of relief of 107 m, an average elevation of 163 m, an average slope of 4° 6', and 1.4 slope direction changes/ km. For the same downland area woodland accounts for 12.5 per cent of land use (1/5th of that woodland comprises Forestry Commission holdings).

A more detailed analysis of forest or mantle characteristics at a local scale is possible with data abstracted from Forestry Commission stock maps. Basic measures of forest geometry relating to size, degree of homogeneity and spatial contiguity can be established for the various sections of a forest. For example, Micheldever Forest comprises 45 spatially spread sections yielding a low "spatial packing" ratio of 0.025 (a single forest unit covering the whole of the regional base area would give the maximum value of 1). The homogeneity of each section can be examined by considering compartment



Figure 11: Location of sample forests. See Note p. 165.

size, age of trees, species variation and compartment subdivision. Micheldever shows a correlation between compartments with many, mixed species (67 per cent) and an above average degree of compartment subdivision (63 per cent): contrasts are again revealed between sections, for Basing Wood appears as a relatively homogeneous coniferous area whilst Black Wood shows a marked species mixture with a high broad-leaf element. Intra-forest accessibility can also be determined, for example, some 40 per cent of Micheldever Forest is more than 0.75 km from a public road.

Map analysis therefore reveals similar and contrasting sections of a forest and allows their comparison with sub-regional and regional standards. Areas of high or low potential recreational interest are tentatively identified for further investigation and testing in the field and against recreational user requirement data. The map analysis has been largely completed for the twenty sample forests.

Field Investigations

Contrasting forest environments have been visited in the field in consultation with Forestry Commission staff. Field research will supplement map analysis by providing data on site, rather than sub-regional, characteristics. The methodology, developed and tested in Maresfield (Sussex) and Gwydyr Forests (Caernarvonshire), requires four traverses, of 0.4 km length, at right angles to each other to be made from a randomly selected point (1 in Fig 12). Traverses 1-2 and 1-4 will be made parallel to the topographical grain of the area: 1-3 and 1-5 at right angles to the grain. On each traverse land, water and mantle characteristics are recorded, e.g. local slopes and amplitude of relief, surface and undergrowth conditions, interface characteristics, passibility for various forms of traffic and at traverse end points and the random point, view confinement and vista potential.

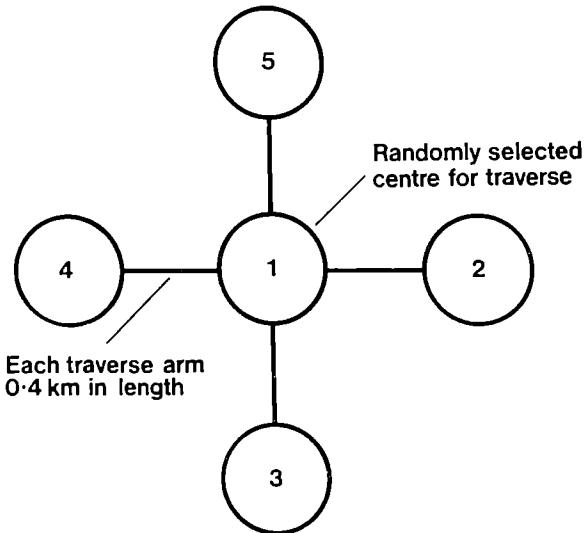


Figure 12: Diagram illustrating relationship between intra-forest sample point (1) and traverse arms (2 to 5).

The number of random points in each forest is selected to give at least a 10 per cent areal coverage. Certain modifications of the length of traverse, based on quadratic nesting principles, are made in forests of under 2000 ha. Collection of this data in the sample forests is now underway.

Current Position

The map analysis of factors pertinent to forest recreational potential is virtually complete, the field collection of data in hand and the user requirement survey at an advanced planning stage. From this data complementarities and incompatibilities amongst recreational activities may be recognised and the associated user requirements correlated with forest characteristics. A recreation capability index will be developed from this information, which will also incorporate the results of the evaluation of the passive recreational role of forest quality.

Note. Since this contribution was completed, certain forests mentioned have re-named as follows (numbers relate to Fig. 11):

- (1) Naver, now part of Borgie Forest
- (2) Slattadale, now part of Achnashellach Forest
- (3) Portclair, now part of Inchnacardoch Forest
- (6) Culbin, now part of Laigh of Moray Forest
- (7) Clashindarroch, now part of Huntly Forest
- (8) Craigvinean, now part of Dunheld Forest

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. (1971). The disparagement of home-grown softwood and its remedy. *Scott. For.* 25(2), 96-100; *Q. Jl For.* 65(2), 166-170.

Discusses the historical reasons for discrimination against home-grown coniferous wood, and demonstrates that the strength properties are on the whole comparable to the equivalent grades of imported wood. The possible role of rate of radial growth as an index of strength is examined and shown to be unreliable.

AARON, J. R. (1971). Forestry Commission's Christmas tree treatment solves needle-fall problem. *Grover*, 4th December, p. 1150.

Describes the development work which led to dip treatment in a solution of sodium alginate becoming widely practised in the Commission. Mention is also made of the fire retardant effect of such treatment.

BANISTER, N. (1971). The value for conservation of plantation forests. *Suppl. Forestry*, pp. 27-29.

Mentions ways in which plantation forest can be managed to get optimum production and optimum conservation.

BARSON, G. (1972). Light trap records for 1969 from Farnborough, Hampshire. *Entomologist's Gaz.* 23(1), 3-12.

An account is given of the macro and micro lepidoptera taken in a Rothamsted light trap at Farnborough, Hampshire, during the whole of 1969 in a well-varied and established garden surrounded by mixed deciduous woodlands. Included are a list of species and the numbers caught together with a discussion of the more interesting species.

A comparison was made of the seasonal variation in numbers and species of the micro and macro lepidoptera and also the seasonal changes in the index of diversity of the two groups.

BELL, T. I. W. (1971). *Management of the Trinidad Mora Forests with special reference to the Matura Forest Reserve*. Trinidad and Tobago: Government Printery, 70 pp. 8 plates, 11 tables.

BEVAN, D. (1971). Notes on *Pissodes validirostris* Gyll. and *P. pini* L. (Col., Curculionidae). *Entomologist's mon. Mag.* 107, 90.

Extra locations of *P. validirostris* are recorded and its infestation of Scots pine shoots is mentioned. Characters for the separation of adults of this species from *P. notatus* are discussed and better characters are suggested.

Additional information on the southerly distribution of *P. pini* is given and the need for more observation is indicated.

Four references are mentioned.

BEVAN, D. (1971). Protection of windthrown, standing and replanted trees: entomology. In *Windblow of Scottish forests in January, 1968* (ed. B. W. Holtam), pp. 38-39. *Bull. For. Commn, Lond.* 45 (HMSO 45p).

Details of the actions required to prevent damage by insects in windblown areas are given. The effective dissemination of such advice within three weeks of the gale and its rapid implementation resulted in no serious damage being caused by insects. Specific notes are given on *Trypodendron lineatum* and *Tomicus piniperda*, the most common pests in such situations.

BEVAN, D., and JONES,* TECWYN (1971). *Report on the beetle Hylastes angustatus in pine plantations of Swaziland and adjacent areas of the Republic of South Africa.* Res. Dev. Pap. For. Commn, Lond. 84.

This paper summarizes the results of an emergency investigation, carried out in 1964, into an outbreak of the European Scolytid species *Hylastes angustatus* Herbst. in *Pinus patula* and *P. eliottii* plantations belonging to the Usutu Pulp Coy., Swaziland. By examination of infested material in the field it was found possible to roughly map the life-cycle of the insect under S. African conditions and to offer some tentative conclusions over host plant preferences. A chemical control method based on treatment of nursery stock, prior to planting, with BHC was recommended for field testing.

BOWEN, M. R., and WAREING,† P. F. (1971). Further investigations into hormone-directed transport in stems. *Planta* 99, 120-132.

The effect of IAA and three synthetic auxins on the upward movement of ^{32}P -orthophosphate and ^{14}C -sucrose has been investigated in decapitated stems of *Phaseolus vulgaris* L., *Pisum sativum* L., *Coleus blumei* L. and *Helianthus annuus* L. IAA greatly enhanced the accumulation of ^{32}P -orthophosphate in *Phaseolus vulgaris* and *Pisum sativum*, whereas in *C. blumei* and *H. annuus* it did not. 2, 4-D, like IAA, caused an increase in ^{14}C -sucrose and ^{32}P -orthophosphate accumulation in *Phaseolus vulgaris* but, unlike IAA, caused no increase in *Pisum sativum*. The downward transport of ^{14}C -IAA, ^{14}C -NAA, ^{14}C -2, 4-D and ^{14}C -2, 4, 5-T from the decapitated apex was also studied. Results are discussed in terms of current theories of hormone-directed transport.

BRASIER, C. M. (1971). Induction of sexual reproduction in single A² isolates of *Phytophthora* species by *Trichoderma viride*. *Nature New Biol.* 231(26), 283.

It was found that *Trichoderma viride* Pers. ex S. F. Gray will induce sexual reproduction (oospore formation) on single A², but not A¹ isolates of heterothallic *Phytophthora* species, apparently by production of volatile stimulants.

BROWN, J. M. B. (1970). The effect of planting trees. In *The flora of a changing Britain* (ed. F. H. Perring), pp. 51-57. Hampton, Middlesex: E. W. Classey, for The Botanical Society of the British Isles. Reprinted as Conference Report No. 11.

Retreat of the last ice sheets left Britain poor in timber trees, while a steadily mounting demand, in the long settled parts, for fuel wood, charcoal and constructional timber laid bare extensive oak forests. Planting trees, for profit, or as a pastime, has always attracted landowners, even before the State, through the Forestry Commission, sponsored the re-forestation of wastelands. A rapidly growing market for softwoods brought it about that conifers have preponderated in afforestation, or replanting, during this century: while the native Scots pine is widely planted, increasing use is made of spruce, fir, pine, or larch from climatically similar regions in Europe and N. America.

The impact, direct and indirect (through the ancillary silvicultural work) of such introduction of (mostly) evergreen trees, both on the relict native deciduous forest and on the diverse wasteland communities, is sketched in its general features. It is pointed out that the loss under shade of territory by some common wasteland plants is offset by the creation of new habitats, along roads and rides, in clearings, at wood edges. The author holds that the oakwoods, or mixed broad leaf woods, are more endangered, and that the dwindling area of these must be safeguarded, in the interest of their rich associated flora, as well as of amenity and recreation.

* East African Agricultural and Forestry Research Organisation.

† Botany Department, University College of Wales, Aberystwyth.

BROWN, J. M. B., and NEUSTED, S. A. (1972). Natural regeneration of conifers in the British Isles. In *Conifers in the British Isles: Proc. R. hort. Soc. 3rd Conifer Conf. Lond.* 1970, pp. 29–39.

Recent research on natural regeneration of Sitka spruce, Lodgepole pine, Scots pine and Douglas fir is described. Various climatic and biological factors which account for the limited extent of natural regeneration are discussed. A check list of coniferous species regenerating naturally in the British Isles is given.

BROWN, R. M. (1971). Cold storage of forest plants. *Q. Jl For.* 65(4), 305–315.

This paper reviews current knowledge on the cold storage of forest plants.

In the last 10 years there has been considerable interest in the use of cold storage for seedlings and transplants. In spite of this there have been only two relevant publications in the last 20 years readily available to the British forester (Aldhous 1964, and Davies 1968).

Cold storage techniques are widely used in Scandinavia, northern Europe and North America. Experience in these countries has been freely drawn upon in an attempt to increase our understanding of some of the factors involved.

BURDEKIN, D. A. (1971). Protection of windthrown, standing and replanted trees: pathology. In *Windblow of Scottish forests in January 1968* (ed. B. W. Holtam), p. 38. *Bull. For. Commn, Lond.* 45 (HMSO 45p).

A leaflet entitled *Protective Measures against Pests and Diseases* was prepared jointly by the Entomology and Pathology Sections of the Forestry Commission's Research Division and was widely distributed to foresters within three weeks of the gale. It included practical advice on how to deal with the two main pathological risks of damage from fungal blue stain in pine and from root and butt rot in conifers caused by the fungus *Fomes annosus*.

BURDEKIN, D. A. (1972). Dutch elm disease. *For. homegr. Timb.* 1(1), 25–26.

The history of Dutch elm disease in Britain is discussed in relation to the present outbreak.

The various courses of action in relation to control are considered including a policy of *laissez faire* with no organized sanitation operations and a policy of action by sanitation felling and destruction of beetle breeding grounds. The former policy is rejected on the grounds that the disease is unlikely to decline rapidly. The latter is currently being practised in Britain. The use of chemicals for the protection of healthy trees cannot be expected to achieve adequate control in the absence of sanitation fellings but may prove to be a useful adjunct.

CARTER, C. I. (1972). A note on the occurrence of *Clubiona juvenis* Simon in the fens of the Norfolk Broads. *Bull. Br. Arach. Soc.* 2(4), 68.

Details are given of taxonomic characters used to distinguish this species from *C. trivialis*. Habitat details of recently captured specimens are discussed.

CHARD, J. S. R. (1971). Wildlife management in Grizedale. *Suppl. Forestry*, pp. 55–62.

The new plantations in Grizedale Forest increased its already rich variety of wildlife. By careful management of deer, and by encouraging wildfowl by the provision of suitably constructed ponds and appropriate cover, it has been shown that recreational activities based on public interest in forest wildlife can be economically profitable.

CHARD, J. S. R. (1971). The Scottish pinewoods. *Suppl. Forestry*, pp. 76–77.

On the evidence of relics of the Caledonian pine forest, where wildlife was abundant, many species need rotting timber for their life cycle, and this should be remembered when establishing special forest reserves.

(TAYLOR, K. D.*), COURTIER, F. A., *et al.* (1971). Movements of the Grey squirrel as revealed by trapping. *J. appl. Ecol.* 8(1), 123–146.

Squirrels were trapped, marked and released initially in a 16-acre (6.5 ha) woodland and later in all woodlands amounting to about 2,000 acres (809 ha), within two miles of the original area. In all, 922 squirrels were marked and released. After 5½ years of live trapping, 1,665

* Ministry of Agriculture, Fisheries and Food, Pest Infestation Control Laboratory, Tolworth, Surrey.

squirrels in the area were killed by shooting and by trapping, and these included 310 marked animals. Squirrels known to have survived for from one to four years covered relatively small distances compared to the size of the experimental area, indicating that individuals tended to remain within the same area for considerable periods, probably amounting to their life span. The average maximum distance moved by adult males caught more than once was 524 yd (479 m) and by adult females 285 yd (261 m). These distances relate mainly to records of movement obtained by operating groups of traps at intervals in time; the effect of trapping on the recorded distances moved is therefore minimal. Where groups of traps were operated concurrently, recorded movements were found to be much smaller. Seasonal movement was characterised by increased movement of males in June; this appeared to be related to the summer breeding season. No evidence was found of numbers of squirrels in the area moving towards attractive sources of food such as cereal crops. Of 57 squirrels trapped at a site within the study area and released 1.6 miles (2.6 km) away, 16 were known to have settled within two miles of their point of release, and four of these returned to sites near their point of capture. The effects of trapping on the recorded movement of squirrels are discussed.

DANNATT, N., DAVIES, E. J. M., and McCAVISH, W. J. (1971). Kilmory, 1971: An investigation into fertiliser response. *Scott. For.* 25(2), 100-109.

In September 1966, 1,000 acres of poorly growing Sitka spruce plantations in Kilmory Forest were top-dressed with 3 cwt of Gafsa per acre (377 kg/ha) by helicopter. Responses in leader length and ring width were investigated and showed that a remarkable improvement had occurred. This brief account reports the results.

DARLINGTON, E. (1971). A simple water-level dipstick for boreholes. *J. agric. Engng Res.* 16, 423-424.

The instrument (the design and construction are described) can be used to measure water levels down to 80 cm below ground; a model twice this length has also been made. A bulb powered by torch batteries lights up when the tip touches the water surface. It is cheap and robust, rapid and simple in use, weighs only 0.45 kg, and is accurate to within ± 0.5 cm.

(SMITH,* T., BRIERTON,† D., and) DAVIDSON, J. L. (1971). Marketing (pp. 27-32); Harvesting (pp. 33-36); Transport (p. 37). In *Windblow of Scottish forests in January 1968* (ed. B. W. Holtam). *Bull. For. Commn, Lond.* 45 (HMSO 45p).

Describes the planning undertaken by working parties set up to deal with the marketing of sawlogs, the marketing of small roundwood, the effect of the deferment of felling in the unaffected areas, harvesting and transport.

The harvesting section incorporates a summary of the lessons learned, such as the need to avoid cutting too far in advance of extraction; and also a list of observations by Professor Steinlin of Freiburg University who toured the blown areas.

DAVIES, E. J. M. (1971). The Argyll tree farming school. *Scott. For.* 25(4), 272-274.

In May 1971, the Royal Scottish Forestry Society visited Argyll and the author gave an account of Forestry practices past and present in the county. A good deal of the talk dealt with recent developments and the emergence of a school of thought which believes in emulating modern agricultural practice in forestry. This paper covers some of the points made in the talk.

DAVIES, E. J. M. (1972). History and background of Sitka spruce in the United Kingdom to the present day. In *Proceedings of the Joint Study Group on Sitka spruce*. *Q. Jl For.* 66(1), 51-67, and *Scott. For.* 26(1), 61-68.

DAVIES, E. J. M., and ADAM,‡ R. H. (1971). Replanting. In *Windblow of Scottish forests in January 1968* (ed. B. W. Holtam), pp. 40-41. *Bull. For. Commn, Lond.* 45 (HMSO 45p).

Discusses the problems, management considerations, programme and methods of restocking the windblown forests.

* Home Timber Merchants' Association of Scotland.

† Scottish Woodland Owners' Association.

‡ Scottish Woodland Owners' Association.

DUNN, M. J. (1971). Public pressure in the Forest of Dean. *Suppl. Forestry*, pp. 101-105.

Considers the high number of visitors each year to the Forest of Dean, and suggests that by good planning and management a total of 1½ million could be accommodated without upsetting the ecology, still keeping very large tracts of forest undisturbed.

EDLIN, H. L. (1971). *The public park*. 66 pp. 36 illus, 2 maps. London: Routledge & Kegan Paul, £1.40 (paper-back 70p).

Designed as a guide for young people doing a project study on one particular, selected park, this book shows what they should look for and suggests ways of following up their interests. It describes methods of investigation, timing, surveying and mapping, and the making of records with notebook, sketchbook and camera. Studies should include the past history of the land, the park's practical administration, wild life and the various recreational uses made by the public during their visits.

EDLIN, H. L. (1971). Woodland notebook: Goodbye to the pollards. *Q. Jl For.* 65(2), 157-165.

Pollarding, or the regular cutting back of broadleaved trees at a height of some six feet above the ground, is a practise of great antiquity. Its objects were to gain firewood and browse for cattle or deer, on a perpetual basis, by promoting regrowth from a point too high for animals to reach. With few exceptions, it ceased in England about 1870. Many pollarded oaks, beeches, hornbeams and willows survive, but only the oaks are likely to remain much longer. The others are likely to succumb to fungal decay before the year 2,000 AD.

EDLIN, H. L. (1971). Woodland notebook: United States amenity. *Q. Jl For.* 65(3), 209-217.

The Cape Cod peninsula in Massachusetts, on the east coast of North America, carries recently-formed forests of Red oak, *Quercus borealis*, and Northern pitch pine, *Pinus rigida*. These trees have colonised abandoned fields during the present century as the farmers, established here since AD 1620, gradually migrated west to more profitable lands. These trees grow poorly on the infertile morainic soils, but have high amenity value, since the whole peninsula is being developed as a seaside residential and recreational region. Woods are worth more as camp sites than as sources of timber. Pressure on open country and holiday beaches has led to restrictions in favour of residents, or punitive charges to outsiders. To counterbalance this, the United States Government has nationalised a long coastal strip, opened nature trails, and established an outdoor educational museum. Similar facilities are maintained by voluntary societies, municipalities and universities.

EDLIN, H. L. (1971). Woodland notebook: Two Scottish forest trails. *Q. Jl For.* 65(4), 327-333.

The modern fashion for nature trails has led to renewed interest in planned walks through woodlands, exemplified by The Hermitage at Dunkeld and the Birks of Aberfeldy, both in Perthshire, Scotland. Revisiting these two places after a lapse of 40 years, the author found a surprising increase in public use and enjoyment, aided by the modern facilities of car parks and trail guides. This revives public interest first manifested 100 years ago, when charges were levied for these same beauty spots, and professional guides provided.

EDLIN, H.L. (1972). Woodland notebook: Photographing trees. *Q. Jl For.* 66(1), 39-49.

Written from the standpoint of the amateur photographer, working with colour transparencies, this article outlines problems peculiar to trees that are not encountered when depicting buildings of similar size. Tree crowns may absorb light, or let some of it through. They have great depth and height, and are seldom motionless. Their appearance varies with the season of the year, while the sunlight that illuminates them has both daily and seasonal variations in direction and intensity. Simple techniques are suggested to secure good representations, and advice is given on the selection of trees as subjects for photographic records, at different stages of growth and times of year.

FAULKNER, R. (1971). Forest tree breeding in the world. 8. An outline of the British tree improvement programme. *Rinboku no Ikusyu* (J. Jap. Forest Tree Breed. Assn) 67, 22-25.

Contains historical notes on the introduction and breeding of tree species in Britain with particular reference to the development of the Genetics Section of the Forestry Commission.

The forest tree improvement programme is described in some detail; reference is made to individual breeding projects, the Forest Seed Association, and lines of research in state and university departments concerned with aspects of tree improvement.

FAULKNER, R. (1972). The selection and breeding of conifers for ornamental and commercial forestry uses. In *Conifers in the British Isles: Proc. R. hort. Soc. 3rd Conifer Conf. Lond.* 1970, pp. 22–28. 94 references.

Gives a brief historical survey of the introduction of conifers into Britain together with recent and likely future trends in the use of ornamentals. Natural variation in vigour, stem and crown form, resistance to pests, diseases and adverse climatic factors are all treated separately. It is suggested that the best prospects for obtaining new ornamental varieties will stem from organised introductions particularly from the periphery of areas of natural distribution, and from the closer examination of forest plantations and particularly from the Forestry Commission's expanding collection of clonal breeding material. Because of the high costs it is unlikely that breeding for ornamental purposes can be justified except for special material which has a large market, for example, Christmas trees in America. The selection and breeding of commercial forest trees is dealt with under the headings short-, mid- and long-term programmes. The first is concerned with the selection and use of seed stands; the second with the establishment of untested clonal seed orchards based on vegetatively propagated Plus trees, or seedling seed orchards based on progenies; and the third with progeny-tested clonal seed orchards and hybridization work.

FLETCHER, A. M., and FAULKNER, R. (1972). *A plan for the improvement of Sitka spruce by selection and breeding*. Res. Dev. Pap. For. Commn, Lond. 85. 86 references.

Describes the main aims of the British Sitka spruce breeding project and sets out the immediate objectives for the period 1972–1977. Detailed proposals for research and development work are given under the headings: provenance; cytology; morphology; hybridization; timber characteristics; seed stands; Plus tree selection; vegetative propagation; tree banks; flowering and pollination; progeny testing; clonal trials; seed orchards and genetic conservation. An appendix describes the methods used for the selection and description of Plus trees.

FOURT, D. F., DONALD,* D. G. M., JEFFERS,† J. N. R., and BINNS, W. O. (1971). Corsican pine (*Pinus nigra* var. *maritima* (Ait. Melville) in southern Britain. A study of growth and site factors. *Forestry* 44(2), 189–207.

Measurements of 50 crop and site factors in 30 planted Corsican pine stands in south and east England were subjected to multivariate analysis by the method of principal components. The correlations between components describing crop and site suggest that low winter minimum temperatures affect growth of Corsican pine more than warmth in the growing season. A component grouping soil total phosphate levels and soil pH also appears to be causally related to growth potential whereas other components describe variables considered to result from the effects of a tree crop. The site water balance, as reflected by growing season rainfall, potential evaporation, and water storage in the soil is apparently unrelated to growth differences.

GIBBS, J. N. (1971). *Dutch elm disease*. Revision of Leaflet For. Commn 19 (HMSO 8p), with new illustrations.

GIBBS, J. N. (1971). Chemicals for Dutch elm disease. *Proc. 6th Br. Insectic. Fungic. Conf.*, pp. 467–468.

No adequate chemical control is at present available for Dutch elm disease. Recent research on the problem is discussed.

GIBBS, J. N. (1971). Some factors influencing the performance of spray programmes for the control of Coffee berry disease. *Ann. appl. Biol.* 67, 343–356.

* Faculty of Forestry, University of Stellenbosch, S. Africa.

† Nature Conservancy, Merlewood Research Station, Grange-over-Sands, Lancashire.

GIBBS, J. N. (1972). Effect of fungicides on the population of *Colletotrichum* and other fungi in the bark of coffee. *Ann. appl. Biol.* **70**, 35-47.

The above two papers discuss the biology and control of the important disease of *Coffea arabica* in Kenya.

GIBBS, J. N., HEYBROEK,* H. M., and HOLMES,† F. W. (1972). Aggressive strains of *Ceratocystis ulmi* in Britain. *Nature, Lond.* **236**, 121-122.

Inoculation experiments on elms in the nursery both at Alice Holt and Wageningen have provided evidence that an unusually aggressive strain of *C. ulmi* is present in the regions of southern Britain severely affected by the current outbreaks of Dutch elm disease.

GIBBS, J. N., and HOWELL, R. S. (1972). Dutch elm disease survey 1971. *Forest Rec., Lond.* **82** (HMSO 25p).

A sample survey providing 0.3 per cent ground cover of 56,600 sq km of southern Britain was conducted in August and September 1971. The estimated population in this area was 18 million trees of which 56 per cent were English, 29 per cent smooth-leaved and 15 per cent Wych elm. Eleven per cent of all the trees were in non-rural sites, 49 per cent in rural sites and 41 per cent in woodland.

Of the 18 million trees it was estimated that 1,650,000 (9 per cent) had slight to moderate symptoms of Dutch elm disease, 376,000 (2 per cent) were severely diseased and 204,000 (1 per cent) recently dead. There were also 205,000 long-dead trees.

There were pronounced regional differences and the worst affected areas were in the west Midlands, in some of the eastern counties and along part of the south coast. Where comparisons could be made, English elm was more affected than Wych elm. Trees in rural sites were the most affected and woodland trees the least.

GODWIN, G. E. (1971). The value for conservation of plantation forests. *Suppl. Forestry*, pp. 24-27.

"Plantation Forests" in this context refers mainly to planted forests of exotic conifers, usually spruce. Contrary to what is often stated, these are of considerable value for the conservation of wildlife. The wise manager does not plant up every square metre of ground. It is important to have the variety of habitats provided by crops of varying age; to leave unplanted stream sides and areas of scrub, thorn, bog and rock, to encourage insectivorous birds by leaving odd hardwoods to decay and die, and to make deer management easier by providing natural feeding grounds. It is not enough to pay lip service to these principles: the manager has to see that it gets done.

Any adverse effect on short-term economics is negligible: the long-term effect is bound to be beneficial.

GORDON, A. G. (1971). Beneficial effects of ultrasound on plants: A review. *Ultrasonics* **9** (April), 88-94.

The majority of articles describing these effects contain insufficient details of experimental parameters to make comparisons valid. The article reviews the work on germination of seeds, growth of seedlings and plants, yield of plants, changes in flowering date and nutritional and genetical effects. It also describes some of the important physical and chemical effects of ultrasound and attempts to relate these to the biological effects previously described. The article concludes that, although many significant effects on plant material can be produced, it is clear that the causes of, and inconsistencies in, the effects are barely understood.

GORDON, A. G. (1972). Seed dormancy, stratification and nursery practice for conifers. *Q. Jl For.* **66**(1), 21-25.

The concept of dormancy is discussed in terms of resistance to germination. Factors in the handling of cones, storage of seed and pre-treatment of seed which affect the germination resistance of seed and thus the fate of seed in the nursery are considered. It is recommended that pre-treatment of seed can be carried out in the controlled conditions of a transplant store rather than the uncontrolled conditions of a stratification pit. The importance of sowing properly treated seed into properly prepared seedbeds is stressed.

* Stichting Bosbouwproefstation, De Dorschamp, Wageningen, Netherlands.

† Shade Tree Laboratories, University of Massachusetts, USA.

GORDON, A. G., ESTABAN,* I. D., and WAKEMAN, D. C. (1972). Cone handling, seed quality and seed testing of *Pinus merkusii*. *Commonw. For. Rev.* 51(1), 70-75.

Details of cone-handling experiments carried out in the Philippines and the UK are described. Up to six separate extraction cycles of wetting and drying cones with increasingly hot air up to 50°C were needed before an acceptably high percentage of non-ripe cones opened adequately. Other methods failed to open cones any more fully. The germination of seed from mature cones in UK exceeded 90 per cent of full seed, but in the Philippines germination of identical lots was much depressed. Methods of handling the cones before extracting are blamed for the differences.

Lots of good quality seed stored at a moisture content level of from 8-10 per cent at 3°C in the UK maintained their quality throughout the period. The best method of testing the seed was found to be alternating 20-30°C or constant 25°C without pre-chill treatment.

GRANFIELD, E. F. (1972). *Protection of small steel structures from corrosion*. Forest Rec., Lond. 81 (HMSO 17½p).

Gives guidance on the preparation of surfaces, the selection of paints and their application, and the combination of these three major factors to provide a complete protective scheme, primarily for small outdoor structures.

GRANT, W. (1971). *Trees are for people*. Res. Dev. Pap. For. Commn, Lond. 83.

A transatlantic study of methods and techniques for the educational aspects of wildlife conservation and outdoor recreation in forests.

GRANT, W. (1971). American practice in conservation. *Suppl. Forestry*, pp. 13-23.

This paper discusses the problems which are thrown up in the National Parks of North America where, until recently, a policy of preservation as opposed to management has been carried out. This has led to serious consequences in terms of destruction to wildlife habitat. The result of a complete lack of forest management within these parks has made this situation even more critical.

This is compared with the situation in National Forests in North America where rotational felling and forest management techniques provide successional areas which are optimum for wildlife use. The coniferous rain forests unique to the North West coastal zone are discussed. Conservation problems associated with the tremendous upsurge of recreation are high-lighted and possible implications are suggested for forest managers in Britain and, in particular, the part that the Forestry Commission can carry out in the field of recreation and conservation.

GREIG, B. J. W. (1971). The adaptation of boring attachments on motor-driven chain-saws, for the detection of decay in trees, and other uses. *Forestry* 44(2), 151-153.

Standard boring attachments which can be fitted to chain-saws were used to power increment borers. They were successfully used to detect decay in trees, stumps, and logs, in a programme of research in *Fomes annosus*.

GREIG, B. J. W. (1972). Fencing stakes as sources of infection for *Fomes annosus* (Fr.) Cooke. *Scott. For.* 26(1), 51-55.

An experiment is described in which stakes cut from timber infected by *Fomes annosus* were placed within a crop of Scots pine. *F. annosus* remained active in the stakes for at least nine years. Some undamaged pine roots which grew into contact with the stakes became infected with *F. annosus*. The use of untreated infected stakes for fences around conifer plantations is not considered a wise practice.

HAMILTON, G. J., and CHRISTIE, J. M. (1971). *Forest management tables (metric)*. Booklet For. Commn, Lond. 34 (HMSO 60p).

This is a revised, metric edition of Forestry Commission Booklet 16, Forest Management Tables, published by HMSO in 1966. The content and coverage remain, with minor exceptions, fundamentally unchanged from the original booklet, although several alterations have been made in the form of presentation.

* Reforestation Administration, Manila, Philippines.

HAMPSON, J. R. (1971). The value for conservation of plantation forests: South Wales. *Suppl. Forestry*, p. 29.

A unique area for appraising the value of conservation of plantation forests is provided by the industrial coalfield region of South Wales, where there is evidence of a renaissance of flora and fauna following enclosure for afforestation.

(ENDERSBY,* H. J., and) HANSFORD, A. C. (1971). Machine stress-grading of Scots pine. *Suppl. Timb. Trades J.* October, pp. 19-22.

Studies on the use of the Computermatic machine of the stress-grading of Scots pine from 11 different sites are described. The out-turn of the highest structural grade of sawn wood was found to be 66.0-75.0 per cent by machine grading, compared with less than 13 per cent when visual grading was employed.

HINSON, W. H. (1971). A simple method of obtaining an analogue output from capacitance as a transducer. *J. Phys. E: scient. Instrum.* 4, 778-779.

A simple novel circuit for producing an analogue voltage or current from the capacitance to ground of water level probes or other capacitance transducers is described. Its inherently good discrimination against the variable capacity of connecting lines avoids the need for either special cables or trimming.

HOLTAM, B. W. (Editor) (1971). *Windblow of Scottish forests in January 1968.* Bull. For. Commn, Lond. 45 (HMSO 45p).

This report by 15 authors describes damage to forests by a very strong westerly gale which blew across central Scotland. It tells how representatives of private woodland owners, home timber trade and Forestry Commission, appointed to a Windblow Action Group, co-operated to appraise and to advise effectively on measures necessary for surveying, harvesting and marketing more than 1.5 million cubic metres of windthrown timber, for safeguarding forest hygiene and restocking the forests with trees. The experiences reported are likely to be of particular interest to forest managers and administrators who might have to deal with a similar occurrence in future.

HOLTAM, B. W. (1971). Research on conservation in the Forestry Commission. *Suppl. Forestry*, pp. 49-54.

Our true conservation objective is the conservation of man, by perpetuating, for him, an increasingly varied and interesting environment. Our investment in forestry and in forestry research is an important contribution to that objective in Britain. Wildlife conservation managers have to make decisions in greater uncertainty than most; time is not on their side. Research aims to steal a march on time, to widen options, to increase flexibility, to reduce the degree of uncertainty in their decisions and so to improve the effectiveness of the investment. We aim to improve the environmental factors, especially the soil, for the growth of trees, to improve the properties of the trees themselves, and to match improved trees to improved environments; this has improved and will continue to improve wildlife conservation prospects.

HOLTAM, B. W. (1971). Northern Research Station. *Suppl. Timb. Trades J.* July, pp. 7-8.

Describes the work and aims of the recently opened Forestry Commission research station at Roslin, near Edinburgh.

INNES, R. A., and SEAL, D. T. (1971). Native Scottish pinewoods. *Suppl. Forestry*, pp. 66-73.

The general case for conservation of the larger natural Caledonian pinewoods is outlined and the Forestry Commission's management of the Glen Affric woods since 1959 is described.

The essential requirement at Affric was to secure an adequate stocking of young trees in the 2,000 acre pine reserve. Efforts to do this by natural and semi-natural regeneration failed but artificial regeneration, using the progeny of the Affric pines, succeeded, and also assisted birch and rowan to regenerate naturally. Restocking is in scattered groups, each of about five acres, to preserve an irregular structure. Progress towards preserving the native pine stock is therefore satisfactory but the importance of withdrawing artificial methods as soon as the future of the tree stock is secure is emphasised, otherwise the natural ecological diversity of the woodlands will be lost.

* Building Research Establishment, Princes Risborough Laboratory.

JOBLING, J. (1970). Aspects of propagation in forestry. *Proc. int. Pl. Propag. Soc.* 20, pp. 342-351.

Comparatively few forest trees are raised vegetatively, but poplars and willows are grown in the open nursery from hardwood cuttings, and several horticultural cultivars including Leyland cypress and selected clones of elm are produced under mist indoors. The methods of propagating these are discussed, and brief reference is made to recent research on the subject.

JOHNSTON, D. R. (1971). In *Report on the FAO/SIDA Seminar on forestry development planning and manpower assessment methodology for English-speaking countries of Africa and Central America*. Rome.

(a) *Principal features of forest sector planning* (pp. 31-37). Government policies have to be interpreted and expressed as explicit and, where possible, quantifiable objectives. Criteria of success must reflect the policies and objectives and have to be expressed in physical terms. The functions of different management levels are discussed and the importance of flexibility is emphasised. The various methods and techniques of planning are briefly described.

(b) *Forest sector planning in the United Kingdom* (pp. 51-53). The principles for planning at the Government and Forest Department levels are discussed and the concept and procedures of planning within the Forest Department are explained by reference to the Forestry Commission's system of financial control.

(c) *Data needs for supply forecasts* (pp. 63-68). A number of technical terms and concepts are explained and a distinction drawn between potential yield and regulated yield or planned production. The paper discusses the economic and physical data required for forecasting and planning the yield from natural and plantation forests.

(d) *Preparing and appraising an afforestation project* (pp. 95-97). The paper discusses the formulation of objectives, the method of financing, the organisation and the social problems arising from an afforestation project in a developing country. The various technical, organisational and staff aspects of the implementation of a project are also discussed.

LEWIS, A. B., and NEUSTERN, S. A. (1971). A preliminary study of soil erosion following clearfelling. *Scott. For.* 25(2), 121-125.

Erosion and surface run-off were studied for two years on enclosed plots. Plots varied in slope and presence of lop and top. Provided lop and top is left in place, there appears to be little risk of serious erosion following clearfelling of spruce crops in high rainfall areas on slopes up to at least 35°.

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

Based initially on Canadian practice, research on the production and use of tubed seedlings in Britain has been in progress for three years (1968-1970), and was begun because of their potential advantages as planting stock. Polythene greenhouses are used to produce pine and spruce seedlings grown in small plastic tubes filled with fertilised peat-sand compost, and planting is possible eight weeks after sowing. On ploughed peatland, step-planted seedlings are capable of high survival and vigorous early growth, with an effective planting season from mid-April to late August. Animal browsing is the main adverse factor encountered, but has been less serious than expected. Very high planting rates are possible with a special tool. Seedling use could lead to large savings in peatland afforestation costs, and large-scale trials are planned. In contrast, seedling performance on ploughed mineral soil has been unsatisfactory owing to severe frost lifting and poor height growth. Results in reafforestation trials have not been very promising.

MACKENZIE, A. M., and MARTIN,* R. K. (1971). Damage to forests: quantitative statements of areas and volumes of timber windthrown. In *Windblow of Scottish forests in January 1968* (ed. B. W. Holtam), pp. 8-13. *Bull. For. Commn, Lond.* 45 (HMSO 45p).

The statistics shown here provided the basis for most of the Windblow Action Group's work described in the Bulletin.

* Scottish Woodland Owners' Association.

MEECHAN, J. (1971). How to prevent Christmas trees from dropping their needles. *Suppl. Timb. Trades J.* October, pp. 10, 12.

Describes experiments in which dipping the foliage of Christmas trees in alginate, or in gelatine or in water-soluble resin solution, is compared with keeping the butt immersed in water, as a means of reducing needle-fall. The effect of these treatments on the flammability was also recorded. Additionally, studies were made on the result of delaying treatment for 14 days after harvesting.

MITCHELL, A. F. (1971). Identifying the hickories. *Int. dendrol. Soc. Yearb.* 1970, pp. 32-34.

MITCHELL, A. F. (1971). The real history in trees. *Suppl. Timb. Trades J.* October, p. 13.

MITCHELL, A. F. (1971). The genus *Abies* in Scotland. *Trans. Bot. Soc. Edinb.* 41, 201-212.

MITCHELL, A. F. (1971). The Conifer Conference, 1970. *Commonw. For. Rev.* 50(3), 241-242.

MITCHELL, A. F. (1971). The Conifer Conference. *Suppl. Timb. Trades J.* July, pp. 18-19.

MITCHELL, A. F. (1971). Some outstanding broadleaved trees in Scotland. *Jl R. hort. Soc.* 96(7), 305-308.

MITCHELL, A. F. (1971). Recent measurements of big trees in Scotland. Pt 1, Argyll. *Scott. For.* 25(2), 109-112. Pt 2, Perthshire. *Scott. For.* 25(3), 206-212. Pt 3, *Scott. For.* 25(4), 277-285.

MITCHELL, A. F. (1972). In *Conifers in the British Isles: Proc. R. hort. Soc. 3rd Conifer Conf. Lond.* 1970:

(a) *Conifers from Europe and Asia*, pp. 9-10. A brief summary of main species introduced, starting with the nearest (France) and ending with Formosa and Korean trees, giving dates of introduction, some indication of growth here and details of a few of the best trees. Top heights at present decline as origin recedes from Britain, from Central Europe, Mediterranean, Asia Minor, Caucasus, Himalayas, China and Japan. This shows the peripheral effect, as the Caucasus and Himalayas can be regarded as peripheral to the Asian land-mass, and a few species from China and Japan seem likely ultimately to make big trees but none from inland Asia.

(b) *Conifer statistics*, pp. 123-285. 7,147 trees on 284 estates listed; height, girth and date given where known. Of the estates 173 are in England, 9 in Wales, 66 in Scotland, 2 in N. Ireland and 34 in Eire.

(c) *Noteworthy specimens of conifers in the British Isles*, pp. 286-293. The tallest tree and the tree with the largest bole is given for each of 221 species and 94 varieties or cultivars.

MITCHELL, A. F. (1972). The snake-bark maples. *Q. Jl For.* 66(1), 12-20.

A fast growing, small sized and decorative group of trees is described. Considerable specific details are given, with a plea that the trees should be correctly named.

NEUSTEIN, S. A. (1971). Damage to forests in relation to topography, soil and crops. In *Windblow of Scottish forests in January 1968* (ed. B. W. Holtam), pp. 42-48. *Bull. For. Commn, Lond.* 45 (HMSO 45p).

The distribution of damage was studied on a sample of forests by means of ground and air surveys. Aerial survey was found to be of value. In the more mountainous western forests topography was important and a hazard classification is offered. Smooth rolling topography, especially if associated with shallow rooted soils, is particularly vulnerable.

PEAL, J. (1971). Conservation in the Forest of Dean. *Suppl. Forestry*, pp. 62-66.

The Forest of Dean owes much of its present day character to a past history of mining, grazing and planting of oak for naval timber, and only in the last 20 years or so has the oak been extensively felled and replaced with conifers. Oak woodlands are particularly rich in wildlife and large tracts of such woodland are becoming increasingly rare. The Forestry Commission's recent decision to perpetuate the broadleaved character of a large part of the Forest of Dean is therefore welcome to naturalists. A number of nature reserves have been established. The author contends that future conservation will best be served by continuing forest management with the object of producing a mixed high forest of broadleaves and conifers.

PENISTAN, M. J. (1971). Studies of conservation by Wessex Group. *Suppl. Forestry*, pp. 78-83.

A contribution to European Conservation Year 1970 by a group of professional foresters took the form of a study of the impact of measures to promote wildlife conservation in woodlands managed for timber production. The study concentrated on a large well-managed estate where sporting and conservation were integrated with timber production. There was one visit to a state forest and another to a woodland managed primarily for amenity. By careful planning to secure "inocula" of broadleaf woodland the fauna and flora of the broadleaf habitat is available to enrich conifer plantation as it becomes receptive. The extent and distribution of these conservation areas, the "inocula", need to be discovered; advice should be sought from County Nature Conservation Trusts and from the Nature Conservancy.

PEPPER, H. W., and TEE, L. A. (1972). *Forest fencing*. *Forest Rec.*, Lond. **80** (HMSO 35p).

Fencing is a necessary but expensive forest management operation. While it is possible to erect a fence that is completely effective against any animals, this is usually too costly. Any forest fence is a compromise between expense and effectiveness.

The introduction of spring steel wire into the construction of forest fences has substantially reduced costs compared with traditional forms of fencing using mild steel wire. The main advantage of spring steel wire is that once it is strained it will remain taut. This allows stakes and straining posts to be widely spaced, so requiring less material and labour without reducing the effectiveness of the fence. Small economies can be made by using spring steel wire for multi-strand and dropper fences but the most suitable application and the greatest economies are in the use of this wire to support wire netting. Further savings have been made by introducing improved methods of working and labour-saving tools.

Any savings obtained can be wasted if the initial planning of the fence has not been thorough. The specification of the materials to be used must be consistent with the period and the purpose for which the fence is required. The amount of material required can be reduced and the problems of negotiating natural obstacles avoided by careful siting.

PHILLIPS, D. H. (1971). Disease and pest control in British forests: An outline. *Proc. 6th Br. Insectic. Fungic. Conf.*, pp. 803-807.

In British forests, disease and pest control is mainly by the careful choice of resistant species or varieties, and by silvicultural means. Direct biological control methods are used, e.g. to control *Fomes annosus* in pines by inoculating stumps with its competitor *Peniophora gigantea*, and to control the pine sawfly by means of a naturally occurring virus. Chemicals are used in the forest to control *Fomes annosus* from the time of the first thinning, and to protect newly-planted stock from attack by *Hylobius abietis* and *Hylastes* spp. Occasionally it has been necessary to spray forest areas to control infestations of the Pine looper moth, most recently with tetrachlorvinphos. Chemicals are also used on a very limited scale to control a few diseases and pests in nurseries and Christmas tree plantations, and to prevent the infestation of felled produce, particularly by ambrosia beetles.

REDFERN, D. B. (1971). Chemical control of Honey fungus (*Armillaria mellea*). *Proc. 6th Br. Insectic. Fungic. Conf.*, pp. 469-474.

A phenolic emulsion marketed as a fungicide under the name Armillatox was tested to assess both its phytotoxicity and its ability to kill *Armillaria mellea*. When applied direct to bark a solution containing 8 per cent a.i. did not injure roots (1.0-4.0 cm diameter) of sycamore trees (*Acer pseudoplatanus*) but even small quantities of a 4 per cent a.i. solution killed roots of sycamore seedlings. When Armillatox was applied to a forest soil and an agricultural soil at rates of 10,000, 1,000 and 500 ppm all three concentrations significantly reduced the total length of rhizomorphs produced by *A. mellea* in the forest soil but only the highest concentration did so in the agricultural soil. Ten thousand ppm Armillatox also caused significant mortality of *A. mellea* mycelium under the bark and in the wood of sycamore stem segments buried in both soils.

ROGERS, E. V. (1971). ULV spraying techniques. *Suppl. Timb. Trades J.* October, p. 22.

The principles, method of use and application of ULV (ultra low volume) sprayers are outlined.

ROGERS, E. V. (1971). Protective clothing for forestry. Part 2: Outer clothing. *Suppl. Timb. Trades J.* July, pp. 20-21; Part 3: Top clothing. October, pp. 25-27.

Part 2 discusses the advantages and disadvantages of the various types of shirts, jackets and trousers available. Part 3 considers the relative merits of various types of top clothing and footwear, for keeping precipitation out and preventing condensation inside the clothing.

ROGERS, E. V. (1971). Keeping out the cold. *Rur. Medicine* 3(1), 20-24.

Clothing for outdoor work is discussed in detail.

ROWAN, A. A., and SAWYER, T. R. (1971). (a) Forestry Commission census of harvesting equipment and methods 1969. *Timb. Grow.* 42, 36-41. (b) A census of harvesting equipment and methods. *Suppl. Timb. Trades J.* July, pp. 13-15.

The results of a census of harvesting equipment and methods carried out in 1969 are analysed and compared with a similar survey which took place in 1960.

ROWE, JUDITH J. (1971). Prevention of damage by mammals and birds in forest nurseries. *Q. Jl For.* 65(2), 148-157.

Finches and sparrows eat seeds of the larger-seeded pines and Norway spruce. They also seriously damage the seedlings. Effective protection is given by covering the seed-beds with taut plastic netting or by dressing seed with Fernasan S (a thiram-based fungicide). Other methods investigated have included shooting, trapping, poisoning, dummy hawks, scarecrows, bangers, distress calls, bitumen and latex sprays and polythene sheet. These were variously impractical, expensive, ineffective, illegal or damaging. Larger mammalian pests can be fenced out. Woodmice can be caught in break-back traps or, if damage is extensive, poisoned with Warfarin-treated bait presented under covers.

Reduction of losses from birds and mice by a method suited to the value of the nursery stock produces increased and more consistent seedling yields.

ROWE, JUDITH J., and JACKSON,* D. A. (1971). An investigation of the problems involved in managing pheasants in extensive upland spruce forests. In *Forestry and Game, Proc. Game Conservancy Symposium*, October 1971, pp. 12-19.

In 1968 a five-year study of the problems, costs and potential value of managing pheasants in spruce forests was begun by the Forestry Commission and Game Conservancy. The investigation initially involved identifying and attempting to solve the problems of pheasant management in the poor habitat provided by the upland spruce forests extensively planted in the last 50 years. If the project is economically viable it will in addition provide a basis for evaluating various types of sporting letting which may be more appropriate to the role of state forests in providing facilities for recreation than traditional block lettings.

Results during the first three seasons from a small rearing and releasing programme have shown that the main problem is lack of ground cover for holding and flushing birds during shoots. Additional ground cover has been established but no data on the costs and benefits of this part of the programme are yet available. The returns from the rearing and releasing programme are generally lower and the costs per bird rather higher than might be expected on most shoots. However, the results of the first three seasons have been too variable to allow any valid conclusions to be drawn on the eventual outcome of the project.

(HILL,** J., and) SAMUEL, C. J. A. (1971). Measurement and inheritance of environmental response among selected material of *Lolium perenne*. *Heredity, Lond.* 27(2), 265-276.

The yield of the families derived from a diallel cross without selfs between six of the genotypes which comprise the basic plant material of the S.24 cultivar of *Lolium perenne* was considered over two growing seasons under two nitrogen levels. Linear regression techniques were used to account for the interactions of the families with various environmental factors. The inheritance of mean yield and linear response to the environment was found to be predominantly additive whilst no clear pattern of inheritance was evident for stability of response. The results are discussed specifically in relation to the past selection history of S.24 although some of the more general implications of these results are briefly outlined.

* Game Conservancy, Fordingbridge, Hampshire.

** Welsh Plant Breeding Station, Plas Gogerddan, Aberystwyth.

SCOTT, A. H. A. (1971). Tree injectors. *Suppl. Timb. Trades J.* July, p. 15.

The use of tree injectors as an alternative to 2, 4, 5-T, applied to the basal bark or in a frill girdle, is described.

SCOTT, T. M. (1971). Tetrachlorvinphos as an alternative to DDT in Pine looper moth control. *Proc. 6th Br. Insectic. Fungic. Conf.*, pp. 480-484.

Screening trials were carried out during 1970 to find an alternative to the standard DDT treatment for controlling an outbreak of the Pine looper moth (*Bupalus piniarius*). Seven insecticides at their highest rates gave similar mortalities to DDT after 60 hours' exposure, with the best in order of merit being phosalone, fenitrothion, NRDC 104 (a synthetic pyrethroid), and tetrachlorvinphos. After exposure to weathering, only phosalone and tetrachlorvinphos were comparable in effect to DDT. Tetrachlorvinphos was selected in preference to phosalone, despite its rather poorer performance, because of its very low toxicity and lower cost. It proved satisfactory in a field trial and gave about 90 per cent mortality in the control operation.

SEAL, D. T. (1972). Conifers in commercial forestry. In *Conifers in the British Isles: Proc. R. hort. Soc. 3rd Conifer Conf. Lond.* 1970, pp. 82-85.

Three periods in the development of commercial forestry with conifers are distinguished and reviewed. The first period, that of exploitation, lasted from ca. 1700 to ca. 1900; the second, a period of preservation of existing forest resources, lasted from about 1900 until 1920; and the last period, that of entirely man-made forests, from 1920 to the present day.

The first two periods are illustrated by reference mainly to the USA, and the last is illustrated by the British example, including a mention of current trends in utilisation of coniferous timbers.

SIDAWAY, R. M. (1971). Public pressures on the countryside. *Suppl. Forestry*, pp. 94-101.

In this paper given to the Society of Foresters of Great Britain Discussion Meeting the author reviews the role forests can play in providing for public recreation in Great Britain. Available data on the underlying social trends which influence use of leisure time are examined together with data on participation in countryside recreation generally and in Forestry Commission woodlands in particular. The difficulties of predicting future use are highlighted. As a result the contribution that can be made by public and private woodland owners is put into perspective.

A wide variety of information is required to plan and manage recreation areas successfully. It is important at the outset to identify the interests of different sections of the public. These interests will include public pressure for recreation and sensitivity to changes in the landscape. In some areas these pressures will conflict and present a serious challenge to the existing skills of the professional forester.

SPENCER, J. A. (1971). Balance: Production v. Conservation v. Recreation. The Forestry Commission's viewpoint. *Suppl. Forestry*, pp. 90-91.

The role of the Forestry Commission is discussed from the "growers' viewpoint".

The forest service should aim to manage the nation's forests so as to provide whatever benefits the community requires. Currently in Britain the primary benefit is timber, but with a rapidly increasing demand for non-timber benefits as well. Shortage of land leads to multiple use of forests. There are conflicts, but these can mostly be overcome by zoning in space and in time. The optimum use of resources is most likely to be obtained by managing a flexible mix which can satisfy varied demands and respond to changing circumstances.

STERN, R. C. (1971). Pruning of free-grown hardwoods. *Q. Jl For.* 65(4), 322-326.

The main hardwood species in the younger age classes in Britain are identified. Consideration is given to oak, elm, ash and sycamore which are the most important timber trees, apart from beech, which are usually self-pruning. Attention is concentrated on free-growth conditions because of the high proportion of these hardwoods growing as single trees, of the need to grow them fast to produce the best timber, and the attractions of short rotations from the economic point of view. Using price differentials for pruned and unpruned logs indicated by certain leading hardwood timber merchants, rates of return for pruning are calculated at different costs; these indicate that pruning in such conditions appears to be a profitable operation.

(CRAWFORD,* D. B., and) STEWART, G. G. (1971). Formation, activities and recommendations of the windblow action group. In *Windblow of Scottish Forests in January 1968* (ed. B. W. Holtam), pp. 14–20. *Bull. For. Commn, Lond.* 45 (HMSO 45p).

The Windblow Action Group was formed during the first two weeks following the disastrous gale of 15th January, 1968, which affected over 8,300 hectares of high forest in central Scotland. It consisted of representatives of the Forestry Commission, Scottish Woodland Owners' Association, and the Home Timber Merchants' Association of Scotland, and became a sub-committee of the Home Grown Timber Advisory Committee.

As a result of the Group's recommendations, the rate of clearance of windthrown timber was stimulated by government encouragement to local authorities and industry to give preference to home-grown timber, and by transport subsidies for moving timber beyond the normal economic limit. Harvesting resources were brought in from other parts of the country and training facilities provided. An 18-month target for clearance ensured acceleration of the work.

SUTTON, A. R., and SAWYER, T. R. (1971). *Loading and unloading timber lorries*. Forest Rec., Lond. 78 (HMSO 30p).

The main systems available for loading and unloading timber lorries are set out.

The advantages, disadvantages, models available, method of use, economics and the place in forestry of each system are discussed. A decision model showing the most economic system of loading and unloading in a given set of circumstances is also included.

(BROWN,† T. R., and) TULEY, G. (1971). A study of a population of birches in Glen Gairn. *Trans. bot. Soc. Edinb.* 41, 231–245.

A small population of birches was studied with a view to measuring the range of morphological variation in *Betula pendula* Roth. and *B. pubescens* Ehrh. The general morphological features of crown and bark of trees in the area indicated that both species were present. A more detailed study was made of leaf and fruit characters, accepted by other investigators as being useful in discriminating between the species. It was shown that such characters varied continuously throughout the population and no tree was wholly *pubescens*-like or *pendula*-like in all characters.

The implications of these results are discussed in relation to the situation in Glen Gairn and to the general taxonomic situation of the British birches.

WHARAM, J. (1971). Forestry Commission aid. In *Windblow of Scottish forests in January 1968* (ed. B. W. Holtam), pp. 21–26. *Bull. For. Commn, Lond.* 45 (HMSO 45p).

The Windblow Action Group recommended the Forestry Commissioners, among other things, to give a transport subsidy to enable an estimated 0·58 million cubic metres of wind-thrown timber to be moved to markets outside normal economic transport distances. Transport subsidies, at varying rates, were paid on 0·65 million cubic metres; £302,800 was spent on 0·421 million cubic metres of sawlogs and £106,100 on 0·225 million cubic metres of small roundwood. Details are given with a map which shows places to which timber was despatched.

WINTER, T. G., and JUKES, M. R. (1972). Notes and observations. *Paracolax derivalis* (Hübner) in Hampshire (Lep., Noctuidae, Hypeninae). *Entomologist's Gaz.* 23(1), 2.

A first county record for this species is noted. Comment is also made on the taking at light of *Archanara dissoluta* Treits., and *Lithophane leautieri* Bois.

WITTERING, W. O. (1971). Work study in forestry. (a) *Wk Study Mgmt Serv.* 15(11), 725. (b) *Suppl. Timb. Trades J.* October, p. 27.

A brief report on a work study course organized by the Forestry Commission on behalf of the Joint FAO/ECE/ILO Committee on Forest Worker Training and Forest Working Techniques attended by officers from eight European countries—Austria, Finland, West Germany, Hungary, Yugoslavia, The Netherlands, Poland and Sweden, together with representatives of private forestry in the UK.

* Scottish Woodland Owners' Association.

† Department of Forestry, University of Aberdeen.

WOOD, P. (1971). Front-end loaders in Thetford. *Suppl. Timb. Trades J.* October, p. 23.

Describes the use of BM Volvo front-end loaders in Thetford Forest together with some cost information.

ZEHETMAYR, J. W. L. (1972). The future of forestry in Great Britain. (a) *Q. Jl For.* 66(1), 5-12. (b) *Commonw. For. Rev.* 51(1), 37-42.

Argues that the main purpose of forestry in Great Britain will remain timber production, and that technological advance will ensure a place for home grown timber for the foreseeable future. But the importance of other roles of forest and woodland will increase, particularly as a haven for quiet recreation with a limited loss in timber production linked to a social and possibly an economic gain.

APPENDIX II

Staff engaged in Research and Development

As at 31st March, 1972

The main centres for research and development are:

FORESTRY COMMISSION RESEARCH STATION

Alice Holt Lodge
Wrecclesham

Farnham, Surrey. Tel. Bentley (Hants) 2255 (STD Code 042 04)

FORESTRY COMMISSION NORTHERN RESEARCH STATION

Roslin
Midlothian

Scotland. Tel. 031-445 2176

Some staff engaged in research and development (or controlled by Director Research) are also stationed at:

FORESTRY COMMISSION

25 Savile Row

London W1X 2AY. Tel. 01-734 0221

Research on timber and other forest products is not carried out by the Forestry Commission but by the Princes Risborough Laboratory of the Department of the Environment's Building Research Establishment, Princes Risborough (Tel. 3101), Aylesbury, Buckinghamshire. The Forestry Commission keeps in close touch with this work, some of which is done jointly by the two organisations.

RESEARCH DIVISION

Director G. D. Holmes, B.Sc. (<i>Alice Holt</i>)
Administration and Finance Officer G. H. Bowers (<i>Alice Holt</i>)
Director's Secretary Mrs. V. O. C. Lampard (<i>Alice Holt</i>)

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, photographic and engineering services).

SEED (*Alice Holt*)

G. M. Buszewicz, Mgr. Eng. (For.), Head of Section
A. G. Gordon, B.Sc., Agric., Ph.D.

Laboratory: D. C. Wakeman: Mrs. L. S. Billany, Mrs E. M. Boswell:
Miss R. E. Crumplin, Mrs. E. Hart-Dyke

Seed Store and Extractory: M. D. Witts (Research Forester): T. A. Waddell: L.
Crumplin

Office: Mrs. B. P. Hartley, B.A.: F. H. Khawaja

ECOLOGY (*Alice Holt*)

J. M. B. Brown, B.Sc., Dip.For., Head of Section

Research Foresters: K. Broad (*Tair Onen*), P. Marsh

Laboratory: Miss F. Campbell-Benzie, B.Sc.

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, M.I.Biol.: Miss S. J. Cross, Miss P. M. Smith:
M. Awdry, Miss A. Trusler

Office: B. D. Higgins: Mrs. B. A. Reynolds (Typist)

Northern Research Station

D. B. Redfern, B.Sc., Ph.D

Research Forester: J. D. Low

Laboratory: Miss S. H. Harris

ENTOMOLOGY, WILDLIFE

D. Bevan, B.Sc., Head of Section

ENTOMOLOGY

Alice Holt

Miss J. M. Davies, B.Sc.

C. I. Carter, M.Sc., M.I.Biol.

T. M. Scott, B.Sc.

Research Foresters: R. M. Brown, L.I.Biol.: D. J. Billany, C. J. King, C. Walker

Laboratory: T. G. Winter: M. Jukes, L. J. O'Neill, Miss J. Slater

Office: Mrs. M. Greenwood

Northern Research Station

J. T. Stoakley, M.A., M.Sc., D.I.C.

WILDLIFE (*Alice Holt*)

Miss J. J. Rowe, B.Sc., Dip.Cons., Head of Sub-Section

Research Foresters: L. A. Tee: R. A. Baldwin, H. W. Pepper, S. J. Petty,
P. R. Ratcliffe

PHOTOGRAPHY (*Alice Holt*)

I. A. Anderson, F.I.I.P., Head of Section

Mrs. T. K. Evans, F.R.P.S.

Mrs. H. J. Geoffrey

J. Williams (Illustrator)

Miss M. Trusler

Office: J. G. Jackman

On detachment from Education and Training Branch: R. W. Twallin (Head Forester)

ENGINEERING SERVICES (*Alice Holt*)

R. E. Stickland

H. G. W. Bodkin, M. F. Johnston, C. H. Bodkin

PUBLICATIONS (*London*)

H. L. Edlin, M.B.E., B.Sc., Dip.For., Head of Section
 P. A. Mayne
 Mrs. G. E. Copeman

Chief Research Officer (North) B. W. Holtam, B.Sc. (*Northern Research Station*)

(With general responsibilities for research in the Northern areas, and with special responsibilities for research in silviculture, soils, genetics and physiology)

SILVICULTURE (NORTH) (*Northern Research Station*)

R. M. G. Semple, B.Sc., Head of Section
 R. Lines, B.Sc.
 A. J. Low, B.Sc., Ph.D.
 S. A. Neustein, B.Sc.
 T. C. Booth, B.Sc.
 J. M. Mackenzie, B.Sc.

Research Foresters:

		<i>Centre</i>
	N. P. Danby	Northern Research Station
<i>North Scotland Region</i>	A. Macdonald	Fort Augustus
North Scotland Area	A. A. Green: M. K. Hollingsworth	Fort Augustus
North East Scotland Area	J. C. Keenleyside: A. McInnes, N. MacKell	Lairg, Sutherland
East Scotland Area	E. R. Robson: A. L. Sharpe, A. W. F. Watson	Newton, Elgin
<i>Central Scotland Region</i>	J. H. Thomson	Northern Research Station
Central Scotland Area	E. A. Crofts, J. D. Lindsay, W. G. Paterson	Kincardine-on-Forth
South East Scotland Area	J. B. McNeill, A. H. Reid	Northern Research Station
Mearns Area	M. Rodgers	Drumtochty, Laurencekirk, Kincardine
West Scotland Area	A. R. Mair: J. E. Kirby, A. B. Lewis	Kilmun, by Dunoon, Argyll
South West Scotland Area	E. Baldwin: J. D. McNeill, K. Mills	Mabie, Dumfriesshire
<i>North England Region</i>	G. Bartlett	Wykeham, Scarborough
North East England Area	K. A. S. Gabriel: J. E. J. White	Wykeham, Scarborough
Borders Area	G. S. Forbes: P. Priestley, D. L. Willmott	Kielder by Hexham, Northumberland

SILVICULTURE (SOUTH) (*Alice Holt*)

J. R. Aldhous, B.A., Head of Section
 R. M. Brown, B.Sc.
 J. E. Everard, B.Sc.
 J. Jobling, B.Sc.
 A. F. Mitchell, B.A., B.Agric.(For.), V.M.H.
 G. J. Mayhead, B.Sc., Ph.D.

<i>Office:</i>	P. H. Hamilton: F. R. W. Stevens (Research Forester): Mrs. A. Johnston: Mrs. S. A. M. Bridger	
<i>Research Foresters</i>	D. J. Williams	<i>Centre</i> (Seconded to Zambia)
<i>South East England Region</i>	R. M. Ure	Alice Holt
South East England Area	P. W. W. Daborn, J. B. H. Gardiner, M. L. Pearce: D. W. H. Durrant, P. D. Howard, A. M. Jenkin, G. Simkins, F. S. Smith	Alice Holt
Wareham Area	L. A. Howe: G. F. Farrimond	Sugar Hill Nursery, Wareham Forest
Bedgebury Area	A. W. Westall: A. C. Swinburn	Bedgebury Pinetum
<i>South West England Region</i>	D. A. Cousins	Westonbirt
South West England Area	K. F. Baker: D. T. A. Hendrie	Exeter
Dean and South Wales Area	F. Thompson: B. C. Carter, A. J. A. Graver	Dean
Westonbirt Area	E. Leyshon: C. W. Webber	Westonbirt Arboretum
<i>North Wales Region</i>	G. Pringle	Betws y Coed
North Wales Area	G. A. Bacon: D. Downs	Betws y Coed
Mid-Wales Area	D. G. Tugwell: R. Dean, C. J. Large	Knighton, Radnor
<i>East England Region</i>	I. H. Blackmore: P. A. Gregory, R. E. A. Lewis	Santon Downham, nr Thetford

SOILS

Alice Holt

W. O. Binns, M.A., B.Sc., Ph.D., Head of Section

W. H. Hinson, B.Sc., Ph.D.

G. P. Moffatt, M.Sc.

Research Foresters:

D. F. Fourt, L.I.Biol.: I. G. Carolan

*Laboratory:*R. Carnell: Miss S. A. Dabek: P. Grosch, Mrs. C. E.
Grosch, Mrs. J. E. Parker, Mrs. D. Wild, Miss S. R. Willcox*Northern Research Station*

D. G. Pyatt, B.Sc.

Research Forester:

T. E. Radford

Laboratory:

J. D. Hanratty

GENETICS (*Northern Research Station*)

R. Faulkner, B.Sc., Head of Section

A. M. Fletcher, B.Sc., Ph.D., A.I.W.Sc.

R. C. B. Johnstone, B.Sc., M.Sc.

G. I. Forrest, B.Sc., M.Sc., Ph.D.

*Research Foresters:*I. J. M. Dawson (*Westonbirt, Glos.*), C. McLean, M. T. T.
Phillips (*Newton, Elgin*): W. Brown, R. B. Collins, D. S.
Coutts (*Fort Augustus*), G. C. Webb (*Westonbirt*)*Laboratory:*

Miss B. P. Branson, M.A., Mrs. N. Campbell

PHYSIOLOGY (*Northern Research Station*)

K. A. Longman, B.Sc., Ph.D., Head of Section

M. P. Coutts, B.Sc., Ph.D.

M. R. Bowen, B.Sc., Ph.D.

Research Forester: J. Howarth*Laboratory:* A. G. Scott

STATISTICS

Alice Holt

R. S. Howell, Head of Section

C. J. A. Samuel, B.Sc., Ph.D.

R. C. Boswell, B.Sc.

C. J. Ashton

G. J. Hall, B.Sc.

Miss C. M. Ironside

Miss C. A. Spence, B.Sc.

Research Foresters: A. E. Coates, I. D. Mobbs, C. A. Thorne: M. H. M. Webb*Machine Operators:* Mrs. J. A. Burningham: Mrs. E. Butler, Mrs. S. D. James
Mrs. S. M. Nicholls, Mrs. E. C. Wilson*Office:* Mrs. C. A. Yeomans: Mrs. A. M. Clements (Typist)*Northern Research Station*

D. H. Stewart, B.Sc., M.I.Biol., F.I.S.

Mrs. J. Birchall

Research Forester: J. Baird*Machine Operator:* Mrs. M. RobertsonRESEARCH INFORMATION SECTION (*Alice Holt*)

O. N. Blatchford, B.Sc., A.I.Inf.Sc., Head of Section

S. H. Sharpley

F. C. Fraass

Miss M. P. Johnston

Mrs. L. D. Birchall (Typist)

ADMINISTRATIVE STAFF

*Alice Holt**Deputy Administration
and Finance Officer:* J. Lax*Establishment:* L. W. Thomas: J. Ellison, Mrs. A. C. Vandeleur-Boorer*Finance:* P. R. R. Phillips: Miss G. B. Hayden, Miss P. A. M.
McCunnin, N. A. Trollope*General Services:* Miss S. B. Page: Mrs. R. J. Gower*Typists:* Miss M. Hopkin (Superintendent): Mrs. E. L. Allen.
Mrs. J. G. Anderson, Mrs. B. E. Dickinson, Mrs. F. E.
Edwards, Mrs. J. Richardson, Mrs. E. A. Walters*Photprinter:* Mrs. M. Butt*Telephone Operators:* Mrs. E. A. R. Empson, Mrs. J. M. Plant*Messengers:* Mrs. K. S. Butcher, Mrs. L. Gower*Gardens:* H. Farr*Workshop:* R. H. Butt, R. D. Butt: E. V. Tattam*Northern Research Station**Office:* P. Hunter: J. F. Black: R. F. Fotheringham, Miss M. E.
Grant, Mrs. E. M. Hiddleston: J. A. Ballantyne, Miss J.
Black

<i>Typists:</i>	Mrs. A. J. Clark, Mrs. E. C. Lawrie, Mrs. E. M. A. Lean, Mrs. I. J. K. Webber
<i>Telephone Operator:</i>	Mrs. A. A. Martin
<i>Messenger:</i>	C. Stewart
<i>Workshop:</i>	R. McLuckie

MANAGEMENT SERVICES DIVISION

(The main O & M Branch, based in London, and the Central Drawing Office, based at Basingstoke, are not included here)

Director D. R. Johnston, M.A. (*Alice Holt*)

PLANNING AND ECONOMICS BRANCH (*Alice Holt*)

A. J. Grayson, M.A., B.Litt., Head of Branch
 *P. A. Wardle, B.Sc.
 R. J. N. Busby, B.Sc.
 J. F. Morgan, B.Sc.
 R. M. Sidaway, M.A.
 E. R. Adams, B.Sc., A.I.S.

Foresters: G. D. Spiller: R. Q. Oakes

FIELD SURVEYS BRANCH (*Alice Holt*)

L. M. Simpson, B.Sc., D.M.S., Head of Branch

FIELD SURVEY SECTION

G. M. L. Locke, B.Sc. (*Edinburgh*)
 D. A. Cooper, B.Sc.

Foresters stationed at Alice Holt:

G. M. Haggett: I. C. Embry, M. D. Whitlock

Foresters stationed throughout England and Wales:

R. F. Bartlett, A. C. Dover: D. A. Bell, P. E. Cliffe, E. B. Cordery, M. W. Davies,
 N. Dixon, D. Ellis, D. Goodbody, P. Green, G. Griffiths, D. Hammond, R. Hoblyn,
 D. R. Hornby, C. E. G. Lawes, R. McKinley, R. Morris, D. Parnall, J. J. Pruden,
 J. L. Read, J. B. Richards, L. G. Starling, R. C. B. Vines, P. C. Westley

Foresters stationed throughout Scotland:

J. Straiton: D. Anderson, J. C. Anderson, H. Bowers, A. R. Brown, N. C. Bunyan,
 A. N. Gordon, P. J. Humphries, C. Kerr, P. J. Lodge, J. A. McIntyre, L. D. McRae,
 K. W. Mills, F. H. Millwood, B. Stanger, F. G. O. Thom, G. A. Watson, P. J. Williams

SITE SURVEY SECTION (*Northern Research Station*)

D. B. Paterson, B.Sc.
 R. D. L. Toleman, B.Sc.

Foresters:

B. R. Bolton, I. A. G. Dale, J. Davidson, D. A. T. Douglas,
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INDEX

	Page		Page
<i>Abies grandis</i> (Grand fir)		<i>Cinara pilicornis</i>	153
artificial regeneration	67	Coalfield forests, tree growth	71
effect of shade on nutrient uptake	145	Computing facilities	107
herbicides	43	Container-grown plants, equipment	110
provenance	41	<i>Cryptococcus fagi</i>	92
roll transplants	31	Cultivation	
seed	22	effect on soil properties	56
timber properties	136	gleys	62
— <i>procera</i> (Noble fir)		ironpan	50, 62
seed	22, 25	machinery	62, 124–126
timber properties	136	peat	29–30, 33, 61
<i>Acer</i> , see Maple and Sycamore		rigg and furr	63, 148
Adelgids, forming pineapple galls	101	spaced furrow ploughing	33, 62–63
Aerial photography	70, 111, 119	<i>Cylindrocarpon</i>	92, 151
Arboreta	42	Cypress, Leyland	
Ash		cuttings in Japanese Paperpots	35
fence posts	133		
seed	76	Deer	
Ball-rooted planting stock	32	chemical repellants	105
Bark		damage	105
beetles, breeding chamber	110	fencing	105
use in horticulture	132	freeze-marking	105
Basal sweep of Lodgepole pine	65	Design of experiments	108
Beech		Diseases of trees survey	95
bark disease	92	Douglas fir (<i>Pseudotsuga menziesii</i>)	
herbicides	43	artificial regeneration	67
seed	22, 26, 76	effect of shade on nutrient uptake	145
<i>Betula</i> , see Birch		fertilisers	50
Biochemical variation	80	grading for building	134
Birch for fence posts	133	herbicides	43, 44
Bracken		progeny tests	78
as green manure	139	provenance	39
control	44	root studies	73, 158
Broadleaved trees (see also individual species)		seed	76
reappraisal	34	sodium alginate root dip	28
<i>Brunchorstia pinea</i>	94	Drainage	
Bud dormancy	86	equipment	61, 124–125
Building, grading of softwoods for	134	peat	61
<i>Bupalus piniarius</i> , pupal survey	99	rigg and furr	63, 148
Cable cranes	128	Dutch elm disease	
<i>Calluna vulgaris</i> , see Heather		control	91
Canopy closure studies	73	in southern England	101
<i>Castanea sativa</i> , see Chestnut		spraying equipment	110
<i>Catalpa bignonioides</i> , wilt	96	survey	90, 108, 121
<i>Ceratocystis ulmi</i>	91	tree injection units	110
(<i>and see</i> Dutch elm disease)		Dwarf conifers	42
Chemical control of weeds, see Herbicides			
Chemical repellants, deer	105	<i>Elatobium abietinum</i>	99, 153, 154
Chestnut, sweet, for fence posts	133	Elgin shoot moth	101
Christmas trees		Elm (see also Dutch elm disease)	
pineapple galls on	101	fence posts	133
reduction of needle fall	133	from cuttings	35

	Page		Page
<i>Fagus</i> , see Beech		Industrial waste sites	35
Fence post trials	133	Japanese Paperpots	30, 35, 36, 67
Fencing	105	Larch	
Fertilisers		—, European (<i>Larix decidua</i>)	133
aircraft studies on distribution patterns	126	—, Hybrid (<i>L. x eurolepis</i>)	
compared with composts in nurseries	139	progeny tests	78
crop rotations	139	seed	23
" Enmag "	30	—, Japanese (<i>L. kaempferi</i>)	
experimental design for reduced plots	47	fence posts	133
" Fison's FL3P "	30	flowering	85
foliar analysis	48, 71	in coalfield forests	71
sampling surveys	49	seed	23
in established crops	52	—, spp.	
nitrogen	51, 146	herbicides	43
nutrient uptake	145	seed	76
phosphate	50	London plane, dieback	93
potash	50	Maple, in arboretum	42
Sitka spruce	143	Measurement	
with herbicides on peat	52	standing timber	122
Fir, see <i>Abies</i>		identification of unsatisfactory young	123
Flowering	84	crops	123
Foliar		<i>Moritziella corticalis</i>	101
analysis	48, 71	Multilift detachable lorry body	129
sampling surveys	49	<i>Nectria</i> spp.	92
<i>Fomes annosus</i>		Needle fall in Christmas trees	133
on alkaline sites	88	Noble fir, see <i>Abies procera</i>	
on freely drained sites	67	Nurseries	
stump removal	88	ball-rooted planting stock	32
treatment by liquid	127	composts	139
<i>Fraxinus</i> , see Ash		fertilisers	139
Fungicides, soil	152	herbicides	27
<i>Gilpinia hercyniae</i>	101	Japanese Paperpots	30
Grading of softwoods for building	134	progeny tests	78
Grand fir, see <i>Abies grandis</i>		provenance experiments	37-41
Green spruce aphid, see <i>Elatobium abietinum</i>		roll transplants	31
Handling equipment	127	root dips	27
Heather (<i>Calluna vulgaris</i>) control	45, 51, 126	regeneration after transplanting	72
Herbicides		seed losses	26
aminotriazole	43, 44	seedling pathology	150
asulam	44	treatment of seed dormancy	25
atrazine	43, 126	tubed seedlings	28
bracken control	44	Nutrition, see Fertilisers	
chlorthiamid	126	Oak	
dicamba	44	fence posts	133
dry application	126	in arboretum	42
heather control	45, 126	<i>Moritziella corticalis</i>	101
herbaceous weeds	43	seed	22, 76
MCPA	44	Pheasants	105
seedbed screening	27	<i>Phytophthora</i> spp.	89, 96
sodium alginate root dips	27, 72	<i>Picea</i> , see Spruce	
ultra low volume spraying	45, 126	Pine looper moth, see <i>Bupalus piniarius</i>	
with fertilisers on peat	52		
woody weeds	45		
Hydratongs	127		
Hydrological relations of forests	158		
Indian bean tree			
(<i>Catalpa bignonioides</i>) wilt	96		

	Page		Page
Pine, Corsican (<i>Pinus nigra</i> var. <i>Maritima</i>)		<i>Pseudotsuga menziesii</i> , see Douglas fir	
bark used in horticulture	132	<i>Pythium</i>	97
dieback	94	<i>Quercus</i> , see Oak	
fertilisers	50, 145	Recreation	
<i>Fomes annosus</i>	88	aerial photography for surveys	119
grading for building	134	day visitor survey	118
in coalfield forests	71	New Forest survey	108, 118
industrial waste sites	36	potential of forests	159
Japanese Paperpots	30, 36	Regeneration, artificial	
roll transplants	31	on freely drained soils	67
root regeneration after transplanting	72	on gleys	67
seed	23, 76	on ironpan	68
sodium alginate root dip	28	Remote sensing	70
—, Lodgepole (<i>P. contorta</i>)		Respacing	122
artificial regeneration	67	<i>Rhizoctonia solani</i>	151
basal sweep	65	<i>Rhyacionia logaea</i>	101
effect of shade on nutrient uptake	145	Rigg and furr	63, 148
herbicides	45	Road work	131
physiology of roots	87	Roll transplants	31
Plus trees survey	77	Roots	
progeny tests	78	physiology	87
provenance	37	regeneration after transplanting	72
respacing	122	sodium alginate dips	27
<i>Rhyacionia logaea</i>	101	studies, hydrological activity	158
seed	22, 23, 78	Sawlog conversion model	138
<i>Sirococcus strobilinus</i>	97	<i>Scleroderris lagerbergii</i>	94
stability trials	66	Scolytids	102
tubed seedlings	28, 29	Seed	
vegetative propagation	77, 83	collection	25
—, Macedonian (<i>P. peuce</i>)	34	dormancy	25, 27
—, Scots (<i>P. sylvestris</i>)		dressings	152
bark used in horticulture	132	extraction	22
fence posts	133	home crops	20, 76
fertilisers	50, 52, 145, 147	imports	22
<i>Fomes annosus</i>	88	plantations	78
grading for building	134	post-sowing losses	26
herbicides	45	pre-chilling to dissipate dormancy	25, 27
in coalfield forests	71	procurement	20
progeny tests	78	production	84
root regeneration after transplanting	73	sources register	20, 76
seed	76	storage	22
stability trials	66	supply	23
virus diseases	153	testing	23, 26
—, spp.		Shade, effect on nutrient uptake	145
herbicides	43	Shoot growth control	86
Pineapple galls	101	<i>Sirococcus strobilinus</i> on Lodgepole pine	97
Planting equipment	33, 110, 124	Sites (see also Soils)	
<i>Platanus x acerifolia</i> , see London plane		classification	69
Ploughing, see Cultivation		industrial waste	35
Plus trees survey	77	survey	122
Production forecasting	117	Soils	
Progeny tests	78	aeration	60
Provenance		analysis	60
<i>Abies grandis</i>	41	cultivation treatments	56
Douglas fir	39	freely drained, artificial regeneration	67
Lodgepole pine	37	fungicides	152
Sitka spruce	135		
Western hemlock	39		

	Page		Page
Soils, <i>cont.</i>		Spruce, <i>cont.</i>	
gleys		roll transplants	31
artificial regeneration	67	root regeneration after transplanting	73
cultivation	62	seed	20-25, 76
heathland		seedling pathology	150
spaced furrow planting	33	sodium alginate root dip	28
water potential and oxygen status	148	stability trials	66
indurated layers, studies	56	tubed seedlings	28
instrumentation	60	vegetative propagation	77, 83
ironpan		virus diseases	153
artificial regeneration	68	wood from different provenances	135
cultivation	62	—, spp.	
cultivation and fertilisers	50	herbicides	43
Lodgepole pine stability trials	66	Spruce sawfly	101
moisture effects on rootlets	158	Squirrels	
peat		conservation (red squirrel)	104
cultivation	33	control	104
drainage	61	damage to beech	104
fertiliser/herbicide trials	52	sycamore	96, 104
Japanese Paperpots	31	survey	104
Lodgepole pine stability trials	66	Stability of crops	64
nitrogen mineralisation	146	Stress grading of softwoods for building	134
tubed seedlings	29	Sycamore	
studies	56-60	fence posts	133
survey	122	seed	76
types, physical and mechanical		wilt	96
properties	56	Systems design	131
Spacing, influence on growth and		Thinning	
management	33	for prevention of windthrow	64
Splitting machine	129	line	122
Spraying, ultra low volume	45, 126	<i>Thuja plicata</i> , <i>see</i> Western red cedar	
Spruce, Norway (<i>Picea abies</i>)		Titmice, population studies	156
<i>Elatobium abietinum</i>	99, 153, 154	Tractors	125-128
fertilisers	52	Tree	
herbicides	44	injection units	110
in coalfield forests	71	processor	129
root regeneration after transplanting	73	pulling	65
seed	22	<i>Trichoderma</i> spp.	89
sodium alginate root dip	28	<i>Tsuga heterophylla</i> , <i>see</i> Western hemlock	
virus diseases	153	Tubed seedlings	
—, Sitka (<i>P. sitchensis</i>)		frames and fillers	124
artificial regeneration	67	in forest	28
biochemical variation	80	Lodgepole pine	28
crop rotations	139	on grass sites	29
effect of shade on nutrient uptake	145	on peat	29
<i>Elatobium abietinum</i>	99, 185, 186	ploughing for	30
fence posts	133	<i>Ulmus</i> , <i>see</i> Elm	
fertilisers	50, 51, 52, 139, 143	Ultra low volume spraying	45, 126
fungicides on seedlings	152	Vegetative propagation	77, 83
grading for building	134	<i>Verticillium dahliae</i>	96
herbicides	27, 44, 45	Virus diseases of conifers	153
identification of unsatisfactory young		Weather of 1971	74
crops	123	Weed control (<i>see also</i> Herbicides)	
in coalfield forests	71	mechanical	126
Japanese Paperpots	30	on early ploughing	126
line thinning	122		
physiology of roots	87		
Plus trees survey	77		
progeny tests	78		
respacing	122		

INDEX

193

	<i>Page</i>		<i>Page</i>
Western hemlock (<i>Tsuga heterophylla</i>)		timber properties	136
artificial regeneration	67	Western red cedar (<i>Thuja plicata</i>)	
effect of shade on nutrient uptake	145	flowering	85
fertilisers	49	herbicides	43
herbicides	43-44	timber properties	136
provenance	39	Windthrow	64
seed	22	Wood residue survey	137

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