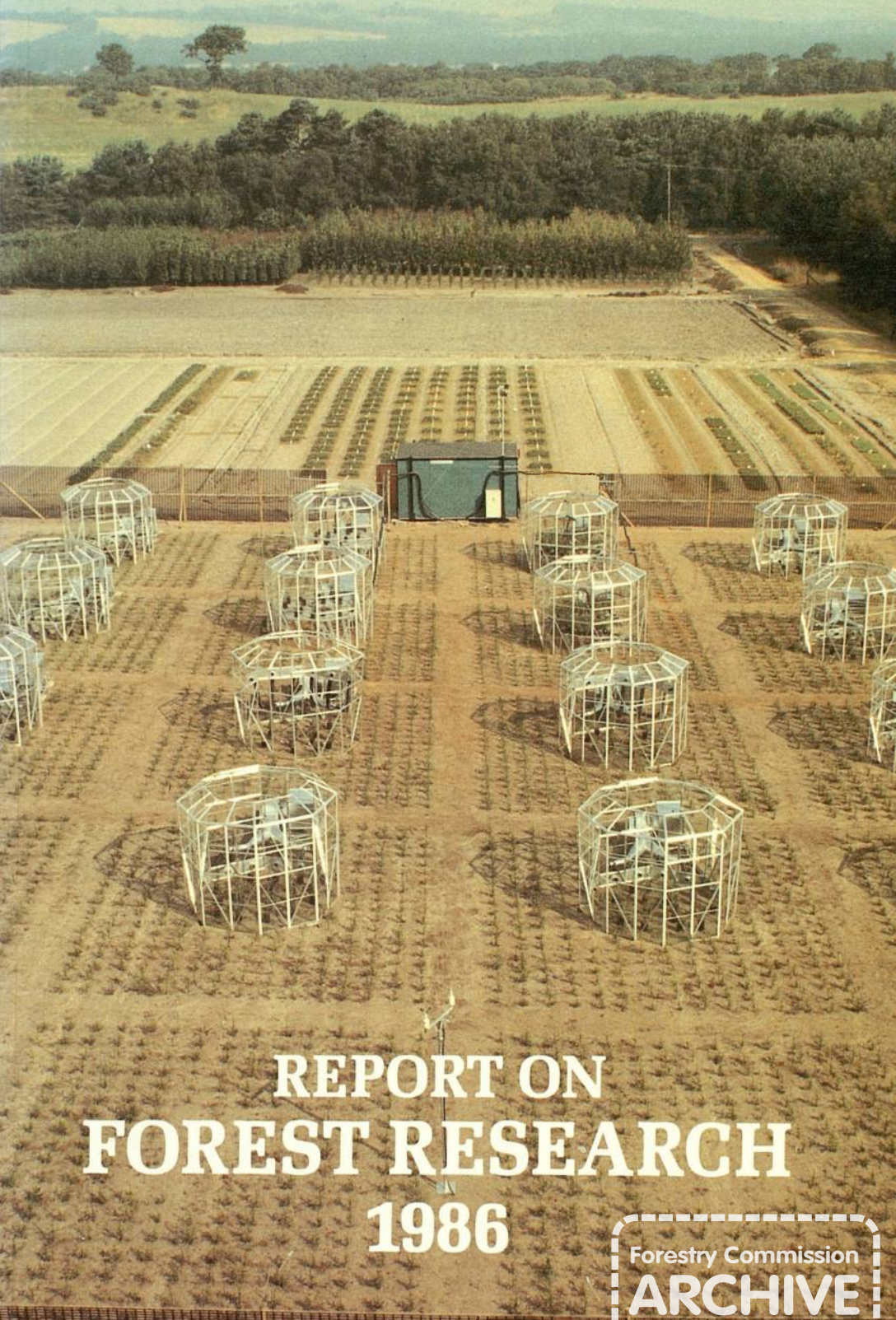
Forestry Commission



REPORT ON FOREST RESEARCH 1986

REPORT ON

FOREST RESEARCH

for the year ended
March 1986

LONDON
HER MAJESTY'S STATIONERY OFFICE

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Front Cover: Open-top chambers at Headley, Hampshire, set up to study the effects of air pollution on tree species. Air quality within the chambers is closely controlled and monitored so that treatments can include clean filtered air, or air to which known concentrations of pollutants have been added. (*CN 183*)

Back Cover: Tawny owl nestlings, west Scotland. Breeding of these birds of prey has been encouraged by the siting of nest boxes in forests at Kielder (Northumberland) and Glenbranter (Argyll), part of the research programme being undertaken by the Forestry Commission's Wildlife and Conservation Research Branch. (*19158*)

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INTRODUCTION

By A. J. GRAYSON
Director of Research

Advisory Committee on Forest Research

The system of reviewing the Division's work through visiting groups has been maintained. The contribution such reviews make is a most valuable one and I take this opportunity to record my gratitude to the chairman and members of these groups for the time and effort they have devoted. In 1985/86, Professor H. D. Patterson, head of the AFRC Unit of Statistics, University of Edinburgh with Dr H. C. Dawkins, Oxford Forestry Institute and Dr D. H. McLain, head of Computing Services, University of Sheffield, reviewed the work of the two Statistics and Computing Branches. They recommended that experimenters be given access to microcomputers in order that they may undertake routine processing of their own data. We are taking action to implement this proposal. I have however not accepted another recommendation on acquisition of a computer at the Northern Research Station: subsequent costing showing this too expensive for any prospective gains relative to continued operation through the Edinburgh Regional Computing Centre.

A second visiting group led by Dr S. R. Draper, head of the Official Seed Testing Station for England and Wales, National Institute of Agricultural Botany, Cambridge assisted by Professor E. H. Roberts, head of Crop Production, Department of Agriculture and Horticulture, University of Reading, reviewed the work of Seeds Branch. The group recommended a limited programme of comparative check-testing and completion of a training manual for seed analysts. The difficulties of undertaking strategic research on dormancy were recognised: though resource limitations preclude any large increase in Forestry Commission involvement with this problem, we hope to take up some of the group's suggested approaches.

Research collaboration and co-ordination

Collaboration with other research institutes has continued and developed. It has proved possible, following staff and consequential programme changes at the Institute of Terrestrial Ecology, to re-arrange responsibilities so as to best exploit our own and the Institute's strengths in tree biology. Apart from this co-ordination which continues as a result of the excellent relations between this Division and the Director, ITE and his staff, other developments of a collaborative nature have occurred in work with agricultural researchers on agroforestry. The Hill Farming Research Organisation and The Animal and Grassland Research Institute of the Agricultural and Food Research Council have continued with planning and setting up experiments to assess, *inter alia*, the effects of different tree spacings on the growth of grass and trees. Though we have still to see the shape of the programmes within the new Horticultural Research Institute of the Agricultural and Food Research Council, valuable collaboration has continued on vegetative propagation and clonal selection with workers at Littlehampton and East Malling.

In the broader field of research co-ordination, the Forestry Research Co-ordination Committee has continued with its cycle of reviews of forestry research subject areas. The Committee established at the beginning of its work the following nine areas: I. Genetics and tree improvement, II. Tree

biology, III. Silviculture, IV. Biotic damage, V. Distribution, composition and properties of dry matter, VI. Harvesting techniques, VII. Wood science and processing, VIII. Environmental interactions, IX. Forest planning. In the course of the year the Committee has issued its responses to four reviews, namely wood science and processing, the integration of farming and forestry in lowland Britain, tree physiology in relation to tree improvement and propagation and broadleaved woodlands. Each report[1] made recommendations on changes in the emphasis to be given to particular areas or research projects and, in certain cases, to the desirable level of effort to be devoted to the subject under review. The essential need is for those responsible for financing research to react to the Committee's responses. In the field of wood science and processing we have recruited a Wood Utilisation Officer, one of whose main duties will be the definition of projects requiring attention and the identification of contractors with whom work is commissioned by the Division. We have extended the period of the project at University College of North Wales on shake in oak timber and have supported jointly with the Timber Trades Federation and the British Wood Preserving Association a lectureship at Imperial College.

In connection with the review of physiology in relation to tree improvement, the main developments concern the subjects of ageing and juvenility and the application in this field and more generally of modern techniques of molecular biology. I am glad to report that as a result of the help of Professor R. Bell, Chief Scientist, Ministry of Agriculture, I was able to call a meeting of research directors and experienced leaders in the field with whose advice and the help in particular of Professor E. C. Cocking, Nottingham University, a workshop was prepared following the year under report. The expectation at the time of writing is that a grouping of research contractors will be arranged to investigate the important features of juvenility and ageing in trees. The current inability systematically to reverse ageing has a major controlling influence on tree improvement, notably on the speed with which it is possible to introduce tested progeny into commercial use.

Research funding

The work described in this Report is funded wholly or in part by the Forestry Commission. The gross expenditure referred to, including commissioned work and support of CASE studentships and the like, amounted to £6.2 millions in 1985–86, including Headquarters' overheads. Receipts from contracts and other services were £0.4 million, leaving net expenditure at £5.8 millions. This represents an increase of 3 per cent on the 1984/85 total for the Branches now included in the Division, implying a slight fall in expenditure in real terms. Accounts showing expenditure by Branch are set out in Appendix IV.

Part II of this Report contains a record 21 contributions, among which it is encouraging to note one where the bulk of the funding has come from a private forestry firm. Fountain Forestry established the project by Mr R. Worrell on growth of Sitka spruce on exposed sites which is recorded on page 59; the Commission has assisted with direction of the work, office space and a small proportion of project costs.

[1]Obtainable from the Secretary, FRCC, Alice Holt Lodge, Wrecclesham, Farnham, Surrey.

Monitoring tree health

There has been a growing concern on the part of those particularly concerned with tree health that damage caused by fungal and insect pests and by mammals and other biotic agents in the forest has not been adequately observed, identified or monitored. A more systematic monitoring system is desirable. Accordingly, in order to heighten the awareness of forest staff as well as to discover whether any important pests and diseases were present without our knowledge, a trial series of forest health days was arranged in one Forestry Commission district in each conservancy. The Forest District Manager and the majority of his professional staff allocated one full day in mid summer to inspecting the health of between 10 and 20 per cent of the stands in his district. In each case briefing and debriefing by Research Division staff were an essential part of the exercise. Though no serious causal agency was found in the seven districts covered, the exercise was universally thought to be useful. It is proposed to introduce this practice into more districts in 1986. Private woodlands were covered by some of the forest health day surveys in 1985 and arrangements are being made with Timber Growers UK to strengthen this connection.

In the study of possible air pollution effects in forestry, progress has been made in the twin aspects of resolving, or attempting to resolve, questions of approach and of carrying out research. In the first, collaboration among the principal researchers has increased and I am happy to report the development of more positive relations with Friends of the Earth on this subject than experienced earlier. So far as research work is concerned the main developments which are recorded in detail in this Report are the establishment of open-top chambers and preliminary testing of plant material, the start of a general study of the health of beech in woodland and the execution of a second survey of three conifer species throughout Britain. The position on tree damage caused or influenced by air pollution is that we have found no objective evidence of damage caused by other than local sources, and that we are intent on adopting rigorous tests to establish whether the ambient air in various regions has such effects. In this we support the aim of providing, if possible, early warning of ill-health in a project being mounted by the European Community. By contrast, general surveys of the condition of tree crowns appear likely to be of little use in advancing the cause of objective determination of air pollution effects and their causes.

Research communication

We have continued to progress contacts with Timber Growers UK. Subject days are a valuable mode of communication and a successful 3-day event was held at the Northern Research Station to make nurserymen aware of the technology of raising Sitka spruce cuttings. A continuing flow of articles has been provided for both *Forestry and British Timber* and, more recently, *Timber Grower:* these are important channels of communication with forest supervisors at all levels.

Research project evaluation

Work has continued on the lines referred to last year (*Report* 1985, pp. 2–3) and in particular further thought has been given to the definition of scientific merit. This term has a qualitative flavour and it is necessary to translate this

into scientific 'value' in order to measure the concept of gains over and above those captured in the other benefits assessed. The need to translate expected environmental benefits into money terms highlights our lack of a mensuration for many such benefits even before the difficulty of assigning unit values. An additional aspect concerns rises in real terms in the price index of research inputs. Such increases have been recognised by Research Councils and the University Grants Committee as highly significant for planning the scale of resources to meet given levels of funding expressed in nominal money terms. An important component in many fields of research is the acquisition of modern equipment and increases in real terms in the price of such material. While this aspect has had little impact as yet on the purchasing power of the R&D £ in forestry, it is a feature which cannot be dismissed. We lack however any measure of the price of output of a man-year of qualified scientist or engineer in association with modern laboratory or other hardware. The concept underlying this highly relevant number is familiar in such areas as manufacturing where it can be readily quantified but in research the lack of an adequate output measure is a fundamental difficulty.

Visits

A series of Subject Days dealing with vegetative propagation of conifers was held at the Northern Research Station in June 1985. Visits to both research stations continued at unabated rates. There were 46 visits of parties or individuals to Alice Holt involving 532 people and 39 to the Northern Research Station involving 398 visitors.

Organisation and staff

I have to report with sadness the death on 1 September 1985 of Miss J. J. Rowe after a long illness. Judy Rowe, who had led the Wildlife Branch from the time of its separation from Entomology in 1972, was well known both inside forestry circles and outside for the foundation of a scientific approach to a number of subjects of concern to wildlife managers, notably the management and control of deer.

I also have to report the death on 3 July 1985 of Mr John Kennedy, who had become the Commissioner responsible for Research Division following the reorganisation of the headquarters structure of the Commission. He was succeeded as Commissioner Private Forestry and Development by Mr Roger Bradley.

The number of non-industrial staff employed in the Division at 1 April 1986 was, at 223, five below the complement and steps were in hand to recruit staff to fill these posts. Industrial labour numbers at 119 rose by two.

Conferences and tours

Divisional staff attended a total of 108 meetings and conferences in Britain at which 28 papers were presented. Staff made 26 overseas visits plus 6 EEC business meetings concerning forestry research and administration of plant health.

As this Report was going to press, we learned of the untimely death of Professor J. Ashton, Professor of Agricultural Economics, University of Newcastle-upon-Tyne. Professor Ashton had been a member of the Advisory Committee for 2 years: the Committee will miss his encouragement and lively advice.

PART I

The Work of the Forestry Commission

RESEARCH DIVISION

SEED

Research

Laboratory experiments

Plant production in Japanese paperpots (JPPs) requires seed with two essential properties:

i. a very low percentage of impurities to prevent the fouling of machinery, permit the reproducible singling of seeds and allow the correct number of seeds to be sown per pot;

ii. a very high germination percentage, so as to make it necessary to sow only one seed per pot and still obtain plants in nearly all pots.

Over the past 10 years tree seed processing has continued to improve quickly, but is still trying to achieve both these aims consistently. Hence, it is commonplace within the Forestry Commission to further grade all seed earmarked for JPP production on a specific gravity (SG) table.

The SG table is designed to improve the maximum percentage germination of seedlots containing a mixture of full-live seed and empty seed, because the dense, full seed migrates to a different position on the table from the less dense empty seed, and the two types can therefore be separated. However, when the maximum percentage germination is not as high as desired because of contamination with full-dead seed, the benefits of further SG grading are questionable.

A trial was carried out to compare the germination of a typical bulk produced seedlot of Corsican pine (CP) 84(4028) with the germination of the same seedlot further separated into three fractions of different densities.

The original seedlot was first shown to contain 0 per cent empty seed. 70 kg of this seedlot were then passed over an SG table and separated into A, B and D fractions containing 46, 44, and 10 per cent of the starting weight. Germination tests were then conducted on samples from all four treatments and the results are shown in Figure 1.

Statistical analysis of the data shows that there is no significant difference in either maximum percentage germination or germination rate between the original seedlot and any of the three fractions. The most likely explanation is that there are insufficient differences in density between full-live and full-dead seed to enable SG table grading to improve the germination of even the densest fraction. Further grading of such seedlots to achieve more synchronous seedling emergence or better stocking densities is therefore pointless.

Service

Official Seed Testing Station

In conjunction with Statistics and Computing Branch, further databases have been created to store results from routine 'weighed replicate', 'tetrazolium', 'excised embryo' and 'cut' tests. A comprehensive menu of powerful prog-

rammes is now available to all seed analysts to facilitate easy input, analysis and retrieval of stored data.

Demand for seed tests by private firms has this year increased 10-fold and tests performed on behalf of other research Branches has risen 100-fold.

P. G. GOSLING

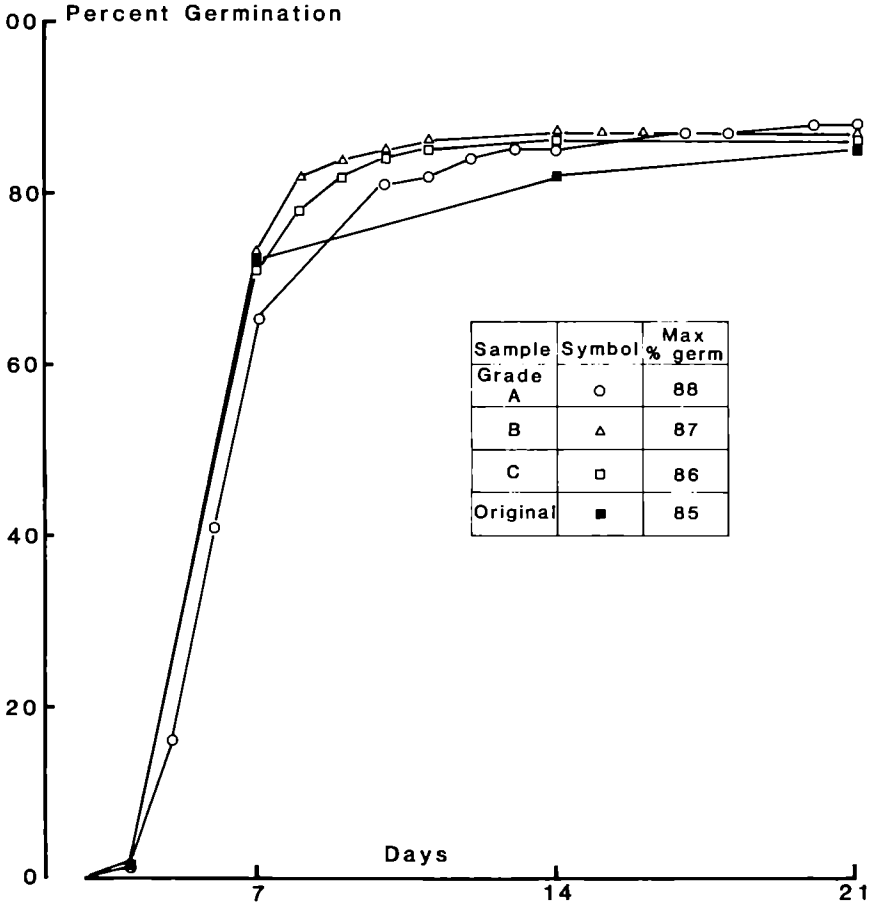

Figure 1. **The germination of Corsican pine 84(4028) seed before and after specific gravity table grading.**

SILVICULTURE (SOUTH)

Plant production

Vegetative propagation

Experiments carried out in glasshouses during the growing season showed that, under automatic mist, softwood cuttings of woodland and hedgerow trees may have rates of rooting in conventional substrates as good as or better than in bark-based media. The results contrast with those revealed by recent horticultural research. This has demonstrated that marked improvements in the rooting rates of a wide range of garden subjects can be obtained by inserting cuttings in substrates composed of equal parts of bark and peat.

Sweet chestnut, English oak, Small-leaved lime and Commelin elm were included in the experiments. Cutting behaviour was compared in three substrates, namely 100 per cent bark, a 50:50 peat:bark mix and a 50:50 peat:grit mix (Sweet chestnut and oak) or 25:75 peat:vermiculite mix (lime and elm). The bark, previously composted, received a base fertiliser dressing and additional nitrogen. Cambark fine grade was used throughout. Two hormone treatments and a no hormone control were compared.

Three tree species had significantly higher rooting rates in conventional substrates than in the bark based media. Oak in peat:grit rooted better ($p<0.001$) than in either bark substrate, Sweet chestnut rooted better ($p<0.05$) in peat:grit than in peat:bark, and elm rooted better ($p<0.05$) in peat:vermiculite than in either bark substrate. Type of rooting medium had no significant effect on the performance of lime cuttings. In general, cuttings dipped in a standard hormone powder (Rhizopon B at 2000 ppm) produced significantly higher rooting rates than untreated cuttings and cuttings dipped in a standard hormone solution (Synergol at 1000 ppm).

A large programme of plant production from cuttings and by grafting was also undertaken to raise stocks for other projects and research workers. The most intensive work was carried out for the open-top chamber experiments of Site Studies (South) Branch. It involved grafting nearly 500 scions of 18 clones of Sitka spruce, the insertion of more than 1300 cuttings of this species taken from 50 stock plants and the insertion of nearly 4000 cuttings of 21 clones of poplar, as well as the production of appreciable quantities of plants from seed in greenhouses.

Additionally five clones of Bird cherry, seven clones of London plane, and five species and two clones of lime were successfully propagated from softwood cuttings in mist. The work on Bird cherry, which is field chip budded in practice, was especially notable as more than 95 per cent of the cuttings rooted. Some 43 oak clones – most of them selected for the Oxford Hardwood Improvement Project – were grafted in late autumn.

J. JOBLING

Cold storage

In a cold store experiment, transplants of Sitka spruce, Douglas fir and Corsican pine were subjected to combinations of spraying with water or a suspension of gamma HCH, different periods of cold storage with wet or dry foliage and storage in open boxes or in polythene bags. Subsequent survival and growth of the plants was good with few significant differences except in the

case of Corsican pine where plants stored in open boxes survived less well ($p<0.001$) and had a lower height increment than those stored in polythene bags ($p<0.05$). The Corsican pine survival was also reduced by storage with wet foliage ($p<0.05$). In no case was any significant difference found between the insecticide and plain water spray treatments.

J. S. P. SALE, P. HOWARD, C. SHANKS

Lowland silviculture

Tree shelters

The large number of experiments established in the early 1980s is now yielding a great deal of information on the response to tree shelters of a wide range of species, both broadleaved and coniferous, as well as on the suitability of this method of establishment for a variety of site types and silvicultural regimes. It is apparent that few, if any, broadleaved species fail to derive benefit from tree shelters; most grow significantly faster when sheltered as well as being easy to locate and protected from animal and herbicide damage. Most conifers also respond well, notable exceptions being Western hemlock and Grand fir.

In enclosing individual trees, tree shelters permit considerable manipulation of the environment around each tree. This feature has been exploited in recent experiments that test the response of young trees to different levels of shading and a range of wavelengths of light. Previously it would have been necessary to undertake such experiments in growth chambers rather than in field conditions and on a large scale. The following table summarises the growth during the first year after planting of three species in the coloured shelter experiment at Alice Holt, which escaped the frost damage suffered at other sites.

The only significant ($p<0.05$) increases in height increment compared with growth in white shelters were experienced with ash grown in the orange, the yellow-green and the green shelters, this being accompanied by a significant reduction in diameter increment in the latter two colours, suggesting an etiolation effect. All other significant effects involve a reduction in height or diameter increment compared to that in white shelters although it was noted that height increment in oak attained high values in the orange shelters and again in the blue and violet shelters. These colours coincide with the peaks of the chlorophyll absorption spectrum. Green radiation in the range 500 nm to 550 nm produces the lowest response in photosynthesis and many other biological processes in higher plants.

An experiment comparing the growth of transplants in a full range of commercially available colours and shades showed slightly lower height increments in green shelters than in brown or translucent models with oak and beech. This effect was small and not statistically significant. With ash, both brown and green shelters increased height increment significantly ($p<0.001$ in the case of brown) over growth in the translucent shelters.

The use of tree shelters has continued to increase rapidly both in this country where around 5 million tree shelters have now been used, as well as overseas with particular interest being shown in France, USA and Australia. Manufacturers have tackled the problems of corner splitting and stem abrasion with the production of several new tree shelters designs.

M. J. POTTER

Table 1 Growth of broadleaved transplants in coloured shelters in the first year after planting (increments adjusted for covariate)

	Colour:	Netguard	White	UV-exluded	Red	Orange	Yellow	Yellow-green	Green	Blue-green	Blue	Violet
	Transmission band (nm):	—	—	—	620+	575–600	560–610	530–570	500–540	470–520	440–490	380–470
A	Mean height increment (cm)	12.3 A B C D	7.7 A	8.3 A	8.8 A B	25.8 B C D	12.0 A B C	29.8 D	29.3 C D	24.9 A B C D	13.1 A B C D	23.0 A B C D
H	Mean diameter increment (mm)	2.688 C D	2.789 D	2.388 C D	1.576 A B	2.977 D	2.740 D	1.439 A B	1.576 A B	0.975 A	1.551 A B	1.926 B C
B	Mean height increment (cm)	6.16 A B	10.32 B	4.63 A B	6.12 A B	2.07 A	10.07 A B	6.19 A B	6.66 A B	5.40 A B	9.93 A B	8.62 A B
E	Mean diameter increment (mm)	1.271 D	0.792 B C D	0.565 A B C D	0.054 A B C	−0.099 A B	1.061 C D	0.047 A B C	−0.094 A B	−0.326 A	0.098 A B C	0.423 A B C D
O	Mean height increment (cm)	6.9 A B C	13.4 B C D	−0.2 A B	9.8 A B C	25.4 D	−0.9 A	5.5 A B C	5.7 A B C	11.1 A B C	16.4 C D	17.1 C D
K	Mean diameter increment (mm)	1.109 C D	1.349 D	0.909 B C D	1.168 C D	1.258 D	0.426 A B C	0.321 A B	0.262 A B	0.064 A	0.161 A	0.286 A B

Duncan's Multiple Range Test:

Establishment of Corsican pine by direct sowing

In an experiment on scarified ground at Thetford Forest to compare different means of establishing Corsican pine, seed protected by small translucent plastic cones survived better than seed sown in the open ($p<0.001$). Survival was better in the bottom of the scarified profile or on level ground than on the top or side of the spoil ridge ($p<0.05$). Height and health scores of the two groups of seedlings were not significantly different. Bare-root transplants and paperpot seedlings planted in the same experiment survived much better ($p<0.001$) than germinated stock but were significantly less healthy in terms of leaf colour ($p<0.001$).

Forest weed control – bracken

A new technique of bracken control was tested in an experiment on a freely drained sand soil overlying chalk. A recently felled area which had been scarified using a Delta TTS and restocked with Corsican pine in paperpots was treated in spring with three different soil acting herbicides – dicamba, hexazinone and a granular product containing dichlobenil and dalapon – by applying a ribbon of relatively concentrated herbicide along the centre line of each inter-row. Good bracken control was achieved by dicamba and hexazinone but the dichlobenil/dalapon mixture was ineffective. None of the herbicides damaged the planted pine. The advantages of this technique, namely simplicity of application, flexibility of timing and ease of access before the bracken fronds grow up, are attractive compared to traditional foliar application methods.

J. S. P. SALE, S. MALONE, T. COOPER

Forest weed control – rhododendron

In an experiment on the control of rhododendron regrowth about one metre tall (*Report* 1985, p. 9), assessments at the end of the 1985 growing season following treatments in June and August 1984 with glyphosate, triclopyr and fluroxypyr with and without the additive Mixture B indicated that the early season applications (just after flowering of the rhododendron) were substantially more effective in controlling rhododendron regrowth than the later applications. The addition of Mixture B (a mixture of surfactants) improved the level of control in all treatments but the already high level of control in the five treatments implied that the added cost of Mixture B was likely to be justified only in late season applications.

J. S. P. SALE, K. BAKER, D. ROGERS

Nutrition of broadleaves

Ten nutrition experiments in pole-stage and coppice stands of broadleaved species have yielded mixed results despite attempting to identify probably deficient crops. Both pole-stage ash experiments have continued to show significantly increased diameter increment due to nitrogen fertilising (*Report* 1984, p. 9). No fertiliser treatment in any of the six experiments in oak stands has led to significantly improved growth though, in most cases, application of phosphate significantly increased phosphorus foliar nutrient level. The two experiments in Sweet chestnut coppice (*Report* 1983, p. 7) have continued to

show depressed increment from heavy liming but the 10-year-old coppice has also shown a significant response to phosphate. An accurate assessment of effects of fertilising on yield will be made in 1986/87 when the older experiment is harvested.

Epicormic branches on oak

No treatment, chemical or wrapping of the stem (*Report* 1984, p. 7), has effected significant long-term reduction in sprouting of epicormic branches. In particular, the initial encouraging suppression achieved with a mid-summer application of maleic hydrazide was only effective for one and a half growing seasons. There is evidence that the season of thinning may influence the number of epicormic shoots which sprout; it is the subject of two experiments.

J. EVANS

Arboriculture

Arboriculture Advisory and Information Service

There has been a continuing demand from all aspects of the population for information on amenity trees. In order to meet this demand five new Arboriculture Research Notes were published and 'Assistance with Arboricultural Reading' was distributed each week. A seminar, 'Advances in Practical Arboriculture', held at the University of York in April 1985 was the largest meeting of arboriculturists ever convened in Britain. The proceedings, which review research in universities, government research establishments and the Forestry Commission, are in course of publication (*Forestry Commission Bulletin* 65).

The number of requests for advice was greater than in any previous year with 2164 people receiving answers to the enquiries, or 8.8 per cent more than in the previous year. The subject of the enquiries did not indicate an increase in any specific area of amenity tree culture.

D. PATCH, F. R. W. STEVENS

Arboriculture: Department of the Environment contract

Landscape tree establishment

None of the proprietary soil ameliorants under test in two experiments had a significant effect on first year tree survival or growth; but Corsican pine survival in one of the experiments was increased by pit planting, irrespective of what if any ameliorant was mixed into the pit (82 per cent) compared with notch planting (36 per cent). Root dipping in 'Alginure' had no significant effect on survival or growth in another experiment. A new experiment investigating the effects of dipping partially desiccated plants has been planted. Further experiments have been established testing the effects of rough handling on broadleaved transplants (*Report* 1985, p. 15 showed that survival of Sitka spruce transplants was reduced by dropping them in bags).

Figures 2, 3 and 4 illustrate the effects of chemical weed control and black polythene mulching on survival and growth observed in a series of experiments started in 1984. In these and earlier experiments survival has been excellent in the early years, but dramatic increases in height, diameter and

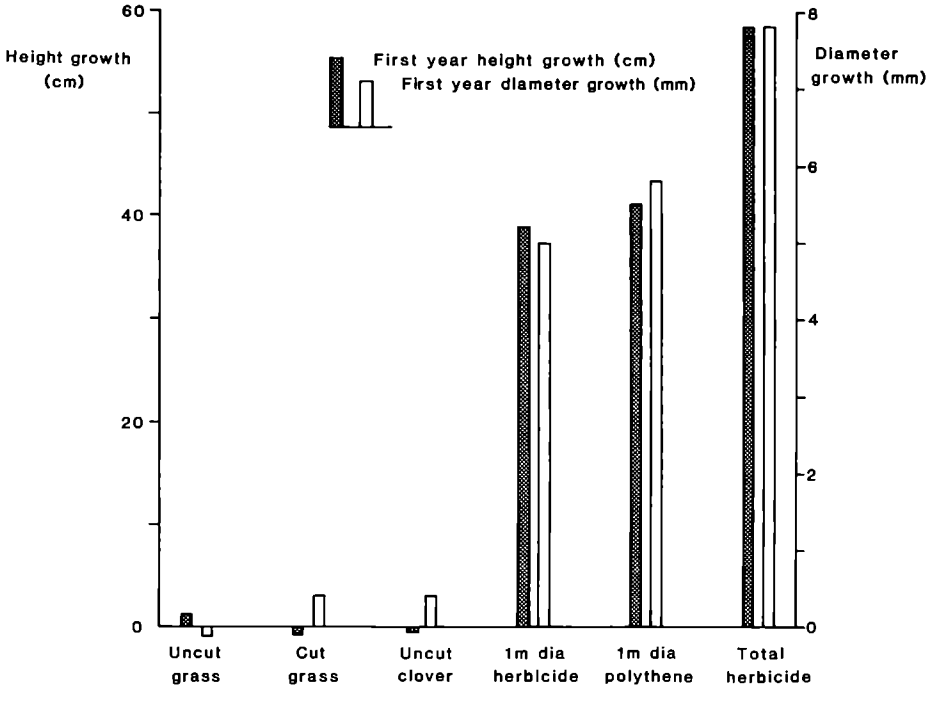

Figure 2. **The effect of six forms of ground cover on first year growth of Silver maple transplants at Alice Holt (Hampshire).**

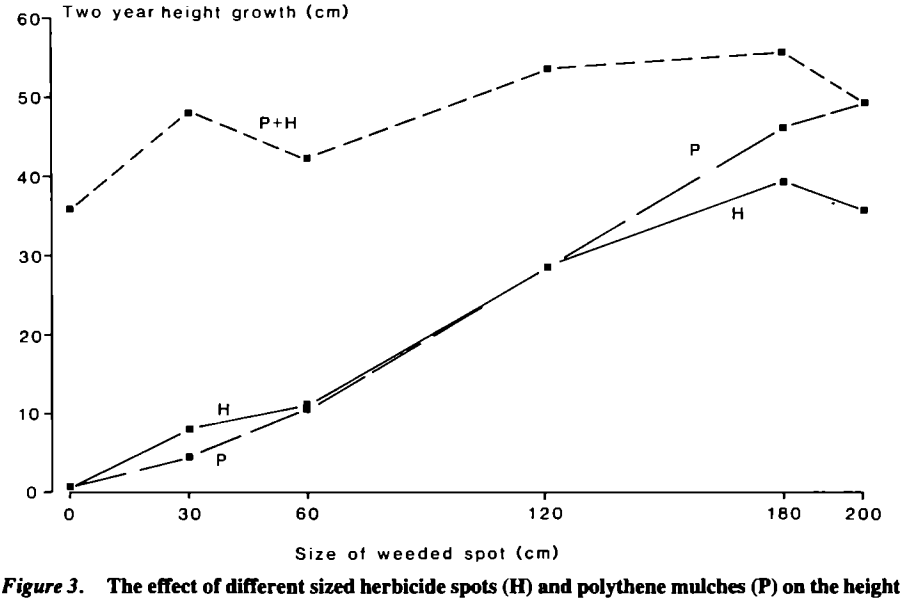

Figure 3. **The effect of different sized herbicide spots (H) and polythene mulches (P) on the height growth of Field maple transplants at Bedford. In some plots (P + H) all weeds between the mulches were treated with herbicide. Square spots and mulches of the indicated sides were used. Planting was at 2 × 2m spacing. Whole plots containing 12 trees were treated with herbicide or covered in polythene in the maximum treatments.**

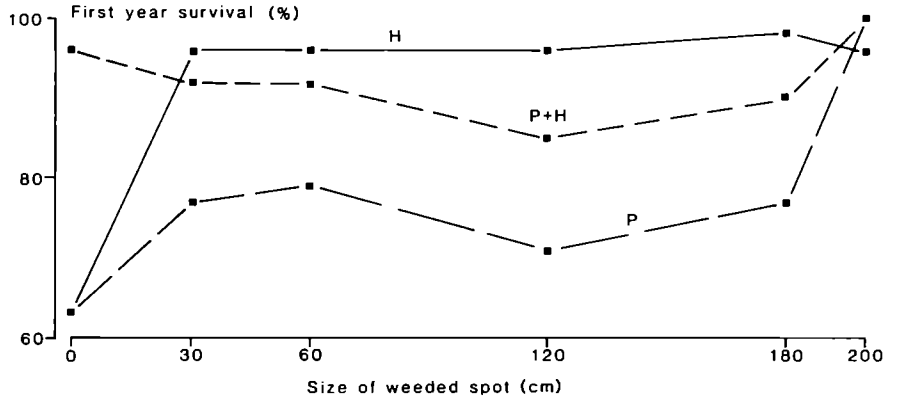

Figure 4. **The effect of different sized herbicide spots (H) and polythene mulches (P) on the survival of poor quality oak transplants at Quedgeley, Gloucestershire. See caption to Figure 3 for explanation of treatments.**

root growth, leaf area and foliar nutrient concentrations have been achieved by effective weeding. Cutting the tops off weeds (Figure 2) has been ineffective and has occasionally invigorated them and depressed tree growth. Survival as well as growth has been reduced by weeds in experiments on very dry sites or where the trees were already weakened; the oak used at Quedgeley (Figure 4) had blackened roots and had set very small buds before lifting from the nursery. Herbicides were reapplied as necessary to maintain fairly weed-free conditions in these experiments; if properly applied, polythene mats require no further maintenance. Both herbicide spots and polythene mats should be at least 1 m diameter.

Horticulture: Department of Transport contract

The Department of Transport requires visually pleasing sight and sound barriers adjacent to some new motorways with limited land take. A trial length of earth-filled wall, about 3m tall and 1.4m wide at the base, has been built. Assessments will be made of the feasibility of growing woody climbers planted into the side of the wall, using various soil mixes in the wall.

R. J. DAVIES, S. M. COLDERICK

Arboreta

Westonbirt Arboretum, Gloucestershire

There was little environmental damage to the collection during 1985, but the cold winds of January and February 1986 caused foliar damage to *Eucryphia, Pyracantha, Juniperus* and *Quercus ilex*. Other genera or species may have been damaged but were without visible signs at the time of reporting. The wet clinging snow of late January 1986 caused severe crown damage, mainly to cedars and Douglas fir, also bringing a final demise to some leaning trees – principally oak and walnut.

A further 207 specimens have been added, including 63 species, cultivars or varieties new to the collection. An avenue of Pedunculate oak has been

established using seedling progeny from 'Savile Glade' which represent the earliest plantings by Robert Holford.

M. L. PEARCE

Bedgebury National Pinetum, Kent

The 60th Anniversary of the first plantings in the pinetum (March 1925) was celebrated with an Open Day in June. A metric-scale atlas of 23 pages has been printed after a re-survey of all trees in the pinetum. It is the basis for a catalogue of the collection currently under production. Work is progressing on new glades for Chinese, Japanese and North American tree species.

M. J. SCOTT

SILVICULTURE (NORTH)

Species

Seed origin experiments

ABIES

In experiments on 11 sites, each with up to 36 seed origins of Grand fir, the relative growth rates after 6 years in the forest follow a similar pattern to those at 3 years (*Report* 1984, p.13 – Table 2). The tallest origin from Gardiner, Olympic Peninsula, Washington had a mean height of 3 m (equivalent to General Yield Class >36) at Drummond Hill, Tay District.

A collection of 23 Pacific Silver fir seed origins was planted on seven sites, ranging from Glen Urquhart (Inverness-shire) to Alice Holt (Hampshire). Parallel experiments are also being planted in Northern Ireland, Eire, W. Germany, Canada and USA.

MACEDONIAN PINE

Thirteen seedlots collected by Bulgarian and Yugoslavian research staff following a study tour (Lines, 1985) were sown in a nursery experiment, together with seven seedlots collected from stands in Britain and Eire. Despite prolonged stratification, some seedlots (mainly from higher elevations) proved to be deeply dormant and germinated as late as October.

ENGELMANN SPRUCE

The 'Interior' spruce collection sown in 1981 (*Report* 1983, p. 12) was planted in 1985 on four sites in Scotland and at Alice Holt (Hampshire). Survival, in an unusually wet year, was excellent.

RED ALDER

Previous trials have shown the lack of frost hardiness of Red alder from southern seed origins. A new collection of 27 seedlots includes five Alaskan origins and others from high elevations elsewhere in its range. These have been planted on a deep peat site in NW Scotland, on a more fertile site in SW Scotland, on a frosty site with a peaty gley soil in the Borders and on a restored gravel pit site in the south of England. Some origins of Common alder and the Alaskan *Alnus sinuata* are also included. Co-operative work

continues with Glasgow University and the Institute of Terrestrial Ecology on the association between Red alder and its *Frankia* endophyte.

BIRCH

An experiment containing 42 open-pollinated progenies from seven seed origins of Downy birch, and planned jointly with Aberdeen University staff, was planted on a poor deep peat site at Shin Forest (Sutherland) in 1984. The seed origins range from the central Grampians to Loch Eriboll. After 2 years there were only slight differences between seed origin mean heights, though highly significant ($p<0.001$) differences among families and within most populations. This suggests that the best prospect for improved growth rates lies in selection of the best families, rather than particular seed origins.

Species trials

Many older species trials are unsatisfactory because they contain seed origins which are now known to be inferior, or because the cultural treatments had become outdated. With the continuing increase in the use of Sitka spruce, it is provident to establish new trials testing alternative species which have potentially valuable properties, e.g. superior resistance to *Fomes* or lower herbicide or nutrient requirements than Sitka spruce. Five new long-term experiments have been planted with 12–15 species and mixture combinations, covering a range of the major site types in Scotland and northern England.

R. LINES

Production of planting stock

Vegetative propagation of Sitka spruce

The effect of different propagation media on rooting performance of Sitka spruce cuttings (*Report* 1985, p. 13) was further examined in experiments at Bush (Lothian) and Newton (Grampian). Results confirmed the beneficial effect of bark incorporation and the detrimental effect of high peat proportions on rooting performance, but otherwise indicated that Sitka spruce cuttings can be rooted successfully in a wide range of media.

Gill (1983) concluded that for commercial success a gross bulking-up factor of 600 cuttings per seed over two cycles would be required for vegetative propagation of Sitka spruce. The large-scale trial at Newton has shown that multiplication factors of 700–800 cuttings per seed can be reliably achieved, confirming the financial viability of investment in vegetative propagation.

Advances in the rooting of micropropagated Sitka spruce seedlings (*Report* 1984, p. 31) have made it possible to examine this technique as the first stage of vegetative propagation. Plants produced by micropropagation are being grown on at Inchnacardoch nursery (Highland) and compared with seedlings of similar origin. After one year, no significant differences in growth have been found.

Some 40 field experiments have been laid down since 1979 to compare Sitka spruce cuttings and transplants. Six year results from the earliest experiments are now available (Table 2). There are no significant differences in height or form between the best cutting and transplant treatments, demonstrating that cuttings of improved genotype can develop normally in the forest and are likely to realise potential genetic gains.

Vegetative propagation of Hybrid larch

Results from Bush and Newton confirmed the feasibility of obtaining over 90 per cent rooting of hardwood Hybrid larch cuttings which practically eliminated the problems of poor form associated with softwood cuttings (*Report* 1985, p. 14). Collection in late February and insertion in early March after 2 weeks cold storage again gave good results. Two experiments compared rooting in 12 different media (peat, bark and grit in various ratios). There were no significant differences between the various mixtures with an overall mean rooting percentage of 96 per cent. Application of a hormone rooting agent (1 per cent NAA/IBA mixture) significantly ($p<0.01$) depressed rooting, the effect increasing with application rate; the untreated control gave the best result. The beneficial effect of incorporated slow-release fertiliser on rooting performance was again demonstrated ($p<0.05$). Seventeen forest experiments have been planted since 1978 to compare the field performance of Hybrid larch cuttings and transplants. Growth of cuttings in the early experiments has been variable, largely because substandard plants were included. However, the best plots of cuttings are indistinguishable from normal stock. Results of current experiments using hardwood cuttings should lead to full scale development by the end of the decade.

Table 2 Forest performance of Sitka spruce cuttings and transplants. Height growth (m) 6 years after planting

Experiment	Treatment C4	C5	T2	T3	SED
Glentress 49 (Borders)	1.3	1.2	1.2	1.3	0.1
Penllyn 13 (Gwynedd)	1.8	1.6	1.4	1.8	0.2
Wauchope 12 (Dumfries & Galloway)	2.3	2.1	1.9	2.4	0.1

Notes: a. C4 and C5 are cuttings from 2 and 3-year-old parents respectively; T2 and T3 are 2 and 3-year-old transplants.
b. Cuttings and transplants are of the same Queen Charlotte Islands Origin.

Precision sowing and undercutting

The large-scale trial at Wykeham (*Report* 1985, p. 14) continued with further sowings of four conifer species. A new sowing drum designed for smaller-seeded species (>100 000 seeds/kg) was tested and found to give some improvement in seed spacing. Germination of all species was high as a result of the moist spring.

Plants undercut in the 1984 trials were planted in forest experiments at three sites in Yorkshire and Northumberland. Undercut stock was compared with transplants and 1+0 seedlings raised in Japanese paperpots. After one season, the precision-sown and undercut stock frequently showed much better survival and height growth than ordinary planting stock (Mason, 1986).

W. L. MASON

Planting

Plant handling

Drying, heating and rough handling treatments were applied factorially to transplants of Sitka spruce and Douglas fir before planting out in spring on an uncultivated site at Glentress (Borders). Root growth potential (RGP), the number of new roots developed after a defined period, was measured in a growth chamber on samples of plants, and survival was assessed at the end of the first growing season. Preliminary results are given in Table 3. For Sitka spruce, there were severe reductions in RGP as a result of rough handling (dropping sealed bags containing 70 plants 15 times from a height of 3 m on to a hard floor) and drying (plants separated and exposed to drying conditions for 2 hours). These treatments also gave significant reductions in survival ($p<0.05$). Combinations of drying and rough handling reduced RGP to zero and survival to 46.7 per cent ($p<0.001$). The heating treatment (heating in growth chambers to foliage temperatures of 33–44°C) produced no harmful effect.

Despite the apparently excellent initial condition of the Douglas fir plants, RGP was generally very low. This accords with results obtained at Bush nursery where plants were lifted monthly and RGP assessed under standard conditions. The RGP of Douglas fir increased from September until the end of November and thereafter declined exponentially, becoming unmeasurable by the end of April. In contrast, Sitka spruce RGP reached a peak at the end of October (at about half the level of the Douglas fir peak) and had declined only slightly by the end of April. This work is currently being repeated with assessments of carbohydrate levels and dormancy status in co-operation with staff of the Institute of Terrestrial Ecology.

Table 3 RGP (total number of new roots after 14 days) and survival after one growing season

Treatment	Sitka spruce		Douglas fir	
	RGP	Survival %	RGP	Survival %
O	37.1	98.3	0.5	91.7
R	7.9	95.0	0.1	81.7
H	28.8	95.0	1.2	90.0
D	1.0	95.0	0.4	81.7
DH	0.2	75.0	0.6	86.7
HR	4.4	93.4	0	91.7
DR	0	46.7	0	70.0
DHR	0	46.7	0.1	65.0

Note: Treatment symbols: O = control, R = rough handling, H = heating, D = drying.

Plant establishment in relation to site preparation

As part of a scarification study on clear felled sites, mounds simulating the output of a Sinkkilä 2 scarifier/mounder were made using a Smalley digger on a peaty gley at Kershope (Cumbria). Temperature was logged hourly at three depths below the mound, scrape and undisturbed ground surfaces. Accumulated temperature sums were greatly increased in the mound, and less so below the scrape for periods during which the soil was warming.

A complementary growth room experiment was carried out at the Northern Research Station with root observation boxes containing Sitka spruce and Douglas fir transplants, placed in soil temperature boxes at 4, 8, 12 and 16°C and comparing careful handling and rough handling (dropped 10 times from a height of 3 m) treatments. The results (Figure 5) show that soil temperature can be critically important in promoting early root growth, particularly for roughly handled plants and for Douglas fir.

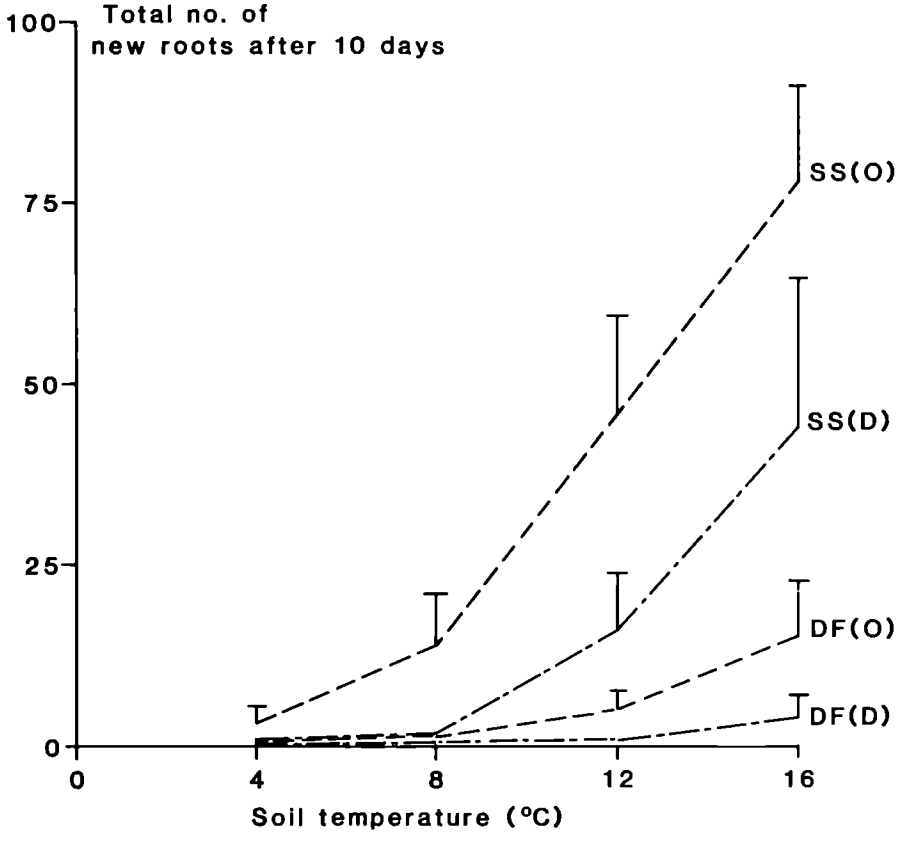

Figure 5. **RGP (total number of new roots after 10 days) in relation to soil temperature for Sitka spruce (SS) and Douglas fir (DF). O = carefully handled, D = dropped in sealed bags 10 times from a height of 3 m. Error bars indicate the upper 95 per cent confidence limits.**

Forest weed control

An experiment at Glentress (Borders) assessed the effects of various additives on the efficacy of 'Roundup' (36 per cent a.e. glyphosate) herbicide for grass control and inluded testing of 'rainfastness' with 'rain' applied by watering can. 'Mixture B' (1:1 'Ethylan D252':'Agral') slightly improved efficacy and definitely improved rainfastness when added as 3 per cent of the total spray volume (200 litres ha^{-1}). 'Ethokem' (tallow amine ethoxylate) at 0.5

per cent slightly improved efficacy and rainfastness, but might be more beneficial at a higher rate.

Rhododendron control trials continued at Benmore (Argyll) with applications of 'Amcide' (ammonium sulphamate) at 400 g l^{-1} of water to confirm the recommendation that the treatment is effective "at any time of year" (FC Booklet 51, Section 8.2). In fact, consistently good control was achieved only during the growing season (March–August), with erratic results between September and February, and hence the recommendation will be revised.

Agroforestry

A study team with two Forestry Commission members (one each from Silviculture (North) and Statistics Branches) and two from the Hill Farming Research Organisation examined possible land-use systems involving sheep grazing under widely spaced trees on upland farms. A computer model was used to predict financial outputs from agriculture, forestry and agroforestry for a range of assumptions. Results suggested situations under which silvipastoral systems might be economically attractive and highlighted a number of gaps in scientific knowledge. Experiments are being established both in forests and on farms to obtain information required for model refinement.

P. M. TABBUSH

Nutrition

Nutrition of coniferous plantations on Moine lithology

A review of experimental results provided fresh guidance on the nutrition of Sitka spruce, Lodgepole pine and Scots pine plantations on Moine lithology. The area involved covers much of north and north-west Scotland, and includes extensive state and private afforestation. On many afforestation sites in this area phosphorus is the main element limiting growth in the early stages. The response period to a phosphate application lasts approximately 6 years for Sitka spruce, but slightly longer for Lodgepole pine. Potassium is not required at planting but becomes limiting to later growth on soils with a peat depth exceeding 30 cm. On certain soil types Sitka spruce will experience severe nitrogen deficiency necessitating nitrogen fertiliser application on a 3-year cyle or planting in mixture with a nurse species. Scots pine crops are most likely to give a worthwhile response to pole-stage fertilising with nitrogen or phosphate, but Sitka spruce may also respond on poor sites where little or no fertiliser was applied during establishment.

There is increasing evidence from restocked plantations and experiments that there are sufficient nutrients from first rotation residues to supply the early establishment needs of second rotation crops (*Report* 1985, pp. 16–17).

Nitrogen deficiency

There are many upland forest sites where pure Sitka spruce crops encounter nitrogen deficiency. To identify the most effective remedial action these sites can be divided into four main categories:

a. Where nitrogen deficiency is transient; the crop is not significantly affected and will grow through it without remedial treatment.
b. Where *Calluna* competition for available nitrogen results in nitrogen deficiency, which can be alleviated by killing the heather.

c. Where deficiency is due to a combination of *Calluna* competition and inherently low nitrogen levels in the soil; heather removal will improve growth temporarily but there will be a requirement for later nitrogen fertiliser inputs.
d. Where the main problem is the low nitrogen status of the site and nitrogen fertiliser application is the only remedial treatment.

Formerly, the first two categories were most commonly encountered, but in the last 10–15 years the latter two have become very important due to increased planting of Sitka spruce on poor heathland and peat sites. Forest managers should be aware that on these poor site types *Calluna* control alone will not cure nitrogen deficiency.

Potassium deficiency

In the autumn of 1985, development of potassium deficiency symptoms was unusually widespread. This may well have been due to last year's particularly wet summer weather causing high water tables and excessive leaching of this readily soluble element. Preliminary investigations in some areas revealed that acute potassium deficiency could be associated with heavy needle loss and shoot dieback. The progress of this effect is being monitored and remedial potassium application is not recommended at this stage on sites with peat depths of less than 30 cm.

C. M. A. TAYLOR

Cultivation, drainage and site preparation

Height growth over the first 10 years was analysed for a restocking experiment on Black Isle (Highland Region) in which the performance of Sitka spruce and Lodgepole pine on contrasting cultivation treatments was compared. The soil is an indurated surface water gley, and since clear felling has developed vigorous regrowth of *Calluna*. The four treatments are:

DDMB – Deep double mouldboard tine ploughing (D60/T90/I4.0)
DST – Deep single mouldboard tine ploughing (S60/T90/I2.0)
DR – Deep ripping with a mole head subsoiler (T90/I2.0)
DCT – Deep complete tine ploughing (S60/T90/I1.0)

Height growth of both species at 3, 6, and 10 years is shown in Figure 6. For Sitka spruce, 10 year mean height was significantly greater on deep double mouldboard ploughing than on the subsoiling treatment ($p<0.001$) and on deep complete ploughing was significantly poorer ($p<0.001$) than on the other three treatments. Lodgepole pine showed a similar trend, although the only significant difference was between the spaced ploughing and the other two treatments.

Twelve-year heights were assessed in an afforestation experiment at Helmsdale (Highland Region) comparing the performances of Sitka spruce and Lodgepole pine on four cultivation intensities. The site has a peaty ironpan soil with induration, and was previously *Calluna* dominated. The four treatments are:

DST – Deep single mouldboard tine ploughing (S60/T90/I1.5)
DCT – Deep complete tine ploughing (S60/T90/I0.8)
D1 – Complete digging to 0.8 m depth by excavator
D2 – Deep complete digging and mixing to 1.3 m by excavator

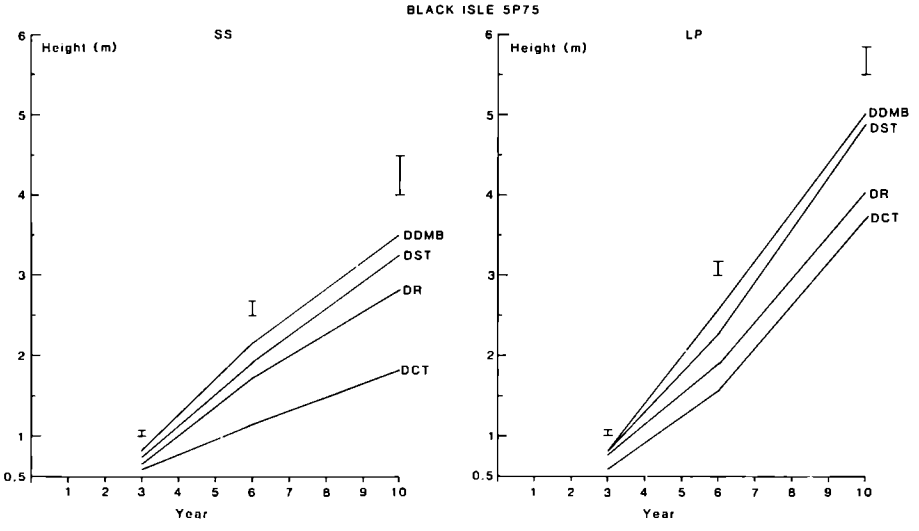

Figure 6. **Height growth of Sitka spruce (SS) and Lodgepole pine (LP) following contrasting cultivation treatments (see text) in a restocking experiment on Black Isle, Highland Region.**

For SS, mean 12 year heights were significantly taller ($p<0.01$) for the ploughing treatments DST and DCT than for the more intensive digging treatments. There were no significant differences for Lodgepole pine. Results from both this and the Black Isle experiments demonstrate the growth penalties (associated with accelerated nitrogen mineralisation) which may accompany over-intensive site preparation on the harder heathlands and support current recommendations for the use of spaced furrow ploughing on indurated and ironpan soils.

Another restocking experiment on a surface water clay gley at Langdale (North Yorkshire) compares a range of species on various sites preparation treatments. For most species, spaced furrow ploughing gave significantly ($p<0.05$) better growth at 6 years than subsoiling which in turn was usually better than planting without cultivation.

Tree growth and root development of Sitka spruce in experiments with ploughing and subsoiling has been analysed and interim managerial guidance has been given (Miller and Coutts, 1986).

Stability

To supplement earlier studies on the influence of thinning on wind damage in plantations (*Report* 1985, p. 19), a new experiment in south-west Scotland investigates the aeromechanical properties of respaced Sitka spruce. A uniform 10 ha area of Sitka spruce, respaced 5 years previously, and surrounded by untreated crops, has been selected for study. The stands have a mean tree height of 7.5 m, and the respaced section has a mean tree diameter of 12.2 cm, 23 per cent larger than the untreated control. Differences in live crown depth, and canopy roughness/openness are expected to interact with the contrasting diameter : height ratios (stem stiffness), producing differences in the momentum exchange and dissipation properties of the two treatments. Vertical

arrays of tri-axial propeller and sensitive cup anemometers have been installed to measure the turbulent wind conditions within and above the stands. Stem-mounted accelerometers located on several trees adjacent to the anemometer masts measure the dynamic responses of trees during gust loading. Data logging started in March 1986.

Two 200 ha areas in Glentrool Forest (Dumfries and Galloway) have been mapped using aerial and ground survey as part of a new programme to monitor endemic windthrow and improve local prediction of windthrow initiation, rates of extension and terminal heights.

K. F. MILLER

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SITE STUDIES (SOUTH)

Chemical analysis

The chemical laboratory received approximately 7000 samples during the year, an increase of 2000 on the previous year. Twenty per cent of these came from conservancy and private growers, the proportion from the latter trebling previous figures. Broadleaved samples from Silviculture (South) research projects have more than doubled this year accounting for 29 per cent of the total.

D. A. WADDELL

Effects of trees on sites

The project on clear felling impact previously detailed in the *Reports* for 1984 and 1985 has continued apace at three upland sites. This work is being done jointly with the Institute of Terrestrial Ecology and Exeter University. The crops were felled 2 years ago. In the main experiment, on seasonally waterlogged soil at Beddgelert Forest in Snowdonia, the leaching pattern of major nutrients following felling has become more obvious in the second year. It is now clear that phosphate has moved down 20–30 cm following felling, but no further. In contrast nitrogen and potassium have appeared in the catchment outflow. The pulse of potassium leaching is largely complete. There is no obvious difference in the form or rate of elemental leaching between conventionally harvested areas and those from which branches and needles were also removed.

However, these harvesting regimes have had markedly different effects on oxycline depth, as shown in Figure 7. On the seasonally waterlogged soil in Snowdonia the oxycline, that is the depth at which oxygen supply becomes too limiting for root survival, moved closer to the surface immediately after felling by an amount 5 cm greater than in the conventionally felled plots. This difference fell to zero after 2 years. In contrast a smaller difference, about 2 cm, persisted after 2 years in a more permanently waterlogged clay soil in north Devon.

M. A. ANDERSON

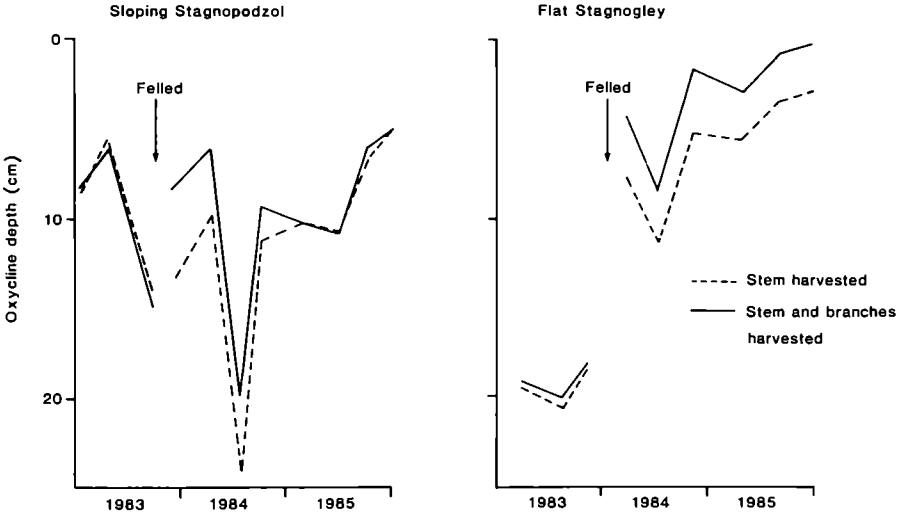

Figure 7. **The effect on oxycline depth, in two seasonally waterlogged soils, of harvesting a Sitka spruce crop. Left, Snowdonia; right, north-west Devon.**

Reclamation

Work has continued at experimental sites at Bramshill, Hampshire (reclaimed gravel workings), St. Austell, Cornwall (china clay spoil), Elstow, Bedfordshire (callow clay spoil), and south Wales and Scotland (open-cast coal spoils) (*Report* 1984, p. 22).

At Bramshill, dip wells have been inserted in the 30 m ridges to examine winter water levels. Initial results show that water level rarely rises above 50 cm in coarse stony loams at Warren Heath, but in medium loams and clays at Bramshill Common frequently rises above 40 cm, notably in mid and bottom slope positions. However, contour maps of Corsican pine top heights reveal better growth in these positions, suggesting that drought may inhibit growth on ridge crests. The maps also reveal patterns of growth perpendicular to slope, and measurements of soil physical properties have begun to attempt to explain them.

Tatter flags have been installed at St. Austell and soil samples taken to characterise the spoil physically and chemically. After the wet 1985 summer survival has been good, particularly where mulches of polythene or mica wastes have been used, and is nearly 90 per cent for some alder plots. Trees

planted at normal depth have a slight disadvantage over those planted deeper. Corsican pine, Sitka spruce and alders have survived much better than Monterey and Bishop pines, and future work will concentrate on the former two species at this very exposed site.

Survival of alders on callow clay at Elstow has been exceptional (>95 per cent), particularly on loose-tipped material. Oak, too, has done best on this treatment; Lawson cypress, however, performed well only on waste ripped with winged tines. These preliminary results indicate the usefulness of the loose tipping approach to land restoration, and future work will make comparisons of its effectiveness in lighter textured materials.

Experimental work in the South Wales coalfield has continued. Foliar analyses show that nitrogen and phosphorus deficiencies are common, but fertiliser experiments at Rheola Forest (*Report* 1981, p. 25) only show responses to nitrogen in those blocks where growth is better than average; poor soil physical conditions are suspected as the cause of poor growth. Trees planted in plots containing nitrogen-fixing legumes have yet to show a response, and in the exposed conditions at Rheola it may be several years before alders can be shown to aid the nitrogen capital of sites sufficiently to increase the growth of conifers interplanted with them.

In Scotland an open-cast coal site has been restored with peat as the growing medium (*Report* 1984, p. 24). Erosion pins have been installed to examine the role of a legume cover in stabilising peat against water and wind erosion.

A. J. MOFFAT

Upland forestry

Drainage: peaty gleys

A drainage experiment in Sitka spruce planted in 1951 at Hafren Forest (Powys) was monitored to seek confirmation of the results obtained at Crychan (*Reports* 1982 and 1984); both are from the same series of pole-stage drainage experiments. Each plot at Hafren was split for a top dressing of PK fertiliser in 1967 after drainage in 1966; a further difference is that it has only three blocks instead of the four at Crychan. Drainage parameters were modelled from a series of daily borehole readings and these showed significant differences ($p<0.05$) of 27 cm in the maximum depth to which soil drained in the absence of rain and of 2.6 cm in the computed infiltration at saturation.

Growth data showed a highly significant ($p<0.001$) effect of fertiliser on mean breast height diameter of mid-plot trees, the improvement being about 6 per cent. There was also an increase in diameter attributable to drainage ($p<0.01$) of about 14 per cent. The interaction between the two effects was also significant ($p<0.05$) with the major fertiliser effects being found in the least drained treatments. Over the whole experiment both computed infiltration at saturation and the maximum depth to which the soil drained correlated strongly with breast height diameter, thus adding weight to the fundamental drainage/growth relationship suggested by the Crychan results.

Impact of forestry on water resources

Table 4 sets out the main locations of collaborative studies and experiments concerning the inter-relations between water quality on the one hand and geology, acid depositions and land use, including forestry, on the other.

R. CARNELL

Table 4 Main areas of experiment and study concerning relations of water quality with forestry

Location	Objectives	Participants	Funding agencies	Reporting date
Llyn Brianne, Dyfed, Wales	Monitor: deposition; meteorology; flows through vegetation, soils, and streams (both quality and quantity) in forested and moorland catchments. Process studies of: acidity generation, speciation of aluminium in soil and stream waters, the role of organic acids, fish toxicity and physiology. Treat selected catchments, e.g. by liming, to abate acidification effects.	Welsh Water Authority. Institute of Hydrology. Institute of Terrestrial Ecology. University Colleges of Aberystwyth, Bangor, Lampeter and Swansea. University of Wales, Institute of Science and Technology. Forestry Commission. Economic Forestry Group.	Welsh Water Authority. Natural Environment Research Council. Department of the Environment.	Mid 1987
Hafren Forest, Powys, Wales	To quantify hydrochemical changes in stream waters consequent on land use changes (afforestation, deforestation and upland pasture improvement). Of particular interest is the measurement of pH, aluminium and sediment yield and the modelling of processes which control them.	Freshwater Biological Association. Institute of Hydrology. Institute of Terrestrial Ecology. Forestry Commission. Economic Forestry Group. Fountain Forestry. Severn Trent Water Authority.	Natural Environment Research Council. Department of the Environment. Surface Waters Acidification Programme*.	End 1987
Balquhidder, Central Region, Scotland	To quantify nutrient, hydrochemical and biological changes in soil, precipitation and stream waters consequent on afforestation and deforestation. Analytical quality control of critical stream water determinands (including pH, aluminium, calcium, manganese, iron, alkalinity, nitrogen).	Macaulay Institute for Soil Research. Freshwater Fisheries Laboratory. Forth River Purification Board. Strathclyde Regional Council. Warren Spring Laboratory. Water Research Centre. Stirling University. Forestry Commission.	Scottish Development Department. Department of the Environment.	End 1988

Table 4 *(continued)*

Loch Ard, Central Region, Scotland	To monitor differences in stream biota and chemistry in a range of catchment classes and changes resulting from clear felling and bankside felling of two forested areas.	Freshwater Fisheries Laboratory. Stirling University. Forth River Purification Board.	Scottish Development Department. Department of the Environment.	
	Detailed investigation of deposition, soil chemistry, soil water interactions and effects of lithology and vegetation on these interactions.	Macaulay Institute. Imperial College. Forestry Commission.	Surface Waters Acidification Programme*.	Mid 1987
Loch Dee, Dumfries and Galloway, Scotland	To monitor a range of acidification abatement practices in the restoration of a freshwater fishery fed by forested and moorland catchments (including stream and land liming).	Nature Conservancy Council. Freshwater Fisheries Laboratory. Forth River Purification Board. Forestry Commission.	Scottish Development Department. Department of the Environment.	1988
Loch Fleet, Dumfries and Galloway, Scotland	To demonstrate that the water chemistry of an acid lake can be brought into a range suitable for salmonids by a range of treatments to catchments and waters.	Macaulay Institute. South Scotland Electricity Board. Central Electricity Generating Board. North Scotland Hydro Board. Stirling University. British Geological Survey. National Coal Board. University College London. Glasgow College of Technology. Glasgow University. University of Liverpool. Forestry Commission.	Central Electricity Generating Board and others.	1988
Various Galloway lochs, Scotland	Paleoecological investigation of historical and land use changes in relation to freshwater acidification.	University College London.	Surface Waters Acidification Programme*.	1987

*Surface Waters Acidification Programme is jointly funded by the National Coal Board and the Central Electricity Generating Board; it is jointly administered by the Royal Society, Norwegian Academy of Science and Letters and the Royal Swedish Academy of Science.

Air pollution

Experimental studies using open-top chambers

Any effects of air pollution on trees which fall short of damage unequivocally ascribable to that cause are hard to prove, let alone detect. One method is to use open-top chambers, as described last year (*Report* 1985, pp. 23–24). The objects of current work are to discover if ambient levels of air pollutants are affecting trees and, if so, to quantify the effects. Detailed studies have begun on two sites: Headley (Hampshire, see Front Cover) and Glendevon Forest (Perthshire); and a third site will be installed during summer 1986 at Chatsworth (Derbyshire). The sites are in the country and have contrasting climates and pollution mixtures.

On each site there are 16 open-top chambers (eight replicates contrasting trees grown in ambient and filtered air) and four control plots in the open air. The size of the chambers (3.2 m in diameter) limits the number of trees which can be grown inside them. To ensure the sensitivity of the experiments, the variability between plants is reduced by using clonal stocks which are derived from a general population. In 1985 the susceptibility of individual trees to an acute dose of ozone was estimated by measuring the relative decrease in transpiration. Three provenances of Sitka spruce and Scots pine have been tested so far; Norway spruce, beech and oak will be tested during 1986. Trees for cloning were selected from the full range of susceptibility measured in this way.

Ozone had no effect upon the transpiration of the plants until the concentration exceeded 400 ppb. This concentration is almost three times that which occurs for short periods during the summer in south-east England. Similar distributions for the clonal plants and the populations will be determined for the other two major air pollutants, SO_2 and NO_2, independently and in combination. There is some evidence from other workers that trees respond differently to short-term acute and long-term chronic air pollution; the effects on these clones of lower concentrations over longer periods have yet to be tested.

A. WILLSON

Forest health (air pollution) survey

The survey reported last year (*Report* 1985, p. 24) was repeated in September[1]. One wind-blown plot of Scots pine in Anglesey was replaced by a plot on the mainland and three further plots of each species (Sitka spruce, Norway spruce, and Scots pine) were selected in north Scotland, an area under-represented in 1984. The total number of plots is now 108.

Some changes were made to assessment procedures, in accordance with the recommendations of a working party of the Executive Body of the ECE Convention on Long-Range Transboundary Air Pollution. The most important of these were to move to a 10-class crown density index with equal intervals and to take foliar samples for chemical analysis from the 7th whorl from all plots. Branch habit in the spruces and the pattern of any defoliation in all species was also noted.

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[1]Forestry Commission Research and Development Paper 147 *Forest health and air pollution: 1985 survey.*

The results for crown density and needle life show a slight improvement over 1984, but this is probably accounted for by the cool wet summer of 1985 (generally favourable for tree growth) and the earlier assessment date. Foliar analysis showed reasonable concentrations of major nutrients and, in particular, no magnesium deficiency.

The survey will be repeated in September 1986, it is intended to add some older Norway spruce plots.

W. O. BINNS

Beech health and site properties

To examine the potential role of moisture supply in the health of beech recorded for the 1985 Beech Health Study (see page 39), a desk exercise was undertaken to estimate the basic elements contributing to it. Rainfall data for the 1984 season from April to August were amended to take account of interception by foliage and branches, and balanced against accumulated potential evaporation data given by MORECS (Meteorological Office Rainfall and Evaporation Calculation System) to give soil moisture deficits. These were then compared with estimates of available water capacity calculated by methods devised by the Soil Survey of England and Wales to allow a ranking of sites according to potential droughtiness. The results suggested that the most droughty sites examined were located in Cumbria, Durham and in parts of south-east England, and least droughty in Argyllshire and Lincolnshire.

Advisory work

Advice on tree planting for reclamation and land-fill sites has been given to a variety of agencies. On the latter, methane within the root zone remains an intractable problem, though loose tipping may be a technique to combat it. The Forestry Commission winged tines have been loaned for use to relieve compaction in reclaimed gravel workings in Berkshire.

A. J. MOFFAT

Once again there were a large number of enquiries on 'acid rain' and forestry, and tree health in Britain continues to attract the attention of both the public and pressure groups. There was again periodic media interest leading to radio broadcasts and interviews.

W. O. BINNS

SITE STUDIES (NORTH)

Classification and improvement of upland soils

Clay soils

The experimental work on a peaty gley soil at Kershope (Cumbria) (*Report* 1981, p. 28; 1982, p. 19; 1983, p. 24; 1984, p. 25; 1985, p. 26) has been completed. Table 5 shows the main hydrological results. The main comparisons are between the two years prior to felling (1981 and 1982) and the two years after felling (1984 and 1985), and between the felled plots and the control

Table 5 Water balance of four 2 ha plots. Crop: Sitka spruce, top height 18–22 m.
Units: mm equivalent depth of water

		Mean of three plots felled during 1983		Control plot (not felled)	
Year	Rainfall P	Drain discharge R	P–R	Drain discharge R_c	P–R_c
1981	1403	692	711	—	—
1982	1568	769	799	710	858
1983	1278	622	656	462	816
1984	1259	837	422	433	826
1985	1688	1173	515	866	822

plot. The summer of 1984 was unusually dry and the summer of 1985 was remarkably wet, so these years provide a wide contrast.

Drain discharge (runoff) from the three felled plots was much greater in 1985 than in 1984 but the difference between precipitation and drain discharge (P–R) was also greater than in 1984. Most of this loss is again ascribed to evaporation of rain intercepted by the layer of lop and top, because although this layer has gradually consolidated it has decomposed little. The increase in evaporation is presumably due to the extended period of wetness. Taking the pairs of years together (total rainfall for 1981–82 was 2971 mm, for 1984–85 it was 2947 mm), the total extra runoff after felling was apparently about 550 mm over the 2 years.

The 4 years of the control plot suggest that annual evapotranspiration is a rather stable component and that variations in annual runoff are closely tied to rainfall. Based on the relativity between runoff in the felled and control plots (R and R_c) in 1982 and part of 1981 (data not given) a second prediction of extra runoff due to felling the three plots is about 570 mm over the 2 years. Hence it may be concluded that in this case runoff after felling has reverted approximately to the pre-planting level.

The whole area felled in the Kershope drainage experiment comprised 9 of the 18 plots. This is being restocked in 1986 as an experiment comprising intimate mixtures of Sitka spruce and a 'nurse' of Lodgepole pine, Scots pine or Japanese larch, in three ratios of nurse:spruce, namely 3:1 2:2 or 1:3. The main objective of the these mixtures is to achieve a more wind-firm final crop (preferably largely of spruce) than is usual with pure spruce.

Damage to soil caused by harvesting

The small feasibility trial at Black Isle (Highland) (*Report* 1976, p. 25; 1983, p. 23) has reached 10 years of age. Complete beating up after the first and second years resulted in high stocking rates after 6 years, but after 10 years survival of Sitka spruce is significantly affected by soil damage on plots which did not receive the remedial ploughing (98, 82 and 69 per cent survival on undamaged control, moderate and severe treatments respectively). Survival of Sitka spruce on all remedially ploughed plots is about 96 per cent and for Lodgepole pine is about 97 per cent with ploughing and 90 per cent without ploughing, the soil damage having no effect.

The mean height of Sitka spruce is adversely affected by soil damage but for Lodgepole pine the differences are not significant (Table 6). Remedial ploughing has had no effect on height growth of Sitka spruce but has significantly improved the Lodgepole pine on previously damaged soil (least significant difference 0.33m). It is concluded that on this gley soil of sandy loam texture damage to the soil such as might be caused by harvesting can greatly restrict the growth of a subsequent crop but ploughing can remedy the problem provided Lodgepole pine (which is more tolerant of waterlogged conditions) is planted rather than Sitka spruce.

D. G. PYATT, A. R. ANDERSON

Table 6 Mean height (m) after 10 years

	Sitka spruce		Lodgepole pine	
Damage treatment	Ploughed	Not ploughed	Ploughed	Not ploughed
Control	3.88	3.90	4.48	4.36
Moderate	3.21	3.46	4.52	3.15
Severe	2.38	2.68	4.00	3.23
Least significant difference ($p<0.05$) between damage treatments	1.01		0.82	

GENETICS

Testing

Pollinations

Flowering in larch, Sitka spruce and Lodgepole pine was very good for the third successive season and this allowed further advancement in the breeding programmes. In larch both polycross and specific crosses were made mainly on European larch clones in the seed orchard at Exeter (Devon) and the clone banks at Newton and Teindland (Grampian). A total of 221 crosses were made involving 15500 flowers.

Sitka spruce at Ledmore (Tayside) and Wauchope (Borders) flowered very heavily including a large proportion of those clones not yet in test and flowering was enhanced by injections of Gibberellin A4/7 in summer 1984. Injections of GA4/7 are now routinely applied one year in advance to all clones required for pollinations. A further 250 clones were poly-crossed and these together with further crossings in the breeding population resulted in 600 crosses, which involved 8000 flower isolations and 33000 flowers.

The series of inter-provenance crosses in Lodgepole pine was continued at Neroche (Devon) where 198 single-pair matings were made to create F_1 hybrids between Southern Interior BC and Queen Charlotte Islands BC parents; evidence from earlier trials showed this hybrid combination to be a most promising one.

A. M. FLETCHER

Forest progeny tests

Open-pollinated families of a further 257 untested Sitka spruce candidate trees selected in Dunkeld (Tayside), Shin and Borgie (Highland) were planted in replicated tests on three sites: Craigellachie (Grampian), Strathyre (Central) and Rheidol (Dyfed). The parent trees were selected from stands probably of the same seed origin as others which had previously proved themselves to be hardy and of good form on higher elevation sites in Wales and northern Scotland. Tested trees from these important sources could form part of the 'Northern Breeding Population', as their growth is markedly superior to the general breeding population on northern exposed sites.

Two further series of experiments to investigate the relative contributions of additive and non-additive genetic variance in the genetic components of Sitka spruce were also established. A 6 × 6 partial diallel and 13 × 4 factorial were planted on each of four sites. These will also reveal families based on genetically superior specific combinations which could be produced artificially for bulk vegetative propagation, and will provide the best trees in the best families as a future source of F_1 breeding material.

Progeny test assessments of vigour and form continued for all species. Analysis of the 15 year diameter data from the oldest fully replicated Sitka spruce progeny test showed good genetic correlations of family means for vigour between ages 6 and 15 ($r = 0.8$). This confirmed an earlier decision to identify the best families for vigour in progeny tests across sites when 6 years old. The extra certainty obtained by delaying decisions until 15 years does not justify the extra 9 years wait.

Provisional data from a 6-year-old Sitka spruce progeny test at Wark Forest (Northumberland) suggested that the families selected as genetically superior for vigour also had narrower crowns for a given height relative to the controls of commerical seed imports from the Queen Charlotte Islands, British Columbia.

S. J. LEE

Seed production

Seed stands and seed orchards

Twelve seed stands totalling 96 ha were registered; 41 ha were of European larch. Eighteen stands were refused registration and 41 stands were re-inspected under the 5-yearly cycle of re-inspections.

Further supplemental and fully controlled pollinations of superior Sitka spruce clones in Brechfa Forest District (Dyfed) resulted in the production of 10200 seeds, a small proportion of which was the F_1 Sitka spruce × White spruce hybrid. Some of this seed will be again made available by sale to commercial propagators. Plants from these seeds are for bulking-up vegetatively by rooting cuttings.

Five new clonal seed orchards were planted, of which 3.6 ha were Scots pine, 9.1 ha Sitka spruce and 3.3 ha mixed European and Japanese larches.

R. FAULKNER

Biochemical variation

Biochemical analyses of Lodgepole pine origins sampled from natural stands in north-west America and from the IUFRO Red Rock collection have clarified the genetic variation occurring over the natural range of the species. It is probable that in northern latitudes the species survived the last glacial period in north-western refugia, and that post-glacial recolonisation has been complicated by introgression from the closely-related Jack pine, the chemical evidence of which is presently widespread across large areas of the central and particularly the north-eastern regions of the range. There is evidence of a more localised and presumably more recent infiltration of Jack pine genes in north-east British Columbia and north-west Alberta.

The susceptibility of Lodgepole pine to the Pine beauty moth *Panolis flammea* has been studied in collaboration with Entomology Branch. Moths preferred to oviposit upon plants having relatively high levels of β-pinene in their shoot oleoresin. Partial defoliation by Pine beauty caterpillars induced a lowering of the β-pinene levels in the following year's shoots, thus rendering them less attractive to the moth. However, moths responded by laying eggs preferentially on undefoliated plants; caterpillars reared on previously 50 per cent defoliated plants grew at a slower rate, reached lower final body weights and suffered higher mortality rates than those reared on intact material.

Biochemical projects currently in progress on Sitka spruce include resistance to *Heterobasidion annosum* (with Pathology Branch) and identification of family mixtures used in vegetative propagation (with Silviculture Branch (North)); these have been given a firmer basis by analysis of monoterpene heritability data derived from the progeny of a complete diallel cross among seven trees, and also from the parent trees and from half-sib open-pollinated families. For most of the monoterpenes in both main stem and branch apical shoot oleoresin systems, practically all the significant variation was attributable to general-combining-ability, the progenies reflecting the differences in parental means in additive combination.

Analysis of a combined study of the shoot resin monoterpenes and of a range of isoenzyme systems in the seed endosperm of Scots pine sampled from native Caledonian woodlands has now been completed. Both monoterpene and isoenzyme data demonstrated the very high amount of variation occurring within individual woodlands. Moreover, the data sets agreed in identifying the Wester Ross woodlands as the most distinctive assemblage. Cluster analyses were used to show the genotypic interrelationships of all woodlands sampled, based on the biochemical data.

G. I. FORREST

PHYSIOLOGY

Flower induction

The role of potassium deficiency in cone production was investigated in the Eddleston deficiency demonstration (Borders) where there are plots which consist of the application of all but one of the major nutrient elements. The treatments are designated by the element omitted, e.g. −N, −P, −K and −Mg (−Ca plot absent from the present assessment). One control receives all

major nutrients (−O) and one lacks all (−All) whilst a further receives +PKCa. In 1984 the 19-year-old Sitka spruce produced male and female strobili and in October the seed cones were counted, current year foliage analysed for N, P and K, and tree height measured in randomly selected trees. With the exception of the −K plot, cone production was low in all plots, ranging from averages of 0 to 2.2 cones per tree with these borne on a maximum of 17 per cent of the trees in a plot. However, in the −K plot the mean number of cones per tree was significantly ($p<0.05$) increased to 13.1, with 39 per cent of the trees coning. These trees exhibited lower potassium concentrations than trees of the other plots and foliar levels indicated deficiency but height growth was not greatly reduced. The −All plot also received no supplemental K but growth was stunted and K levels were not deficient. Thus it appears that a potassium imbalance in trees which are growing well, but which show potassium deficiency, may be an important factor in cone-bud differentiation. It is not known how potassium elicits this response, but it is an important ion in stomatal action and may affect water relations. These findings could lead to advice on methods of improving cone production in seed orchards or potted grafts.

J. J. PHILIPSON

Vegetative propagation

Micropropagation

The induction of vitrification is now used as a standard technique for the proliferation of Sitka spruce *in vitro* (*Report* 1985, p. 30). The cultures, established on MS medium, are flooded with sterile distilled water for 6 weeks. The water is poured away and the cultures left in air for 4 weeks, followed by subculture and retreatment. Experiments are under way, with up to five cycles of treatment, to test both clonal variation in multiplication rates and the effect of flooding on the various types of buds and shoots formed. It is estimated that up to 250000 micropropagules per clone per annum could be produced using this relatively simple technique.

Rooting of the micropropagules is still under investigation. *In vitro* and mist propagation systems have been abandoned in favour of a high humidity, non-mist system. The micropropagules are struck as cuttings, without pretreatment, into compost in seed trays and covered with a clear plastic lid. The cuttings are maintained in a growth room at 20°C with daylength 16 hours and sprayed twice daily with water. Preliminary experiments have demonstrated that rooting levels of 80 per cent can be achieved in a 1 : 1 peat : bark compost under fluorescent light (37 $\mu Em^{-2}s^{-1}$) supplemented with incandescent light (13.5 $\mu Em^{-2}s^{-1}$).

A. JOHN

Mycorrhizas

The field experiments – afforestation at Shin Forest (Highland) and restocking at Kielder Forest (Northumberland) – examining growth of mycorrhizal, container-grown Sitka spruce planting stock were measured after their second growing season. Height increase reported for plants inoculated with *Thelephora terrestris* last year (*Report* 1985, p. 32) had increased from 18 to

24 per cent relative to non-mycorrhizal controls. Although there were no significant differences at Kielder, there are indications that the same isolate of *T. terrestris* is beginning to show an effect there too.

Previous experiments on mycorrhizas have not had controls representing the type of plant used in normal forestry practice. A new experiment, also to be sited at Shin and Kielder, has therefore been started to remedy this deficiency. Sitka spruce seedlings, grown and overwintered in plastic containers, were inoculated with one of six isolates of mycorrhizal fungi, or with nursery soil containing natural mycorrhizal inoculum. Seedlings and transplants from a normal forest nursery were included for comparison, in addition to a non-mycorrhizal control.

Nursery work continued with an experiment to assess the effects of soil sterilization with methyl bromide on success of inoculation with a mycorrhizal fungus. Fruiting bodies of the introduced fungus occurred in almost all the inoculated, sterilized plots, but not in uninoculated plots, or in the inoculated, unsterilized treatment. The fungus has evidently become established where the soil has been sterilized, though more detailed analysis has yet to be completed to see if establishment has failed in the other inoculated plots, or if the fungus is present, but not fruiting.

C. WALKER

INTER-BRANCH REPORT: PHYSIOLOGY, SILVICULTURE (NORTH), SITE STUDIES (NORTH), STATISTICS AND COMPUTING (NORTH), SITE STUDIES (SOUTH) AND ENTOMOLOGY

Reduced growth and bent top of Sitka spruce

Stem analysis of two crops in the South Wales Coalfield planted in 1961, one of which is now growing well and one poorly, demonstrated that similar reductions in growth rate occurred in both crops during years when the Green spruce aphid is known to have caused widespread defoliation, but that the crop now growing well had shown greater ability to recover. The dieback of branches and outgrowth of epicormic shoots characteristic of trees in decline has been simulated in potted mature Sitka spruce grafts by defoliating with scissors.

Measurements of climate, pollution, soil water regime and tree responses have continued on the 20 sites which were selected to cover a range of growth rates and tree health (*Report* 1985, p. 32). There was no large-scale aphid outbreak in 1984 or 1985 and tree growth rate was not influenced by spraying with insecticide. Foliar concentrations of potassium, and to a lesser extent nitrogen and phosphorus, were related to growth rate, indicating a possible link between nutrition and growth decline. A weak inverse relationship between growth rate and foliar concentrations of magnesium contrasted with some reports on forest decline in Germany. Lead dioxide gauges indicated a mean sulphation rate for 1985 of 0.29 $\mu g\ SO_3\ m^{-2}s^{-1}$ – well below rates recorded for the southern Pennines in 1979/80. On some trees, necrotic flecking was observed on the upper surfaces of needles, increasing with needle age, and similar in appearance to that described on Norway spruce in

Germany (Lang and Holdenrieder, 1985). Flecking has also developed on needles of the spruce seedlings growing in bins of horticultural peat and exposed on towers at tree top height in an attempt to assay the aerial environment. This symptom has also been noted elsewhere in crops which are growing satisfactorily.

M. P. COUTTS, A. J. LOW, D. G. PYATT, A. BURNAND, W. O. BINNS, C. I. CARTER

REFERENCE

Lang, von K. J. and Holdenrieder, O. (1985) Nekrotische Flecken an Nadeln von *Picea abies* – ein Symptom des Fichtensterbens? *European Journal of Forest Pathology* **15**, 52–58.

PATHOLOGY

Advisory services

Southern England and Wales

The growing season of 1985 was very wet and cool and this weather was probably responsible for the many cases of leaf disease caused by *Gloeosporium fagicolum* on beech, *Marssonina juglandis* on walnut and *Gnomonia platani* on London plane. Surprisingly there were only a few reports of Weeping willow anthracnose (*M. salicicola*). Brown 1984 and 1985 needles of a Noble fir Christmas tree crop bore pycnidia and perithecia of what appeared to be *Rehmiellopsis bohemica* but the symptoms did not match those described for the disease by Wilson and MacDonald (1984).

Rising 1-year-old Douglas fir seedlings and 1+1 transplants in a Forestry Commission nursery were damaged by *Phytophthora citricola*. Death of infected plants occurred in only a small proportion of the stock but root damage resulted in many culls. *P. citricola* also killed small numbers of 1-year-old Sitka spruce in a private nursery – only the third record of *Phytophthora* damage on this species in Great Britain, minor damage having occurred in a Forestry Commission nursery in Galloway, Scotland in 1982 and 1984.

Among shoot diseases, moderately severe outbreaks of *Ramichloridium pini* occurred on Lodgepole pine in mid Wales. Cases of fireblight (*Erwinia amylovora*) and bacterial canker of flowering cherry (*Pseudomonas syringae* pv. *mors-prunorum* or *syringae*) were also numerous.

The slow decline and death of several London plane in a London park was attributed to *Armillaria mellea* (*sensu stricto*) – our first record of Honey fungus killing this common ornamental. Deaths of 2-year-old *Eucalyptus archerii* coppice shoots in a biomass experiment appeared to be due to the Silver leaf fungus (*Chondrostereum purpureum*) which had entered the stools through wounds made when the maidens were stumped back in early 1984. Five cases of the uncommon decay fungus *Perenniporia fraxini* were reported – three from ash, one from robinia and one from oak. There were also two reports of *Ganoderma lucidum*, both on yew, one clearly associated with a pruning wound. A fungus fitting cultural descriptions of *Poria vaillantii* (DC ex Fr.) Cke. was isolated from basal decay in a Lawson cypress. It is known to cause root and butt rot of certain conifers in North America but has hitherto been known here only in structural timbers.

Experiments arising from advisory work over the last few years have shown *Bulgaria inquinans* to be the cause of serious stem bark lesions on Scarlet oak, *Amylostereum laevigatum* to cause a severe canker-rot of *Thuja*, and *Cytospora laurocerasi* to account for a very common branch-killing disease on Cherry laurel.

R. G. STROUTS, D. R. ROSE, T. C. REFFOLD

Scotland and northern England

The weather during the 1985 growing season was even cooler and wetter than in the south. This led to an unusually large number of enquiries involving waterlogging. Damage was not only suffered by established plants in nurseries and plantations but the wet soil conditions also contributed to losses following transplantation and probably exacerbated a number of other cultural problems, especially in nurseries. This was believed to have been the case in some occurrences of severe damage to 1+0 seedlings associated with use of the normally safe herbicide, diphenamid.

The wet season also provided ideal conditions for infection by a number of foliage pathogens, most notably *Meria laricis*. In nurseries, *Meria* attacked Japanese and Hybrid larches as well as the more susceptible European larch and first year seedlings were also attacked in some cases. Even more remarkably, severe *Meria* attacks were found in plantation trees in south Scotland. The needle rust *Chrysomyxa abietis* caused severe foliage damage to some Norway spruce stands and in parts of Scotland dramatic late-summer discoloration of birches was associated with massive infections by another rust, *Melampsoridium betulinum*. In Scots pine plantations in northern Scotland, infection of 1985 foliage by *Lophodermium seditiosum* was evident as severe foliage yellowing and loss by the unusually early date of mid-October.

In contrast to problems associated with the wet 1985 season, drought damage attributable to the summer of 1984 was diagnosed on several occasions, most notably in mature beech. Drought in 1983 and 1984 may also have been a predisposing factor in a number of cases investigated this year in which death of mature conifers was caused by the combined effects of attack by bark beetles and infection by fungi vectored by the insects. These cases involved damage to larch by *Ips cembrae/Ceratocystis* sp. and to Scots pine by *I. acuminatus/Trichosporium tingens*.

During autumn and winter, browning and loss of pre-1985 foliage was a marked feature in several Sitka spruce plantations. The affected needles were heavily colonised by one or other of the needle fungi *Rhizosphaera kalkhoffii* and *Lophodermium nanakii,* though their role in the syndrome is uncertain.

Other notable records made during the year were *Antrodia lindbladii* causing decay of a Sitka spruce stem killed by suppression and a *Rosellinia* sp. associated with foliage damage to recently imported *Picea orientalis* 'Aureospicata'. The fungus had enveloped the lower branches and foliage on several plants and caused severe foliage loss although most of the affected shoots appeared to be alive. This case was investigated jointly with MAFF and Dr S. Francis of CMI.

D. B. REDFERN, S. C. GREGORY, J. E. PRATT

Resin top caused by *Peridermium pini*

In Britain, this disease is recognised to be a problem in two areas, north-east Scotland and Thetford Forest (Norfolk and Suffolk), and little is known about its presence in other parts of the country. In 1985 searches for the fungus were made in a number of forests in which Scots pine is an important species, and these resulted in a number of new records. In the New Forest, diseased trees were found on four sites. The affected trees were mainly Scots pine in the age range 35–125 years but one infected Corsican pine was also found. In Exeter Forest several diseased trees were found in a 63-year-old Scots pine plantation and a single infected Scots pine was found at Rendlesham (Suffolk). From examination of the stem lesions it was apparent that the disease had been present in all three forests for at least 10–15 years. Comparisons are being conducted on the cytology and morphology of germinating aeciospores of *P. pini*. It has been discovered that spores from Thetford produce short septate germ tubes. By contrast those from Scotland, the New Forest and Exeter produce long non-septate germ tubes which may develop short side branches and which often end in an 'appressorium-like' structure. Further work on the biology and pathogenicity of these forms of the fungus is in progress.

B. J. W. GREIG, J. N. GIBBS

Dutch elm disease – *Ophiostoma (Ceratocystis) ulmi*

The emergence of EAN and NAN hybrids in Europe

The future of the elm in Europe will be largely conditioned by the outcome of the current interaction between the non-aggressive, NAN aggressive and EAN aggressive subgroups of *O. ulmi*. Of these the non-aggressive subgroup seems likely to be eliminated (Brasier, 1983). It now appears that despite the existence of partial reproductive barriers between the EAN and NAN subgroups, hybrids are appearing in areas where their ranges overlap. The first putative hybrids were detected in a sample of Dutch isolates in 1980 and since that time they have become increasingly common. Thus, whereas only 1 out of 23 isolates from the Dutch province of Limburg in 1980 had the characteristics of a hybrid, the equivalent figure in 1983 was 55 out of 107. Hybrid (H) isolates commonly resemble the EAN in morphology but are similar to the NAN in fertility reactions and growth rate. In an analysis of their vegetative compatibility types they were found to possess properties of both EAN and NAN groups. Since it seems likely that H isolates, or a new form of *O. ulmi* derived from them, may now become a major, possibly the major, component of the *O. ulmi* population in Europe, it is clearly important to assess their pathogenic potential and other characteristics, and to monitor their spread. In 1985 samples of Limburg EAN, NAN and H isolates were inoculated into clonal English and Commelin elm. On English elm the H group was a little less pathogenic than the EAN and NAN groups. On Commelin elm the H group and the NAN group were slightly more pathogenic than the EAN.

Discrimination between H isolates and EAN or NAN isolates by current methods is extremely laborious. An attempt is therefore being made, in collaboration with Dr M. Dewey of Durham University, to identify them using monoclonal antibody techniques.

C. M. BRASIER

Vegetative compatibility 'super groups' in O. ulmi (Ceratocystis ulmi)

The vegetative compatibility (vc) system of *O. ulmi* can be used to identify different genotypes in a population (*Report* 1984, pp. 35–36). Samples at current epidemic fronts in Europe have revealed a single predominant vc 'super group' in the EAN and NAN aggressive populations respectively. The remainder of each sample is heterogeneous for vc group genotypes (Brasier, 1984, 1986). Available evidence suggests that selective pressures operating at an epidemic front may result in the partitioning of the aggressive population into (i) a highly fit asexually maintained component, the super group and (ii) a heterogeneous component largely derived from sexual outcrossing (Brasier, 1984, 1986).

By contrast, no such super group has been found in the non-aggressive subgroup population in Europe, a population which, for some time, has been in reasonable balance with its host population. Thus, samples of isolates from across the continent and a local sample from Italy (Brasier, 1984), together with several recent local samples from Spain, have all been highly heterogeneous for vc genotypes. In North America, however, where the non-aggressive strain has caused a sustained epidemic among the susceptible American elms, a vc super group does occur – 83 per cent of a recent sample of 63 isolates from the N.E. USA and Canada being of one group. This again is consistent with an 'epidemic pressure' model. These observations may have wider implications for the response of fungal pathogens to ecological and epidemic pressures, as well as for the general epidemiology of Dutch elm disease.

C. M. BRASIER, A. G. MITCHELL*

Table 7 Comparison of d^2-infected and *d*-free *O. ulmi* conidia in feeding grooves

	Density of conidial inoculum						
	50000	10000	5000	1000	500	100	50
d-free conidia							
% persisting in feeding grooves after one month	98	98	93	83	78	48	23
% xylem infection	55	40	45	15	0	0	0
d^2-infected conidia							
% persisting in feeding grooves after one month	93	55	50	8	10	0	3
% xylem infection	16	0	0	0	0	0	0

d^2-infected conidia were significantly less good at persisting in feeding grooves ($p<0.001$) when compared with *d*-free spores in a χ^2 contingency table.

Colonisation of beetle feeding grooves by O. ulmi spores carrying a d-factor

The presence of a virus like agent, the '*d*-factor', has been found to reduce spore germination and hyphal growth in *O. ulmi* (*Report* 1983, p. 32). In

*NERC Institute Research Student.

order to determine whether the *d*-factor also reduces the ability of *O. ulmi* spores to infect elms, NAN aggressive isolates were transformed using the d^2-factor. Between 50 and 50000 conidia from these cultures were then introduced into artificially made wounds resembling beetle feeding grooves in young English elm; control inoculations being made with conidia from the original *d*-free cultures. Isolations made one month later indicated a significant effect of the d^2-factor in decreasing the ability of conidia to persist in feeding grooves and to invade adjacent xylem tissue (Table 7). Most notably, *d*-infected conidia had to be present in numbers of at least 50000 for xylem infection to occur as compared to 1000 for *d*-free spores. Since only 2 per cent of vector beetles carry 50000 spores, and fewer than half carry 1000 spores (Webber and Brasier, 1984) the potential of *d*-factors to reduce *O. ulmi* infection via feeding grooves may be considerable.

J. F. WEBBER

Beech health study

In view of concern over the state of broadleaved trees in Britain, a study of the health of woodland beech was initiated. Detailed data were collected from individual trees, covering the main symptoms of beech decline as reported from Germany. Scrutiny of these reports indicated that the symptoms were not specific for any particular cause of damage, such as pollution, but that any exceptional upsurge in their instance would give grounds for suspecting the involvement of some factor in addition to the known ones: insect and fungal agents, drought, etc.

The 19 study plots, which covered most regions of Great Britain, were set up using a system similar to that used for the conifer survey (Binns *et al.*, 1985) but including trees up to 120 years of age. At most plots, one or more symptoms of poor health, chiefly foliar yellowing, crown thinness and a 'fastigiate' branching pattern were present to a slight extent, but in no case did the degree of decline exceed that which could be explained by the 'natural' factors mentioned above. This does not exclude the possible involvement of pollution, and further studies are planned in order to obtain more critical data.

Arboriculture: Department of Environment contract

Decay in amenity trees

It is now widely accepted that, with regard to decay, flush pruning is at least as undesirable as the retention of long stubs. The wound position shown in Figure 8 minimises injury to tissues which belong to the main stem rather than to the base of the branch, and is recommended on the basis of many observations which have indicated that the retention of branch tissues favours an effective defensive reaction against decay fungi and encourages callus formation all around the edge of the wound. In an experiment on Swedish whitebeam, callusing has proceeded more rapidly over five growing seasons on wounds where the branch collar was retained. Early data for beech also show an advantage in retaining the 'branch bark ridge', as compared with flush pruning which seems to discourage vertical closure of the wound, and

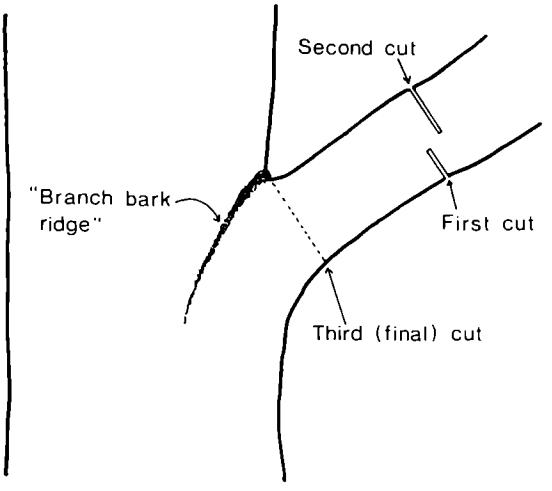

Figure 8. **Diagram of branch junction, showing the recommended pruning position (as a dotted line). The tree illustrated here does not have a branch collar and the angle of cut is a 'mirror image' of the bark ridge. Where a collar is present the cut should be made just outside it.**

with stub retention which discourages callusing generally. Sealant treatment, especially with a sealant containing 6 per cent thiophanate methyl, enhanced wound closure, particularly in the vertical direction.

Following the encouraging performance of the fungus *Trichoderma* sp. in protecting beech wounds against invasion by decay fungi, trials have been established on several other tree genera. One year after inoculation, 100 per cent of wounds on oak, cherry and birch gave re-isolation of the fungus, but on Lombardy poplar the figure was 80 per cent, and two of the wounds contained both *Trichoderma* and the pathogenic fungus *Chondrostereum purpureum*. Work on other potential biocontrol agents and on novel wound sealants continues.

D. LONSDALE

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Plate 1 In a joint experiment at Torridge Forest (Devon) with the Institute of Terrestrial Ecology the impact of clear felling on site properties is being monitored (see p. 22). Left: conventional felling; right: whole tree harvesting. (*B9255*)

Plate 2 Red deer hind. Some forest populations of red deer are increasing at a rate of over 20 per cent each year. The effective and humane control of breeding hinds is an important part of forest and wildlife management. (*A3551*).

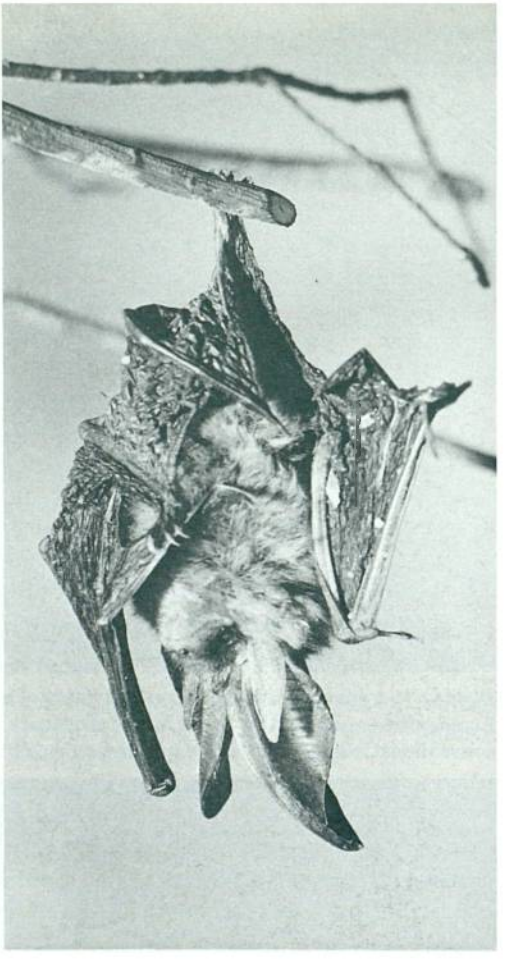

Plate 3 A project to investigate the improvement of forest habitats for bats has been started. A study of the use of bat boxes will be an integral part of this research. (*A7726*)

Plate 4 Brown long-eared bats are regular users of bat boxes. (*D5509*)

Plate 5 Measurement of stemflow at Kershope Forest, Cumbria (see p. 29). (*ED2378*)

Plate 6 Measurement of runoff in a clear felled area at Kershope Forest, Cumbria (see p. 29). (*ED2379*)

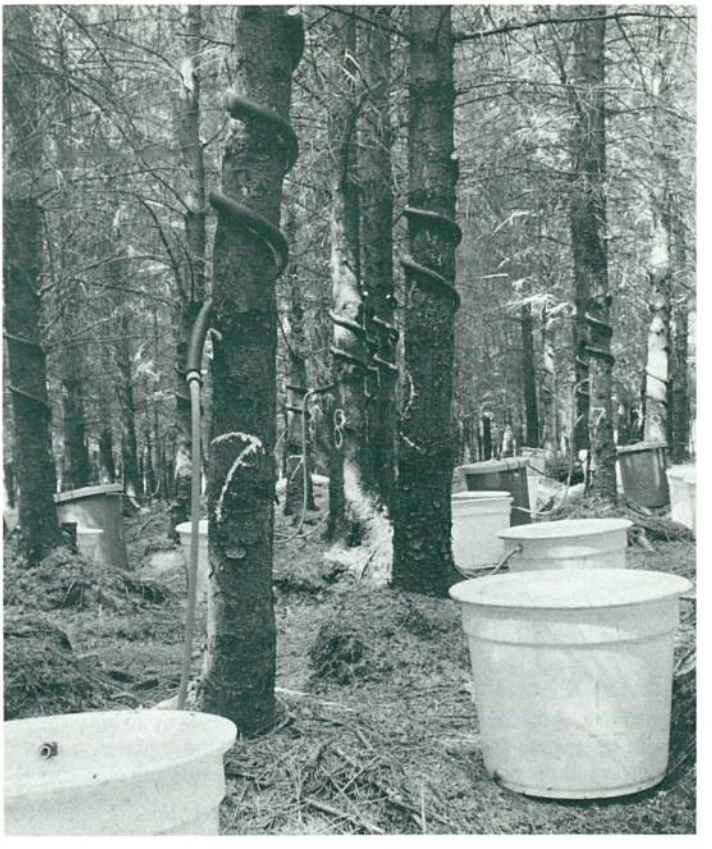

Plate 7 Investigations into the biological control of the Great spruce bark beetle *Dendroctonus micans*. Spruce logs are incubated in breeding units; the fully fed larvae of the predator *Rhizophagus grandis* emerge from the logs and drop through collecting funnels into plastic trays (see p. 41). (*ED2997*)

Plate 8 A group of *R. grandis* larvae feeding on a larva of *D. micans*. Empty outer skins of previously predated *D. micans* larvae are seen nearby. (*ED2135*)

ENTOMOLOGY

Great spruce bark beetle, *Dendroctonus micans*

Research on *D. micans* is now carried out under three projects each dealing with particular aspects of the beetle's biology and control.

Interactions of D. micans and spruce

Early work has concentrated on the relative susceptibilities of Norway and Sitka spruces to attack by *D. micans*. Experiments using logs have shown that adults emerging from Norway spruce are slightly, but significantly ($p<0.05$), larger than those from Sitka spruce, but otherwise development in the two species is similar. Future work will examine development in living trees and the importance of host defence mechanisms in relation to susceptibility.

D. WAINHOUSE, A. CLEAVER

Biological control of Dendroctonus micans

The mass rearing and release of the specific predator *Rhizophagus grandis* Gyll. continued during 1985. A total of 43000 predators was produced; of these 34500 were released at 648 sites (184 FC and 464 private). Despite a much greater input of breeding material than 1984, a number of factors reduced the projected yields. Viability of the original *R. grandis* in culture declined by some 60 per cent and incidence of the entomopathogenic fungus *Beauveria bassiana* increased. To overcome the possible decline in *R. grandis* performance, new origins of the insect were obtained from five European locations. Initial results from these are encouraging.

Improved hygiene methods in the preparation of breeding material and formalin fumigation of all insect stages show promise from early results. Forty seven forest sites where *R. grandis* was released in 1984 were sampled for the presence of the predator. *R. grandis* was found in nearly half of these areas indicating that it is apparently adapting well to British forest conditions. Evidence for spread of at least 200 m from a release point was obtained during detailed survey at one site.

C. J. KING, N. J. FIELDING, A. F. MARTIN

Predatory behaviour of Rhizophagus grandis

Laboratory experiments are being carried out to quantify the impact of the predator *R. grandis* within the broods of *D. micans*. Preliminary results indicate that more individuals, but a lower proportion of prey, were consumed per predator as the number of prey available increased. *R. grandis* also produced more offspring per single adult as prey density increased but at higher predator densities the egg production per adult declined.

H. F. EVANS, G. A. TINGLEY

The Pine beauty moth, *Panolis flammea*

Monitoring and control

High moth populations in Lodgepole pine plantations in the Highland Region of Scotland, indicated by pupal counts in autumn 1984, were confirmed by egg

counts in May 1985. Aerial application of insecticides to a total of 4860 ha was carried out in June 1985. Treatment was mainly by ultra-low volume application of fenitrothion. Where satisfactory spray coverage was achieved control was good. Two blocks totalling 66 ha were treated with Dimilin (diflubenzuron), ODC formulation (oil dispersable concentrate), previously used in British forests only against Pine looper moth; application was at either the manufacturer's recommended rate of 67.5 g a.i. ha^{-1} or at half that rate and both gave 100 per cent control. Successful trials with virus by the Institute of Virology will be extended in 1986. Trials using *Bacillus thuringiensis* (Microbial Resources Ltd.) produced some mortality but at a lower level than either insecticide or virus. Pupal counts in autumn 1985 showed a probable need to treat new outbreaks totalling 1400 ha plus retreatment of a substantial area which received inadequate spray coverage in 1985.

J. T. STOAKLEY, H. F. EVANS

Population ecology

P. flammea populations on Lodgepole pine on deep peats in the Elchies Block of Speyside Forest (Grampian) remained higher than those on ironpan sites. Moth populations were, however, lower than in 1984 but still higher than in 1983. Tree vigour, nutrient status and site characteristics appear to be linked and all are important in determining the build-up of *P. flammea* populations.

Experiments demonstrated that the rate of adult eclosion was directly proportional to the length of time pupae were exposed to temperatures above a 6°C threshold. A delay in oviposition, due to a cold spell immediately after adult emergence, resulted in reduced fecundity and a shortened life span. This was particularly marked in mated females. It was shown that female moths responded to monoterpenes directly and laid their eggs in response to the presence of alpha and beta pinenes.

S. R. LEATHER

The Pine weevil, *Hylobius abietis* and Black pine beetle, *Hylastes* spp.

Experiments to compare levels of phytotoxicity to Douglas fir, Hybrid larch and Sitka spruce between two formulations of gamma HCH (emulsifiable concentrate and colloidal suspension) and the pyrethroids permethrin and cypermethrin were concluded. Plants were dipped in insecticides at concentrations previously found to give adequate levels of beetle control; HCH at 1.5 per cent a.i. (e.c.), 1.6 per cent a.i. (colloid) and both pyrethroids at 0.5 per cent a.i. Tests were also carried out at twice these rates to examine the effects of over-dosing. There was no significant loss of Douglas fir height increment using any of the treatments.

In the first season after treatment of Sitka spruce and Hybrid larch, trees dipped in permethrin, cypermethrin and HCH (e.c.) showed no significant loss of height increment although only permethrin gave no phytotoxic effect at double rate. There were no significant differences in Sitka spruce height increment in the second season after treatment. The mean increment for Hybrid larch for the second season was significantly greater for plants dipped in pyrethroids than in HCH ($p<0.05$ for cypermethrin and $p<0.01$ for permethrin). The protection of Sitka spruce transplants using a field application

of permethrin was also tested. A complete season's protection against beetle attack was given by spraying with a 0.05 per cent solution.

The European pine sawfly, *Neodiprion sertifer*

Following a survey of numbers of egg clutches, Virox, a commercially prepared fomulation of a nuclear polyhedrosis virus specific to this insect, was applied as previously described (*Report* 1985, p. 39) to 2765 ha of young Lodgepole pine plantations mainly in Highland Region during late May and early June. Assessments of feeding larvae and of egg clutches in the succeeding generation indicated that very good control was achieved.

J. T. STOAKLEY, S. G. HERITAGE

Pheromone trapping for exotic bark beetles

A new bark beetle monitoring scheme was set up using Norwegian-made 'Icopal' traps (Borregaard Ind. Ltd.). Traps baited with specific pheromone lures for the bark beetles *Ips typographus, Dendroctonus rufipennis, D. frontalis* and *D. ponderosae* were deployed at 20 different locations around the country. Docks, timber yards and ladder factories were monitored. Two species of exotic bark beetles were trapped as well as six established British species. Single specimens of *I. typographus* were caught at a timber yard in Grangemouth and at Southampton docks: follow-up investigations did not reveal any timber infestation in either case. The ambrosia beetle *Xyleborus eurygraphus* was trapped at Ellesmore Port, a new British record.

D. A. BARBOUR, H. F. EVANS

Pine looper moth, *Bupalus piniaria*

Pupal surveys were carried out in 39 areas. Counts declined in almost all locations; exceptionally low populations were recorded in Scotland. Highest compartment means (HCMs) fell from 22.4 to 0.8 m^{-2} at Tentsmuir (Fife), from 12.0 to 1.6 at Cannock (Staffs), 11.2 to 2.0 at Swynnerton (Staffs), and 14.8 to 1.2 at Sherwood III (Notts). Sherwood IV, however, increased strongly to give a HCM of 24.4. The contrasting behaviour of populations in adjacent Sherwood blocks shows that these changes are not attributable chiefly to weather, but to density-related factors operating separately on each population.

D. A. BARBOUR

Advisory and taxonomic services

During the year all current advisory records at Alice Holt were entered into a computerised system enabling more efficient clerical processing and information retrieval.

There were fewer reports of insect defoliation in 1985 than in recent years. *Coleophora laricella* caused some damage to larch in southern England. Further north there were several instances of *Yponomeuta evonymella* larvae enveloping Bird cherry trees completely in silk. A rowan tree in Lancashire was similarly affected by a *Yponomeuta* sp. In Scotland, 1985 was notable for there being no *Neodiprion sertifer* damage enquiries. In nurseries *Argyrotaenia pulchellana* was found on spruce transplants but experimental inves-

tigation of multiple budded leaders on Sitka spruce seedlings established that the cause was not entomological. Diptera larvae found in resin around wounds on spruce and pine trunks were identified as *Chyliza fuscipennis*. The scolytid beetle *Phloeosinus thujae* was reported from London and Surrey on juniper.

Forestry Commission plant health inspectors found *Ips typographus* on three occasions under Norway spruce bark in dunnage from Europe. The woodwasp *Tremex columba* was also found associated with elm timber from N. America.

The total number of enquiries received at Alice Holt was 306 of which 86 were Forestry Commission and 220 private, while 97 were received at NRS made up of 40 Forestry Commission and 57 private.

T. G. WINTER

INTER-BRANCH REPORT: ENTOMOLOGY AND SITE STUDIES (SOUTH)

The Green spruce aphid, *Elatobium abietinum*, and secondary chemicals in spruce foliage

Work to locate secondary compounds in spruce foliage related to susceptibility and attack by the Green spruce aphid has continued. Oils from three susceptible spruce species *(Picea sitchensis, P. abies* and *P. asperata)* and five species showing varying degrees of resistance *(P. glehnii, P. omorika, P. koyamai, P. smithiana* and *P. breweriana)* have been extracted and tested in bioassays using the aphid. Volatile oils in the resistant species appear to repel the aphid.

The oils from three species *(P. koyamai, P. breweriana* and *P. smithiana)* were fractionated, using carbowax coated silica-gel and three solvent systems, n-pentane, chloropropane and methanol (each giving a fraction from which the solvent was removed by evaporation). Bioassays of the pentane fraction produced the most significant response by the aphid, i.e. distress and sometimes death. Further bioassays are in progress with fractionated oils of both resistant and susceptible species.

J. F. A. NICHOLS, L. SUR, M. COX

WILDLIFE AND CONSERVATION

The inclusion of conservation in the title of the Branch emphasises an increased commitment to conservation research which now includes plants as well as vertebrate animals. Two main objectives in this area of work are to investigate the habitat requirements of sensitive or endangered species, and to assess the effects of management practices with a view to improving forests for wildlife. Projects, either commissioned or in-house, are now under way on the ecology of woodlarks, black grouse, bats and red squirrels, and a number of projects on the effects of management practices on plants and animals are in the planning stages.

P. R. RATCLIFFE

Deer

The retrospective reconstruction of populations of red deer, using cohort analysis from aged jaw bones over a generation span, is confirming results from indirect methods of determining population size.

Foetal weights of red deer were used to estimate conception dates. In previous studies on open-range populations (Mitchell and Lincoln, 1973), conceptions were found to be spread between 12 September–1 January, and hinds in poor condition conceived later than those in good condition. The period of conception in forest populations generally is completed earlier than those on open range, spanning the 7 September–24 November period. In high performance forest populations from Cowal and mid-Argyll most hinds conceived between 6–13 October, while in poor performance populations most hinds conceived between 13 October–3 November. Preliminary analyses also suggest that the heaviest hinds conceive earlier than lighter ones. The hypothesis that poor quality hinds conceive later, therefore, appears to hold good.

Detailed relationships between fertility and body weight in forest red deer indicate that lactating hinds conceive at lower body weights than non-lactators, an opposite result to that obtained for open-range populations (Albon, Mitchell and Staines, 1983). A possible reason for this may be that the low proportion of non-lactating forest hinds are poor quality individuals with a low lifetime reproductive output who rarely produce calves, while most non-lactating open-range deer are good quality hinds which are recovering from the high energy cost of calf production and lactation in the previous year.

The collection of reproductive material and jaw bones for age determination from Sika deer populations is continuing and a preliminary appraisal of the past 3 years' material suggests that reproductive rates in most populations are as high as those previously recorded from high performance red deer populations. A collaborative study with the Monitoring and Assessment Research Centre (MARC) at King's College, London, on the use of roe deer antlers to monitor environmental pollution has been initiated. Roe deer antlers from nine forests in England and Scotland are being analysed by MARC for heavy metals.

P. R. RATCLIFFE, B. A. MAYLE

Rabbits

The effectiveness of magnesium phosphide 'Mag discs' for rabbit control was tested. The discs, individually sealed in foil, were claimed to be safer and be a quicker acting fumigant than phostoxin. Three sites with well used burrow systems were chosen on three different soil types – chalk, sandy loam and clay. Every burrow entrance was treated with a disc and inspected 48 hours later. Results are set out in Table 8.

The discs gave effective control. Spontaneous combustion was occasionally experienced and an applicator was developed to overcome this. Unfortunately the manufacture of these discs ceased soon after the trials were completed.

Enclosure and cage trials showed a high tensile polypropylene netting, Tensar SS2, to be an effective barrier against rabbits and resistant to gnawing. A 500 metre trial rabbit fencing using Tensar SS1 (a lighter netting than SS2)

Table 8 Effectiveness of magnesium phosphide for rabbit control

Soil type	Number of burrow entrance/exit holes			
	Gassed	Currently used	Opened after 48 hours	
			from inside	from outside
Chalk	279	271	0	3
Sandy loam	215	205	0	2
Heavy clay	218	204	3	3
All types	712	680	3	8

supplied by Netlon Ltd. was sited along the boundary between a woodland with high rabbit population and a field of winter wheat. This fence was checked at 2, 4, 6 and 18 weeks and rabbits were found to have gnawed access holes through the netting (Table 9). The following year a 200 metre length of SS1 was removed and replaced with SS2. All the holes in the remaining SS1 were repaired. Checks at similar intervals were made over the same time of year (Table 9). The gnawing on the SS1 was unacceptably high whereas that on the SS2 required no more maintenance than is necessary on a conventional rabbit fence. However, SS2 is currently too expensive to be considered as an alternative to wire netting.

Table 9 Number of holes gnawed through Tensar mesh

Mesh type	Number of holes at:			
	2 weeks	4 weeks	6 weeks	18 weeks
SS1 (1984)	8	14	22	33
SS1 (1985)	11	32	53	90
SS2 (1985)	1	2	3	4

H. W. PEPPER

Voles

The trial of plastic tree guards to protect a motorway planting of sycamore and ash against field voles is now 2 years old. 'Netlon tree guard 1', spiral guards and two types of split tube guards of four different heights were compared. Thirty trees of each species, for each tree guard type, were assessed monthly for bark stripping damage. The results after 2 years are summarised in Figure 9. Height and diameter measurements were taken at the end of each growing season and at present no significant differences are evident, however, it is expected that the severe damage inflicted on some ash stems may result in their death.

H. W. PEPPER, R. J. DAVIES, B. A. MAYLE

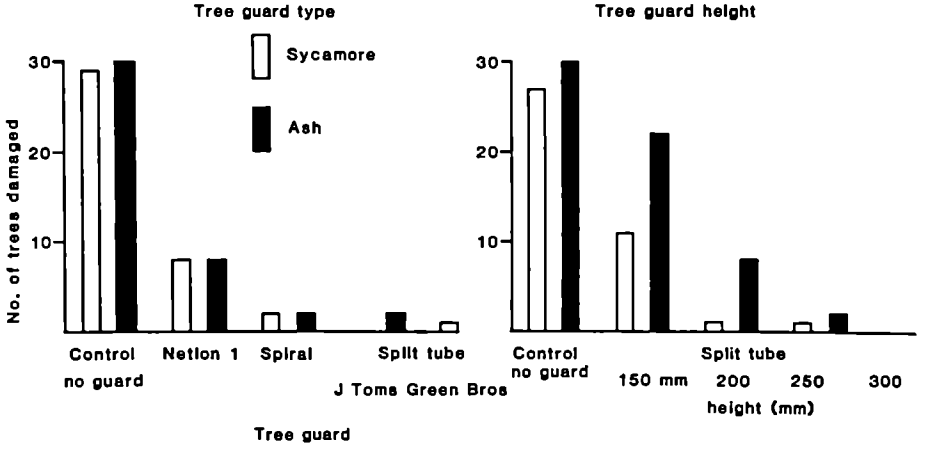

Figure 9. **Bark stripping damage by the field vole *Microtus agrostis;* effect of protection by tree guards.**

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MENSURATION

Growth and yield studies

Yield tables were prepared for 2.0 and 2.4m spacing line thinned crops of Scots, Corsican and Lodgepole pine and Norway and Sitka spruce. The tables will be used in the Forestry Commission's production forecast and will be published in due course.

As a result of recent upgrading of computer hardware, the Sample Plot Database holding all measurements of sample plots in Great Britain was transferred from the Rutherford Appleton laboratory in Oxfordshire to Alice Holt for permanent mounting on the Prime computer. The immediate benefit has been more rapid access to data.

Data collection using Epson HX-20 microcomputers

An extended field trial of the Epson HX-20 has taken place this winter to test the modified data collection program and to assess the machine's ease of operation and reliability in the forest. Five teams each equipped with an Epson measured over 80 sample plots throughout Great Britain. A wide range of sites, species, spacings, thinning treatments and measurement procedures were encountered so any necessary program changes have been identified. The machines have proved reliable with continued use and in a variety of weather conditions. After further program development this summer, the Epsons will be used in all sample plots due for measurement during the 1986/87 measurement season.

Yields from unthinned crops

A comparison of actual and yield table predictions of volume (to 7cm top diameter over bark) for 64 unthinned sample plots of Sitka spruce showed that on average there were no significant differences ($p<0.01$) between actual and yield table predictions. However for individual plots the differences were often as much as ±20 per cent indicating considerable variation around the mean. These differences can be accounted for by the usual range of variation in the relationship between top height (used in estimating General Yield Class) and cumulative volume production.

Distribution of production class

An investigation into differences between Local and General Yield Class estimates of sample plots of the major conifers throughout Great Britain indicated that there is no particular bias in the distribution of Production Class for Scots pine, Corsican pine, Sitka spruce, Norway spruce, European larch or Japanese larch. However, for Lodgepole pine more than 50 per cent of the sample plots are Production Class 'a' indicating that this species consistently puts on more volume for a given height than is suggested in the published yield tables. Also, for Douglas fir, about 45 per cent of the sample plots were outside the range of Production Classes 'a', 'b' or 'c' indicating that the relationship between top height and cumulative volume production is more variable for this species than for the other conifers. The analysis indicates that the assessment of Production Class is probably much more important than has generally been recognised. In particular, any detailed management enquiry which involves the use of General Yield Class to derive felling volumes from yield tables may be subject to considerable error if Production Class is not assessed.

Yield class changes

Patterns of top height growth for Sitka spruce were investigated to establish how frequently crops are likely to change yield class as assessed by top height growth to a given age. The changes in yield class between the first and latest measurement of 208 sample plots were as follows:

Table 10 Yield class changes of Sitka spruce

Yield class change	Number of plots	% of total number
0	105	51%
±1	76	37%
±2	21	10%
±3	3	1%
±4	3	1%

A number of plots (about 20 per cent) with top heights close to the boundary between one yield class and another would be expected to be changing yield class anyway; 29 per cent of the plots went down by one yield class or more and 20 per cent went up by one yield class or more. These results indicate that

large changes in yield class are rare (only 2 per cent of plots showed a yield class change of three or more).

The yield from Sweet chestnut coppice

In a continuation of work reported last year (*Report* 1985, p. 45), the following simple yield table was derived:

Table 11 Simple yield table for Sweet chestnut coppice

Mean diameter* (cm)	Volume (m^3/ha) to 7cm top diam.	Fresh weight (tonnes/ha) to 7cm top diam.
9	65	60
11	135	135
13	200	200
15	255	250
17	300	295
19	335	330
21	360	355
23	375	370

*Of stems with a diameter at breast height of 7cm or more.

Air pollution

Work reported last year (*Report* 1985, p. 44) was extended to investigate apparent changes in rates of growth in sample plots of Scots pine, Norway spruce and Sitka spruce. The rate of growth of plots established after 1935 for Scots pine and about 1940–45 for Norway and Sitka spruce is significantly greater ($p<0.01$) than before these dates. Regression analysis indicated that site factors such as elevation, rainfall and lithology could not satisfactorily explain the change. Errors between actual and estimated growth rates were regressed on levels of dry deposition of sulphur (derived from the 1983 Warren Spring report). The level of dry deposition was significant ($p<0.05$). Although the analysis indicated that dry depositions of sulphur appear to explain some of the increase in growth rate of sample plots established after 1935–45, improved establishment techniques such as ploughing and fertilisation are likely to explain most of the change. The sample plots are not a good source of data for comparisons of growth rates with levels of sulphur pollution as few of them lie in areas expected to receive high pollution loadings. However, the comparison of rates of growth over time does not provide evidence of a decline in growth in recent years. The interpretation of dendrochronological evidence is liable to be difficult in most circumstances. In Great Britain, in contrast to the position in Germany where stands of trees are managed on long rotations, the sample plots only infrequently cover the stage of a crop's life where current increment has fallen to a more or less stable level. Thus, identification of the normal pattern of decrease of radial growth associated with age is difficult. Annual variations in weather and the longer term changes in climate create their own sources of variation in ring width which obscure the detection of trends.

Advisory

Advice on measurement procedures continues to absorb a significant part of the Branch's resources. Following a series of seminars to field staff on tariffing procedures during 1984/85, the number of requests for advice increased substantially. The tariff checking service at Alice Holt was used for 442 tariffs and 146 assortment forecasts were processed, of which 90 were run as a separate project for Work Study Branch.

T. J. D. ROLLINSON

INSTRUMENTATION

Much of the Section's effort has been devoted to instrumentation of the open-top chambers being set up for air pollution studies. In addition several hundred metric girth bands have been made for various customers as well as a cut-away model for an animal poison-bait hopper. An apparatus to measure the permeability to air of tree stem specimens was also made. Collaboration with the Industrial Electronics Group at Surrey University has produced a modular multiplexer allowing our Microdata logger to be expanded from 10 channels to 400 at low cost. Small (<10g) prototype radio transmitters for tracking owls and squirrels have also been made. Several more seed incubators were completed and further modifications to the seed germination tanks carried out.

R. CARNELL

STATISTICS AND COMPUTING

Statistics

Alice Holt

Analyses of data from current silvicultural experiments have required the writing or updating of nearly 200 Genstat programs. Particular attention has been given to the visual presentation of results to help with their interpretation.

The second year's data from the national survey of health of Scots pine and Norway and Sitka spruce has been analysed, again using multiple regression methods. Based on results for plots observed by more than one team it was shown that a high proportion of the variation in apparent tree health was accounted for by differences between observers. After removing this 'observer' effect there was no evidence of any significant damaging effects of either sulphur or nitrogen deposition levels, the two pollutants for which country-wide data were available.

A set of programs was developed to provide Wildlife Branch with an index of deer population levels for different forest structures defined by height classes. Counts of deer faecal pellet groups obtained from areas in different canopy stages, unplanted through to late pole stage were fitted to the negative binomial distribution. This distribution is described by two parameters; the mean, m, and the positive exponent, k, which is a measure of contagion.

Estimates of m and k are obtained by the method of maximum likelihood for a set of four cases according to whether m and k are assumed common among the canopy stages or not. Likelihood ratio tests are then used to choose between these models. These methods are essentially those developed by White and Eberhardt (1980).

Further supplementary analyses of the 1979–82 Census of Woodlands and Trees were programmed for the BBC 'Domesday' microcomputer project.

R. C. BOSWELL, A. J. PEACE

Northern Research Station

Studies of crop stability often assess tree root weights in sectors. Silvicultural treatments may affect the distribution of the roots among these sectors, and in particular may influence the uniformity of the distribution. Various scores have been used to measure lack of uniformity but a more comprehensive treatment of such data by multivariate analysis has allowed for its 'compositional' nature (Aitchison, 1982).

Initial studies were made of tree motion in a given direction and the related component of wind velocity. Simple autoregressive equations adequately described the individual series of measurements but the cross-correlation function was atypical of impulse-response behaviour, even when a pre-whitening transformation was applied (Box and Jenkins, 1970). The gain functions resulting from cross-spectral analysis had a dominant peak near 0.5 Hz, which corresponded well with the tree's natural sway period, but the coherency spectrum, measuring dependence over a range of frequencies, was flat and uninformative.

Schemes for sampling the degree of canopy closure (taken as the proportion of inter-tree positions with canopy contact) were evaluated on data from small plots, by generating exact probability distributions for various transect samples.

I. M. S. WHITE

Modelling

Alice Holt

Loss of staff has curtailed drastically the effort which could be devoted to modelling this year. In particular no further work on the Integrated Forest Process model has been possible. Some work by P. Blackwell, a temporary member of staff, continued on the simulation of the windthrow of trees for Physiology Branch.

The Silviculture project 'Coppice trees and energy crops' was examined for possible modifications to allow information obtained to be used in conjunction with other growth models. A transformation of the data was suggested and a new sampling scheme proposed for the assessment of dry matter.

A computer program is under development to simulate the spread, over a domain of susceptible trees or forested areas, of an infection which is capable of developing both locally and at a distance from its sources. The aim is for it to provide some help in problems of the control of such infections. The case of *Dendroctonus micans* has been foremost in the conception of the program but it may be applicable to other infections.

The method developed for spreading tree-related times over end products in shortwood harvesting has been incorporated into the Work Study data

analysis system. An end-product approach to estimating time for felling Sitka spruce has been compared with whole tree methods and found to be as precise. The method will be used to produce new standard time tables for felling.

I. D. MOBBS, R. S. HOWELL

Northern Research Station

A FORTRAN program was written to model the spread of the root rot fungus *Heterobasidion (Fomes) annosus* through a first rotation stand of Sitka spruce. Probability distributions for the initiation and spread of infection were assumed and, for a range of estimated parameters, the program calculated the expected number of infected and decayed trees at each thinning and at clear felling. The results will be used to estimate revenue losses from the disease.

A. C. BURNAND

Computing

Alice Holt

The private-wire link between the UCC bureau in London and Alice Holt which had been first installed in 1971 was closed down at the end of this year, as the Prime computer is now capable of coping with the work. New versions of the Prime operating system, the Sheffield University editor and Pascal compiler and the Culham GHOST 80 graph-plotting system were installed; the Salford University Fortran 77 compiler was also purchased and installed.

Entomology Branch was provided with a RAPPORT database, similar to that used by Pathology Branch, for recording enquiries and insect sightings. Further development of databases based on the RAPPORT system of Logica Ltd. has been halted and a reappraisal of future database work is being made because of Logica's announcement that they were to cease development and eventually support for RAPPORT.

The in-house Subcompartment database and production forecasting system was completely reviewed and parts rewritten to make them more suitable for an interactive system and easier to maintain in the future. The dependence of the system upon RAPPORT has been minimised by allowing the processes to run using sequential files. This also utilises the PRIME more efficiently by obviating the need for several expensive accesses to RAPPORT to complete a job. Parallel running of this work on the UCC system and the Prime proved successful.

Data from the Bedgebury Arboretum were mounted on the Prime and the Westonbirt Arboretum records were updated. Plans have been made to replace the present obsolete microcomputer at Westonbirt with a new one on which it will be possible to manage the catalogue completely independently of the Prime.

An IBM PC/AT and the Alvey Expert System Starter Pack and several other software systems for use on it were purchased.

B. J. SMYTH, G. J. HALL, R. S. HOWELL

Northern Research Station

A data-capture program for the Epson HX–20s was completed and used fairly successfully in Silviculture Branch nurseries at Bush and Newton for end of season assessments. Further programs were written to enable the Epsons to collect data from the on-site Polycorder and Squirrel data encoders used by Site Studies (North) Branch. New micro software was developed to digitise the traces recorded by Grant temperature recorders and to provide terminal emulation and a text editor for the Epson HX–20. A set of notes was written to guide users of microcomputers and some of the more specialised features of the UCSD operating system (e.g. PATCH, a byte-level editor) were investigated.

Work started on designing a microcomputer system to control Silviculture's nursery stocks.

A Camtek PAD in the station's computer network has quadrupled the operating speed of attached terminals and has allowed staff freer access to an Epson FX–100 printer and a Phillips GP300 letter-quality printer. Most of the station's program libraries have been converted to run under the improved EMAS–3 operating system; they also benefit from the greater power and cheaper storage of the Amdahl machine recently acquired by the Computing Centre.

During the year 1000 input forms were received for the Experiment Register database. Some 3000 have now been checked and loaded with 1000 still to come. This database was taken out of the Rapport database management system to make record updates and structure changes easier. With the help of some specially developed programs and with experienced use of standard EMAS editing and sorting routines it has proved simple and cheap to search the ordinary computer files and answer queries.

Between 1976 and 1982 some 25 megabytes of experiment assessments had accumulated as decks of punched cards. To save space and improve their accessibility these were read in to the computer and archived under EMAS.

R. W. BLACKBURN, K. P. DONNELLY

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Box, G. E. P. and Jenkins, G. M. (1976). *Time series analysis: forecasting and control.* Holden-Day.

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COMMUNICATIONS

LIBRARY

A study was made of computerised information retrieval systems to replace the previously highly successful, but now outdated, ACE system. Keyword searching by users is being planned which could ultimately extend to use in Forest District and other offices.

PHOTOGRAPHY

Attention has been directed towards video and by the end of the year the Section was equipped for video photography.

A review was undertaken of the role of the Section's aircraft in aerial photography, taking account of the needs of Forest Surveys Branch and Research Division, and examining alternative means of obtaining aerial photographs. Arising from this review it was decided to dispose of the aircraft at the end of 1986.

PUBLICATIONS

A review of the Commission's family of technical publications led to proposals for a new system designed to improve the targetting of information to specific uses and users.

The following publications were published during the year ending 31 March 1986.

Report

Report on forest research 1985 (£7.10)

Bulletin

14 Forestry practice, 10th edition, edited by B. G. Hibberd (£5.25)

Booklets

15 Conifers, 3rd edition, revised by A. F. Mitchell (£2.95)
20 Broadleaves, 2nd edition, by H. L. Edlin (£3.95)
54 Thinning control, by T. J. D. Rollinson (£2.00)

Forest Records

129 Forest pathogens of N.W. North America and their potential for damage in Britain, by E. M. Hansen (£1.35)
130 Thetford Forest management plan, by L. M. Simpson and D. B. Henderson-Howat (£2.00)

Leaflets

12 Taxation of woodlands, 7th edition (£1.15)
83 Coppice, 2nd edition, by R. E. Crowther and J. Evans (£1.75)
85 Windthrow hazard classification, by K. F. Miller (£1.75)
86 Glades for deer control in upland forests, by P. R. Ratcliffe (£1.45)
87 Forest fencing, 2nd edition, by H. W. Pepper and L. A. Tee (£3.20)
88 Use of broadleaved species in upland forests – selection and establishment for environmental improvement, by A. J. Low (£2.50)

Arboricultural Leaflet

10 Individual tree protection, by H. W. Pepper, J. J. Rowe and L. A. Tee (£2.00)

Research and Development Papers

135 Site characteristics and population dynamics of Hymenopteran and Lepidopteran forest pests, edited by D. Bevan and J. T. Stoakley (£7.50)

136 Tree planting in colliery spoil, by J. Jobling and R. Carnell (50p)
138 Champion trees in the British Isles, by A. F. Mitchell and V. E. Hallett (£1.00)
141 A guide to the reclamation of mineral workings for forestry, by K. Wilson (£2.50)
142 Forest health and air pollution – 1984 survey, by W. O. Binns, D. B. Redfern, K. Rennolls and A. J. A. Betts (£1.40)
143 Environmental influences on forestry investment in the British uplands, by D. L. Foot (50p)
144 Investment in wood processing in developed countries, by G. J. Francis (50p)
145 Developing the economic arguments for investment in forestry: a survey, by D. S. Grundy (50p)

Occasional Paper

14 The Gwent small woods project 1979–84, by J. W. Ll. Zehetmayr (£3.50)

Miscellaneous

Wood as fuel – a guide to burning wood efficiently, by G. D. Keighley (20p)
British native trees at Westonbirt, by J. Bailey and J. White (95p)

Arboriculture Research Notes

59/85/ARB	The effects of weed competition on tree establishment, by R. J. Davies and J. B. H. Gardiner
60/85/ENT	Oak defoliation, by T. G. Winter
61/85/PATH	Ceratotect – a fungicide treatment for Dutch elm disease, by B. J. W. Greig
62/85/PATH	Beech health study, by D. Lonsdale and J. N. Gibbs
63/85/SILS	Treeshelters, by J. Evans and C. W. Shanks
64/86/SILN	Rough handling reduces the viability of planting stock, by P. M. Tabbush

Research Information Notes

97/85/WU	Timber research on the output of structural grade timber in unthinned Sitka spruce grown at different spacings, by R. G. Hands
98/85/SILS	The effects of weed competition on broadleaved tree establishment, by R. J. Davies and J. B. H. Gardiner
99/85/FS	Forest use of aerial photography, by A. J. A. Betts
100/85/PATH	Beech health study, by D. Lonsdale and J. N. Gibbs
101/85/SILN	Rough handling reduces the root growth potential and survival of barerooted conifer transplants, by P. M. Tabbush
102/85/SILS	Natural regeneration of broadleaves, by J. Evans
103/86/SILN	Forest drainage, by D. G. Pyatt and A. J. Low
104/86/SILN	A provisional comparison of ploughing and subsoiling in relation to growth and stand stability of Sitka spruce in upland forests, by K. F. Miller and M. P. Coutts
105/86/SILN	Precision sowing and undercutting of conifers, by W. L. Mason

B. G. HIBBERD

OTHER HEADQUARTERS DIVISIONS

PLANNING AND SURVEYS

ECONOMIC PLANNING BRANCH

Forest Investment Appraisal Package (FIAP)

The Forest Investment Appraisal Package (FIAP), described last year (*Report* 1985, pp. 55–56), is now available to users of the VAX computer in Headquarters. Work is underway to develop a version which will run under the BOS operating system used by the Forest District microcomputers to allow independence from the distributed network.

Unstable crops – a decision making program for clear felling

A program has been developed to assist Forest District managers to decide when to clear fell crops which have begun to blow down. This program will run on the microcomputers installed in Forest District offices. The intention is to move away from a decision to fell at arbitrary terminal height (i.e. when 40 per cent of the crop has blown). It has been demonstrated using the program that for crops whose value is increasing rapidly there is considerable economic benefit in delaying felling even when blow has been extensive. Alternatively, for crops approaching economic rotation age often a limited amount of blow tips the balance in favour of felling immediately.

W. C. G. HARPER, J. THOMPSON

FOREST SURVEYS BRANCH

Census of woodlands and trees

During the year the publication of the remaining County Reports was completed and information in a standard format is now available for Great Britain, all three countries, all Conservancies and all counties in England and Wales; regional information relevant to each of the four Scottish Conservancies in existence at the time of the Census is contained at the rear of these Reports. The main Report, which deals in much greater detail with the background to the Census and the survey methods adopted, but also includes the main results and comments on them, was completed during the year (Forestry Commission Bulletin 63). A continuing flow of queries on Census matters was dealt with.

Fieldwork for the Department of the Environment and the Countryside Commission, in which the Forestry Commission acted as sub-contractors to Hunting Technical Services Ltd., continued throughout the year under review. This involved assessing current land use, existing field boundaries, presence of woodlands and trees and other features on 140 sample strips in England and Wales which had originally been selected for use in the Census of Woodlands. The bad weather throughout the year, and on occasion difficulty of access, hampered progress but the work was virtually complete by March 1986.

G. M. L. LOCKE

PART II

Work done for the Forestry Commission by Other Agencies

SILVICULTURE

Control of wood quality in the British oaks

by G. S. HENMAN and M. P. DENNE
Department of Forestry and Wood Science,
University College of North Wales, Bangor, Gwynedd, LL57 2UW

This project is concerned with variations in the structure and properties of oak timber, with a strong emphasis on factors that may affect the formation of shakes. Ring and star shakes are serious defects that reduce the timber value of up to 70 per cent of the trees in many stands of oak in Britain. These shakes develop in the living tree, being formed when internal or external stresses split the wood along points of weakness. Such predisposing weaknesses may result from wounding or other environmental factors, or may be associated with a genetically determined pattern of wood structure.

One of our main aims is to identify factors that predispose the timber to shake, and to evaluate the possibility of selecting for types of wood structure that may be less prone to shake. We are quantifying variations in wood structure and properties between trees and between seed origins, using material from the Penyard (Forest of Dean) oak seed origin trial. Variation between seed origins are being found in parameters such as heartwood:sap wood ratio, density, and cell size and proportions. We are also comparing wood structure patterns found in shaken with those in unshaken trees growing on the same site, and examining effects of severe frosting and defoliation on wood development.

Results from our site surveys, and from a questionnaire to timber merchants and growers, confirm that shake is usually most severe on sites having sandy or stony soil, gravel, or other conditions associated with fluctuating water table. In our future work we plan to investigate the link between site factors and the level of internal growth stresses which are likely to trigger the shakes.

Epicormic bud dormancy in oak

by T. A. WIGNALL, G. BROWNING and K. A. D. MACKENZIE
Institute of Horticultural Research,
Bradbourne House, East Malling, Kent

New techniques for endogenous IAA and c,t ABA purification were successfully applied to extracts of oak cambial explants. Unequivocal mass spectra of cambial explant IAA and c,t ABA were obtained after methylation and trimethysilylation (IAA) and capillary column gas chromatography of extracts from only 2g fresh weight of tissues. Measured by GC–MS MIM, using pentadeutero IAA as the internal standard, IAA levels at different times during the summer were found to be decreased in explants taken from trees thinned early

during the spring. Measurement of cambial explant fresh/dry weight ratios indicated that the decrease in IAA was associated with a reduction in the water content of the cambial region. The stimulation of epicormic bud emergence by thinning appears to result from an increase in water stress, presumably associated with the increase in canopy exposure. Cambial explants were found readily to transport exogenous IAA basipetally, and experiments are planned to investigate the link between water stress in the cambial region, endogenous IAA levels and IAA transport.

Further evidence implicating auxin in the control of epicormic bud emergence was obtained when NAA and TIBA, each at 100 mg l^{-1} in lanolin, were found to affect epicormic emergence. Application of NAA within a partial stem girdle was found to inhibit the stimulation of bud emergence associated with the girdling. Application of TIBA, an auxin transport inhibitor, in a narrow band over a shallow cut in the trunk was found to stimulate bud emergence. These results, combined with those from experiments, repeated this year, in which trees were partially girdled at different heights and at different times during the summer, were consistent with a mechanism of bud dormancy controlled by a balance between a basipetally-transported inhibitor, putatively IAA, and an acropetally-transported promoter.

Herbicide evaluation for forestry uses

by D. V. CLAY and W. G. RICHARDSON

University of Bristol, Long Ashton Research Station, Weed Research Division, Begbroke Hill, Yarnton, Oxford

Herbicides for seed beds

Screening of 20 new herbicides as pre-emergence treatments was carried out on Douglas fir, Japanese larch, Lodgepole pine and Sitka spruce. Diflufenican, isoxaben, oryzalin and certain coded compounds were found to be safe on some or all the species and merit further testing.

Herbicides for transplant lines and young plantations

New herbicides were tested for activity on bracken, four grass weed species (*Calamagrostis epigejos, Deschampsia caespitosa, Holcus mollis, Molinia caerulea*), heather (*Calluna vulgaris*), *Rhododendron ponticum*, the four conifers above, beech and birch. Further investigations were made on the use of mixtures of herbicides with surfactants and/or adjuvants to increase activity and permit reduction in dose. Herbicides were applied in summer and regrowth assessed the following summer.

Imazapyr at 1 and 4 kg a.i. ha^{-1} severely reduced or killed *M. caerulea*. The 1 kg ha^{-1} dose severely damaged all tree species, particularly beech, birch and Douglas fir. Sulfometuron (0.5 kg ha^{-1}) severely reduced growth of *D. caespitosa* but appeared safe on some tree species. Imazapyr (4 kg ha^{-1}) and sulfometuron (2 kg ha^{-1}) all gave good control of *R. ponticum*. Control of bracken was improved by mixtures of certain of the additives with asulam, imazapyr and sulphonyl urea herbicides. On heather the additives did not

improve control with atrazine, glyphosate and 2,4–D amine or ester. Activity of fluroxypyr on *R. ponticum* was appreciably improved by the addition of Ethylan D252 + Agral. Some of the additives increased activity of glyphosate on *M. caerulea* and *C. epigejos* and propyzamide on *D. caespitosa*. Glyphosate as an oil-soluble formulation (see *Report* 1985, p. 58) appeared more active than the 'Roundup' formulation on *R. ponticum* and *M. caerulea* but less active than 'Roundup' on birch and beech.

Transfer of work

With the closure of the former Weed Research Organization site at Begbroke Hill on 31 March 1986, the project has been transferred to the Long Ashton Research Station, Weed Research Division, Bristol; the programme of herbicide screening and investigations on pot-grown forest weed and crop species is continuing there.

The influence of major site factors on the growth of Sitka spruce on exposed sites

by R. WORRELL

Fountain Forestry Ltd.

(under the supervision of Edinburgh University and the Forestry Commission)

This project aims to develop a practical basis for predicting the yield of Sitka spruce in upland areas of Scotland and northern England for use in land acquisition, production forecasting and land use planning.

A total of 190 0.04 ha temporary sample plots were established in 15 to 50-year-old Sitka spruce stands at 25 sites in Scotland and northern England, mostly spanning the upper 200 m range of plantations. In each plot estimates of General Yield Class (GYC) were made and the following site factors were assessed, and their effects analysed by correlation and regression techniques: elevation, geomorphic shelter (topex), aspects, slope, soil type, rooting depth. In addition estimates of wind climate, accumulated temperature and rainfall were made by extrapolating from tatter flag records and meteorological data.

GYC declined by about 3.5–4.0 $m^3\ ha^{-1}\ yr^{-1}$ per 100 m of elevation due to the effects of increasingly adverse soils and climatic conditions. The geographical pattern of decreasing GYC with increasing elevation correlated well with patterns of windiness defined by Forestry Commission wind zones. GYC was best correlated with estimates of accumulated temperature above 5.6°C and site windiness (tatter rate), which together accounted for 77 per cent of the variation in GYC for the 144 plots which had received standard modern silvicultural treatment. A model has been developed which uses major site factors to predict accumulated temperature and windiness and hence Sitka spruce productivity and planting limits for exposed sites. The site factors included were geographical location and elevation for accumulated temperature, plus topex and aspect for windiness. The inclusion of soil type in the model did not significantly improve its predictive power.

SITE STUDIES

Effects of afforestation on water resources

by J. R. BLACKIE and I. R. CALDER
Institute of Hydrology, Crowmarsh Gifford, Wallingford, Oxon

Balquhidder catchments

A preliminary analysis of the data obtained in Phase I has been completed. Over a 3 year period annual precipitation in the Kirkton (35 per cent mature forest) averaged 2200 mm, some 400 mm lower than in the Monachyle (heather, grass, bracken) only 4 km to the west. Although the catchments are physically similar the Monachyle streamflow was found to be flashier, with higher flood peaks and lower dry season flows. Despite this the suspended sediment loads from the Kirkton were three times and the bedloads at least ten times greater.

Water balance estimates suggest that annual water use by the Monachyle, at 21 per cent of the precipitation, was some 120 mm greater that that by the Kirkton at 19 per cent of precipitation. The Monachyle figure is comparable to the Penman potential evaporation estimate whilst the Kirkton figure is considerably lower. Although some uncertainties remain, these data suggest that differences in water use between forest and the indigenous vegetation in wet upland in Scotland may be less than those observed between forest and grassland in Wales.

Physical process studies

Investigations of seasonal differences in evaporation from forest canopies have continued with further analysis of snow interception data and the development of a simple daily interception model requiring only daily rainfall measurement as inputs. The model was used (Calder, 1986) to assess the effects of afforestation on water supplies to the Crinan canal in a drought year.

Continued measurements of interception losses from a thinned forest have confirmed the first year's results: the annual *total* interception loss is unaffected by thinning.

No ideal site has been found for an interception study of larch using the gamma-ray attenuation technique but a plantation at Plynlimon offers several scientific advantages and is the most likely candidate.

REFERENCE

Calder, I. R. (1986). The influence of land use change on water yield in upland areas of the UK. *Journal of Hydrology* (in press).

Summary of fertiliser runoff studies at Glenorchy

by J. F. SOLBE
Water Research Centre, Medmenham Laboratory

In November 1985 WRC finished the field work stage of its four-year paired catchment study at Glenorchy, Highland Region. The objective of the work was to examine the runoff of forms of phosphorus from the catchments of the Ghaill (the control, unfertilised since 1972) and the Daimh, which was to be fertilised in 1982. In fact the control catchment also received phosphorus and potassium (in 1984) so the original study plan was not appropriate. Each catchment can act as its own control over time however, with due regard to changes in rainfall and temperature, and some inter-catchment comparison will still be possible.

The data records available from the study, now being analysed, are as follows:

- mean daily flow of the two rivers – from August (Daimh) and September (Ghaill) 1981;
- rainfall (and other meteorological information) and some chemistry of rain water, from July 1982;
- forms of phosphorus and nitrogen in river water leaving forest, from March 1982, although problems with contamination of samples were not fully resolved until June (Daimh) and July (Ghaill) 1983. In addition a network of raingauges was read whenever conditions permitted, and towards the end of the study a particular effort was made to assess the phosphorus draining from the unforested areas upstream of the plantations.

Nutrition and forest soils

by M. F. PROE
The Macaulay Institute for Soil Research, Aberdeen

Work has continued on a major collaborative study designed to elucidate the processes by which nitrogen and other nutrients cycle more rapidly in mixed spruce-larch and spruce-pine stands than in pure spruce stands (*Report* 1984, p. 62). Collaborators include the Irish Forest and Wildlife Service, the Forestry Commission and the Universities of Aberdeen and Edinburgh. Nutrient inputs from the atmosphere have been measured together with fluxes in throughfall, stemflow and litterfall. Soil water chemistry has been monitored and whole tree sampling carried out to estimate rates of nutrient immobilisation within the tree biomass. Field and laboratory incubation studies have been used to quantify rates of mineralisation and immobilisation of nitrogen and phosphorus in each system. Microbial activity and fine root dynamics have also been monitored and the types of mycorrhizae present identified. Results to date suggest that no single mechanism is responsible for the 'mixture effect' but rather a number of different factors may interact, with the key perhaps lying at the microbe/mycorrhizal level. Investigations are now focused on this area.

A second collaborative project, set up under the auspices of a consortium including the Forestry Commission and the Scottish Development Depart-

ment, is investigating the effects of afforestation and deforestation on water quality (Miller, 1984a). In conjunction with the Institute of Hydrology, the loss of nutrients is being monitored from the Kirkton (forested) and Monachyle (unforested) catchments near Balquhidder, in the Central Highlands of Scotland. Measurements will continue during the progressive clear felling of Kirkton Glen and afforestation of Monachyle. In addition, atmospheric inputs to the forested site have been quantified together with throughfall and stemflow. Whole tree sampling was carried out to enable estimation of nutrient retention within the trees so that a nutrient budget for the catchment as a whole can be derived.

Processing of results from earlier fertiliser experiments has continued and a review of nutrient cycling dynamics in forest plantations has been published (Miller, 1984b). A simulation model of growth and nitrogen cycling in Corsican pine has been developed to examine further the concepts of nutrient cycling within forest ecosystems (Miller and Proe, 1984).

Environmental studies of forests and other upland ecosystems have continued. The results will provide information about the processes by which acidic forms of atmospheric deposition may cause acidification of soils and surface waters (Miller, 1984c). Current work also includes a contribution towards a collaborative project between the Forestry Commission, the Water Research Centre and the University of Aberdeen into the potential benefits of sewage disposal in forest ecosystems and an assessment of the possible hazards to nearby watercourses. The nutritional status of the trees and the accumulation of heavy metals within the system following sewage application are being monitored.

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GENETICS

Variation and inheritance of wood properties of Sitka spruce

by P. E. WOOD

Department of Plant Sciences, University of Oxford

Following the pilot study of variation in wood properties of two provenances of Sitka spruce, at Clocaenog Forest (Clwyd), three locations of the 15-year-old open-pollinated progeny test have now been examined, at Tywi (Dyfed), Garcrogo (Dumfries and Galloway), and Glendaruel (Strathclyde).

Forty-seven families, including three controls, are fully replicated at all sites and have been assessed for 'Pilodyn' penetration (*Report* 1985, p. 61). At each site, 27 families and the controls were also selected for densitometry.

Density is strongly associated with major strength properties and is the single most useful measure of wood quality. Mean density is therefore the main parameter considered. Analysis of variance indicates that variation between trees is much greater than variation between families or blocks, but between-family variation is still highly significant. Analysis over more than one site indicates large between-site variation in some cases, but the family × site interaction, a measure of genotype-environment interaction, is not significant. The family heritability of mean density is high ($h^2 = 0.63$ to 0.82), but has a high error term ($\sigma = 0.21$ to 0.38).

In addition to mean density, within-sample variability of density and the breast height diameter (dbh) of the trees were also evaluated. The variability of density tends to increase with mean density ($r = 0.45$ to 0.76), while dbh is negatively correlated with density ($r = -0.34$ to -0.69). On a family mean basis, there are families which are exceptions to the above trends, i.e. having a higher density with a lower variability or higher dbh. These may be more valuable than those families which only have a very high density. Of the three controls, Sitka (from Alaska) and Masset (from British Columbia) generally have a very high density, but a low dbh. The third, Hoquiam (from Washington) is in the middle range of values for all the parameters.

Analysis of 'Pilodyn' penetration results indicates that the 'Pilodyn' may be a useful instrument for screening large numbers of trees or families, but it is not sensitive enough to detect small differences between families.

Investigation of the early failure of Sitka spruce grafts

by I. WEATHERHEAD

Plant Science Laboratories, University of Reading

Continued investigations indicate a higher sensitivity of Sitka spruce scions to desiccation compared with larch and pine species. This sensitivity is illustrated by the profound effect of prolonged cold storage upon subsequent grafting success. Scions grafted after 1, 3 and 7 days cold storage (1–2°C) showed no significant difference in graft success. However, scions grafted following 14 days cold storage formed a successful union much less readily. This fall-off in graft success corresponds with a gradual lowering of scion leaf water potential.

Accordingly, numerous procedures are being tested to maintain scion water potentials at high levels prior to grafting, including the application of anti-transpirants (Wilt-Pruf S600, and Manutex alginate) and the storage of freshly-cut scions in soaked hessian to minimise transpiratory water loss.

In an attempt to determine the level of genetic incompatibility between clones, 250 rooted cuttings from Newton nursery used as rootstocks were grafted, either to ramets of the same clone, or to ramets of four other clones. This experiment revealed a highly significant difference between the success of what may be termed 'clonal homografts' (40 per cent) and 'clonal heterografts' (9 per cent). In an experiment to establish the most successful graft type, the apical side-veneer graft produced a higher success rate than three other graft types; cleft, saddle and whip-and-tongue grafts.

Scanning electron microscope studies on the development of a union between rootstock and scion (Weatherhead and Barnett, 1986) have revealed

the importance of the establishment of a mixed callus in providing the first system of water exchange between the two graft partners. Lagerstedt (1984) found that the application of heat (25°C) to graft unions sped up the process of callus formation and increased the likelihood of graft success in *Corylus* species. A warming tape wrapped around the point of grafting and heated by electricity is currently being tested experimentally on Sitka spruce grafts in an attempt to reduce the time span over which callus is formed, and thus to minimise the water stress on the detached scion.

Transmission electron microscope studies are also being undertaken in an attempt to locate cytoplasmic communication between the living cells of the rootstock and scion. Kollmann and Glockmann (1985) observed plasmodesmata interconnecting the protoplasts of unrelated callus cells forming an interspecific cell bridge. It might be that the establishment of a continuum of cytoplasm, or symplast, is essential to graft development.

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Lagerstedt, H. B. (1984). Hot callusing pipe speeds up grafting. *American Nurseryman*, 5th October 1984, 113–177.

Weatherhead, I. and Barnett, J. R. (1986). Development and structure of unusual xylem elements during graft union formation in *Picea sitchensis*. *Annals of Botany* **57**, 593–598.

PHYSIOLOGY

The callusing of needle explants taken from Sitka spruce plantation trees treated *in situ*

by M. J. STEELE

Department of Botany, University of Edinburgh

An experiment is under way to obtain and examine the regenerative potential of callus derived from needle explants taken from 8-year-old trees (see *Report* 1985, pp. 62–65). In March 1985, a number of plantation trees in Glentress Forest (Borders) were paired before one of each pair was cut off just above the second whorl from the ground. In August, the current season's growth of three shoot-types (Figure 10) was taken from five tree-pairs and their needles were cultured using the basal media of Cheng (1975) (C), Von Arnold and Eriksson (1979) (VA) and Gresshoff and Doy (1974) (GD), each supplemented with three auxin (IBA at 0.0, 5.0 and 10.0 μM) × three cytokinin (BAP at 0.0, 5.0 and 10.0 μM) treatment combinations. The eight blocks (three tree-pairs contributing to two blocks each and the other two tree-pairs to one block each) of 81 treatment combinations were assessed after 7 weeks for the percentage of needles callusing per culture vessel, and each callus was scored ($1 \leqslant 2$ mm to $5 \geqslant 12$ mm) according to its size.

The analyses showed no overall differences between the explant sources for the mean percentage (above 30 per cent) of needles that callused. There was, however, a significant ($p<0.001$) difference between the basal media used, with mean levels of callusing of 2.5, 24.1 and 62.6 per cent for the C, VA and GD media respectively. Auxin was more important than cytokinin to the

Table 12 The mean percentage of needles callusing per culture vessel, the mean score per callus and the number of needles callusing per explant source for the Von Arnold and Eriksson (VA) and Gresshoff and Doy (GD) basal media containing either 5.0 or 10.0 μM IBA

Explant source	VA						GD					
	Mean % callus -ing	5 μM Mean callus score	Number of needles	Mean % callus -ing	10 μM Mean callus score	Number of needles	Mean % callus -ing	5 μM Mean callus score	Number of needles	Mean % callus -ing	10 μM Mean callus score	Number of needles
Cut tree epicormics	36.1	2.7	14	40.3	2.7	21	76.7	2.6	36	65.0	2.8	28
Cut tree laterals	22.5	1.1	10	30.8	2.5	2	71.1	1.9	34	66.9	1.8	37
Intact tree laterals	24.2	1.0	6	34.2	1.0	7	77.2	2.0	30	73.3	2.1	31

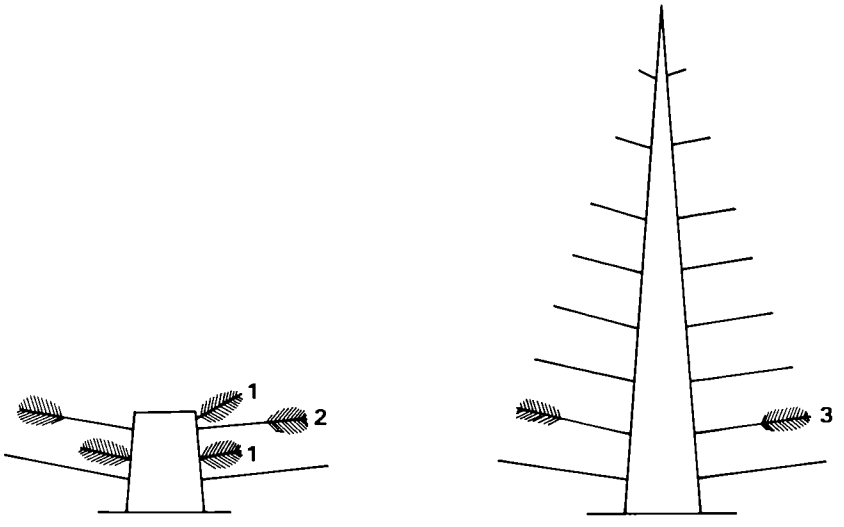

Figure 10. **The origins of the three explant sources derived from each tree pair. 1 and 2, epicormic and lateral shoots of tree cut off above the second branch whorl; 3, lateral shoots of control tree.**

production of callus. The percentage of needles callusing in the GD media was two to three times greater than that for the VA media, and the needles of the epicormic shoots produced the largest pieces of callus (Table 12).

The calluses were transferred to one or more culture vessels having an identical medium treatment combination. Each culture vessel carried an identity number relating to an individual needle. This process of subculturing was carried out every 6 weeks and at all stages each callus was assessed for growth, type and colour. The type of callus produced was influenced by the initial explant type and by the culture medium.

In March 1986, approximately 1500 pieces of callus derived from the three explant sources in each of the six remaining auxin × cytokinin treatment

Table 13 The mean, minimum and maximum number of pieces of callus obtained per needle from needles cultured in August 1985 when they were subcultured for bud induction in March 1986

	VA				GD			
Explant source	Mean	Minimum	Maximum	Number of needles	Mean	Minimum	Maximum	Number of needles
Cut tree epicormics	9	1	28	30	8	1	67	63
Cut tree laterals	5	2	11	3	5	1	49	65
Intact tree laterals	1	1	3	5	5	1	20	51

combinations for both the VA and GD media were subdivided and transferred to nine different auxin × cytokinin treatment combinations in an attempt to induce buds. The epicormic needles in the GD media produced the most pieces of callus of about 5 mm diameter per needle and the needles of the intact laterals in the VA media the least (Table 13).

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Gresshoff, P. M. and Doy, C. H. (1974). Derivation of a haploid cell line from *Vitis virifera* and the importance of the stage of meiotic development of anthers for haploid culture of this and other genera. *Zeitschrift für Pflanzenphysiologie* **73**, 132–141.

Von Arnold, S. and Eriksson, T. (1979). Bud induction on isolated needles of Norway spruce (*Picea abies* (L.) Karst.) grown *in vitro*. *Plant Science Letters* **15**, 363–372.

Measurement of root extraction forces

by D. L. O. SMITH

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The forces required to extract small roots from soil are being investigated as part of a study on the mechanics of windthrow. The apparatus, shown schematically in Figure 11, is designed to measure the force required to extract and/or break roots, of 3–10 mm diameter, protruding from the outer faces of trenches excavated for measuring *in situ* shear strength (*Report* 1985, p. 65). The method involves attaching a drill-chuck with serrated jaws to an exposed root and then applying a tensile force by means of a rope and manually operated winch. Applying the tensile force via a pulley allows roots to be pulled at various angles of inclination. The force required to extract the root is measured by a load cell and is recorded on a chart recorder. Satisfactory performance was achieved in preliminary tests and measurements are to be made in conjunction with *in situ* shear strength measurements on 35-year-old Sitka spruce growing in the peat of a peaty gley.

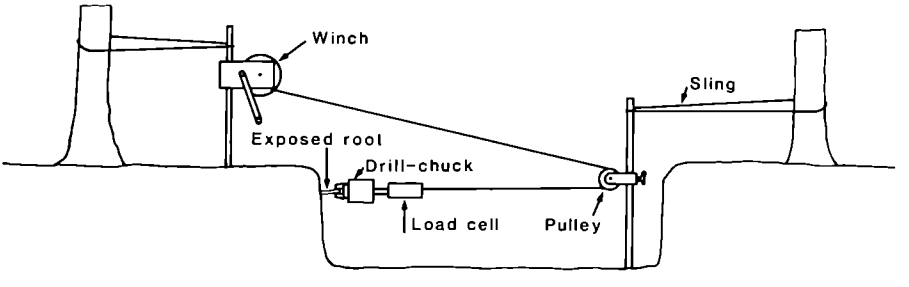

Figure 11. **Apparatus for measuring root extraction forces.**

Root strength in relation to windblow

by G. J. LEWIS

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The techniques described in *Report* 1985, p. 65 for the tensile testing of small diameter woody roots were applied to an extended range of Sitka spruce root diameters and the data further analysed.

The relationship between ultimate tensile stress (UTS) and root cross-sectional area (CSA) was significant ($p<0.01$) and remained linear to a root CSA of 160 mm^2 (mean root diameter 7 mm). The following equation accounted for 83.7 per cent of the variation:

$$UTS = 0.94 + 14.8 \times CSA.$$

There was no significant effect of root CSA on root tensile strength (TS) ($p<0.05$), but variation in TS increased directly with root CSA. This variation could be explained by cumulative differences in growth pattern between the larger (usually older) roots due to differing soil environments and/or by cycles of sub-critical wind-stressing and continued growth. The roots of 1 + 1 Sitka clones are currently being tensile tested.

Non-standard microtensile, compression and static bending tests have been devised and applied to samples of 'green' wood taken from large lateral roots. A computer model which uses such strength values plus root cross sectional configuration data to predict the bending behaviour of large lateral roots is being developed. It includes the capacity to deal with differences in the modules of elasticity in bending between the top and bottom of the root cross section.

ENTOMOLOGY

Regulating interactions of the pine aphid *Schizolachnus pineti* Fabr. and host plant growth

by G. B. LEWIS

Department of Zoology, University College, Cardiff

Two experiments were undertaken to investigate the effects of *S. pineti* on the growth of a number of *Pinus* species. These were initially described in *Report* 1984, pp. 66–67. The first involved a year of infestation (either low or high) followed by an aphid free year, when most effect on growth is expected due to the removal of stored material in the previous year. Only *P. sylvestris* and *P. nigra*, those species on which the aphid reached damaging levels, are described here. The second experiment involved only *P. sylvestris* and looked at a further aphid free year (two in all) plus the cumulative effects of two successive years of high infestation followed by an aphid free year.

In Experiment 1, the only significant effect on the growth of *P. sylvestris* in the year of infestation was an increase in needle length and dry weight. This was maintained in the second year only in the low infestation group. This response was not found in *P. nigra*. At the end of this experiment total losses (dry weight) were 20–25 per cent for *P. sylvestris* but only 10–15 per cent for

P. nigra in the high infestation groups. In the low infestation groups, *P. nigra* showed a weight loss but *P. sylvestris* showed an increase of up to 50 per cent.

In Experiment 2, when *P. sylvestris* was infested for 2 years it showed cumulative losses in dry weight by the end of over 50 per cent. After two aphid free years, however, losses were down to less than 10 per cent. A large increase in needle biomass (not shown by other tissues) seems to be part of a compensatory mechanism resulting in increased growth rates following infestation (see Ericsson *et al.*, 1980).

REFERENCE

Ericsson, A., Larsson, S. and Tenow, O. (1980). Effects of early and late season defoliation on growth and carbohydrate dynamics in Scots pine. *Journal of Applied Ecology* **17**, 747–769.

Host plant interactions with the pine aphid *Cinara pini* L.

by S. D. J. SMITH

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Larsson (1985) attributed the seasonal changes in distribution of *Cinara pini* mainly to quantitative and qualitative changes in phloem sap through the course of the growing season. However, evidence suggests a more complex system of interactions including the tree response to intensive feeding and possible role of ant attendance.

A study was made of the seasonal distribution of aphids introduced to uncaged trees attended by the wood ant *Formica sanguinea*. Investigations into seasonal trends in amino acids, phenolics and terpenes of different aged tissues were also carried out. Early in the summer aphids were aggregated on young internodes in the upper parts of the crown (site of introduction), moving back on to older internodes in the lower parts of the crown during midsummer. Production of sexual forms coincided with movement on to young internodes for egg laying (Figure 12).

Amino acid analysis is not yet complete, but there is no evidence of a correlation between aphid movement and amino acid composition. Likewise seasonal trends in phenolic compounds have not been implicated. Histological comparison of the bark of infested and control trees indicated deterioration in parenchyma cells and possible disruption of sap flow when phloem was penetrated by large numbers of stylet sheaths. The chemical nature of this response to intensive feeding is being studied.

A simulation model is to be constructed incorporating factors such as changes in nutritional quality and role of attending ants on the population dynamics of the aphid as a result of this year's work.

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Larsson, S. (1985). Seasonal changes in the within-crown distribution of the aphid *Cinara pini* on Scots pine. *Oikos* **45**, 217–222.

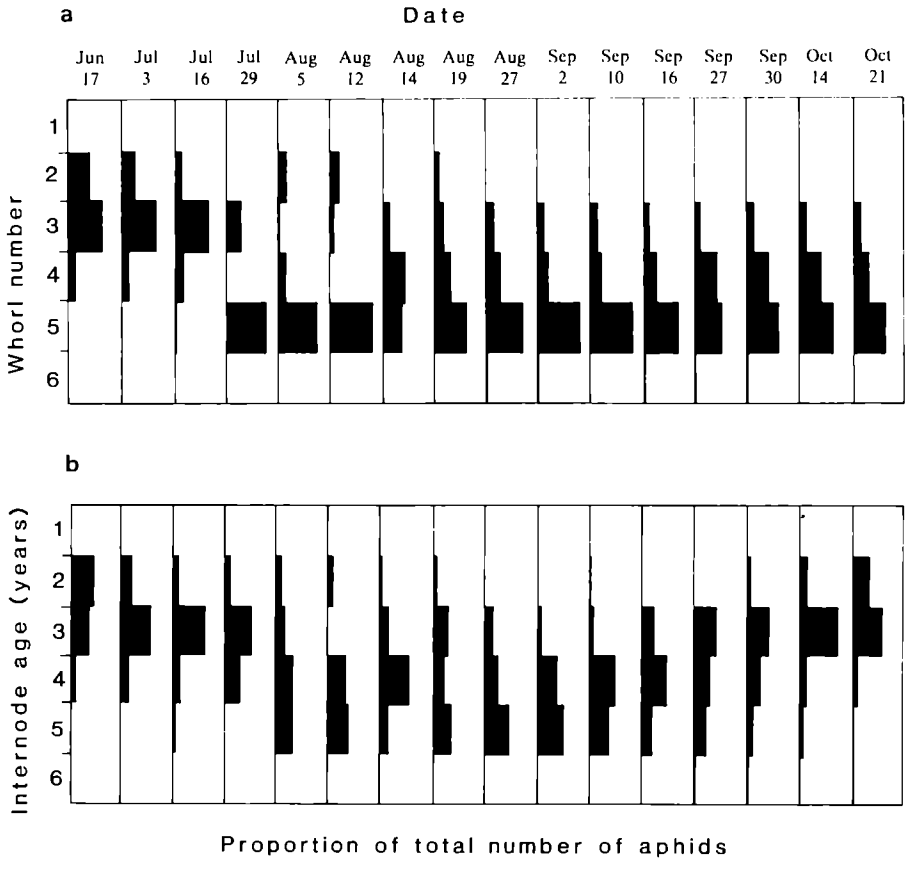

Figure 12. **(a) Distribution of *Cinara pini* on branch whorls (whorl 1 = whorl of current year's growth) at different observation dates.**
(b) Distribution of *C. pini* on internodes of different ages (internode 1 = internode of current year's growth) at different observation dates.

The influence of host plant chemistry on the population dynamics of the Large pine aphid *Cinara pinea* Mordv.

by N. A. C. KIDD and G. B. LEWIS
Department of Zoology, University College, Cardiff

The Large pine aphid is found most commonly on Scots pine where it feeds by extracting phloem sap from the foliated shoots of the current and previous year. This may result in reduced tree growth (Kearby and Bliss, 1969). The aphids only become abundant in midsummer during the period of shoot and needle extension, showing a characteristic single population peak followed by low numbers until eggs are laid in October–November.

Using performance data from the field, a computer simulation model of the population system of this aphid has been developed. This has shown density-dependent processes occurring, e.g. alate production, adult size and nymphal mortality, but they are of little significance in determining population num-

bers. The important factors are (1) natural enemies, which affect egg numbers and thus population numbers the following year, and (2) plant quality, which affects aphid development and mortality. The latter is largely responsible for variations in peak densities between years and between trees.

A detailed study of host plant quality is now being undertaken. This involves analysis for amino nitrogen (the most likely nutritional factor to be limiting), as well as phenols and terpenes (non-nutritional 'secondary' compounds that have been found to influence insect performance in other studies). Correlation with individual aphid performance will allow the most likely candidates to be identified and subsequently tested using artificial diets. Through the model their impact on the aphid's population dynamics can be determined. It is hoped that the model will provide a tool for predicting aphid outbreaks.

REFERENCE

Kearby, W. H. and Bliss, M. (1969). Field evaluation of three granular systemic insecticides for control of the aphids *Eulachnus agilis* and *Cinara pinea*. *Journal of Economic Entomology* **62**, 60–62.

The number of instars of alatae of the Green spruce aphid, *Elatobium abietinum* (Walker)

by M. FISHER

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Cunliffe (1924) measured the number and duration of the nymphal instars of apterae and alatae of the Green spruce aphid, *Elatobium abietinum* (Walker), and found apterae to have four and alatae to have five instars. Hussey (1952) stated that alatae have five nymphal instars, but gave no further details. To count the number and duration of instars, careful daily observation for cast exuviae is required. Since both apterae and alatae of other species of Aphididae pass through four instars, and Cunliffe (*op. cit.*) measured the number of instars for only two individuals, his experiment was repeated.

During the spring apterous and alate Green spruce aphids were reared singly in cages fitted on one needle of a Sitka spruce tree and kept at 16h photoperiod and 15 ±2°C, (Fisher, 1982). Fisher and Dixon (in press) give the conditions required for development of alatae of the Green spruce aphid. One adult aptera was placed in each cage, allowed to produce one nymph, and then removed. Aphids were observed daily. A piece of black card at the bottom of the cage allowed exuviae to be counted.

Both apterae and alatae passed through four nymphal instars, but alatae had a longer total developmental time and were heavier than apterae (Table 14). The longer total developmental time of alatae was due mainly to the increased length of the fourth instar. Alatae of the Green spruce aphid therefore conform with other aphid species in the number of nymphal instars.

This work was carried out while the author was in receipt of a CASE studentship with SERC and the Forestry Commission at the University of East Anglia.

Table 14 Mean length of each nymphal instar (S.E.), mean developmental time (S.E.) and mean adult weight (S.E.) of apterous and alate *E. abietinum* on Sitka spruce at a 16h photoperiod and 15°C.

		Aphid morph	
		Apterae	Alatae
Mean length of each instar S.E. (days)	1st instar	4.22 0.13	3.78 0.15
	2nd instar	3.35 0.10	3.67 0.17
	3rd instar	3.48 0.11	3.78 0.15
	4th instar	3.96 0.08	5.89 0.11
Mean developmental time S.E. (days)		15.00 0.17	17.11 0.20
Mean adult weight S.E. (mg)		0.46 0.01	0.55 0.01
Number of aphids		23	9

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WILDLIFE AND CONSERVATION

Factors affecting the distribution and feeding ecology of bats in Grampian forests

by P. A. NEVILLE

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Optimal foraging theory predicts that efficient predators will maximise their food intake by selecting which types of food to eat and where and how to forage. This study investigates how these decisions are made by comparing bat activity with levels of food availability in three different woodlands: in a Scots and Lodgepole pine plantation, a beech/oak forest and a birch woodland. At sites of closed canopy, open canopy and an area of freshwater, bats were both remotely monitored using ultrasonic receivers and tape recorder and mist-netted. Insects were caught in actinic light traps and suction traps at two heights. Data were collected on 90 nights during the summer months May to September over a 2 year period.

During May, June and July the patterns of bat activity were found to be markedly similar irrespective of habitat, (and/or site), and were positively correlated with the daily energy requirements of bats through pregnancy, parturition and lactation.

Site choice between habitats was also very similar with areas of still water producing the highest levels of activity in all months. On a nightly basis, bat activity was inversely related to available insect biomass. At times when

biomass was very low over areas of water, bats still used such sites preferentially. On these occasions bats could only forage optimally by increasing both their individual level of activity and foraging duration, which did, on occasion, extend beyond dawn.

But why should bats have chosen to forage at such sites when more productive areas, in terms of insect abundance, existed? From an analysis of feeding height, faecal content and laboratory investigations of water balance, it is suggested, that choice of foraging area may be severely restricted by an individual or species specific requirements for water. Furthermore, in entomologically poor habitats, such as Culbin Forest (Grampian), ponds and water courses take on a disproportionate importance to bats and may form a major factor influencing their distribution and activity.

Current statistical treatment of the data is examining trends due to the activities of volant young in August and September, and ways of predicting levels of bat activity, with the overall aim of both defining 'good bat habitat' and producing a management plan for the conservation of bats in coniferous plantations.

This project was the subject of a CASE studentship which was jointly funded by the FC and a NERC award to Professor P. A. Racey at the University of Aberdeen.

The behaviour of Sand lizards in relation to forest management

by S. DENT (née WRIGHT) and I. F. SPELLERBERG
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The field work for this project was completed in 1983 and the data have now been analysed and will be published in detail elsewhere.

The habitat use of the Sand lizard *Lacerta agilis* L. was investigated in Wareham Forest, Dorset, within the following three forest habitats:

(i) small open areas;
(ii) the ground level vegetation underneath a growing crop (stands);
(iii) the strip of vegetation between a ride and the adjacent plantation (ride verges).

With respect to the ground level vegetation of a habitat, *L. agilis* was found to be strongly associated with dry heathland vegetation dominated by *Calluna vulgaris*. There was some evidence of seasonality in the use of other vegetation types such as heathland or *Molinia caerulea* dominated bog. These areas were used in the late spring and summer after they had dried out and when presumably their microclimates were more suitable. Within small open areas and stands there was some evidence that they avoided areas with a high tree canopy cover. Along ride verges, the distribution of *L. agilis* was influenced by characteristics associated with both the ground level vegetation and the surrounding tree canopy cover. In particular the distribution of *L. agilis* was influenced by the aspect of, and the number of sunshine hours received by, an area of ride verge.

The ride verges are regarded as the 'key' habitat providing not only a habitat in their own right but also a system of corridors for the movement of *L. agilis* throughout the forest. The maintenance of open areas would be

essential in order to provide some stability in the system as these are the only permanently available forest habitats. It is envisaged that stand habitats will be used by *L. agilis* where they are adjacent to open areas or ride verges supporting *L. agilis* populations and during the period which the vegetation remains suitable.

A model has been developed which can could be used to predict the suitability of an area of ride verge for use by *L. agilis* and to predict how this area might change through time. In this way the management of an area of forest can be aimed towards sufficient area of *L. agilis* habitat being maintained at any given time.

This project was the subject of a SERC award to Dr I. F. Spellerberg at the University of Southampton and was supported and partially financed by the Forestry Commission.

Ecology of red and roe deer in a Scottish Sitka spruce forest

by M. D. C. HINGE

Department of Zoology, University of Aberdeen and the Institute of Terrestrial Ecology, Banchory

The aims of the four year study were to determine how sympatric populations of red and roe deer use available habitats in a second rotation Sitka spruce forest and to examine the influence of these habitats on deer behaviour.

Radio-collared red and roe deer in Glenbranter Forest (Argyll) were located using radio triangulation techniques. Red deer selected areas of spruce approximately 20 years old following canopy closure incorporating checked clearings. Roe deer made greater use of slightly younger forest stages up to 15 years. The distribution of both species differed in crops older than 35 years. Red deer moved further into cover to rest whereas roe were found closer to the edge. This was considered to be related to the fact that red are less tolerant to disturbance and more secretive than roe. In tree crops where food and cover were intimately mixed, usage was high, but in crops where favoured plant species had been shaded out, increased usage of adjacent open hill and recently planted or restocked areas occurred. Few animals were seen in the open by day. Activity of individuals was synchronised around dawn and dusk with another peak around midday. This peak was related to feeding in small checked areas or on rides, deer only venturing out on to larger open areas at dusk, returning back to cover at dawn.

Differences in the usage of *Calluna vulgaris* communities (*Report* 1983, p. 64) were reflected in the winter diet of red and roe deer (Figure 13). Both red and roe rely heavily on heaths, particularly *Calluna*. The proportions of broad and narrow leaved grasses in the diet of red deer were much greater than the proportions found in roe, whereas greater proportions of forbs (mainly *Galium saxatile*) and trees/shrubs (mainly *Myrica gale*) were found in roe diets. The amount of conifer material in both species varied between 14 and 18 per cent, but in areas where extensive heather eradication occurs the proportion of conifer material in the diet may increase.

This study was funded by NERC and the Forestry Commission.

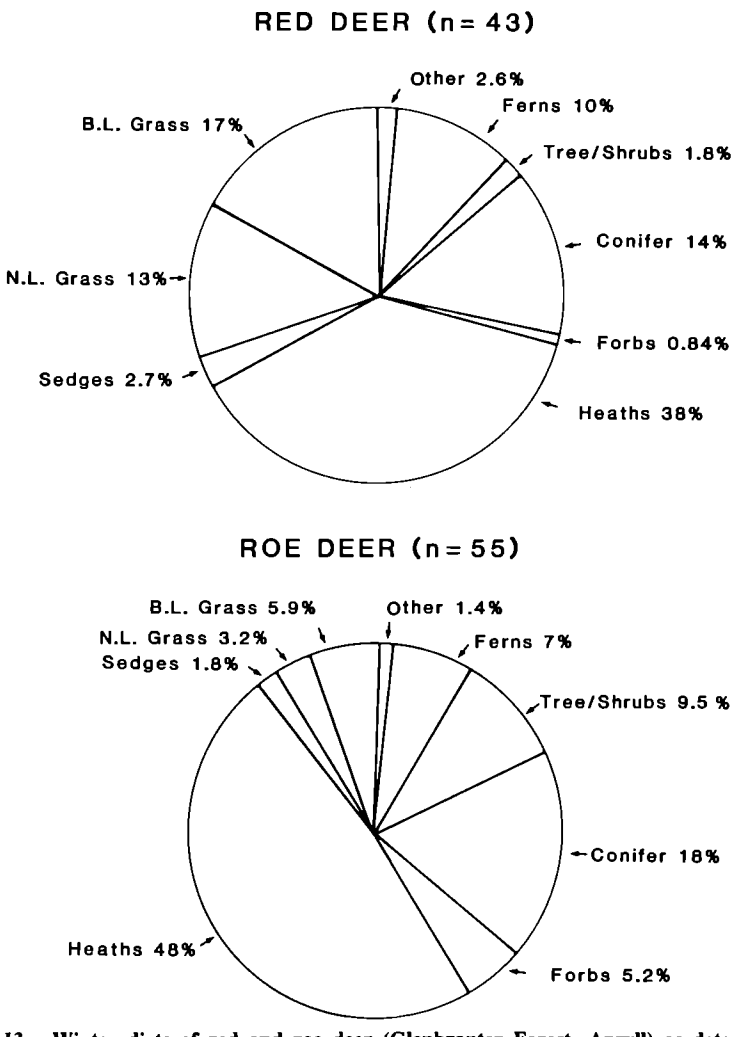

Figure 13. **Winter diets of red and roe deer (Glenbranter Forest, Argyll) as determined by botanical analysis of rumen samples.**

Fallow deer genetics

by R. H. SMITH

Department of Pure and Applied Zoology, University of Reading

Long-haired fallow deer

Controlled crosses in a New Forest (Hampshire) enclosure were terminated when vandals released the enclosed deer. In a Mortimer Forest (Shropshire) enclosure, a short-haired fawn was born from long-haired parents in 1985, confirming the earlier result showing that long hair is genetically dominant (Smith, 1982). Ten years observations on many individually marked deer have shown that long hair is highly variable in expression, and that the character becomes less apparent from the second year onwards.

Biochemical genetics

An extensive survey (794 deer from 37 sites) was carried out by Josephine M. Pemberton under the SERC CASE scheme between 1979 and 1982, using electrophoresis to investigate the breeding system. In contrast with other deer species studied, no genetic variation in tissue proteins was found in British fallow deer (Pemberton and Smith, 1985).

This work was partially supported by the Forestry Commission.

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WOOD UTILISATION

Joint research programme on British-grown timber

by T. HARDING

Princes Risborough Laboratory, Building Research Establishment, Department of the Environment

The effects of spacing on stress-graded yields of Sitka spruce

Structural wood yields of Sitka spruce from 13 sites planted at spacings ranging from 0.9 m to 2.7 m and thereafter left unthinned have been determined. There is a reduction in yield as planting distance widens and this reduction becomes more significant at higher levels of structural performance. Arising from this work, it is recommended that in normal plantation practice for Sitka spruce a planting spacing of 2 m (2500 trees ha^{-1}) should be adopted to minimise plantation establishment costs without jeopardising the future of Sitka spruce sawnwood in the structural market.

Effect of wood characteristics on machine grading of Sitka spruce

Equipment to measure grain inclination and knot distribution in sawn battens has been commissioned and the collection of data describing the strength reducing growth features has continued. Data collected have been processed and assembled into a data bank which describes each machine-graded 900 mm span. Methods of weighting various descriptive parameters about the centre span are being tested and an analysis of the initial data collected is in hand to establish useful parameters which describe the strength reducing features.

Conversion of British-grown timber

Work to improve accuracy in sawing British softwoods, using bandsaws and reducer bandsaws, has continued. Of the two types of accuracy, between piece and within piece, the former is readily dealt with by closer quality control in sawmills. The latter is dependent on saw/sawblade parameters and is the subject of further study. There are some indications that British-grown softwoods require more care in conversion than their imported counterparts.

APPENDIX I

Publications by Forestry Commission Staff

BARBOUR, D. A. (1985). Two records of *Eupithecia abietaria* Goeze. *Entomologist's Record* **97**, 146.

This rare conifer-feeding Cloaked pug moth was reared from collections of Sitka spruce cones at Fort Augustus and Norway spruce cones at Redesdale Forest.

[BARRETT, D. K. and] GREIG, B. J. W. (1985). The occurrence of *Phaeolus schweinitzii* in the soils of Sitka spruce plantations with broadleaved or non-woodland histories. *European Journal of Forest Pathology* **15**, 412–417.

The soils of 35 Sitka spruce plantations in southern Britain were surveyed for the presence of the root- and butt-rotting fungus *P. schweinitzii*. As a soil inhabitant, the fungus was found to be present in plantations with both broadleaved woodland histories and non-woodland histories, but it was normally isolated at a higher frequency from those ex-broadleaved woodland sites which contained diseased Sitka spruce. The implications of the presence of the fungus in the soils of the formerly non-woodland sites, where no disease has been observed, is discussed in relation to its infection biology, as currently understood.

BILLANY, D. J., WINTER, D. G. [and GAULD, I. D.] (1985). *Olesicampe monticola* (Hedwig) (Hymenoptera: Ichneumonidae) redescribed together with notes on its biology as a parasite of *Cephalcia lariciphila* (Wachtl) (Hymenoptera: Pamphiliidae). *Bulletin of Entomological Research* **76**, 267–274.

The sawfly *Cephalcia lariciphila* (Wachtl) is a pest of larch that has recently become widespread in Britain. Before taking measures to control the sawfly the status of parasites in the infestations was investigated. The only insect parasite species found was the ichneumonid *Olesicampe monticola* (Hedwig), which is new to Britain. As this insect is taxonomically so poorly known it is redescribed from specimens collected in south Wales. The preliminary biological observations show *O. monticola* to be well adapted to its host and that it can significantly reduce an infestation.

BINNS, W. O. (1985). Are Britain's forests threatened by acid rain? *Report of the Acid Rain Inquiry*, Edinburgh, September 1984. Scottish Wildlife Trust, 64–72.

Foresters are, of course, concerned about tree health and forestry specialists are well-equipped to see changes in it. Needle loss in conifers is non-specific and can be caused by many different stresses. Britain's unpredictably wet and windy climate – though with periodic droughts – provides large year-to-year variations in 'health'; and health itself is a variable state, trees being in a dynamic equilibrium with pests, diseases and climatic stress. Until the causes of forest decline are understood it is not possible to rule it out in Britain, though at present it seems unlikely.

BINNS, W. O. (1985). Effects of acid depositions on forests and soils. *The Environmentalist* **5** (4), 279–288.

Concern about damage from acid depositions – polluted air and rainwater – has been increasing with the realization that damage to forests in Central Europe is spreading and intensifying and has also appeared in southern Sweden. There is naturally concern as to whether this phenomenon will appear in Britain – indeed there have been allegations that British forests are already suffering from acid deposition damage. However, we understand neither the mechanisms by which pollutants and other stressing factors may affect forests, how much of the damage seen is due to pollutants and how much would have occurred in their absence.

BINNS, W. O., REDFERN, D. B., RENNOLLS, K. and BETTS, A. J. A. (1985). *Forest health and air pollution: 1984 survey*. Forestry Commission Research and Development Paper 142.

Ninety-nine plots of Sitka spruce, Norway spruce and Scots pine throughout the mainland of Great Britain, aged between 30 and 45, were assessed for crown sensitivity, needle life and needle discoloration or browning. There was no evidence of any new form of forest damage and stands in less that perfect health could be accounted for without involving pollution. The survey will be repeated in 1985.

[BRAZIER, J. D.], HANDS, R. and SEAL, D. T. (1985). Structural wood yields from Sitka spruce: the effect of planting spacing. *Forestry and British Timber* **14** (9), 34–37.

Comparisons between the outturn of battens reaching specific stress grading limits were made between logs taken from plots planted at 0.9, 1.4, 1.8 and 2.4m spacings and subsequently left unthinned. Results suggest that there is considerable variation between sites and that wider spacings may produce more sawn battens which fail to meet normal structural grades.

BURDEKIN, D. A. and RATCLIFFE, P. R. (1985). Deer damage to Sitka – what does it really cost? *Forestry and British Timber* **14** (8), 26–27.

Report of a meeting to discuss the results of research into deer damage and highlight future research requirements.

[BURNHAM, C. P. and] MOFFAT, A. J. (1985). Soil acidification in south-east England. *Journal of the South East England Soils Discussion Group* **2.**

This volume contains papers on (a) acid deposition and soil acidity and (b) the occurrence of acid sulphate soils in south-east England.

DAVIES, R. J. (1985). The importance of weed control and the use of tree shelters for establishing broadleaved trees on grass-dominated sites in England. *Forestry* **58** (2), 167–180.

The results of seven experiments are used to illustrate the mechanisms of weed competition and its effects. Studies of soil moisture tension and foliar nutrient content indicated that competition was primarily for moisture and nutrients reducing the survival and growth of young trees. These effects are greater on soils with poor moisture retention, or where the climate results in high soil moisture deficits. To be effective, weed control must eliminate root competition. This can be done by cultivation, herbicides or mulching; cutting weeds above ground level is ineffective. Tree shelters accelerate the height growth of young trees and protect them from mammals and herbicide drift.

DAVIES, R. J. (1985). To weed or not to weed? *Timber Grower* 95, 12.

Forestry Commission hoeing experiments conducted in the 1920s and 1930s and more recent herbicide experiments are briefly reviewed. A survey in 1982/83 found that 63 per cent of the area weeded was weeded by methods which merely cut the tops of the weeds; the value of these methods is questioned. The need for further research is indicated.

EDLIN, H. L. (1985). *Broadleaves*. 2nd edition, revised by A. F. Mitchell. Forestry Commission Booklet 20.

Describes about 40 of the commoner species of broadleaved trees found in Great Britain. The 53 colour plates and 119 line drawings provide aids to identification, whilst the text provides fascinating details of tree biology, habitat and end uses.

[ENTWISTLE, P. F. and] EVANS, H. F. (1985). Viral control. In *Comprehensive insect physiology, biochemistry and pharmacology,* eds. Kerkut, G. A. and Gilbert, L. I. Pergamon Press, Oxford.

A review article covering all aspects of the control of insects using pathogenic viruses. Emphasis is placed on understanding the ecological role of viruses as a means of improving their use as control agents.

EVANS, H. F. (1985). Great spruce bark beetle, *Dendroctonus micans:* an exotic pest new to Britain. *Antenna* **9,** 117–121.

An article describing the history and status of *Dendroctonus micans* in Europe and in Britain. Current strategy for control has changed from survey and sanitation felling to a combination of timber movement restriction and release of an imported predator, *Rhizophagus grandis*.

EVANS, H. F. (1986). Viruses. A realistic alternative in crop protection? *Biotechnology and Crop Improvement and Protection BCPC Monograph* **34,** 161–172.

The role of viruses in crop protection is discussed, with emphasis on their use to control insect pests. A number of successful viral products have been registered but there has been relatively little progress in the field, despite the large number of viruses pathogenic to insects. The reasons

for this are discussed and suggestions made for future development, including formulation, application methods, costs and the rapidly expanding field of genetically engineered viral agents.

EVANS, J. (1985). The development of tree shelters as an aid to tree establishment. *IX World Forestry Congress*, Mexico, July 1986. Paper E–I.1.2.2.C.

Tree shelters aid establishment and early growth, provide complete protection and permit easier and safer weeding of broadleaved species with herbicide. Nearly all broadleaved and coniferous species so far tested benefit from tree shelters. In 1984/5 planting season about 1.5 million tree shelters were used throughout Britain.

EVANS, J. (1985). Plantation forestry in the tropics – developments since the Jakarta Congress and an assessment of current trends. *IX World Forestry Congress*, Mexico, July 1986. Paper E–I.3.1.2A.

Great changes are taking place in plantation forestry. The rate of new planting is expanding. Most new initiatives aim principally to meet social and environmental objectives. Integration of farming and forestry is widely seen as a key development. Arid zone planting for fuelwood and fodder supplies is now important.

EVANS, J. (1985). A time to plant – the complementary need to expand intensive forestry programmes in developed and developing countries. *Journal of World Forest Resource Management* **1** (2), 151–161.

The major constraints on future wood supplies are discussed. Both local shortages and global trends point to the need for increased planting of trees. There is a review of the prospects for improving wood supplies by means of intensive fast-growing plantations both in the tropics and temperate regions. This could help reduce pressure on natural forests, especially the tropical moist forests.

EVANS, J. and POTTER, M. J. (1985). Manchons forestiers – un nouveau matériel pour la reprise des arbres. (Tree shelters – a new aid to tree establishment). *Plasticulture* 68, 7–20.

A tree shelter is a transparent or translucent plastic tube erected around a newly planted tree in order to provide a warm, humid microclimate free from most of the stresses which cause slow and poor establishment in young plants. The favourable environment within a shelter enables plants to function very efficiently and early growth rates can be greatly enhanced. The conspicuous nature of tree shelters also allows young plants to be easily located and the physical protection afforded from mammals also makes hand and chemical weeding safer.

GRUNDY, D. S. (1985). *Developing the economic arguments for investment in forestry: a survey*. Forestry Commission Research and Development Paper 145.

The early theories of economic development that emphasised industrialisation are now seen to be dangerously over-simplified. The case for investment in forestry as a source of raw material for industrial processing, which seemed to follow from them, is also too generalised. Only where the proposed investments offer a satisfactory return is there a good economic case. Fortunately much forestry investment, contrary to the widely held view that its economic return is low, can readily pass this test, as recent work has shown, for a very wide range of projects. The resources allocated to forestry can be increased by designing investment programmes which meet the standard tests of project appraisal. Forest sector surveys can be useful in identifying these projects.

HIBBERD, B. G. (Editor) (1985). *Forestry practice*. 10th edition. Forestry Commission Bulletin 14.

A practical account of current forestry activities in Britain, with advice on planning and management for growers, owners, planners and students.

HIBBERD, B. G. (1985). Restructuring of plantations in Kielder Forest District. *Forestry* **58** (2), 119–129.

A forest management plan for Kielder Forest District has been developed from earlier projects in Northumberland forests. It has been designed to cope with the forest management and landscape problems arising from the clear felling and restocking of large areas of even-aged forest in the Borders where windthrow is prevalent and protection from deer is necessary. The aim has been

to restructure the forest by creating distinct permanent felling coupes with relatively windfirm boundaries conforming to the scale and shape of the landscape. Thereafter the felling sequence for these new compartments has been arranged so far as possible to improve the distribution of age classes within the forest by exploiting any differences in species and rates of development in the present crops at different elevations.

INSLEY, H. [and BUCKLEY, G. P.] (1985). The influence of desiccation and root pruning on the survival and growth of broadleaved seedlings. *Journal of Horticultural Science* **60** (3), 377–387.

Describes experiments in which the roots of ash and birch seedlings were artificially dried before the plants were grown in either nutrient solution or nursery conditions. Loss of root tissue by desiccation was simulated using pruning treatments. The amount of stored carbohydrate lost to the plants as a result of root drying was measured and related to the reductions in root regeneration capacity and shoot growth.

JOBLING, J. and CARNELL, R. (1985). *Tree planting in colliery spoil.* Forestry Commission Research and Development Paper 136.

Spoil cultivation just before planting improves the quality and rate of planting, and also increases tree survival and growth rates. Planting and cultivation practices are discussed along with field experiments designed to examine the relationship between cultivation method and tree behaviour.

JOHN, A. (1986). Vitrification in Sitka spruce cultures. In *Plant tissue culture and its agricultural applications,* eds. Withers, L. A. and Alderson, P. G., 167–174.

Vitrification can be induced in Sitka spruce cultures by the addition of sterile distilled water to shoot cultures established on agar medium. Both spontaneous and induced vitrification are associated with morphological, anatomical and physiological changes that result in accelerated growth and development. Cultures revert to normal when the water is poured away.

KEENLEYSIDE, J. C. (1985). Loch Ossian plantations, Courrour, Invernessshire. A fresh look at species and growth, August 1982. *Scottish Forestry* **39** (4), 275–281.

These plantations were started in 1892 and lie at elevations of 391–487 m, largely on poor sites and with a severe winter. This report up-dates the results to 1951 given by Sir John Stirling-Maxwell. Notes are given on the performance of 20 species. Sitka spruce is the most adaptable and productive species. Some *Abies* species have grown surprisingly well considering the difficult conditions.

[KOSKE, R. E., FRIESE, C.] WALKER, C. [and DALPE, Y.] (1986). *Glomus pustulatum:* a new species in the Endogonaceae. *Mycotaxon* **26,** 143–149.

A new species of mycorrhizal fungus is described and illustrated from the USA and Canada. The fungus is characterised by possession of spores which have pustule-like processes ornamenting their outer walls.

[KOSKE, R. E. and] WALKER, C. (1986). *Glomus globiferum:* a new species of Endogonaceae with a hyphal peridium. *Mycotaxon* **26,** 133–142.

A new species of endomycorrhizal fungus was described. The spores of the fungus possess a peridium of hyphae which bear vesicle-like structures, making recognition of the fungus relatively easy.

[KOSKE, R. E. and] WALKER, C. (1985). Species of *Gigaspora* (Endogonaceae) with roughened outer walls. *Mycologia* **77,** 702–720.

Examination of soil samples from sand dunes of the eastern seaboard of the USA revealed three previously undescribed species of *Gigaspora* (*G. dipapillosa, G. persica* and *G. verrucosa*) producing spores with roughened outer walls. These were described, illustrated and compared with other, similar species. Spores of *G. coralloidea, G. heterogama* and *G. gregaria* were redescribed.

LEATHER, S. R. (1985). Atmospheric humidity and aphid reproduction. *Zeitschrift für angewandte Entomologie* **100,** 510–513.

Apterous exules of the bird cherry-oat aphid, *Rhopalosiphum padi* (L.) were significantly more fecund on oat seedlings at lower relative humidities (35 per cent RH) than at higher relative humidities (55 per cent RH). This was considered to be due to the increased transpiration rates of the plants under low humidity conditions. The significance of these results in relation to the practice of spring irrigation of cereals in Finland is discussed.

LEATHER, S. R. (1985). Does the bird cherry have its 'fair share' of insect pests? An appraisal of the species-area relationships of the phytophagous insects associated with British *Prunus* species. *Ecological Entomology* **10,** 43–56.

Field and published data reveal that there are at least 23 species of phytophagous insects associated with *Prunus padus* L. in Britain. Most of these species occur on the tree between May and September. Interspecific competition does not appear to be severe. There are a total of 196 species of phytophagous insects feeding upon the various tissues of *P. avium, P. cerasifera, P. cerasus, P. domestica, P. laurocerasus, P. padus* and *P. spinosa.* A highly significant species (S)–distribution (A) relationship of the form ln (S+1)=0.92 lnA−2.19. was obtained for the *Prunus* species examined within Britain (excluding Ireland), i.e. the wider the distribution of the plant the greater the number of insect species associated with it. However, critical analysis of the data indicates that *P. padus* does not support as many different insect species as expected. Neither plant form nor age of establishment within the British Isles accounted for this discrepancy.

LEATHER, S. R. (1985). Oviposition preferences in relation to larval growth rates and survival in the Pine beauty moth, *Panolis flammea. Ecological Entomology* **10,** 213–217.

Adult female Pine beauty moths, *Panolis flammea* (D&S), when given a choice of whole plants or needle pairs of four provenances of Lodgepole pine, laid most eggs on that provenance on which the larvae attained their greatest growth rates. When presented with a greater number of Lodgepole pine provenances and Scots pine, *P. flammea* oviposition preferences reflected the trade-off between growth rate and survival. There is some evidence to suggest that the moths are responding to the monoterpene competition of the plants. Adult moths showed no preference for Lodgepole pine needles of a range of ages (1–4 years), ovipositing uniformly on all ages classes.

LEATHER, S. R., [WATT, A. D. and] BARBOUR, D. A. (1985). The effect of host-plant and delayed mating on the fecundity and lifespan of the Pine beauty moth, *Panolis flammea* (Denis & Schiffermüller) (Lepidoptera: Noctuidae): their influence on population dynamics and relevance to pest management. *Bulletin of Entomological Research* **75,** 641–651.

The effects of provenance, delayed mating and adult mortality were demonstrated through a simulation model; the effect of delayed mating was particularly marked when adult survival was poor. Egg production in the field in Scotland varied by 30 to 123 eggs per female, but this variation could largely be explained by spring temperature. It was concluded that this relationship was due to the influence of temperature on mating and egg laying. The relationship between temperature and egg production forms a basis for predicting damaging levels of *Panolis flammea* from either pupal or adult numbers. The effects of provenance and delayed mating demonstrated that the frequency of *P. flammea* outbreaks in the UK may be reduced by the planting of less preferred Lodgepole pine provenances and by mating disruption methods.

LINES, R. (1985). Lodgepole pine management in the United Kingdom. In, Symposium Proceedings, 1984, *Lodgepole pine, the species and its management,* eds. Baumgartner, D. M., Krebill, R. G., Arnott, J. T. and Weetman, G. F., 219–224. Washington State University.

Lodgepole pine represents 12 per cent of Forestry Commission conifer high forests. There are about 26 000ha in private forests. It was first planted in forest trials in 1912 and there was a large increase in planting after 1948. It is present in over 400 experiments, of which 83 are provenance trials with 340 seedlots. High genetic variability and use of inferior seed origins led to many management problems: instability, poor growth, slow drainage, etc. For use in mixture with spruce, slow-growing Alaskan types are superior as a nurse. Pioneer crops on poor peatlands have been successfully replaced by more productive species.

LINES, R. (1985). The Macedonian pine (*Pinus peuce* Grisebach) in the Balkans and Great Britain. *Forestry* **58** (1), 27–40.

Stands of *Pinus peuce* in Yugoslavia and Bulgaria were visited in 1982. Early growth was slow but improved later, form was excellent. In Britain height increment is steady but basal areas can exceed that of other pines and the species can grow on a wide range of sites. Timber tests on young trees in Britain show that the wood density is low but could be used in joinery.

LINES, R. (1985). *Pinus nigra* in the Pennine Hills of northern England. *Quarterly Journal of Forestry* **79** (4), 227–233.

Two series of trials with *Pinus nigra* are described. One set of species trials compared Corsican and Austrian varieties with 24 other species under conditions of moderate pollution by SO_2. The other series comprised four provenance trials with a total of 47 seed sources. Results at 10 and 20 years are given. *Brunchorstia* dieback terminated the trials on the higher elevation moist sites at 20 years.

LINES, R. (1985). The Scottish Wildlife Trust 'Acid Rain Inquiry'. *Botanical Society of Edinburgh News* **42,** 12–18.

A brief summary of the 17 papers presented at the conference held in Edinburgh, 27–29 September 1984.

LOW, A. J. (1986). *Use of broadleaved species in upland forests – selection and establishment for environmental improvement*. Forestry Commission Leaflet 88.

Guidance is given on how best to select and establish broadleaved species for conservation, amenity and landscape purposes in the upland coniferous forest areas of Britain. Information on appropriate species is tabulated where conservation is important. Successful results can readily be obtained by sensible choice of species, planting site and establishment practice (including adequate protection).

MASON, W. L. [and MUETZELFELDT] (eds.) (1986). *Computers in forestry*. Institute of Chartered Foresters. 256 pp.

Proceedings of a conference held at Herriot Watt University, Edinburgh, on the application of computers to the management and administration of forests, the harvesting and marketing of timber, and to forest research.

[MILLER, D. D., DOMOTO, P. A. and] WALKER, C. (1985). Colonization and efficacy of different endomycorrhizal fungi with apple seedlings at two phosphorus levels. *New Phytologist* **100,** 379–391.

Six species of mycorrhizal fungi were used in tests to estimate growth effects on apple seedlings. At low phosphorus levels there were distinct differences among fungal species, whereas at high levels of that element root colonization was poor and the fungi had little influence on plant growth.

[MILLER, D. D., DOMOTO, P. A. and] WALKER, C. (1985). Mycorrhizal fungi at eighteen apple rootstock plantings in the United States. *New Phytologist* **100,** 393–402.

Mycorrhizas and associated fungal species were studied from 18 apple orchards. Different methods of assessment of mycorrhizal potential of sites were compared. Proportion and intensity of colonization were negatively correlated with soil zinc. Colonization of rootstocks varied among but not within orchards. There was no evidence of any lack of colonization even though there had been no deliberate introduction of mycorrhizal fungi.

[MILLER, D. D. and] WALKER, C. (1986). *Glomus maculosum* sp. nov. : an endomycorrhizal fungus. *Mycotaxon* **25,** 217–227.

A new species of *Glomus* is described and named *Glomus maculosum*. The fungus is characterised by spores which have a distinct 'endospore' formed by an inner, membranous wall that may invaginate and thicken in places to appear as if covered by 'spots' when viewed by low-power microscopy. The fungus forms endomycorrhizas with apple, sorghum and probably *Coleus*.

MILLER, K. F. (1985). The influence of wind on commercial forestry in Scotland. In, *Climatic hazards in Scotland,* ed. Harrison, J. Geo Books, Norwich.

A descriptive review of the detrimental effects of wind on tree growth and stand stability in Scotland, emphasising the economic penalties associated with damage. Methods of exposure assessment are presented, and the nature and extent of wind damage is described, together with an outline of windthrow prediction techniques.

MILLER, K. F. (1985). *Windthrown hazard classification*. Forestry Commission Leaflet 85.

Description of a simplified system of classifying forest land according to its windthrow vulnerabil-

ity. The practical applications and limitations of the classification are outlined, together with a review of the main factors involved in endemic windthrow in conifer plantations.

MITCHELL, A. F. (1985). *Conifers*. 3rd edition. Forestry Commission Booklet 15.

Describes about 40 species of conifers commonly grown in Great Britain. Includes 46 colour plates and 82 line drawings to aid identification.

[MITCHELL, B.,] ROWE, J. J., RATCLIFFE, P. R. [and HINGE, M.] (1985). Defecation frequency in roe deer (*Capreolus capreolus*) in relation to the accumulation rates of faecal deposits. *Journal of Zoology (London) (A)* **207**, 1–7.

Describes defecation rates of roe deer in Britain (17–23/day) for use in estimating site occupance and animal abundance from faecal accumulation.

MOBBS, I. D. (1986). Simulation techniques and harvesting systems. In *Computers in forestry*, eds. Mason, W. L. and Muetzelfeldt, R., Institute of Chartered Foresters, 147–155.

When machines work together in complex harvesting systems it is useful to be able to isolate and examine factors that affect harvesting costs. This is possible with computer simulation. Cable crane extraction is used to illustrate the type of questions that can be answered by simulation.

MOFFAT, A. J. (1985). William Cobbett: politician and soil scientist. *The Geographical Journal* **151** (3), 351–355.

In his book *Rural rides*, William Cobbett often described the soils of the districts he visited. His writings show that his knowledge of soils, their behaviour and cropping potential was considerable; many of his statements still hold true today. He was particularly perceptive with respect to soils of the chalklands. Cobbett clearly understood that soil type is determined by factors of geology, relief, vegetation and man's actions; modern soil mapping bears out most of his observations on soil distribution and land quality.

MOFFAT, A. J., [CATT, J. A., WEBSTER, R. and BROWN, E. H.] (1986). A re-examination of the evidence for a Plio-Pleistocene marine transgression on the Chiltern Hills. I. Structures and surfaces. *Earth Surface Processes and Landforms* **11**, 95–106.

Borehole and surface outcrop data are used to construct sub-Chalk, sub-Upper Chalk and sub-Tertiary contour maps for the Chiltern area. The results show a southwest-northeast monocline, which coincides with the change of slope at the lower boundary of the morphological bench on the Chalk dipslope that Wooldridge and Linton attributed to Plio-Pleistocene marine erosion. Younger northwest-southeast synclines coincide with the main transverse river valleys of the Chilterns. The monoclinal flexuring casts doubts on the value of the bench as evidence for a Plio-Pleistocene transgression.

MOFFAT, A. J. [and CATT, J. A.] (1986). A re-examination of the evidence for a Plio-Pleistocene marine transgression on the Chiltern Hills. II. Drainage patterns. *Earth Surface Processes and Landforms* **11**, 169–180.

The dry valley pattern of the Chiltern Hills is divided into 55 third order drainage basins which are grouped morphometrically into five groups. The character and distribution of the groups are determined mainly by the lithology of surface deposits and the structure of the underlying chalk. No evidence has been found for different drainage patterns on the parts of the dipslope equivalent to the 'Mio-Pliocene peneplain' and 'Plio-Pleistocene marine platform' of Wooldridge and Linton (1955), nor for superimposition of drainage from covers of Plio-Pleistocene or Palaeogene sediments.

PEPPER, H. W. (1985). Another look at trees. *Timber Grower* 96, 11 and 21.

Recent developments to the spring steel wire fencing techniques are outlined with particular reference to reducing the cost of rabbit fencing.

PEPPER, H. W., ROWE, J. J. and TEE, L. A. (1985). *Individual tree protection*. Arboricultural Leaflet 10.

The design specification and use of tree guards for individual protection in urban and rural situations are reviewed.

PEPPER, H. W. and TEE, L. A. (1986). *Forest fencing*. Forestry Commission Leaflet 87.

The leaflet describes the techniques and application of fencing with spring steel wire. Details of specifications of materials and complete fences and working methods are given. The basic principles of when and where to fence and what to use are discussed.

PETTY, S. J. (1985). Counts of some breeding birds in two recently afforested areas of Kintyre. *Scottish Birds* **13** (8), 258–262.

A study of Tawny owl ecology in Glenbranter Forest, Argyll and Kielder Forest, Northumberland has shown that the main prey of Tawny owls is the Field vole. A vole abundance index was calculated using a trapping method. Comparing study areas in 1984, the vole index was over four times higher in Kielder, where each breeding pair produced almost twice as many young. The greatest loss of productivity to Tawny owls in Glenbranter was through nestlings starving.

PETTY, S. J. (1985). A negative response of kestrels *Falco tinnunculus* to nest boxes in upland forests. *Bird Study* **32** (3), 194–195.

Nest boxes are widely advocated for the encouragement of kestrels. The establishment stages in upland forests provide good foraging habitat for kestrels, and to determine whether they would breed in nest boxes, two trials were undertaken. In mid Wales, boxes were erected on poles in a recently afforested area which lacked natural nest sites. In Northumberland, boxes were attached to spruce trees around the edge of restocked sites, where kestrels usually bred in old crows' nests. Over four years in both study areas, no boxes were occupied by kestrels; this negative response is discussed.

PETTY, S. J. (1985). A study of tawny owls in commercial spruce forests in the uplands. *Second Argyll Bird Report* 1984, 70–71.

Two recently afforested areas of Kintyre, covering a total of 5600ha, were visited to determine the status of Merlins. No Merlins were located. The distribution of divers, corvids and raptors was probably associated with the relative availability of suitable nesting habitat and food.

PHILIPSON, J. J. (1985). The effect of top pruning, girdling and gibberellin $A_{4/7}$ application on the production and distribution of pollen and seed cones in Sitka spruce. *Canadian Journal of Forest Research* **15** (6), 1125–1128.

On Sitka spruce grafts with 10 whorls, seed cones were largely confined to the upper four whorls but pollen cones were broadly distributed throughout the tree. Even following treatment with $GA_{4/7}$ and girdling the lower crown of intact trees remains a zone that does not produce seed cones. However, when trees were top pruned and treated numerous seed cones were produced on whorls previously in the non-producing zone in the lower crown. Top pruning thus improved the accessibility of seed cones and appears to be a practical management technique for Sitka spruce breeding programmes and seed orchards.

PYATT, D. G., ANDERSON, A. R., STANNARD, J. P. and WHITE, I. M. S. (1985). A drainage experiment on a peaty gley soil at Kershope Forest, Cumbria. *Soil Use and Management* **1**, 89–94.

The effects of ditch spacing (10, 20 and 40m) and depth (60 and 90cm) on water table depth were measured in a Sitka spruce plantation before and after drainage and finally after part of the plantation had been clear felled. No significant differences in water table depth were recorded between drainage treatments mainly because the ditch spacings were too large but also because of inadequate calibration of the site before the drainage treatments were applied. A significant rise in the water table was recorded after felling.

RATCLIFFE, P. R. and ROWE, J. J. (1985). A biological basis for managing red and roe deer in British commercial forests. In, *Transactions of the XVII Congress of the International Union of Game Biologists*, Brussels, 917–925.

Discusses reproduction and density in red and roe deer and summarises management recommendations based upon the collection of biological data.

RATCLIFFE, P. R. (1985). *Glades for deer control in upland forests*. Forestry Commission Leaflet 86.

Gives practical guidance in the preparation and maintenance of glades, aimed at increasing the opportunities for controlling deer populations by shooting in dense woodland habitats.

RATCLIFFE, P. R. (1985). Population density and reproduction of red deer in Scottish commercial forests. *Acta Zoologica Fennica* **172**, 191–193.

Commercial spruce and pine forests support densities of red deer equal to those on open range. In some areas these populations are reproducing at a level close to the biological maximum for the species. Short rotations are likely to maintain these populations in perpetuity.

RENNOLLS, K., [GEARY, D. N. and] ROLLINSON, T. J. D. (1985). Characterizing diameter distributions by the use of Weibull distribution. *Forestry* **58** (1), 57–66.

The well known Weibull distribution is fitted to sampled diameter distributions from 120 Sitka spruce stands and 90 stands of other conifer species, these being spread throughout Great Britain and having a wide range of ages. The parameters of the Weibull distribution, estimated by the method of Maximum Likelihood, are then regressed, using weighted least squares, upon mean diameter at breast height, d say, hence yielding a family of Weibull distributions indexed by d. The results are compared with the Forestry Commission's Stand Tables and are found to be an improvement.

RENNOLLS, K. and ROLLINSON, T. J. D. (1986). Stand growth and modelling – the value to forest managers. In, *Computers in forestry*, eds. Mason, W. L. and Muetzelfeldt, R., Institute of Chartered Foresters, 96–102.

Some of the limitations of traditional yield tables are discussed and the advantages of using computer-based simulation growth models are presented. The model currently under development by the Forestry Commission, which depends on individual trees competing for limited resources, is briefly described and set within the context of other simulation models of forest growth. Possibilities for the long-term widespread use of computer models in forest management are highlighted.

ROLLINSON, T. J. D. (1986). A comparison of selective and systematic respacing of Sitka spruce. *Scottish Forestry* **40** (1), 19–25.

Results of comparing selective and systematic respacing treatments are described. Selective respacing resulted in:

1. Gains in volume production, basal area production and mean diameter, but the differences are not statistically significant ($p<0.05$).
2. Increased mean height and a truncated lower end to the diameter distribution compared with the systematic treatment.
3. Some gains in tree quality. Both the proportion of forked trees and the diameter of branches are smaller in the selective treatment.

It is too early to conclude whether there will be significant long-term gains in yield, quality or stability by selective respacing.

ROLLINSON, T. J. D. (1985). *Thinning control.* Forestry Commission Booklet 54.

Contains three sections. The first describes the yield class system and the assessment of yield class in a stand. The second section covers thinning practice, that is, the type, intensity and cycle of thinning, how to calculate the thinning yield, the timing of thinning, and how to control the thinning. The third section describes the field procedures for estimating by height, basal area and volume marked, and how to calculate mean diameter. A checklist of office and field procedures is provided.

ROLLINSON, T. J. D. (1985). Windthrow and price are main thinning practice factors. *Forestry and British Timber* **14** (10), 22–24.

Thinning practice in Great Britain has been dominated in recent years by two main factors: the threat of wind damage and the decline in the price of small roundwood. The use of economic appraisals to determine whether or not – and how – stands should be thinned is discussed. The control of yield in the forest is described.

ROLLINSON, T. J. D. and MOBBS, I. D. (1986). Data capture in the field. In, *Computers in forestry*, eds. Mason, W. L. and Muetzelfeldt, R., Institute of Chartered Foresters, 130–135.

A wide range of portable electronic data loggers currently on the market are suitable for use in a forest environment. Microfin data loggers have been selected for recording time-study information, and Epson microcomputers for entering, checking and summarising sample plot measure-

ments. As prices fall and memory sizes increase, wider use of data-capture devices can be expected in both research and management applications.

[SAVILLE, P. S. and] EVANS, J. (1986). *Plantation silviculture in temperate regions – with special reference to the British Isles.* Clarendon Press, 246 pp.

An account of the principles of plantation silviculture drawing substantially on experience in the British Isles. Specialised forms of plantations, e.g. on derelict land, short rotation crops, and considerations of protection, are included.

STEVENSON, A. W., [THOMPSON, S.] and BIGGIN, P. (1985). The effects of clear polythene cloches on conifer seedling growth and shoot morphology. *Forestry* **58** (1), 41–56.

Nursery seedbeds sown with Lodgepole pine, Scots pine, Douglas fir, Japanese larch and Sitka spruce are covered with clear polythene cloches for 0, 8, 13 or 18 weeks from sowing. Sitka spruce germinated poorly and was not studied further. In both pine species longer durations of cloche cover increased the number and length of stem units resulting in taller 1 + 0 seedlings. The number of internodes held at the apex for elongation in the second season was also increased but transplant shock prevented full expression of this potential such that differences between the treatments were reduced. Only when covered for 18 weeks did Douglas fir and Japanese larch produce 1 + 0 seedlings which were taller than the uncovered treatments. Through the production of 'summer shoots' in their second season, Douglas fir and Japanese larch were able to compensate partially for the reduction in 'spring shoot' length caused by transplanting.

TABBUSH, P. M. (1985). Phytotoxic effects of gamma-HCH and bare rooted conifer transplants during handling and storage. *Scottish Forestry* **39** (3), 167–172.

The experiments reported demonstrate phytotoxic effects of gamma-HCH when applied as a top dip to protect bare rooted transplants against the Large pine weevil (*Hylobius abietis* L.) and Black pine beetles (*Hylastes* spp.). In forest trials, top dipping of Sitka spruce transplants in a 1.6 per cent active solution of 'Gamma-Col' (80 per cent colloidal formulation) consistently reduced height growth, and reduced survival on a difficult site. In a nursery experiment, Sitka spruce and Douglas fir transplants were cold-stored in sealed polythene bags for 3 to 5 months after top dipping in 1.6 per cent gamma-HCH, either as 'Gamma-Col' or as the 20 per cent emulsifiable concentrate 'Strykol-BHC'. The plants were either placed wet into the bags or first dried by heeling-in in the open. Douglas fir was killed by 'Strykol-BHC' in all treatments, and Sitka spruce was also damaged, especially when stored wet. In contrast, 'Gamma-Col' produced no significant adverse effects. Dipped plants should be stored in the presence of wet insecticides, and great care must be exercised to avoid fine root contamination during handling.

TABBUSH, P. M. (1986). What's new in plant handling? *Forestry and British Timber* **15** (1), 30–32.

Recent research at the Northern Research Station on the vulnerability of bare rooted transplants is reviewed and practical advice given on plant handling methods. Causes of damage are classified as mechanical, heating, drying or chemical, and research findings are reported under each heading. The root growth potential test for plant viability is briefly described and its usefulness discussed.

TABBUSH, P. M., [TURNER, D. J. and] SALE, J. S. P. (1986). What about additives? *Forestry and British Timber* **15** (2), 12–13.

Laboratory and greenhouse works sponsored by the Forestry Commission and carried out by the Weed Research Organisation has opened up exciting new possibilities for the use of additives to improve the efficiency of herbicides when applied to forest weeds. Several additive products are described and the laboratory experiments and field trials of mixture B to enhance rhododendron control are discussed. Field experiments on the effect of additives on the rainfastness of grass herbicides are reported.

TAYLOR, C. M. A. (1985). The return of nursing mixtures. *Forestry and British Timber* **14** (5), 18–19.

On many poor heathland and peat sites pure Sitka spruce will suffer from nitrogen deficiency. This can be prevented by planting in mixture with a nurse species such as Scots pine, Lodgepole pine or Japanese larch.

WALKER, C. (1985). Taxonomy of the Endogonaceae. In, *Proceedings of the Sixth North American Conference on Mycorrhizae*, eds, Trappe, J. M., Molina, R. and Berch, S., 193–199.

The taxonomy of this major group of mycorrhizal fungi was discussed in this invited paper given at the 6th North American Conference on Mycorrhizas. The history, generic concepts, infrageneric taxonomy, and isolation of the fungi were discussed, along with the particular problem of identification of the species *Glomus fasciculatum*.

WALKER, C. (1986). Taxonomic concepts in the Endogonaceae: II. A fifth morphological wall type in endogonaceous spores. *Mycotaxon* **25**, 95–99.

A newly recognised type of wall in spores of endogonaceous fungi was described and illustrated, and its value in the taxonomy of mycorrhizal fungi discussed.

WALKER, C., [PFEIFFER, C. M. and BLOSS, H. E.] (1986). *Acaulospora delicata* sp. nov.: an endomycorrhizal fungus from Arizona. *Mycotaxon* **26**, 621–628.

A newly discovered fungus, *Acaulospora delicata*, which forms typical vesicular-arbuscular mycorrhizas with Sudan grass and sorghum, is described and illustrated.

WEBBER, J. F. [and HEDGER, J. N.] (1986). Comparison of interactions between *Ceratocystis ulmi* and elm bark saprobes *in vitro* and *in vivo*. *Transactions of the British Mycological Society* **86** (1), 93–101.

Of 19 species of fungi isolated from elm bark, 16 significantly reduced the growth of *Ceratocystis ulmi* during competitive interactions in culture. When directly confronted with the pathogen in elm bark only three species were capable of replacing already established *C. ulmi* colonies, while four others showed some potential to exclude *C. ulmi* during the initial stages of bark colonisation by virtue of their effectiveness as primary colonisers. On the basis of these results the potential for natural biological control of *C. ulmi* by competitive saprobes in elm bark is discussed. The common practice of basing conclusions about interactions between fungi in nature, based solely on *in vitro* experiments, is also questioned.

[WILSON, J. and] COUTTS, M. P. (1985). Exploiting tree crop-symbiont specificity. In, *Attributes of trees as crop plants*, eds. Cannell, M. G. R. and Jackson, J. E., Institute of Terrestrial Ecology, 359–379.

The selection of microorganisms symbiotic with tree roots for improving tree growth is reviewed, together with methods of inoculum production and inoculation techniques. Examples are cited showing short-term benefits of inoculation, but interactions between soil microorganisms and roots are complex and can lead to replacement of selected symbionts by others. Information is generally lacking on long-term effects.

WILSON, K. (1985). *A guide to the reclamation of mineral workings for forestry*. Forestry Commission Research and Development Paper 141.

Techniques which have been successful in restoring mineral sites to forestry are recommended and factors affecting the growth of trees on restored sites are considered. Tables provide a clear summary of nitrogen-fixing plants recommended for reclamation sites and of the choice of tree species for forestry.

WINTER, T. G. (1985). Is *Ips typographus* (Linnaeus) (Coleoptera: Scolytidae) a British insect? *Entomologist's Gazette* **36** (2), 153–160.

The paper examines the history of *Ips typographus* in the British Isles, lists all records traced, and discusses whether it was ever a breeding species.

WINTER, T. G. (1985). The tree creepers. *GC & HTJ* **198** (24), 17.

Examines patterns of oak defoliation by Oak leaf roller moth (*Tortrix viridana*) and Winter moth (*Operophtera brumata*) caterpillars.

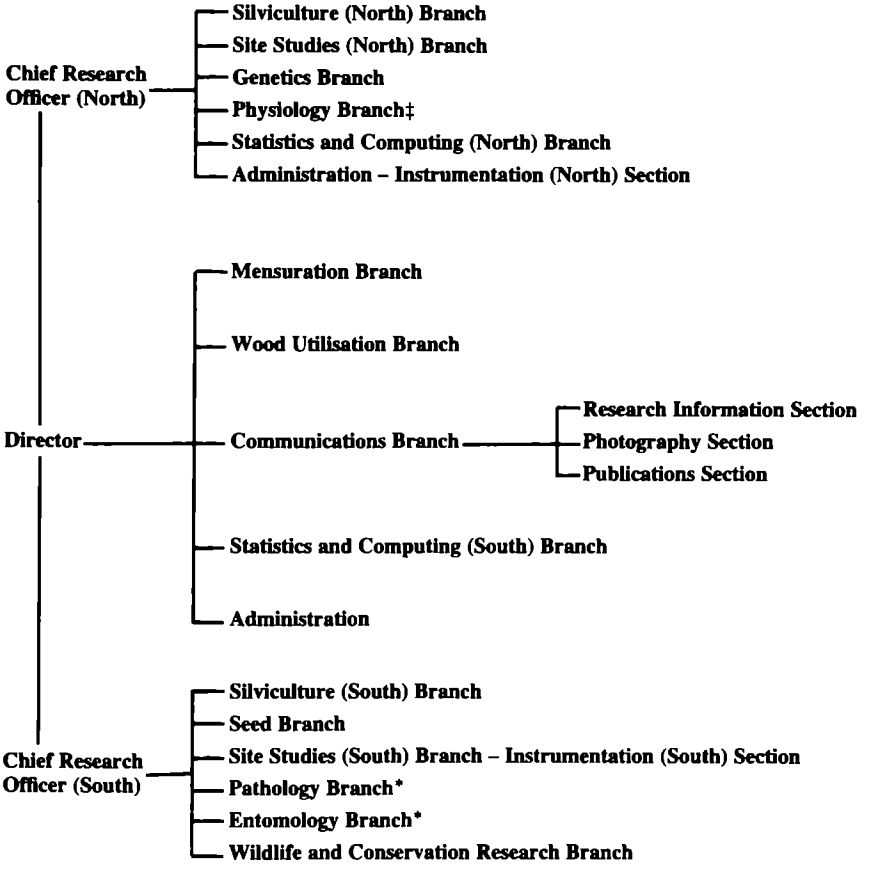
WINTER, T. G. (1985). A second record of the Least carper *Idaea vulpinaria* H.-S. in Hampshire. *Entomologist's Record and Journal of Variation* **97** (3–4), 69.

WINTER, T. G. (1985). A new larval food plant for *Epiphyas postvittana* (Walker) (Lepidoptera: Tortricidae) in Cornwall. *Entomologist's Gazette* **36** (1), 1.

Larvae of *E. postvittana* were found on *Pinus muricata* seedlings at Truro, the first record of this insect on a coniferous host in Britain.

APPENDIX II

Research Division Organisation



‡Branch with Section at Alice Holt.
*Branches with Sections at the Northern Research Station.

APPENDIX III

Research Division Branches and their Project Groups‡

Seed	Project leader(s) at 31/3/86
Research	P. G. Gosling
Service	P. G. Gosling
Silviculture (South)	
Plant production	J. Jobling, J. S. P. Sale
Species	M. J. Potter
Establishment	M. J. Potter
Contracts: arboriculture advisory service	D. Patch
arboriculture research	R. J. Davies
short rotation coppice	R. E. Crowther
Silviculture (North)	
Plant production	W. L. Mason
Species	R. Lines
Planting	P. M. Tabbush
Nutrition	C. M. A. Taylor
Cultivation	K. F. Miller
Stability	K. F. Miller
Site Studies (South)	
Effects of trees on sites	M. A. Anderson
Lowland production forestry	A. J. Moffat
Reclamation	A. J. Moffat
Upland production forestry	R. Carnell
Air pollution	W. O. Binns, R. Carnell, A. Willson
Chemical analysis	A. Willson
Instrumentation	R. Carnell
Site Studies (North)	
Clay and ironpan soils	D. G. Pyatt
Indurated soils and loamy gleys	D. G. Pyatt
Deep peats	D. G. Pyatt
Genetics	
Testing progeny	S. J. Lee
Production for clone and scion banks	A. M. Fletcher
Stands: location and registration	R. Faulkner
Biochemical variation	G. I. Forrest
Biometrical studies	C. J. A. Samuel
Physiology	
Root growth and form	M. P. Coutts
Flowering	J. J. Philipson
Bent top	M. P. Coutts
Micropropagation	A. John
Rejuvenation	A. John, A. M. Fletcher
Mycorrhizae	C. Walker

‡'Advisory' is distinguished as a separate project group in certain Branches but is an activity in all.

Pathology	
Heterobasidion annosum	D. B. Redfern, B. J. W. Greig
Dutch elm disease	C. M. Brasier
Peridermium	J. N. Gibbs, B. J. W. Greig
Armillaria	S. C. Gregory
Beech health	D. Lonsdale
Contract: decay in amenity trees	D. Lonsdale
Advisory	R. G. Strouts, D. B. Redfern
Entomology	
Dendroctonus micans	H. F. Evans, D. Wainhouse, C. J. King
Panolis flammea	J. T. Stoakley, S. R. Leather
Beech bark disease	D. Wainhouse
Elatobium abietinum	C. I. Carter
Hylastes and *Hylobius*	J. T. Stoakley, S. G. Heritage
Bupalus piniaria	D. A. Barbour
Advisory and taxonomic	T. G. Winter
Wildlife and Conservation	
Red deer	P. R. Ratcliffe
Other deer	P. R. Ratcliffe
Squirrels	H. W. Pepper
Birds	S. J. Petty
Damage assessment and effects	L. A. Tee
Repellents	L. A. Tee, H. W. Pepper
Mensuration	
Sample plots	T. J. D. Rollinson, J. M. Gay
Measurement studies	T. J. D. Rollinson
Yield modelling	T. J. D. Rollinson
Wood Utilisation	
Wood quality	D. A. Thompson
Preservation	D. A. Thompson
Utilisation of broadleaves	D. A. Thompson
Statistics and Computing (South)	
Forest growth modelling	Vacant

APPENDIX IV

Expenditure of Research Division 1985/86

Branch[a]	Expenditure by Branch direct[b]	Net value of in-house services received less than those provided[c]	Commissioned[d] research	£000 Expenditure attributable to Branch[e]
Seed	75	28	—	102
Silviculture (South)	676	94	28	798
Silviculture (North)[f]	1357	40	28	1426
Arboreta	330	3	—	332
Site Studies (South)[g]	423	−25	8	406
Site Studies (North)	85	34	—	119
Genetics	608	40	21	669
Physiology	189	55	46	290
Pathology	375	79	1	455
Entomology	343	45	30	417
Wildlife and Conservation	173	33	1	206
Mensuration	82	110	—	191
Wood Utilisation	46	—	224	270
Statistics and Computing (South)	321	−321	—	—
Statistics and Computing (North)	141	−141	—	—
Communications	257	−119	—	138
Total[e]	5480	−45[h]	386	5820

Notes:

(a) Ordered as in text of this Report.

(b) All directly incurred expenditure on wages and salaries, pension provisions, travelling and subsistence, materials, etc., plus office overheads of the Division, including net contribution to overheads of income from contract services provided to outside parties, plus Forestry Commission headquarters overheads for common services of £394(000).

(c) Figures show net effect of charges for services received (principally research information, engineering workshops and statistics and computing) less charges for services provided by the specific Branch to other Branches.

(d) Work commissioned at other government institutes, universities, etc.

(e) Totals do not always add owing to rounding.

(f) Including Experimental Workshop (North).

(g) Including Experimental Workshop (South).

(h) Net value of services provided to Branches of other Divisions, namely Forest Surveys and Work Study, equals £45(000).

APPENDIX V

Staff Engaged in Research

As at 31 March 1986

The main centres for research are:

FORESTRY COMMISSION RESEARCH STATION
Alice Holt Lodge
Wrecclesham
Farnham, Surrey GU10 4LH. Tel. 0420 22255

FORESTRY COMMISSION NORTHERN RESEARCH STATION
Roslin
Midlothian EH25 9SY
Scotland. Tel. 031 445 2176

Some staff engaged in research are also stationed at:
FORESTRY COMMISSION HEADQUARTERS
231 Corstorphine Road
Edinburgh EH12 7AT. Tel. 031 334 0303

RESEARCH DIVISION

Director ..... A. J. Grayson, M.A., M.Litt., M.I.C.For. (*Alice Holt*)
Administration and Finance Officer ..... J. Lumley (*Alice Holt*)

Chief Research Officer (South) ..... D. A. Burdekin, B. A., Dip.Ag.Sci. (*Alice Holt*)
(With general responsibilities for research south of the Mersey/Humber line, and with specific responsibilities throughout Britain for research in arboriculture, seed, pathology, entomology, wildlife and conservation, in silviculture and site studies in the lowlands, instrumentation and technical aspects of legislation relating to plant health.)

Chief Research Officer (North) ..... S. A. Neustein, B.Sc., F.I.C.For. (*Northern Research Station*)
(Head of the Northern Research Station with general responsibilities for research north of the Mersey/Humber line, and with specific responsibilities throughout Britain for research in silviculture and site studies in the uplands and for research in tree phsyiology and genetics).

STAFF AT ALICE HOLT LODGE

SEED BRANCH

P. G. Gosling, B.Sc., Ph.D., Head of Branch

Laboratory: Miss A. E. J. Pocock, Mrs P. J. Rigg, Mrs Y. K. Samuel, D. C. Wakeman

SILVICULTURE BRANCH (SOUTH)

T. C. Booth, B.Sc., M.I.C.For., Head of Branch
H. L. Davies, B.Sc., R. J. Davies, B.Sc., M.I.C.For., J. Jobling, B.Sc., M. L. Pearce, M.I.C.For., M.I.Hort.(*Westonbirt*), M. J. Potter, B.Sc., J. S. P. Sale, M.A., M.I.C.For.

Foresters:		*Centre*
East England Region	S. M. Colderick, D. Elgy, P. D. Howard, P. Marsh, P. H. Priestley, C. W. Shanks	Alice Holt
	M. J. Scott, R. E. Preston	Bedgebury
	S. E. Malone, T. D. Cooper	Thetford
West England Region	J. E. J. White	Westonbirt
	P. A. Gregory, M.I.Hort	
	K. F. Baker, D. G. Rogers	Exeter
	M. W. Allen	Dean

ARBORICULTURE ADVISORY SERVICE (Department of the Environment)
D. Patch, B.Sc., M.Sc., M.I.C.For., N.D.Arb., F.Arbor.A.,
F. R. W. Stevens

SITE STUDIES BRANCH (SOUTH)

W. O. Binns, M.A., B.Sc., Ph.D., F.I.C.For., Head of Branch
M. A. Anderson, B.Sc., R. Carnell, A. J. Moffat, B.Sc., Ph.D., A. Willson, B.Sc., Ph.D.

Foresters: D. W. H. Durrant, B.A., C. J. Roberts, B.A.
Laboratory: Mrs C. A. Baker, Miss S. J. Lee, Mrs D. A. Waddell

INSTRUMENTATION SECTION (SOUTH)

R. Carnell, Head of Section
R. D. Butt

PHYSIOLOGY SECTION (of Branch at Northern Research Station)
R. Harmer, B.Sc., Ph.D.

PATHOLOGY BRANCH (with Section at Northern Research Station)

J. N. Gibbs, M.A., Ph.D., Sc.D., Head of Branch
C. M. Brasier, B.Sc., Ph.D., D.Sc., D. Lonsdale, B.Sc., Ph.D., Ms J. F. Webber*, B.Sc., Ph.D.

Foresters: B. J. W. Greig, M.I.C.For., I. T. Hickman, B.Sc., D. R. Rose, R. G. Strouts

Laboratory: Miss S. E. Chuter, B.Sc., Mrs S. A. Kirk, Mrs T. C. Reffold

ENTOMOLOGY BRANCH (with Section at Northern Research Station)

H. F. Evans, B.Sc., D.Phil., F.R.E.S., Head of Branch
D. A. Barbour, B.Sc., Ph.D., F.R.E.S., C. I. Carter, M.Sc., C.Biol., M.I.Biol., F.R.E.S., N. J. Fielding, M. R. Jukes, C.Biol., M.I.Biol., Miss J. F. A. Nichols, B.Sc., M.Phil., C.Biol., M.I.Biol., D. Wainhouse, M.Sc., Ph.D., F.R.E.S., T. G. Winter, F.R.E.S.

Foresters: C. J. King, A. F. Martin, B.Sc.(For.)

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*Seconded from the University of Southampton, financially supported by the Pilkington Trust.

WILDLIFE AND CONSERVATION RESEARCH BRANCH

P. R. Ratcliffe, C.Biol., M.I.Biol., M.I.C.For., Head of Branch

Foresters: L. A. Tee, H. W. Pepper, S. J. Petty (*Cowal, Strathclyde*)

Laboratory: Mrs B. A. Mayle

MENSURATION BRANCH

T. J. D. Rollinson, B.Sc., M.I.C.For.
Miss J. M. Gay, B.Sc.

Forester: E. J. Fletcher

WOOD UTILISATION BRANCH

D. A. Thompson, B.Sc.(Hons.), M.I.C.For.

STATISTICS AND COMPUTING BRANCH (SOUTH)

R. S. Howell, Head of Branch
R. C. Boswell, B.Sc., M.I.S., G. J. Hall, B.Sc., B.A., Miss L. M. Halsall, B.Sc., Miss T. J. Houston, B.Sc., I. D. Mobbs, M.I.S., A. J. Peace, B.Sc., Miss B. J. Smyth, B.Sc.

COMMUNICATIONS BRANCH

B. G. Hibberd, M.I.C.For., Head of Branch

RESEARCH INFORMATION SECTION

B. G. Hibberd, M.I.C.For., Head of Section
Mrs E. M. Harland, M.A. (Librarian)

PHOTOGRAPHY SECTION

I. A. Anderson, F.I.I.P., Head of Section
G. L. Gate, Miss M. Trusler

PUBLICATIONS SECTION

E. J. Parker, Ph.D., C.Biol., M.I.Biol., Head of Section
J. Williams (Graphics Officer)

ADMINISTRATIVE STAFF

HEO: R. Murray (*Accounts*)

EOs: P. A. Lodge (*Estabs.*), Miss J. R. Lacey (*Accounts*), Miss K. Beattie (*Office Services*)

STAFF AT NORTHERN RESEARCH STATION

SILVICULTURE BRANCH (NORTH)

A. J. Low, B.Sc., M.Sc.F., Ph.D., M.I.C.For., Head of Branch
R. Lines, B.Sc., F.I.C.For., W. L. Mason, B.A., B.Sc., M.I.C.For., K. F. Miller, B.Sc., M.I.C.For., P. M. Tabbush, B.Sc., M.I.C.For., C. M. A. Taylor, B.Sc., M.I.C.For.

Foresters:		*Centre*
Special Projects	B. R. Reynard, J. B. McNeill	Northern Research Station
North Scotland Region	J. C. Keenleyside	Newton, Grampian
North Scotland Area	W. G. Paterson N. M. Proctor, B.Sc.	Lairg, Highland
North East Scotland Area	A. A. Green, J. Davidson	Newton
North West Scotland Area	D. R. Tracy, D. S. Coutts	Fort Augustus, Highland
Central Scotland Region	J. D. McNeill	Northern Research Station
East Scotland Area	A. H. Reid, W. F. Rayner	Perth, Tayside
South East Scotland Area	M. K. Hollingsworth, J. G. Whyatt	Northern Research Station
West Scotland Area	A. B. Lewis, S. Stables, B.Sc.	Kilmun, by Dunoon, Strathclyde
Borders and North England Region	E. Baldwin	Mabie, Dumfries and Galloway
Borders Area	J. Stannard, P. W. Gough, D. Kerr	Kielder, by Hexham, Northumberland
South West Scotland Area	F. S. Smith, P. Harrison, N.D.F.	Mabie
North East England Area	A. L. Sharpe, R. E. J. Howes	Wykeham, Scarborough, North Yorkshire
Wales Region	N. P. Danby, S. J. Corcoran, B.A., N.D.F., S. A. Mead	Brecon, Powys

SITE STUDIES BRANCH (NORTH)

D. G. Pyatt, B.Sc., Ph.D., Head of Branch
A. R. Anderson, D. Ray, B.Sc.

GENETICS BRANCH

R. Faulkner, B.Sc., M.I.C.For., Head of Branch
A. M. Fletcher, B.Sc., Ph.D., A.I.W.Sc., M.I.C.For., G. I. Forrest, B.Sc., M.Sc., Ph.D., S. J. Lee, B.Sc., M.I.C.For., C. J. A. Samuel, B.Sc., Ph.D.

Foresters: W. Brown, R. B. Collins, M. J. Crosby, B.Sc., I. J. M. Dawson, (Westonbirt), C. J. E. Fleming (Newton), M. T. T. Phillips (Newton), G. C. Webb (Shobdon)

Laboratory: Miss C. M. M. Baldwin

PHYSIOLOGY BRANCH (with section at Alice Holt)

M. P. Coutts, B.Sc., Ph.D., D.Sc., M.I.C.For., Head of Branch
A. John, B.Sc., Ph.D., J. J. Philipson, B.A., Ph.D., C. Walker, B.A., Ph.D.

Laboratory: Miss M. Brown, K. Clifford, B.A., Mrs D. Harvey, C. McEvoy, Miss G. Peaston

PATHOLOGY SECTION (of Branch at Alice Holt)

D. B. Redfern, B.Sc., Head of Section
S. C. Gregory, M.A., Ph.D.

Forester: J. E. Pratt

Laboratory: Miss G. A. MacAskill

ENTOMOLOGY SECTION (of Branch at Alice Holt)

J. T. Stoakley, M.A., M.Sc., D.I.C., F.I.C.For., Head of Section
S. G. Heritage, C.Biol., M.I.Biol., S. R. Leather, B.Sc., Ph.D., C.Biol., M.I.Biol., F.R.E.S.

Forester: J. C. G. Patterson, B.Sc.

STATISTICS AND COMPUTING BRANCH (NORTH)

D. H. Stewart, B.Sc., C.Biol., M.I.Biol., F.I.S., Head of Branch
R. W. Blackburn, B.Sc., Miss A. C. Burnand, B.Sc., K. P. Donnelly, B.Sc., M.Sc., Ph.D., I. M. S. White, B.Sc., M.Sc.

ADMINISTRATIVE STAFF

HEO: J. McA. Smith
EO: I. D. S. Macleod

INSTRUMENTATION SECTION (NORTH)

D. J. Brooks, Head of Section

STAFF CHANGES

Transfers in: Miss K. Beattie (Executive Officer) from Headquarters to Office Services, Alice Holt. T. C. Booth (Principal Forest Officer) from North England Conservancy to Silviculture South, Alice Holt. S. M. Colderick (Forester) from Wales Conservancy to Silviculture South, Alice Holt. M. J. Crosby (Forester) from Mid Scotland Conservancy to Genetics, Northern Research Station. H. L. Davies (Forest Officer II) from Wales Conservancy to Silviculture South, Alice Holt. D. Elgy (Chief Forester) from West England Conservancy to Silviculture South, Alice Holt. D. Kerr (Forester) from North Scotland Conservancy to Silviculture North, Kielder. J. Lumley (Principal) from Headquarters to Administration, Alice Holt. S. A. Mead (Forester) from Wales Conservancy to Silviculture North, Brecon. W. F. Rayner (Forester) from North Scotland Conservancy to Silviculture North, Perth. D. A. Thompson (Forest Officer I) from secondment with Overseas Development Administration, Jamaica to Wood Utilisation, Alice Holt.

New appointments: Miss A. C. Burnand (Scientific Officer) Statistics and Computing North, Northern Research Station. R. Harmer (Senior Scientific Officer) Physiology, Alice Holt. P. A. Lodge (Executive Officer) Establishments, Alice Holt. A. J. Moffat (Senior Scientific Officer) Site Studies South, Alice Holt.

Transfers out: Miss C. I. Derrick (Executive Officer) from Establishments, Alice Holt to Wales Conservancy. Mrs K. A. Fielding (Executive Officer) from Establishments, Alice Holt to Headquarters. R. G. Hands (Forest Officer I) from Wood Utilisation, Princes Risborough to East England Conservancy. G. R. Menzies (Head Forester) from Silviculture North, Northern Research Station to South Scotland Conservancy. C. D. Rider (Head Forester) from Silviculture North, Northern Research Station to South Scotland Conservancy. J. Stannard (Head Forester) from Silviculture North, Kielder to Mid Scotland Conservancy. R. E. Stuart (Forester) from Genetics, Northern Research Station to Wales Conservancy. R. J. Wallace (Forester) from Silviculture North, Lairg to Mid Scotland Conservancy. M. G. Wheeler (Executive Officer) from Office Services, Alice Holt to Wales Conservancy.

Promotions: S. J. Corcoran (Silviculture North, Brecon) to Head Forester. N. P. Danby (Silviculture North, Brecon) to Chief Forester. P. G. Gosling (Seed, Alice Holt) to Senior Scientific Officer. I. D. Mobbs (Statistics and Computing South, Alice Holt) to Principal Scientific Officer. P. R. Ratcliffe (Wildlife and Conservation, Alice Holt) to Principal Scientific Officer. D. R. Rose (Pathology, Alice Holt) to Head Forester. C. W. Shanks (Silviculture South, Alice Holt) to Head Forester. D. Wainhouse (Entomology, Alice Holt) to Principal Scientific Officer. C. Walker (Physiology, Northern Research Station) to Senior Scientific Officer.

Resignations: K. Rennolls (Senior Scientific Officer) Statistics and Computing South, Alice Holt. J. P. Wright (Scientific Officer) Site Studies South, Alice Holt.

Retirements: R. M. Brown, MBE (Chief Forester) Entomology, Alice Holt. R. E. Crowther (Principal Forest Officer) Silviculture South, Alice Holt. P. W. W. Daborn (Chief Forester) Silviculture South, Alice Holt. D. F. Fourt (Chief Forester) Site Studies South, Alice Holt. J. B. H. Gardiner (Chief Forester) Silviculture South, Alice Holt. E. R. Robson (Chief Forester) Silviculture North, Brecon. D. T. Seal (Principal Forest Officer) Chief Research Officer North, Northern Research Station.

Death: Miss J. J. Rowe (Principal Scientific Officer) Wildlife, Alice Holt.

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GLOSSARY

Latin names of trees cited by common name in this Report

Broadleaves

Alder, Common	*Alnus glutinosa*
Red	*A. rubra*
Ash	*Fraxinus excelsior*
Beech	*Fagus sylvatica*
Birch, Downy	*Betula pubescens*
Silver	*B. pendula*
Cherry, Bird	*Prunus padus*
Flowering	*Prunus* spp.
Chestnut, Sweet	*Castanea sativa*
Elm, Commelin	*Ulmus* × *hollandica* 'Commelin'
English	*U. procera*
Laurel, Cherry	*Prunus laurocerasus*
Lime, Common	*Tilia* × *europaea*
Small-leaved	*T. cordata*
Maple, Field	*Acer campestre*
Silver	*A. saccharinum*
Oak, English (Pedunculate)	*Quercus robur*
Scarlet	*Q. coccinea*
Plane, London	*Platanus* × *hispanica*
Poplar,	*Populus* spp.
Lombardy	*P. nigra* 'Italica'
Robinia	*Robinia pseudoacacia*
Rowan	*Sorbus aucuparia*
Sycamore	*Acer pseudoplatanus*
Walnut	*Juglans regia*
Whitebeam, Swedish	*Sorbus intermedia*
Willow, Weeping	*Salix* × *chrysocoma*

Conifers

Cypress, Lawson	*Chamaecyparis lawsoniana*
Cedar, (true)	*Cedrus* spp.
Western red	*Thuja plicata*
Fir, Douglas	*Pseudotsuga menziesii*
Grand	*Abies grandis*
Noble	*A. procera*
Pacific silver	*A. amabilis*
Hemlock, Western	*Tsuga heterophylla*
Juniper, Common	*Juniperus communis*
Larch, European	*Larix decidua*
Hybrid	*L.* × *eurolepis*
Japanese	*L. kaempferi*
Pine, Bishop	*Pinus muricata*
Corsican	*P. nigra* var. *maritima*
Jack	*P. banksiana*
Lodgepole	*P. contorta*
Macedonian	*P. peuce*
Monterey	*P. radiata*
Scots	*P. sylvestris*
Spruce, Engelmann	*Picea engelmannii*
Norway	*P. abies*
Sitka	*P. sitchensis*
White	*P. glauca*
Yew	*Taxus baccata*

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