



Forestry Commission

REPORT ON  
FOREST RESEARCH  
1989

Forestry Commission  
ARCHIVE

REPORT ON  
FOREST RESEARCH

for the year ended  
March 1989

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**Front Cover:** Aerial view of the Thetford wet timber store. The store was established to house stocks of windblown timber following the storm of October 1987 in south-east England. Wet storage reduces the risk of timber deterioration and significantly extends the marketable life of the produce. (38790).

**Back Cover:** A native Caledonian pine in Glen Affric.  
(D. A. Burdekin)

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## INTRODUCTION

By D. A. BURDEKIN

*Director of Research*

### **Advisory Committee on Forest Research**

Two visiting groups, one on Wildlife and Conservation and the other on Wood Utilisation Research, met and reported during the year. The first was chaired by Professor R. J. Berry (University College, London) and included Dr M. B. Usher (University of York), Dr W. E. S. Mutch (University of Edinburgh) and Mr G. F. Peterken (Nature Conservancy Council) as members. The group was clearly impressed with the high standard of research and the enthusiasm that they found in the Branch. They felt that there was a need to alleviate the heavy advisory load and they proposed, and it was accepted, that Private Forestry and Environment Officers in Conservancies should play an important role in providing the first point of contact rather than Forest District staff. The group also felt that interdisciplinary links were of critical importance. This coincided with the current emphasis being given to synecological rather than autoecological studies.

The second visiting group, to the Wood Utilisation Branch, was chaired by Dr G. K. Elliott (Price & Pierce Ltd) and had one member, Dr A. J. Petty (University of Aberdeen). The Branch has only one member and the visiting group thus outnumbered the staff! It was not surprising therefore that the group commented on the need for more staff but they also highly commended the current programme. Much of the Branch's work is undertaken by commissioning research and I welcomed the Group's recommendation that collaborative projects should be undertaken with industrial sponsors and with EEC projects.

I am most grateful to the chairman and members of these two visiting groups for giving so freely of their time and their interest and clear views on the future development of research in these areas. I would also like to thank Professor John Cooper for his great interest in forest research and I very much regret his retirement from Chairman of the Research Advisory Committee owing to ill health. At the same time, I welcome Dr J. P. Dempster, until recently Director South of the NERC Institute of Terrestrial Ecology, as the new Chairman.

### **Forestry Research Co-ordination Committee**

The total expenditure on forestry research in Britain increased to an estimated £16 million in 1988 largely due to increased support by the Agriculture Departments for research in farm forestry. The Forestry Research Co-ordination Committee (FRCC) has paid particular attention to this areas of research during the year. A sub-group on farm forestry collected detailed information and concluded that research in the socio-economic and environmental fields was underfunded. Members of the FRCC agreed for the first time to provide funds for open competition mainly from university researchers which would be administered under a NERC Special Topic scheme.

Two review groups reported during the year, one on the physiology of the growth of trees in stands and the other on forest economics and planning. Both made important recommendations, pressing for greater research efforts. The first



particularly recommended the need for one or more integrated experiments. These experiments would be monitored in as much detail as possible and would include treatments to promote the maximum growth of trees on the site.

The review group on economics and planning drew attention to the paucity of forest economics research generally and to the need to draw together the current rather disparate efforts. It was proposed that the Forestry Commission and the Economic and Social Research Council should collaborate in drawing up plans for the future development of a comprehensive research programme.

### **Research funding**

The total Forestry Commission expenditure on research during 1988/89 was £7.9 million, details of which can be found in Appendix IV. Expenditure has risen broadly in line with inflation and the number of non-industrial staff employed during the year was only marginally reduced. It will be noted that the two main areas of commissioned research funds were wildlife and conservation and wood utilisation. These are two expanding areas of research where resources for in-house research have not been available.

### **Highlights**

For the first time last year the Director drew attention to a number of items which might be of particular interest to the reader. A selection has been made below from this year's activities but it should be emphasised that these items do not represent a comprehensive summary of current research.

*Seed.* Studies of seed dormancy are showing interesting interactions between moisture and temperature in the prechilling period.

*Vegetative propagation.* The use of vegetatively propagated Sitka spruce has now become commercial practice but further improvements to propagation of this and other species are being sought.

*Tree improvement.* A wider range of Sitka spruce provenances is being investigated in order to cover the more extreme climatic regions of the UK. At the same time a detailed biochemical study has revealed identifiable differences within the native Scots pine populations.

*Farm forestry.* A total of 14 plots have now been laid down to demonstrate best practice in the establishment of trees in farm woodlands.

*Poplars.* There has been a resurgence of interest in poplars particularly as short rotation crops. Trials with improved clones from Belgium are now being established.

*Blue stain.* A joint study between entomologists, pathologists and timber technologists has revealed that logs harvested after the 1987 storm can be stored free of blue stain provided they are kept under constant water sprinklers.

*Effects of air pollution.* Studies in open-top chambers have demonstrated that beech seedlings grown in ambient air have different types of root systems from those exposed to filtered air.

*Grey squirrel control.* Newly designed 'environment-friendly' hoppers ensure that only grey squirrels feed on the poisoned bait and all other small mammals and birds, previously at risk, are denied access.

*Aeromechanics.* Aeromechanical studies of wind profiles above and within forest crops are beginning to yield interesting and potentially valuable results. A new design of a model tree is of special interest for wind tunnel experiments.

*Peat soils.* This soil type, with its peculiar shrinkage characteristics, continues to yield interesting results in relation to the soil water and oxygen regimes.

*Mr Arnold Grayson*

Mr Grayson retired on 17 April 1989 after serving for 7 years as an energetic and enthusiastic Director of Research. He took a keen interest in research on air pollution and resolved that adequate evidence should be obtained before determining whether trees were damaged by this agent. The multiple cause theory has now gained ascendancy with many factors, biotic and abiotic, likely to be involved.

He was very keen to evaluate the cost and benefits of many of the research projects undertaken by the Research Division. His publication on this subject (Occasional Paper 15) is a treatise which explores new techniques in this field.

I wish him well in his retirement; I am sure he will pursue his forestry interests with even more vigour!



## PART I

*The Work of the Forestry Commission*

## RESEARCH DIVISION

## SEED

**Research**

Noble fir (NF) seed commonly exhibits dormancy and for official seed testing purposes a 3 week prechill period at 4°C on top of moist filter paper is recommended to overcome this. But in the nursery NF emergence is only between 20 and 60 per cent of the seed capable of germinating in the laboratory. Hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) soaks at various concentrations have been successfully used to overcome dormancy in, for example, Douglas fir (Ching, 1959); western larch and Douglas fir (Shearer and Tackle, 1960); and subalpine larch (Shearer, 1961). The effect of using H<sub>2</sub>O<sub>2</sub> soaks to overcome dormancy in NF was therefore investigated.

NF seed were soaked at *c.* 25°C in water and 2, 7.5 and 30 per cent H<sub>2</sub>O<sub>2</sub> solutions for ½, 5 and 50 hours, drained and then set to germinate on top of moist filter paper at an alternating 20/30°C. Untreated seed and seed prechilled on top of moist filter paper at 4°C for 3 weeks were also set up and achieved germination levels of 61 and 73 per cent respectively. All soak treatments, whether in water or H<sub>2</sub>O<sub>2</sub> significantly reduced seed germination in comparison to these results (Table 1). The degree of damage was greater with increasing duration of treatment or H<sub>2</sub>O<sub>2</sub> concentration. Clearly for this NF seedlot H<sub>2</sub>O<sub>2</sub> soaks are not a suitable alternative to the laboratory top of paper prechilling method.

The most disturbing observation was the damage caused by soaking NF seed in water at 25°C. The universally adopted method for the bulk prechilling of NF seed, prior to nursery sowing, is to soak seed at 4°C for 48 hours, drain off the excess water and replace the moist seed at 4°C for 3–5 weeks. We subsequently tested the effect of water soaks at different temperatures and confirmed that a 4°C water soak for 50 hours also damaged the seed reducing germination to 31 per cent. It seems possible that the preliminary water soak is the major cause of poor nursery emergence in bulk prechilled NF.

**Table 1** Germination percentages after 35 days at an alternating 20/30°C of unsoaked noble fir seed and seed soaked in water and 2, 7.5 and 30 per cent hydrogen peroxide solutions for ½, 5 or 50 hours at *c.* 25°C.

Time (hours)	Hydrogen peroxide concentration (%)			
	0	2	7.5	30
½	54	53	48	11
5	45	17	8	2
50	17	1	0	0

*Report* 1988, pp. 5–6, reported the results of laboratory studies on a Corsican pine seedlot that was harmed by a 3-week moist prechill during official seed testing. This work was repeated on three newly acquired seedlots of Scots pine exhibiting similar harmful effects when germinated in official tests. In addition, the work was extended to a field experiment. Two hypotheses under test were that prechilling would reduce the germination of such seedlots when incubated over seven constant temperatures (10–40°C) in the laboratory or when sown in the field and that prechilling would delay field emergence, thereby shortening the growing season and reducing the end of season seedling size. In the laboratory study, two seedlots showed harmful effects of prechill on germination capacity at most temperatures but the other seedlot did not. In the field there were no significant differences in accumulated germination percentage, survival, seedling height or root collar diameter caused by prechill for any seedlot. Prechilling also increased field emergence for the first 15–20 days after sowing. These results are surprising in relation to the official test results at 20/30°C. Possible explanations are that the harmful effects of prechilling to germination rate and germination capacity observed in the official seed test results were reliable indicators of potentially adverse effects at most temperatures but their accuracy did not extend to 10°C. At 10°C in the laboratory study the germination capacity of all seedlots was unaffected by prechilling and the rate was improved. Nursery temperatures before and during seed germination were in the region of 10°C or lower.

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P. G. GOSLING, S. K. JONES

#### Service

Official and advisory seed testing occupied *c.* 70 per cent of staff time. Six hundred and eighty nine tree seed samples were tested: 186 from seed merchants and nurserymen, 67 from the Oxford Forestry Institute and 436 of the Forestry Commission's own seedlots.

P. G. GOSLING

## SILVICULTURE (SOUTH)

#### Plant production

Rooted cuttings of several broadleaved species, which included oak, elms, gean and poplars, were propagated for other research programmes. Work has continued for the East Hampshire Hangers Project on the propagation of selected trees of *Tilia cordata* Mill. from ancient woodlands. Rooted cuttings, which were propagated from 19 trees in 1986, were planted out in an outdoor

stock bed. Plants propagated from these stock plants will be used to reintroduce the original clones into the hangers.

R. L. JINKS

### Treeshelters

The main problem relating to current usage of this now established technique concerns the unreliable performance of beech when grown in treeshelters. It appears that the most likely cause of failure is infestation by the beech woolly aphid (*Phyllaphis fagi*) on the thinly cuticularised leaves formed in the protected environment of the treeshelter.

Two series of experiments have been established to examine this hypothesis; the first used shelters ventilated to varying degrees, the second compared growth rates in shelters where the aphids were introduced to susceptible trees while others were treated with insecticide. In neither series have significant differences been recorded.

Further work during the summer of 1989 will examine more closely the occurrence of this insect on ailing sheltered beech.

M. J. POTTER

### Natural regeneration

During the summer of 1988 a survey was undertaken to record the amount of natural regeneration on broadleaved sites devastated by the great storm of October 1987. Such natural regeneration could be an attractive means of restocking where sites are small or inaccessible and 1987 was a good seed year for beech in southern England and good, in parts, for oak.

Forty-five sites in 15 areas of forest were sampled and regeneration of principal broadleaves, mainly beech and oak, assessed. The results are shown in Table 2. About one-quarter of beech and oak stands which had been windblown appeared to have an acceptable stocking ( $> 2000$  trees  $\text{ha}^{-1}$ ) of timber species. However, it was clear from the survey that to take advantage of any regeneration mammal protection would be needed. Already by the time of the survey occurrence of regeneration was associated with patches of bramble, piles of branches, holly, etc., which had afforded some protection from browsing. Treeshelters offer the most convenient means of protection of small numbers of seedlings.

M. J. POTTER, J. EVANS

**Table 2** Density of natural regeneration by species (percentage of plots achieving a certain stocking level)

Stocking (plants $\text{ha}^{-1}$ )	Beech	Oak	Ash
Over 10000	5	14	95?
Over 2000	24	26	100
Over 1000	33	31	100
Over 200	65	49	100
0-200 (no regeneration in plot)	35	51	0

### Forest weed control

An experiment was established in 1988 to determine the tolerance of Corsican pine to terbuthylazine/atrazine at 2.5–20 kg a.i./treated hectare compared with standard atrazine at 5.0 kg a.i./treated hectare and untreated control. Herbicides were applied pre- and post-flush. Results showed that after one growing season there was no significant difference ( $p < 0.001$ ) in tree health following any of the treatments pre- or post-flush.

The control of woody weed growth (mostly birch) in young plantations of Corsican pine was investigated using imazapyr and two formulations of glyphosate at two dates (August and September). Imazapyr proved too damaging to the pine although it provided excellent control of the birch. The two formulations of glyphosate performed in a broadly similar manner when applied at medium and low volumes. There was no significant damage to the pine and good control of the birch with 0.72 kg a.i./treated hectare.

An experiment concluded this year showed that on Corsican pine, which had received 5.0 kg a.i./treated hectare of atrazine in years 1 and 2, there was no significant difference in tree height or stem diameter when similar applications of atrazine were made in years 3 and 4 compared with trees which were untreated in these later years. This was despite a highly significant reduction ( $p < 0.001$ ) in vegetation cover, particularly grass. The trees which were treated with 5.0 kg a.i./treated hectare for four consecutive years did show a transient and slight reduction in health but this had disappeared by the end of the fifth growing season.

D. R. WILLIAMSON

### Farm forestry

The joint FC/ADAS series of experiments has been expanded this year, adding sites at Boxworth (Cambs.) and Liscombe (Devon) Experimental Husbandry Farms to that established at Drayton (Warwicks.) in 1987. The experiments at Boxworth are similar to those at Drayton except that treatments are superimposed on to stubble rather than pasture. The experiment at Liscombe is a large species/mixtures trial.

In the species trial at Drayton, survival at the end of the first growing season ranged from 75 to 90 per cent, except for poplar. Unrooted cuttings of *Populus trichocarpa* 'Fritzi Pauley' failed to establish, probably due to the high pH of the soil. Several of the coniferous species appear to be suffering from lime-induced chlorosis.

In the establishment trial, growth and survival of the ash has been very good in all treatments, with no significant differences between stock type or ground preparation. For Corsican pine, however, survival was significantly ( $p < 0.001$ ) affected by stock type; mean survival for bare-rooted and containerised plants being 57 and 85 per cent respectively. Planting in raised plough ridges or black polythene mulching has not benefited survival or growth for either species.

C. J. POTTER, M. W. ALLEN

## **Arboriculture: Department of the Environment contract**

### *Urban tree study*

Study sites selected in 1987 continue to be monitored to examine relationships between tree growth, tree health, and soil conditions. The rusting pattern of steel rods placed in the soil is being analysed to derive information on soil oxygen profiles. A survey of 3600 urban trees throughout England has been initiated to collect data on tree species, health, planting position and growth, and to highlight future research needs.

### *Establishment of trees in hedgerows*

Three hedgerow trials have been established in addition to the five set up in 1987/88. Areas of investigation include:

1. the use of different sizes of treeshelters for establishing trees in existing hedges;
2. the effect on tree growth of controlling competition from weeds and from the hedge itself by cutting gaps in the hedge and using black polythene mulch mats;
3. the use of a range of planting stock, from seed to standards, for establishing trees in a new hedgerow;
4. the use of mechanically laid sheet mulches for hedgerow establishment.

### *Demonstration plots*

Amenity tree establishment demonstration plots have now been established at nine sites; with plots at Cannington College and Durham College being established in early 1989 (Figure 1). Demonstrations include the effects of weed control, stock size and individual tree protection on successful establishment. Seminars will be held at demonstration plots to encourage good establishment practices.

### *Plant quality*

Experiments were established in 1987 to test the field performance of hardy ornamental stock raised under nursery spacings of 10–50 cm at Luddington Experimental Horticulture Station. Second year results indicate no significant differences between treatments.

### *Release of trees in check*

Checked trees of a range of ages have been given repeated herbicide and fertiliser treatments. Younger checked trees respond most vigorously to herbicide and fertiliser, but often nearly as vigorously to herbicide treatment alone. Fertiliser treatment alone is generally little better than no treatment. The situation with semi-mature trees is not so clear, and research in this area continues as opportunities arise.

### *Stock size*

It has long been observed that smaller stock sizes (transplants and whips) establish more quickly and tend to grow more rapidly than larger stock sizes (standards and half standards). An experiment has been established to quantify differences and compare rates of growth and cost effectiveness of tree establishment using standards, whips, transplants and seed.



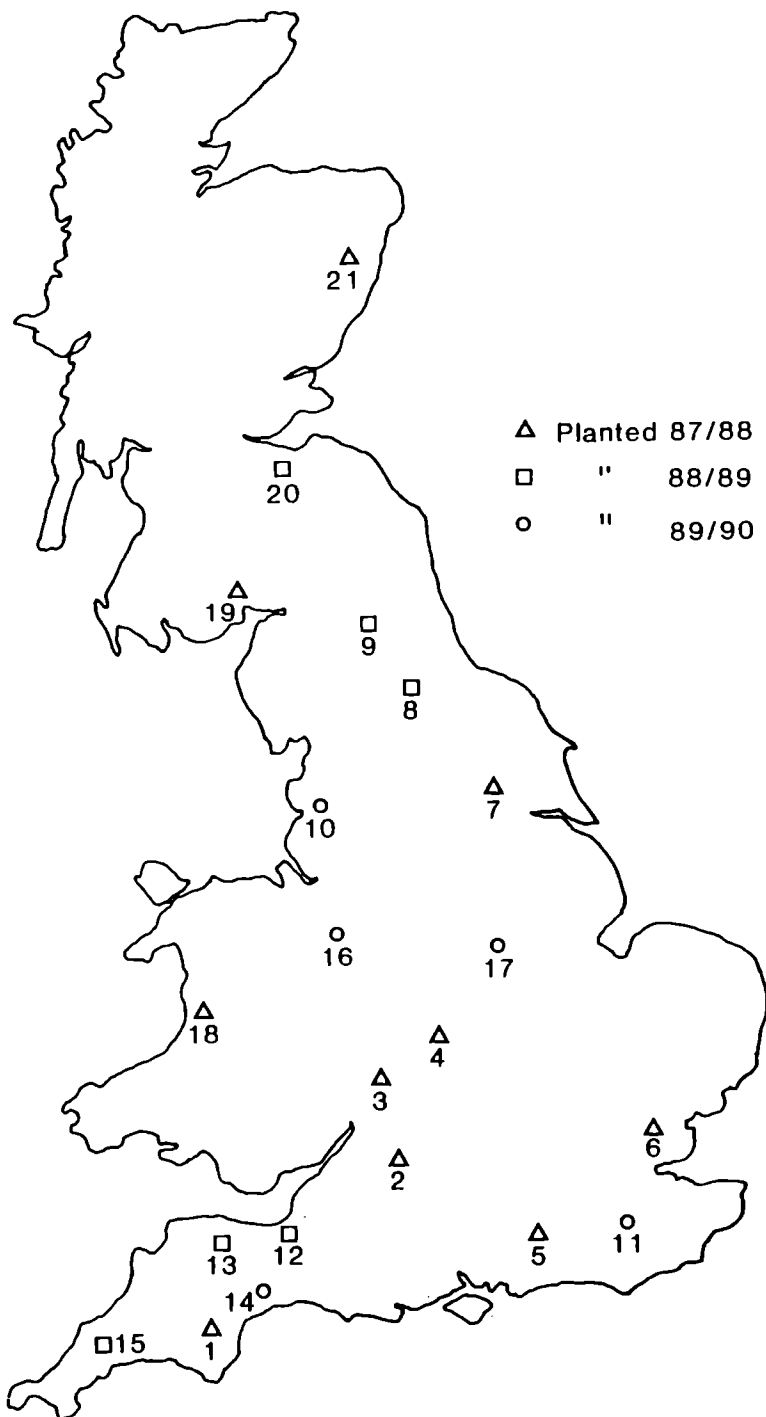


Figure 1 Location of tree establishment demonstration plots.

*Soil ameliorants*

A comprehensive trial has been established to test two widely used soil additives which the manufacturers claim improve survival and growth during prolonged dry periods. Previous trials of similar products have found no significant benefits from their use. The current trial will test them more severely under drought conditions created by an automatic rainshelter.

S. J. HODGE, S. M. COLDERICK

**Biomass: Department of Energy (ETSU contract)**

Rationalisation of this series of experiments on short rotation coppice crops for energy production has continued. Unsuccessful crops have been removed or replaced with new species/cultivars. These include *Salix aquatica* 'Gigantea', *Eucalyptus archerii* and red alder. *Populus* 'RAP' has continued to grow extremely well on the three southern sites. Growth of all species at Aberfoyle, near Glasgow, has been slow due to unfavourable climatic and site factors. The maiden cut was carried out in early 1989.

Biomass yields from last year's harvest were generally higher than for the previous one in 1985/86. This is thought to be due mainly to the increased number of shoots per stool, especially for poplar. Overall, yields for poplar were higher than for willow, although there was considerable variation between sites for both species. Rotation length had a greater effect on yield than spacing, although the effect of rotation is confounded with number of cuts which also affects yield. In most cases, yields for 1 m spacing and 2 year rotation were higher than for 2 m spacing and 4 year rotation.

C. J. POTTER, A. T. ARMSTRONG

**Long rotation coppice**

The 1986 *Report* (p. 11) cited two fertiliser trials in sweet chestnut coppice which indicated a significant response to applications of phosphate. This, plus anecdotal evidence of yield decline with successive rotations on infertile sites, has prompted two new nutrition experiments examining four rates of phosphate. They were laid down in the spring of 1989 in Kent and Sussex.

**Dendrology**

During the year, 2600 tree measurements were added to the British Isles Tree Register from 100 locations. Following the great storm in 1987 effort has been concentrated in south-east England. In London remarkably few notable large trees blew down but in Essex, Kent and Sussex the problem was more serious and assessment is still going on. Advantage was taken of work by the Forestry Commission Pathology Branch who assessed storm casualties. Their largest measurements have been incorporated into the register. Contributions have also been received from various outside organisations and several private individuals; collaboration which we welcome.

The total number of items now in the woody plant herbarium at Westonbirt Arboretum exceeds 1260. This facility is used to help answer the many plant identification enquiries received each year.

At Highnam Court in Gloucestershire a young previously unrecorded hybrid tree was discovered, a spontaneous cross between *Quercus ilex* 'Fordii' and *Quercus robur*. This plant has been moved to a more secure site in Buckland Arboretum, near Brecon, Powys.

J. E. J. WHITE

## Arboreta

### *Westonbirt Arboretum, Gloucestershire*

The last 12 months have seen many achievements at the Arboretum. In line with the 5-year management plan, eleven work sections were completed on schedule, including the thinning and redevelopment of the beech bank to increase representation of the genus *Fagus*.

New plantings totalled 756 of which 62 are new taxa added to the collection.

Propagation plans are well advanced with priority given to plants that are now rare in their natural habitat. Westonbirt now has 23 such plants identified.

Visitor numbers are well up on last year at 185 351. Numbers of school children visiting the educational unit was 11 566. Particularly pleasing features are a two-fold increase in school parties participating in the full day programme and a steady rise in numbers of college students.

The weather has been uneventful and only two trees were lost. Unfortunately one of these was the biggest silver maple (*Acer saccharinum*) in the country.

H. C. ANGUS

### *Bedgebury National Pinetum, Kent*

Clearance and restoration of storm damage continued throughout the year. The main Pinetum was re-opened for public access at Easter 1988.

The development of propagated materials retrieved from blown specimens has been excellent, particularly the *Chamaecyparis lawsoniana* cultivars. Donations of natural source seed are still being received.

The species collections of *Juniperus*, *Taxus* and the cultivars of *Chamaecyparis lawsoniana* have been registered and accorded National Collections status by the National Council for the Conservation of Plants and Gardens (NCCPG). Preparations are in progress to establish a collection of  $\times$  *Cupressocyparis leylandii* clones.

Harvesting of timber from the devastated forest plots has been completed. Sawlogs from 46 species are being used to investigate wood properties and conduct stress and grading tests by Wood Utilisation Branch.

Visitor numbers were only slightly down during the summer months despite the periods of closure and adverse weather.

J. A. McINTYRE

## INTER-BRANCH REPORT:

### SILVICULTURE (SOUTH) AND SILVICULTURE (NORTH)

#### Nursery herbicides

Joint experiments were carried out at Bush (Lothian) and Headley (Hampshire) to test potential nursery herbicides. Napropamide, tank mixes of diphenamid with both chlorthal-dimethyl and isoxaben, bifenox, cinmethylin and diflufenican were compared with diphenamid (standard) and untreated control for pre-emergence use on seedbeds. Three rates of each herbicide were tested on Sitka spruce, Japanese larch, birch and common alder. A summary of the results is given in Table 3.

Eight herbicides (diphenamid, napropamide, oryzalin, propyzamide, isoxaben, chlorthal-dimethyl, metazachlor, chloridazon) were applied to seedbeds at approximately one half and one quarter of the recommended rate at 6-week intervals during the growing season. The first application was made when the tree species (Sitka spruce, Japanese larch, birch and common alder) had reached the first true leaf stage. Two further applications were made before the end of the growing season. Weed control (on previously sterilised beds) was excellent; only the high rate of isoxaben and chloridazon gave slight tree damage.

Control of groundsel in Sitka spruce transplant lines was investigated using three rates of cyanazine + clopyralid, metazachlor, clopyralid and chloridazon + chlorbufam with atrazine and diphenamid (standards), glyphosate as a potentially damaging treatment and an untreated control.

No crop damage was detected from any treatment. All herbicides gave good post-emergence control of groundsel and all but glyphosate provided good residual control. Cyanazine + clopyralid and metazachlor also gave good control of invasive spurrey.

D. R. WILLIAMSON, W. L. MASON

**Table 3 Crop tolerance and overall weed control of pre-emergence seedbed herbicides**

	Tree species				Overall weed control
	Sitka spruce	Japanese larch	Alder	Birch	
Diphenamid	xx	xx	xx	xx	xx
Napropamide	xx	xx	x	xx	xx
Diphenamid/chlorthal-dimethyl	xx	xx	x	xx	xxx
Diphenamid/isoxaben	xx	xx	x	xx	xx
Diflufenican	x	x	x	x	xxx
Bifenox	xx	xx	x	x	xxx
Cinmethylin	xx	x	x	xx	x

Key: x Much poorer than diphenamid; xx equal to diphenamid; xxx better than diphenamid.

#### Farm forestry

Joint projects are planned on short rotation broadleaved crops for industrial feedstock and the impact of trees on field drainage systems.

Fourteen farm woodland demonstration plots have now been set up

throughout England, Scotland and Wales. These are part of a larger series run in conjunction with a similar project under the DOE arboriculture contract (see Figure 1). Their purpose is to demonstrate the effects of good and bad establishment practices on the survival and growth of broadleaved and coniferous trees. Differences in growth response to weed control, cultivation and treeshelters are already apparent at some sites. The plots at the Royal Showground proved very successful at the 1988 Show, convincing farmers and other tree-planters of the benefits of good establishment practices.

### Agroforestry

Collaboration with other research organisations through the United Kingdom Agroforestry Discussion Forum has continued. The three national network systems experiments planted in conjunction with the Institute of Grassland and Animal Production at North Wyke (Devon), the Macaulay Land Use Research Institute at Glensaugh (Grampian) and the Welsh Plant Breeding Station at Bronydd Mawr (Powys) have now had one complete growing season. Overall, tree survival has been good, except for the sycamore at North Wyke, where large numbers of plants had to be replaced after the first winter. With the provision of a short front stake to prevent the shelters twisting and the extension of the shelters to a height of 1.5 m, damage in these experiments, which are all grazed by sheep, has been largely confined to broken stakes, although vigorous rubbing has caused some treeshelters to be permanently distorted. Wilful damage by butting has only been observed when wethers (castrated young males) were introduced. Ewes and lambs appear largely disinterested in the trees.

C. J. POTTER, C. M. A. TAYLOR

### Poplars

Eleven new poplar clones were imported into Britain in 1985 from the Belgian Poplar Research Centre at Geraardsbergen (see Table 4). A series of clonal trials, which started in 1987, is being expanded to cover the whole of the country. Six of these clones ('Primo', 'Ghoy', 'Gaver', 'Gibecq', 'Boelare' and 'Beaupre') have now been registered in Britain under the Forest Reproductive Material Regulations 1977. This provisional registration is on the basis of screening for disease resistance and productivity in Belgium.

**Table 4** New poplar clones from Geraardsbergen, Belgium

Parentage	Clone
<i>Populus × trichocarpa</i>	'Colombia River' 'Trichobel'
<i>Populus nigra × deltoides</i> ( <i>P. euramericana</i> )	'Primo' 'Ghoy' 'Gaver' 'Gibecq'
<i>Populus trichocarpa × deltoides</i> ( <i>P. interamericana</i> )	'Unal' 'Beaupre' 'Boelare' 'Raspalje' 'Hunnegem'

Survival and growth of rooted cuttings planted in treeshelters has been excellent but rapid growth and large crowns have led to problems of instability and stem abrasion. Two-year height growth at Bedgebury (Kent) and Amphill (Bedfordshire) was between 2 and just over 3 m. In general, the *P. × trichocarpa* clones did least well with *P. × euramericana* clones intermediate and *P. × interamericana* best.

C. J. POTTER, C. J. NIXON

## INTER-BRANCH REPORT: SILVICULTURE (SOUTH), ENTOMOLOGY AND WORK STUDY

### Lowland restocking

The composition of the Lowland Restocking Special Project Team has been extended to include specialists in plant production, herbicides and plant physiology.

Studies of the size of containerised planting stock at Alice Holt and Thetford have indicated that within any batch of plants there is likely to be a very wide range of heights, with a high proportion of the planting stock – perhaps as much as half – not reaching prescribed standards. In light of this information, data from experiments with Corsican pine in Japanese paperpots (JPPs) established between 1972 and 1986 were re-analysed to examine in detail the effects of initial height. This revealed that in all cases examined the initial height of these plants exerted very little influence on subsequent growth or survival. This was also true of undercut stock. By contrast, in the one experiment that included transplants, survival declined as the size of plant increased.

The following new experiments have been established to examine aspects of restocking. Entomological studies have extended the work on the phytotoxic effects of insecticides and the effectiveness of different methods of application. A work study trial compared the efficiency of different planting methods for containerised stock; the growth rates of trees planted by each method will be monitored. A series of silvicultural experiments will compare the growth of containerised trees after careful handling and careful planting with that of trees from a range of less favourable treatments.

Root development mechanisms are not fully understood but it has been shown that root constriction by bending can inhibit translocation of carbohydrates (Hay and Woods, 1978). In order to examine whether this is reflected in root growth potential (RGP) – see *Reports 1985–87* – 20 Douglas fir plants were carefully planted in pots, ensuring that the root systems were well-distributed, and 20 plants were similarly treated except that the main roots were bent through 90° at 5 cm below the root collar. After 21 days RGP of all plants was assessed and no significant difference between treatments was detected (the mean RGP for the bent roots was 20.2 and for the controls, 19.6).

RGP testing of insecticide treated planting stock at Thetford will be expanded using dedicated controlled environment facilities.

M. J. POTTER, S. G. HERITAGE, J. C. CLARKE

## Reference

Hay, D. L. and Woods, F. W. (1978). Carbohydrates in planted root. In, *Root form of planted trees* symposium. Canadian Forest Service, BC, Canada.

## SILVICULTURE (NORTH)

### Silviculture (North) Branch re-organisation

Following the closure of Fort Augustus Station in 1987, staffing and organisation was again reviewed and the four Regions have been reduced to three Regions as shown in Appendix V. This has been accompanied by a reduction of one Forest Officer IV at each of Lairg and Kielder areas.

In order to increase the capacity to publish experimental data from the species project group and to undertake research on broadleaves in the uplands and to verify the forest capability classification for various species, a new project leader was appointed (C. J. Nixon).

D. B. PATERSON

### Production of planting stock

Research continued on a wide range of plant production systems including vegetative propagation, precision sowing and undercutting, and containerised seedlings.

#### *Vegetative propagation of conifers*

The effect of incorporating different nutrients in the propagation medium upon the subsequent rooting of Sitka spruce cuttings was investigated at Bush nursery (Lothian). Nitrogen, phosphorus, potassium, calcium, magnesium and fritted trace elements were incorporated singly or in combination in a 2<sup>6</sup> factorial design. The propagation medium used was a 1:1 pine bark:sphagnum peat mixture with a further 10 per cent added grit. Cuttings were inserted in March and rooting and growth were assessed after 24 weeks. Fertilisers had no effect upon rooting percentage since all treatments showed very good rooting with an overall mean of 99 per cent rooted. Incorporating nitrogen significantly increased root volume ( $p < 0.001$ ) and this effect was greater in the absence of phosphorus ( $p < 0.01$ ). Both nitrogen and trace elements improved height growth ( $p < 0.001$  and  $p < 0.01$  respectively) and there was a positive interaction ( $p < 0.01$ ) between these treatments. The results confirm earlier work indicating that rooting percentage of Sitka spruce cuttings is not enhanced by incorporating basal fertilisers. However, they also show that performance after rooting can be improved by appropriate nutrients, e.g. nitrogen and trace elements.

Further work was carried out to investigate the rooting of first and second cycle hardwood cuttings of hybrid larch (*Report* 1987, p. 20). First and second cycle cuttings of six hybrid larch families were inserted in March at Newton nursery (Grampian) and assessed after 22 weeks. Overall rooting percentage was 95 per cent. There were significant differences between families for both root score ( $p < 0.001$ ) and rooting percentage ( $p < 0.01$ ). However, no differences were found between cuttings of the two cycles, which confirms the previous work. The

results indicate that a two propagation cycle system could be used for bulking up hybrid larch without loss of rootability.

W. L. MASON, M. K. HOLLINGSWORTH, A. A. GREEN, J. DAVIDSON

#### *Accelerated transplant system*

Field scale trials have been carried out since 1986 to test the feasibility of growing conifer seedlings in small modules (20–30 cc) in a greenhouse for 2–3 months and then transplanting them into an open nursery using specialist machinery (Plate 4). After transplanting, the seedlings are grown on for 16–20 months to produce a plant of usable size. This system should provide more uniform seedlings without the root distortion characteristic of bare-root transplant production. The favourable germination conditions in a greenhouse should increase seedling yields compared with open nursery production. Although usable plants of Douglas fir, Sitka spruce and Scots pine have been produced, costs of production have been high and transplanting outputs have been disappointing. The basic problem identified has been one of variable seedling quality, particularly in relation to the coherence of the rooting plug once the seedling is extracted from the module. In these small modules, plug cohesion is critically influenced by compost structure and watering regimes, and requirements vary by species. Therefore, this system cannot be recommended for operational use until growing regimes in the greenhouse have been defined more closely.

W. L. MASON, R. E. J. HOWES, T. COOPER

#### *Inoculation of alders*

Collaborative work with Glasgow University and ITE has shown that nursery and forest performance of red alder seedlings can be improved by inoculation with selected *Frankia* strains (McNeill *et al.*, 1989). Unfortunately, these selected strains are not yet available in commercial quantities, so nursery managers wishing to inoculate alder seedbeds must rely upon nodules collected from roots of mature trees. These nodules are crushed and homogenised prior to application in aqueous suspension.

An experiment at Bush nursery examined the rate of application that was required to achieve adequate nodulation. All inoculated treatments were found to have significantly ( $p < 0.001$ ) greater nodule dry weight than uninoculated controls, and differences within inoculated treatments were minor. There were no significant differences in height growth. The results suggest that a rate of 1–2 g crushed nodule fresh weight  $m^{-2}$  should produce satisfactory nodulation.

W. L. MASON, M. K. HOLLINGSWORTH

#### Reference

- McNeill, J. D., Hollingsworth, M. K., Mason, W. L., Moffat, A. J., Sheppard, L. J. and Wheeler, C. T. (1989). *Inoculation of Alnus rubra seedlings to improve seedling growth and forest performance*. Research Information Note 144. Forestry Commission, Edinburgh.



## Species

### *Yield prediction at low elevations*

The increasing emphasis on planting at lower elevations has highlighted the need for more accurate predictive yield models for the wide range of species that can be grown successfully on these favourable sites. A preliminary investigation was conducted to establish how much of the required data could be extracted from experiments, records and sample plots and previous site-yield studies. Data were included from crops below 250 m elevation which were 15 years or older and amounted to some 237 data sets for the 10 species chosen. This proved inadequate for multivariate analysis for any of the species, with the possible exception of Sitka spruce. The coverage for broadleaves was particularly poor. Therefore, a field sampling programme will have to be initiated in state and private forests to provide sufficient yield data for subsequent analysis.

C. J. NIXON

## Nutrition

### *Copper deficiency*

During the Forest Health Day at Rothbury Forest District (Northumberland) in July 1988 some young Sitka spruce trees displaying severe growth distortion were collected. The most severely affected tree had lost apical dominance and shoots were twisted and growing towards the ground. However, the growth was vigorous and there was no sign of needle loss or discoloration.

A subsequent survey of Harwood Forest, the origin of the samples, indicated that a number of recently restocked compartments contained trees with similar growth disturbances. The crops ranged from 3 to 5 years of age and had been planted on double mouldboard ploughing on peaty soils, ranging from peaty gley to deep peat, overlying Carboniferous limestone. In some compartments trees had lost leading shoots due to frost damage, with many affected trees unable to re-establish apical dominance. A few trees in two compartments were multi-stemmed, but this had occurred prior to planting and was assumed to be due to damage in the nursery.

In addition, several pole-stage Sitka spruce stands (planted in the 1950s) demonstrated loss of apical dominance and distorted growth on otherwise vigorous, healthy stands. These symptoms have only been noticed in pole-stage stands on two other occasions – on a flushed peat at Loch Assich in Inverness Forest District (Highland) and on cutover and raised bogs in Eire. Based on the visual symptoms and preliminary foliage analysis results, copper deficiency was diagnosed, which has previously only been recorded in plantations on fertile peat sites where there are high levels of available nitrogen. Normally crops affected in this manner do not cover large areas, but the area at Rothbury was felt to be sufficiently large to warrant further investigation. The first stage has been initiated, involving an intensive survey and sampling of two restocking areas by the Department of Forestry and Natural Resources at Edinburgh University.

### *Sewage sludge*

The first stage of the investigation into utilising sludge as a forest fertiliser in Scotland has now finished, with five experiments established in conjunction with the Water Research Centre on a range of crop and site types. Although these experiments are designed to run for some time, promising early growth responses

have led to the initiation of the second stage – the establishment of operational pilot trials. These trials will allow greater practical experience to be gained, widen the crop and site type coverage and enable managers in the forest industry and local authorities to gain confidence in the techniques.

Discussions have taken place with Highland, Grampian, Tayside, Strathclyde and Borders Regions and the Forestry Commission, Economic Forestry Group and Tillhill to establish a series of trials. These will link towns with current or predicted sludge disposal problems and forest areas which require addition of nutrients. Treatment has commenced on two sites and a further eight sites are at different stages of progress.

C. M. A. TAYLOR

### **Cultivation, site preparation and drainage**

The work with Site Studies (North) Branch to quantify water-table depth on spaced-furrow ploughing and mole-drained ground has continued (*Report* 1988, p. 18). Further borehole water level readings were taken at the experiments at Glendaruel (Strathclyde) and Angus (Tayside) during a 12-week period in autumn 1988. The results confirm the initial findings that mole drainage at 2 m intervals to a depth of 40 cm is more effective than D45/T60 ploughing at controlling winter water-tables on loamy-textured gleys. There is no sign in the monitored water levels of any deterioration in performance of the mole channels but the situation will be studied again in the future.

An analysis of growth of Sitka spruce to age 7 in an experiment in Moffat (Borders) (*Report* 1982, p. 15) has demonstrated the poorer establishment performance experienced using only ripping plus additional herbicide treatment on a peaty ironpan soil. The mean height growth to year 7 was 1.57 m on the ripping and was significantly poorer ( $p < 0.001$ ) than that on spaced furrow (1.82 m) or complete ploughing (1.98 m). The height increment between years 6 and 7 was also significantly poorer ( $p < 0.05$ ) on the ripping at 37.3 cm compared with 43.5 and 45.3 cm on the spaced furrow and complete ploughing respectively. In addition to the height penalty there was also poorer survival on the ripping treatment during the first 6 years, with 9.8 per cent beat-up required whereas only 1.8 per cent required replacing on the spaced furrow ploughing and 2.8 per cent on the complete. In operational practice these differences are likely to be magnified. Work on the rooting patterns on the different treatments is planned for the coming year.

C. P. QUINE

### **Stability**

#### *Windthrow*

Work continues on the network of windthrow monitoring areas (*Report* 1988, p. 19). Priorities for ground survey have now been determined and baseline aerial photography has been obtained. In autumn 1988 a network of 10 anemometers and windvanes was established on exposed sites within or adjacent to the monitoring areas. These will act as reference indicators of the annual wind input, as well as giving a unique insight into the wind climate of upland Britain. The selected sites range from 140 m asl (Leanachan, Highland) to 479 m asl (Kielder,

Northumberland) with eight situated above 300 m. In contrast only five of the 133 sites in Britain currently contained in the Meteorological Office Monthly Weather Report are sited above 300 m asl.

The winter of 1988/1989 marked the return of damaging winds to northern Britain after a series of relatively 'quiet' years. For hours with gusts in excess of 47 knots (54 m.p.h.,  $24 \text{ m s}^{-1}$ ), 1985 and 1987 rank as the two least windy years in the last 21 at both Prestwick and Eskdalemuir, the third and fourth at Wick and the second and fourth at Dyce.

In most parts of northern Britain the strongest winds of the winter were experienced in the period 12–14 February 1989 and damage was reported from northern England to north Scotland. The Black Isle forests (Easter Ross) were particularly badly affected by the strong north-westerly winds. The highest windspeeds recorded on our network were from a hilltop site at Glentroll (Dumfries and Galloway) where the maximum mean hourly windspeed was  $35 \text{ m s}^{-1}$  (78 m.p.h.) and the maximum gust was in excess of  $47 \text{ m s}^{-1}$  (105 m.p.h.) – the highest gust recorded at the Meteorological Office site at Prestwick, only 40 km away but at lower elevation, was  $35 \text{ m s}^{-1}$  (78 m.p.h.). Unseasonal strong winds on 25 July 1988 also caused some windthrow particularly in north-east Scotland and resulted in considerable leader breakage in many crops.

Data collected by Forest Surveys during routine crop survey were collated in an attempt to assess the performance of the Windthrow Hazard Classification over a wider area than that covered by the monitoring areas. The data from this trial, together with those obtained from Conservancy harvesting managers, proved useful in broadly confirming the choice of terminal heights for the forthcoming production forecast initial run. Minor adjustments were made to Windthrow Hazard Class 4 predictions.

### *Exposure*

Two hundred and thirty two exposure flags are currently in use to provide estimates of wind exposure – of these 79 are to improve the wind zonation, 35 to define plantable limits for afforestation schemes and the bulk of the remainder are to compare exposure between experimental sites. Researchers from Japan and Iceland have enquired into the technique with a view to obtaining supplies from us of the special Madapolam cloth used for the flags.

C. P. QUINE, B. R. REYNARD

### *Aeromechanics*

Measurements have continued at Rivox (Nithsdale Forest District) on the interaction between wind and trees (*Report* 1988, p. 19). The 30 m mast had eight additional fast response anemometers attached, to give seven anemometers above the canopy and five within the canopy. Data recording began at the end of October 1988 and continued until the middle of January 1989, whenever suitable weather conditions existed. Some extremely strong winds were recorded during this period and a unique data set has been obtained. This will provide information on the structure of the wind field above and within the forest canopy and the mechanism by which downdrafts penetrate the canopy and transfer energy to the trees. During a period of a week, three anemometers were moved from the 30 m mast on to another mast 12 m away. These anemometers were placed at the same height as three anemometers on the 30 m mast so that

horizontal continuity of the airflow above and within the canopy could be investigated. The experimental equipment has now been moved to Kershope Forest (Kielder Forest District) where the relative stability of trees subjected to different respacing treatments in a mensuration experiment will be assessed.

Following assessment of the mechanical characteristics of ten Sitka spruce of approximately 15 m height, a detailed requirement has been set out of the necessary characteristics for the model trees to be used in the wind-tunnel work with Oxford University (*Report* 1988, p. 19). A prototype model tree has been produced by plastic injection moulding techniques which closely fits these requirements and production of 12 000 models will begin shortly.

Intensive measurements of the characteristics of the airflow over the Kintyre peninsula, Argyll were carried out during a 5-week period starting at the beginning of February 1989. This was part of a joint project with the University of Manchester Institute of Science and Technology (UMIST) to investigate the nature of airflow in forested upland terrain. Wind speed and wind direction at a height of 10 m were recorded continuously throughout the period at nine sites and were also available from the permanent meteorological station operated by the Meteorological Office at Machrihanish Airfield. During periods of particular interest the information from two fast response sonic anemometers mounted at 5 and 10 m on a radio mast was also recorded. For the final 2 weeks of the project the UMIST instrumented aircraft made measurements over the area of wind speed, wind direction, turbulence levels, temperature and humidity at heights up to 9000 ft above MSL. Conditions throughout the period were ideal with a persistent westerly airflow which on a number of occasions reached speeds of over 100 m.p.h. at the most elevated sites.

B. A. GARDINER, B. R. REYNARD

### **Upland restocking**

The restocking special project team completes its 3-year term in April 1989. Due to the recognised importance of plant quality in achieving establishment success, a training course entitled 'Plant care and planting' has been prepared in conjunction with Education and Training Branch to transfer the results of recent research to silvicultural managers. Research continues to assess the effects of planting position on root spread and stability and, in conjunction with Physiology Branch, to develop a method suitable for use by nursery staff to assess plant quality rapidly and to determine safe lifting dates and storage schedules for the major commercial species of conifers and broadleaves. Co-operative work is being carried out with Work Study Branch in evaluating mounding machinery; recent trials assessed the Donaren moulder on an Osa 280 forwarder chassis.

D. G. NELSON

### **Establishment specification for Sitka spruce restocking**

Three experiments planted in 1982 compared the survival and early height growth of Sitka spruce on uncultivated restock sites in Glenbranter (shallow peat), Huntly (surface water gley) and Kershope (flushed gley). Two plant sizes were specified, small (10–20 cm) and large (21–50 cm), plus or minus complete weeding and plus or minus deer fencing.

*Fencing*

With the levels of browsing present at that time, fencing has had no significant effect ( $p < 0.05$ ) on survival of either small or large plants, though there was almost always a small improvement with fencing.

For both plant sizes, fencing increased 6-year height significantly ( $p < 0.05$ ) at Glenbranter and Kilmichael, while at Huntly the increase was not significant (Table 5).

**Table 5** Height at 6 years of two plant sizes of Sitka spruce, fenced or unfenced, on three uncultivated restock sites (cm)

Treatment Plant size		Forest		
		Glenbranter	Kershope*	Huntly
Fenced	large	193	153	169
	small	167	143	76
Unfenced	large	137	118	158
	small	108	118	65
LSD(5%)		19	23	22

\*the 'small' plants here were within the large plant specification at an average of 22 cm.

*Weeding*

## 1. SURVIVAL

On the less weedy site at Glenbranter, herbicide application over the complete plot did not have a significant effect on survival of either plant size. On the two surface water gley sites the results were mixed. At Huntly large plants survived well and small plants did not on both weeded and unweeded sites. At Kershope survival was significantly ( $p > 0.05$ ) better where grass weed control was carried out, and this may be explained by the large degree of grass cover here (66–75%) when planted (Table 6.)

**Table 6** Survival at 6 years of two plant sizes of Sitka spruce, weeded or not weeded, on three uncultivated restock sites

Treatment Plant size		Forest		
		Glenbranter	Kershope	Huntly
Weeded	large	90	87	93
	small	87	92	66
Unweeded	large	89	60	93
	small	76	63	34
LSD (5%)		12.3	19.1	10.6

On potentially weedy sites, this suggests that the large (30 cm) plants used can become established adequately without herbicide or cultivation if planted before the coarse grasses invade, but if planting is delayed, grass control is necessary. Survival of small (9–15 cm) plants is not acceptable on such weedy uncultivated sites, and they should therefore not be used in such conditions.

## 2. HEIGHT

The results are not clearcut. Where there was a difference in initial plant size, the taller trees grew faster, and in all cases the weeded trees grew faster than the unweeded ones, though the differences were not always large. At Glenbranter this was only 1 cm for the weeded large plants over the unweeded large plants. Unweeded small plants at Huntly were frosted.

D. G. NELSON

## Herbicides

### *Rhododendron control*

Complete bushes were sprayed with a 40 per cent solution of ammonium sulphamate (Amcide) monthly between August 1984 and July 1985 through a Tecnomat T16P knapsack sprayer and the degree of control assessed annually. Good control of the 1.0–1.5 m high bushes was only achieved with applications between March and June but, after apparently getting complete control for 2 years at these application times, regrowth began in year 3. A further consolidation treatment would therefore be required in the third or fourth year if complete control is to be achieved.

Glyphosate was applied to freshly cut stumps at a range of concentrations (0, 25, 50, 75 and 100 per cent) at 2-monthly intervals through the year from May 1984 till March 1985, and the degree of control assessed annually. After 3 years complete control was achieved with the 25 per cent solution only from May to July and November to January. As the maximum concentration of glyphosate which can be used for stump treatment is 20 per cent (see Field Book 8), complete control is only likely to be achieved by treating freshly cut stumps during the above months. Even with the 75 per cent solution complete control could not be achieved with the March application when sap would be flowing in the plant.

D. G. NELSON, D. R. TRACY

## Treeshelters on upland sites

Two experiments were planted in 1983 to extend the lowland work on treeshelters to upland sites and these are now providing interim results. Both the 3 and 6 year height and survival of the tree species used have been analysed. On a severely exposed site at Tummel Forest there were no significant differences between the height growth of oak, birch, rowan, alder, Sitka spruce, Douglas fir or hybrid larch protected by Netlon treeguards, shelterguards and Correx polypropylene treeshelters. The survival rates of the oak and alder were markedly reduced in the unsheltered controls because of browsing damage, mainly by hares (see Table 7). The second experiment, on a sheltered site at Glengarry, has shown greater species/shelter interactions with the growth of oak in particular being significantly ( $p < 0.01$ ) enhanced by the polypropylene shelters. Conifers have gained little benefit, other than protection from browsing, from the shelters on either site.

The mesh treeguards used (N), while proving very robust, have produced much distorted growth as tree branches and leaders have tended to grow through the plastic mesh and become constricted. Trees emerging from the top of all types

of shelter have also suffered some abrasion. Both sites have emphasised the need for continued maintenance when using treeshelters, especially under exposed conditions and cast doubt on their value for most upland species except where browsing levels are high.

**Table 7** Height and survival of oak, alder and Sitka spruce after 6 years, planted in both treeshelters and guards

Species	Shelter type	Tummel		Glengarry	
		Height (m)	Survival (%)	Height (m)	Survival (%)
Oak	O	0.17	47	0.98	27
	N	0.76	100	1.37	87
	P	0.95	100	2.15	67
	S	0.73	100	1.95	87
Alder	O	0.11	7	2.54	53
	N	1.27	80	2.38	53
	P	1.21	67	2.07	20
	S	1.25	67	2.14	67
Sitka spruce	O	0.71	80	0.33	13
	N	0.70	93	0.72	47
	P	0.81	93	0.00	0
	S	1.00	73	1.09	60

O = No shelter; N = Netguard; P = Polypropylene (Correx); S = Shelterguard.

Tummel: Severely exposed site with a peaty podzolic soil. Subjected to extensive browsing by hares.

Glengarry: Sheltered site with a brown earth soil, but situated in a frost hollow.

The 3-year results from a second series of four treeshelter experiments set up in 1986 are tending to confirm these initial findings. Further assessments will help illustrate the specific benefits and the problems arising from the use of treeshelters in the uplands.

C. J. NIXON, D. G. NELSON, F. S. SMITH, D. R. TRACY

### Farm forestry

Four demonstrations of tree establishment methods on farmland have now been established in Scotland and Wales – one in conjunction with each of the Scottish Agricultural Colleges (SAC) and one with ADAS (Wales). Differences in the growth response to different levels of weed control and cultivation appear to be emerging across the sites. This has led to agreement with the SAC Conservation and Environment Committee on conducting joint research on establishment techniques, involving a series of experiments covering the major site types likely to be removed from agricultural production.

C. M. A. TAYLOR

## INTER-BRANCH REPORT:

### SILVICULTURE (NORTH) AND SITE STUDIES (SOUTH)

#### Reclamation of upland sites

At Benbain opencast coal site in the Kyle block of Ayrshire and Arran Forest District, several experiments have recently been established to investigate the nutritional problems of conifers planted on reclaimed land. Fairly severe climatic conditions combined with the poor nutritional status of the site make species choice very limited. Parts of the area have been restored with redistributed stored topsoil which is very stony and low in humus content. However, the majority of the site has received a final top layer of about 1 m of redistributed peat over the mineral soil. One experiment (Kyle 9 P86) particularly investigates various inputs of nitrogen to pure Sitka spruce on both peat and mineral sites and, although there are no major treatment differences within the sites to date, there is a very definite colour and growth response between sites in favour of the peat topsoil. Table 8 shows height and increment responses achieved up to 3 years.

**Table 8** Comparison of the height and increment of Sitka spruce on opencast spoil with and without a top layer of peat

Treatments*	Height (cm)				Increment (cm)	
	At planting		3 years		3 years	
	Peat	Mineral	Peat	Mineral	Peat	Mineral
No nitrogen	39.0	39.9	90.2	52.2	51.2	12.3
Legume (Maku) sown	38.7	37.5	80.4	54.4	41.7	16.9
Above + added phosphate	36.5	38.3	85.6	54.2	49.1	15.9
Interplanted RAR	35.3	38.3	83.3	57.9	48.0	19.6
Biennial urea (2 applications to date)	37.7	43.8	87.5	61.9	49.8	18.1
Periodic urea (1 application to date)	35.4	38.5	87.4	63.0	52.0	24.5
Mean	37.1	39.4	85.7	57.3	48.6	17.9

\*Standard phosphate/potash application to all plots at planting

Statistical analysis shows height and increment after 3 years significantly improved on peat ( $p < 0.01$ ). This treatment may provide an alternative to supplying nitrogen by nodule fixation in alder mixtures where peat is the original land surface and where alder is less suitable because of exposure.

J. D. McNEILL, A. J. MOFFAT



## SITE STUDIES (SOUTH)

### Chemical analysis

Analysis for major nutrients was carried out on 350 whole shoot and 4400 foliar samples during the year. The shoot samples were from the Silviculture (South) Branch biomass experiments funded by the Energy Technology Support Unit of the Department of Energy. In addition, 3500 samples from Silviculture (North) and Site Studies (South) Branches were submitted for starch and soluble sugar analysis. Changes in the methods have made these analyses less labour intensive so that 1400 samples which had been submitted last spring were also analysed by the end of 1988.

E. WARD, S. E. BENHAM, P. CROW

### Reclamation

#### *South Wales opencast spoil*

The growth of conifers planted on restored opencast spoil in South Wales is very variable; some sites which give moderate yields adjoin areas of very poor yields. Under a 1-year contract from British Coal this variability is being investigated to devise remedies to improve the poorer growth, and to aid future restoration practice. Ten study areas have been identified on opencast soil in Rheola Forest District, and work has begun to examine the growth and foliar nutrient concentrations of Japanese larch in relation to site factors. Boreholes, tensiometers, gypsum blocks and steel rods have been installed to assess soil drainage and aeration status, and soil samples from each site have been analysed for selected chemical properties. Work has begun in the examination of soil physical properties in relation to tree rooting.

A. J. MOFFAT, N. A. D. BENDING, C. J. ROBERTS

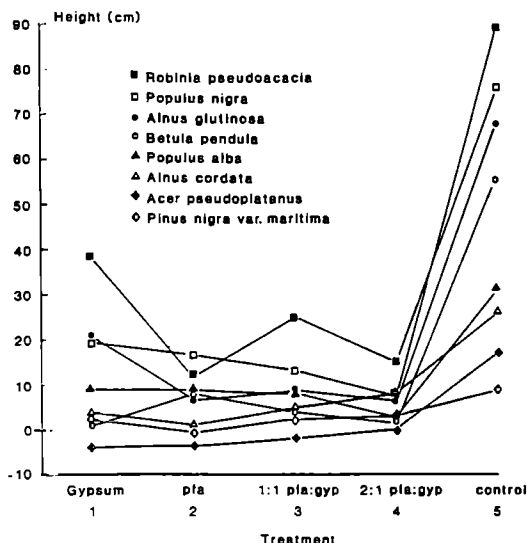


Figure 2 Mean height increment of eight tree species after one season's growth in gypsum and/or pulverised fuel ash substrates.

### *Tree growth on waste products from coal burning power stations*

Coal burning power stations are being fitted with flue gas desulphurisation plants which will produce large quantities of gypsum as a by-product. The Central Electricity Research Laboratories (CERL) have awarded a 3-year contract to study the performance of trees on this material, and to compare it with performance on pulverised fuel ash (pfa). A nursery experiment at Alice Holt is examining the growth of eight tree species planted in four combinations of these two materials. Figure 2 shows the mean height increment of these species after one season. Growth on all substrate mixtures was less than in a potting compost control, but some species, notably common alder, false acacia and black poplar, have shown reasonable tolerance to gypsiferous materials. A second experiment to examine the rooting habit of these trees in different layers of gypsum and pfa has been established at Headley Nursery.

### **The use of sewage sludge in reclamation**

In 1986 an experiment was set up at Rogate, West Sussex, to examine the use of 'cake' sludge as a topsoil substitute. At 3 years of age growth of larch has increased by 117 per cent on plots given 300 tonnes ha<sup>-1</sup> compared with the control, and foliar nitrogen concentrations increased from 1.35 to 2.12 per cent, bringing the trees out of deficiency levels. Trials to examine the role of liquid sewage sludge on the growth of larch and alder planted on opencast coal spoil in South Wales have been set up.

A. J. MOFFAT, C. J. ROBERTS

### **Air pollution**

#### *Monitoring of forest condition*

Two projects to monitor forest condition were continued in 1988. The first is a systematic assessment of forest condition and is part of an annual assessment undertaken throughout the European Community. The results indicate that there has been a slight deterioration in the crown densities of trees since the 1987 assessment. This has mainly taken place among the conifers. An exception was lodgepole pine which has shown a substantial improvement during the year. Broadleaves were very variable, with ash and birch deteriorating and sycamore improving.

The second project is an extension of the forest health surveys undertaken in previous years (*Reports* for 1985, 1986, 1987 and 1988). As a result of the storm of October 1987 in south-east England, together with normal felling operations and a certain amount of plot rationalisation, 22 plots used in the 1987 assessment were abandoned. These were replaced by 69 new plots, giving a total of 309 plots. The results (Figure 3) indicate that the crowns of Sitka spruce and Scots pine have deteriorated during the past year, whereas Norway spruce has remained approximately the same. No clear trend is apparent among oak, whereas beech has shown an improvement.

J. L. INNES

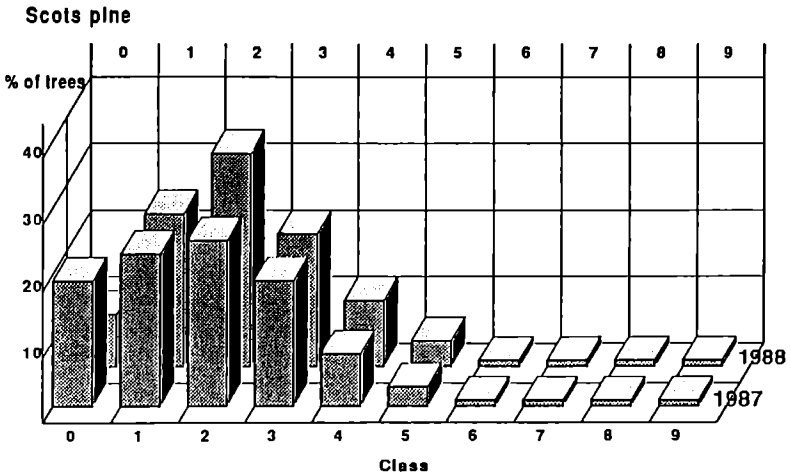
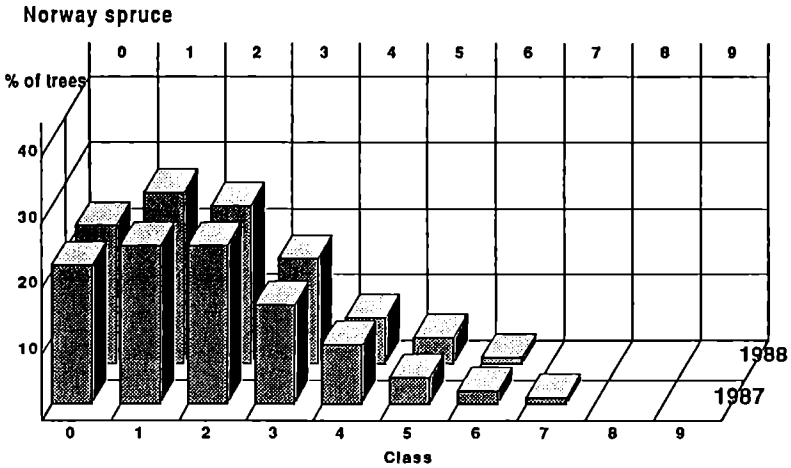
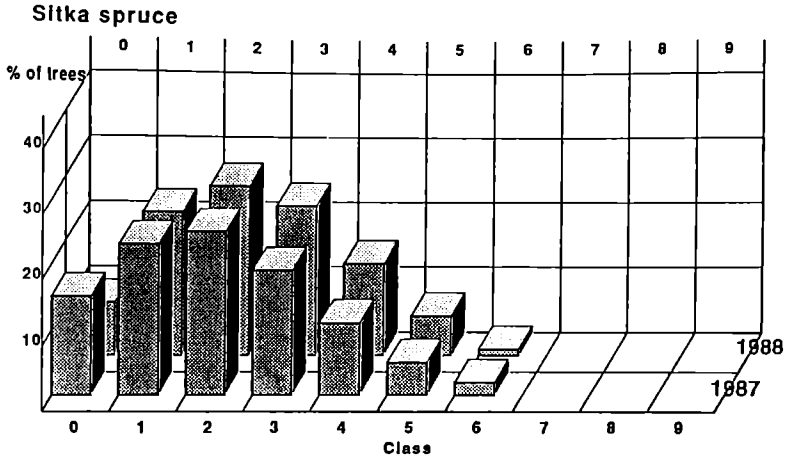


Figure 3a Comparison of 1987 and 1988 main forest health survey results. (Only sites assessed in both years are included.)

*Experimental studies*

In early 1988, a long-term experiment was begun at the three sites with open-top chambers (*Report 1987*, pp. 30–31) to assess the effect of ambient air quality on important tree species. The treatments contrast trees growing in filtered and unfiltered air. Four species are being studied – Sitka spruce, Norway spruce, Scots pine and beech. Some rooted cuttings taken from the crowns of 30-year-old Sitka spruce trees have been included to permit an investigation into the interaction between the age of the plant and air pollutants.

A. WILLSON, D. A. WADDELL, D. W. H. DURRANT

An open gas-exchange system has been constructed for measuring the rates of photosynthesis and transpiration of shoots or small trees during exposure to ozone and sulphur dioxide. When Sitka spruce are exposed to O<sub>3</sub> concentrations of the range experienced in Britain, the uptake rates of this pollutant have been shown to increase with concentration and with stomatal opening. During short

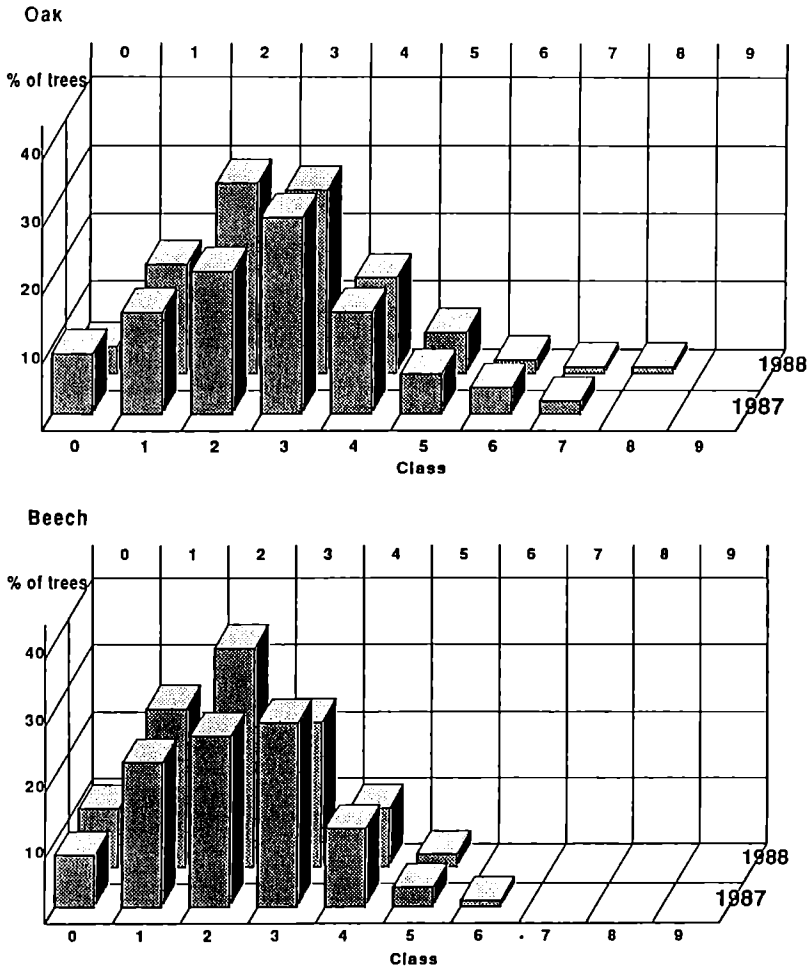


Figure 3b

episodes  $O_3$  has been shown to stimulate stomatal opening hence increasing the transpiration rates and photosynthesis of Norway and Sitka spruce. In joint work with the University of Lancaster, the physiological characteristics of small trees grown in different pollutant treatments and of foliage sampled from Norway spruce selected from the forest health surveys have been measured. Both experiments have identified physiological responses associated with the morphological changes resulting from pollutant exposure and site conditions respectively.

P. H. FREER-SMITH, M. C. DOBSON, G. TAYLOR

### Hydrology: water quality

#### *Thetford wet timber store*

Following the decision to set up a wet store of windblown timber at Thetford Forest (see Front Cover illustration and pp. 59–60), a study was initiated to monitor the effect of this operation on drainage water quality. The timber is kept wet by sprinkling with water drawn from an adjacent gravel pit, into which it subsequently drains. Concern mainly focused on the leaching of organic compounds from the bark and sapwood, which could have an adverse effect on water colour and biological oxygen demand (BOD). Measurements have shown that the drainage water quality has remained within acceptable standards to date, both colour and BOD fluctuating around the guide values (50 hazen units and  $5 \text{ mg l}^{-1}$ , respectively) that are specified in the European Community Water Directive (75/440/EEC) for normal water treatment (Figure 4).

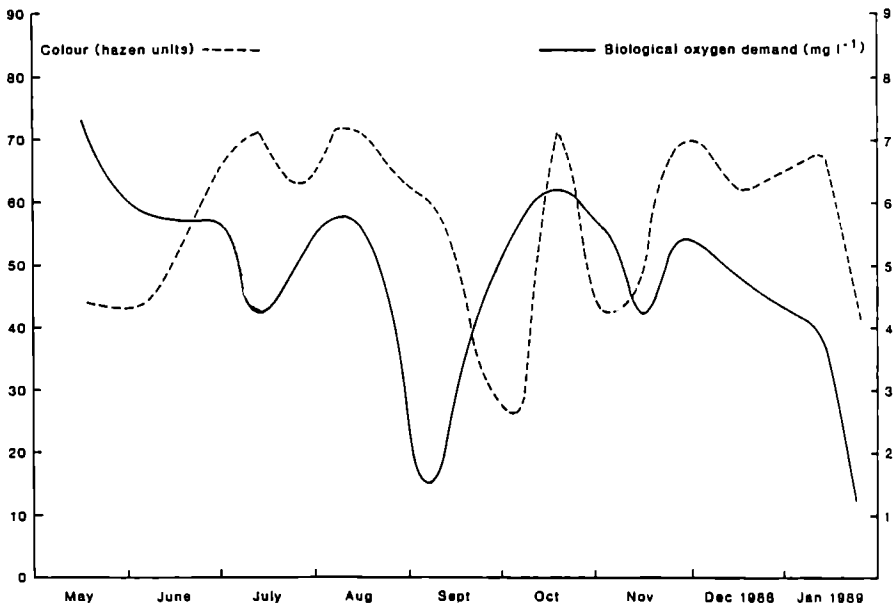


Figure 4 Drainage water quality at the Thetford wet timber store.

*Liming in acid catchments*

In collaboration with the Welsh Water Authority, a pelletised limestone treatment was carried out in a forested catchment of Llyn Brianne, mid Wales. One hundred and five tonnes of limestone pellets were applied by helicopter to three boggy areas (totalling 12 ha) in an attempt to ameliorate surface water acidity. The effects of this application on tree growth, nutrition and soil and drainage water chemistry are being monitored.

T. R. NISBET

**Advisory work**

The effects of pollution on trees, identification of damage caused by environmental conditions, reclamation of land to forestry after mineral extraction or landfill operations and the impacts of forestry on water resources have remained the main areas of concern. There has also been interest in the long-term monitoring of forest ecosystems for environmental change and, more recently, in the potential impacts of increasing CO<sub>2</sub> concentrations and climatic change.

P. H. FREER-SMITH, J. L. INNES, A. J. MOFFAT

**INTER-BRANCH REPORT****SITE STUDIES (SOUTH) AND SILVICULTURE (SOUTH)****Alder inoculation**

A previous experiment investigating the nodulation of alders after inoculating them with *Frankia* showed that common alder performed poorly with the *Frankia* strains used (*Report* 1987, p. 28). An experiment using an alternative strain (UGL 010708) has been more successful, and nodulation and growth of seedlings have been markedly improved in comparison with seedlings given standard nursery fertiliser regimes.

A. J. MOFFAT, D. R. WILLIAMSON, J. S. WRIGHT

## SITE STUDIES (NORTH)

### Clay soils

A second small, short-term drainage experiment has been set up at Kielder Forest District (see *Report* 1988, p. 32 'Loamy gleys' and this *Report*, p. 33). The soil is a peaty gley with clayey subsoil and the objective is to find the optimum ditch spacing for restock sites. The layout of boreholes has been modified so that a 55 channel logger can monitor the whole experiment at one time.

### Deep peats

At the 21-year-old afforestation experiment at Rumster (Caithness) (*Report* 1988, p. 31) drains have been deepened by excavator in three of the five cultivation/drainage treatments. These drains had gradually reduced to about 45 cm depth mainly as a result of subsidence and were thought to be limiting further increase of rooting depth and progress of the irreversible drying of the peat (*Report* 1987, p. 35). The hydraulic conductivity of the peat below the water table (50 cm depth in the summer) is very low and a response to drain deepening is dependent upon the formation of shrinkage cracks which are in their early stages at this site (*Report* 1985, Plate 5).

An experiment is being established (Rumster 17, P89) to allow us to measure the changes in physical properties of peat during irreversible drying in relation to the water balance of the site, starting from ploughing, draining and planting. Staff of Macaulay Land Use Research Institute will measure the chemical composition of the precipitation, soil water and drainflow in a concurrent study of the effects on stream water quality.

Throughout the winter, spring and summer of 1987/88 we monitored the water regime and oxygen concentration of a peat soil under a 20-year-old mixed stand of Sitka spruce and lodgepole pine at Leadburn (Borders Region). At positions close to the stems we measured the water table depth, and analysed samples of soil air or water taken from porous pots buried in the peat at depths of 25, 50, 75 and 100 cm.

Surprisingly, the water table was slightly (5 cm) but significantly deeper under spruce than under pine, whereas Booth (see *Report* 1972, p. 66) and King *et al.* (1986) demonstrated drier conditions under pine. However, the concentration of oxygen beneath each species was very similar. The peat became deficient in oxygen at 25–50 cm depth, the concentration decreasing sharply from between 12–15% v/v to 2–5% v/v. The greatest density of rooting occurred at a greater depth in lodgepole pine than in Sitka spruce. Sitka spruce roots were not found below a depth of 30 cm, whereas some pine roots were found to depths of 50 cm.

It would be of interest to examine the soil water and oxygen regimes of an afforested peat under pure spruce, pure pine and a spruce/pine mixture to establish whether a similar water and oxygen regime under each species in mixture is a direct result of 'good nursing'.

### Ironpan soils

Previous work (Pyatt, 1987) has shown that in the pole stage trees exert a drying effect which tends to eliminate the 'perched' water table overlying the ironpan and thereby improve soil aeration. This enables roots to penetrate the ironpan

and extend into the subsoil provided that it is not indurated. We have not studied the earlier stages in the process nor have we looked at ironpan soils in high rainfall areas (> 1200 mm per year). At a 6-year-old cultivation experiment at Moffat (Borders Region), where the rainfall is 1400 mm, we have installed deep boreholes which penetrate the ironpan and shallow ones which do not. Three kinds of cultivation are being compared with uncultivated soil in their ability to improve soil aeration in the pre-canopy closure stage.

### Loamy gleys

In the 'Z' drainage experiment at Angus (Tayside Region) (*Report* 1988, p. 32) water levels were recorded 6-hourly before and after the ditch was dug. Only half of the boreholes could be monitored at one time by the 55 channel logger, which meant changing over from one half of the experiment to the other twice. The equipment proved to be unreliable and the data are patchy and intermittent. It was intended to model the response to rainfall of each borehole (Rennolls *et al.*, 1980) but continuity of data is inadequate. 'Contour maps' of borehole water level suggest a lowering of the water table within several metres of the ditch and it is intended to collect data manually to confirm this.

D. G. PYATT, A. R. ANDERSON, D. RAY

### References

- King, J. A., Smith, K. A. and Pyatt, D. G. (1986). Water and oxygen regimes under conifer plantations and native vegetation on upland peaty gley soil and deep peat soil. *Journal of Soil Science* **37**, 485–497.
- Pyatt, D. G. (1987). The effect of afforestation on the water and oxygen regimes of stagnopodzols. *North of England Soils Discussion Group Proceedings* **22**, 93–108.
- Rennolls, K., Carnell, R. and Tee, V. (1980). A descriptive model of the relationship between rainfall and soil water table. *Journal of Hydrology* **47**, 103–114.

## INTER-BRANCH REPORT:

### SITE STUDIES (NORTH) AND SILVICULTURE (NORTH)

#### Upland restocking: soil temperature and site preparation

The temperature below mounds, screefs and uncultivated soil was measured for a year at a restocking site at Kershope (Cumbria). Results are summarised in Table 9.

Mounds provide a slightly better soil temperature regime than screefs, although the difference is small enough to allow other factors to be considered in the choice of planting position, e.g. winter waterlogging. Both were better than no cultivation.

The idea that mounds warm the surrounding air at night and thus reduce frost, is being tested at a Douglas fir restock cultivation experiment at Corris (Powys).



**Table 9** Summary of 1 year's soil temperature measurements at a restocking site. Air temperature in a louvred screen is included for comparison

Treatment	Depth (cm)	Minimum (°C)	Maximum (°C)	Mean (°C)	Root growth index* (× 1000 °C hours)
Mounds	5	-7.7	32.7	7.3	27.9
	20	-2.1	23.2	7.2	25.3
Screefs	5	-1.5	25.7	7.8	26.3
	20	-0.8	16.3	7.6	21.9
Uncultivated	5	-0.5	20.0	7.3	24.1
	20	1.1	14.9	7.3	20.8
Air		-7.7	28.7	6.9	23.1

\*The total number of degree-hours above a threshold of 5°C can be used as an index of root growth. Here the figures are the year's total excluding September and October.

A. R. ANDERSON, D. G. NELSON

## TREE IMPROVEMENT

### Re-organisation of Branch

Towards the end of the year, staff of Physiology concerned with flowering and micro- and macro-propagation were amalgamated with the staff of Genetics to form a new Branch, Tree Improvement. This decision arose out of a recommendation of the 1986 visiting group on tree improvement research for full integration of the work on vegetative propagation and the control of flowering with the tree breeding programme and for the Forestry Commission to take new initiatives in breeding and propagation of broadleaved forest species. Implementation of this integrated programme is requiring a re-examination of which species, what degree of effort, and which biotechnology options, offer the best prospects. Sitka spruce, hybrid larch and Scots pine will continue as conifers of importance, and oak, ash, and sycamore have been selected as the most important broadleaved species. The amount of effort which should be devoted to lodgepole pine, Douglas fir, Corsican pine and beech needs fuller discussion.

D. A. ROOK

### Forest progeny tests

As the Sitka spruce breeding programme matures, so the number of progeny tests for General Combining Ability (GCA) decrease and more complex progeny and clonal tests are established. Only one of the former series was planted this year as compared with two clonal test series using single plant plots with 15 replications. One of the clonal series was planted over four sites as opposed to the more normal three when testing for GCA, as more accurate information is desired on site × genotype interactions. In each series, cuttings had been taken from the five individual trees considered to be most superior, phenotypically in terms of form, branching pattern and vigour, within each of the 18 superior families as determined from 6-year height data in an open-pollinated progeny test. Selection at an older age is desirable in providing more confidence in selection criteria and in allowing considerable savings in numbers of clones to be tested. However the older material is more difficult to root without extra

treatment and also may result in some loss in vigour. The genetic gain would have to more than compensate for these disadvantages. These clonal tests will allow the gains attained from 6-year-old ortets to be compared with the estimated gain available from phenotypic selection based on 2-year-old seedlings.

Other field tests established this year include three series of lodgepole pine provenance hybrids of individuals selected within Queen Charlotte Island (QCI) crossed with Skeena River origins; these have been planted on three sites across the north of Scotland. Another series of various bulked seed orchard lots of Douglas fir collected by Weyerhaeuser Company in the Pacific north-west of America has been planted at four sites across Britain. Similar material is also being tested in a number of European countries. This collaborative project will test the performance of some previously untried origins of Douglas fir seed and compare them with a known origin.

As more wood density assessments by the Pilodyn method are carried out to investigate family performance, it is becoming apparent that only a small number of clones selected for vigour have wood density as high as the QCI control. The importance of wood density in determining timber strength of Sitka spruce needs to be critically evaluated in order that appropriate weighting can be given to this factor. A high weighting in favour of density could entail having to forego a substantial increase in volume increments.

S. J. LEE

### **Pollinations and seed production**

Flowering of the major coniferous and broadleaved species in 1988 was the poorest for several years and only a small programme on Sitka spruce was undertaken. This programme was only possible because a number of clones were injected with the gibberellins, GA<sub>4/7</sub>, in 1987. Injection with GA<sub>4/7</sub> is very successful in Sitka spruce and an extensive programme of treatment was carried out in June and July 1988 including all the clones in the breeding programme which had not flowered previously or been tested.

Two new polythene flowering tunnels (21 × 11 × 9.4 m) and (20 × 16 × 4.9 m) have been erected at NRS to provide warmer drier environmental conditions which are known to enhance flowering. The first tunnel is a mobile one which can be easily moved on fixed rails to provide protection for a greater number of plants without having to transfer plants, thus running the risk of damage or having to provide extra space and lifting machinery. Seed of hybrid larch and Sitka spruce will be produced in both tunnels for use in vegetative propagation programmes and also for production of special controlled pollinations. The protection which will be provided by these houses in March and April, although unheated, should reduce flower losses in larch from low temperatures and wind rubbing and should also increase numbers of viable seed per cone. Each tunnel will be able to produce, in a good flowering year, sufficient seed of improved Sitka spruce for 5 million cuttings using present techniques for vegetative propagation of bulked family mixtures. The composition of the clonal material of the mini-orchards can be readily changed in response to the results from progeny trials and thus allow rapid implementation of further genetic gain. Flowering of the grafts will be increased by manipulative treatments such as drought, GA<sub>4/7</sub> injections, and increased temperatures.

A. M. FLETCHER

### National Register of Forest Reproductive Material

The National Register of Forest Reproductive Material was first compiled in 1973 in accordance with EEC Directive 66/404. The data were originally recorded in writing but during the last 5 years, a computer database within the Tree Improvement Branch records has been prepared and a programme developed to enable the register to be readily updated and reproduced. Since 1988 was a poor flowering year only a small number of stands were added to the register (mainly oak); advantage was taken of the reduced activity to review the quality of many of the stands and seed orchards listed. Several stands of lodgepole pine were deleted because of the possibility of contamination by pollen from neighbouring stands of inferior quality or undesirable seed origin.

C. J. A. SAMUEL

### Variation in biochemical characteristics

Analyses of terpene composition of foliage and shoot cortical tissue have continued to be used in a range of genetical investigations, including the four studies now described.

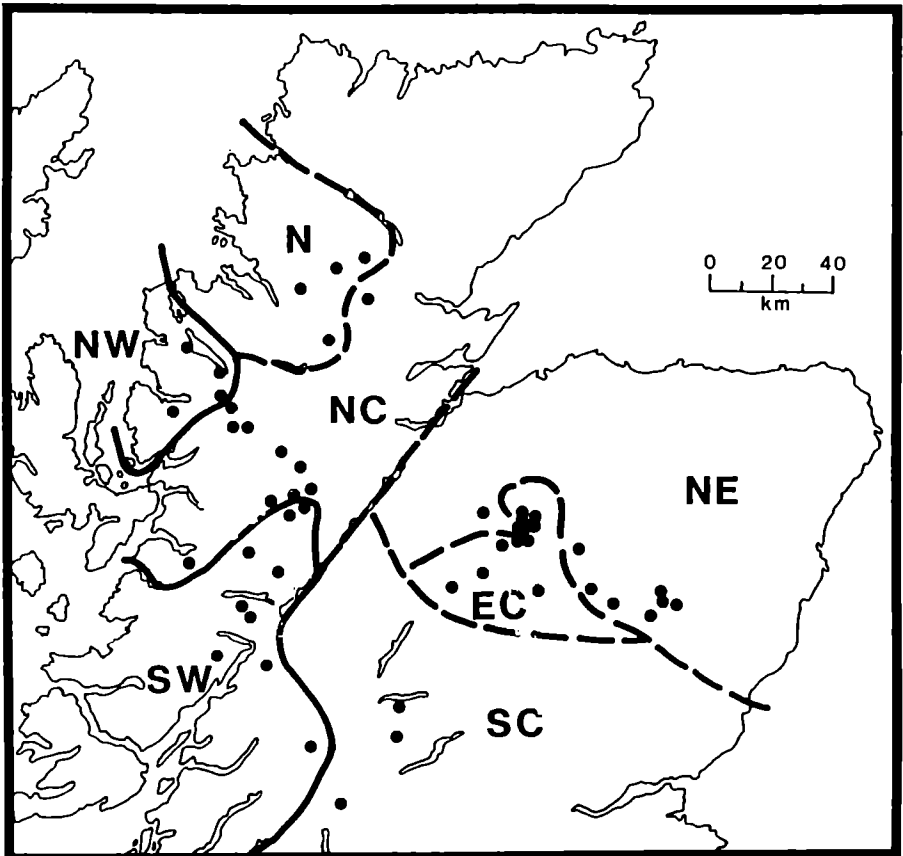


Figure 5 Regional grouping of native Scots pine woodlands adopted in the new Native Pinewood Grant Scheme, on the basis of variation in shoot resin composition.

In collaboration with Entomology Branch the work on the biochemical interactions between the pine beauty moth, *Panolis flammea*, and its host lodgepole pine has been extended to a study of the within-tree effects during and following defoliation by larvae confined within muslin sleeves on shoots of a range of genotypes from Alaskan and south coastal origins. The study is seeking to find relationships between terpene composition of the genotypes, long-term effects of localised herbivore attack and any resultant changes in terpene composition.

Analyses of biochemical changes associated with the ageing of Sitka and Norway spruce have indicated several age-related features. In particular the concentrations of the terpene, bornyl acetate, appear to be inversely related to age in the stem cortex of both species and in the leaves of Sitka spruce.

Virtually all the native Scots pine remnant woodlands (see Back Cover illustration) have now been biochemically characterised by their shoot cortical resin compositions, and the results have been used to define the boundaries of zones for replanting in the new native pinewood grant scheme (Figure 5). Woodlands in the north-western zone are distinct in consisting of genotypes that are rare in the more general Caledonian populations, while those in the south-western zone are less variable. For these reasons these two zones have accordingly been defined as 'exclusion zones' to discourage the introduction of and therefore contamination by non-local genotypes.

Biochemical characterisation of individuals, families, and seed origins has continued to be applied to practical problems including those involving doubtful identities. A case of a high incidence of basal bud outgrowth in young plants of a Sitka spruce family mixture used for vegetative propagation was shown to have only a small genetic component and therefore most likely to have been induced by cultural treatment.

G. I. FORREST

## PHYSIOLOGY

### Root growth and form

#### *Tolerance to waterlogging*

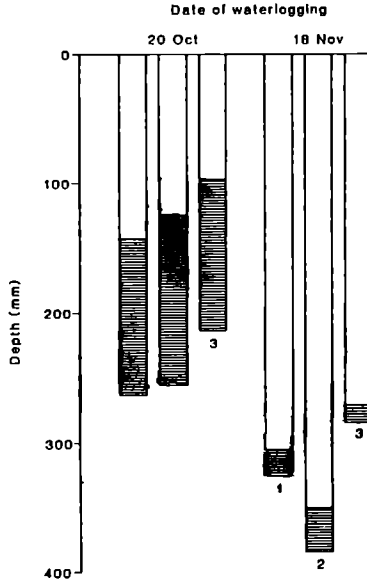
Rooted cuttings of three clones of Sitka spruce were grown in 2 m tall transparent acrylic tubes of peat in insulated boxes out of doors. Roots of many of the trees formed mycorrhizas with *Thelephora terrestris*, the extra-matrical mycelium and associated strands were visible in the tubes, together with the roots (Plate 7). Some of the tubes were waterlogged in 1987 to submerge the lower part of the root and mycelial systems. Waterlogging was carried out in October, when roots were growing slowly, and in November when growth had just ceased. The fungal mycelium was growing on both occasions.

The tubes were drained in March 1988 and survival of fungus and main roots was measured to the point of regeneration. The extra matrical hyphae of *T. terrestris* died in both treatments but all of the strand systems survived and regenerated in the following spring. There were large differences in root survival between the two waterlogging treatments (Figure 6). October waterlogging

caused substantial dieback, roots survived to a mean depth of only 122 mm below the water table. November waterlogging resulted in little dieback and survival depth was 308 mm. Differences among clones in root survival were statistically significant, but small.

The results imply that if waterlogging is delayed until roots have stopped growing, Sitka spruce roots will survive to a considerable depth even when waterlogged continually through the winter.

M. P. COUTTS



*Figure 6* Response of the roots of three Sitka spruce clones (1, 2 and 3) to waterlogging at different times. The lengths of the bars show mean depth below the water table and the shaded and open areas represent dieback and survival respectively.

### Propagation of oak

During spring 1988 observations were made of shoot development from the overwintering buds in the crowns and epicormic buds on the trunks of 20 approximately 40-year-old pedunculate oak trees. Shoot growth was divided into stages of bud expansion, leaf emergence, stem elongation, leaf expansion and end of flush; stage of development of the most advanced bud of each type was assessed weekly. The pattern of growth varied between type of bud: leaf emergence from crown buds occurred shortly after bud expansion but before the new shoot extended; in contrast, the apical bud of shoots developing from epicormic buds on the trunk produced leaves throughout the period of shoot extension. The dates by which buds on 50 per cent of trees reached the different states of development are shown in Figure 7. Growth began in April, crown shoots developed most rapidly completing the flush by mid-May. Epicormic buds became active later and rate of development was slower, the flush of growth

continuing until July. The delayed development of epicormic buds has important consequences for their use in vegetative propagation.

R. HARMER

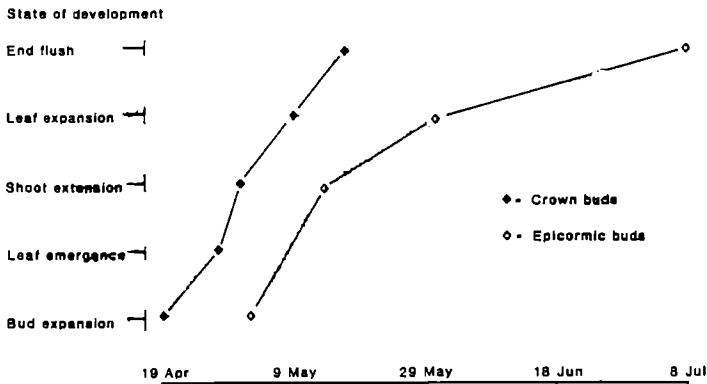


Figure 7 State of bud development on pedunculate oak during spring 1988

### Flowering

Flowering is thought to be associated with high levels of solar radiation. For example, flowering often increases after good summers or in forest clearings. Thus the absence of coning of Sitka spruce grafts in experiments in growth chambers may be due to the low light levels ( $400 \mu\text{mol m}^{-2} \text{s}^{-1}$  compared with  $2000 \mu\text{mol m}^{-2} \text{s}^{-1}$  in full sunlight). Evidence for the importance of high light levels also comes from experiments with Sitka spruce in polythene houses, in which shading reduced coning by at least two-thirds. Increasing light by using white reflective surfaces on the polyhouse floor significantly increased flowering under inductive conditions. This research is of basic interest in view of the Polish work in which directing light on to developing buds through optical fibres enhanced male flowering in Scots pine. In practical terms the research emphasises the importance of selecting polythene house materials that produce minimum shading and has resulted in the selection by Tree Improvement Branch of a white reflective ground surface in the new polythene houses.

Dr J. N. Owens, University of Victoria, British Columbia, visited the laboratory for 3 months to work on anatomical aspects of cone bud development. Studies were initiated with Sitka spruce and larch during cone induction. Subsequent pollen meiosis and seed development were studied during treatments to force early shedding of pollen.

J. J. PHILIPSON

### Micropropagation

Work has continued on refining techniques used in the micropropagation of Sitka spruce. Rooting has proved to be poor in a fogging chamber and it would appear that Sitka spruce micropropagules must have water droplets on the needles for rooting levels to be high. Storage of Sitka spruce cultures under long days at  $2^\circ\text{C}$  resulted in a survival rate of 95 per cent after 8 months. Experiments have been initiated in collaboration with the Botanic Garden, Copenhagen on

the micropropagation of Norway spruce and hybrid larch. Early results suggest that flooding the cultures does not result in the high multiplication rates observed in Sitka spruce.

### Rejuvenation

The joint project with Unilever Research has continued and the results suggest that more accurate estimates of changes in physiological age during rejuvenation experiments can be made using biochemical rather than morphological or physiological techniques. Rapidly growing calluses have been established *in vitro* from needles. Excised, naked, dormant buds from mature trees will be grafted on to them to attempt rejuvenation *in vitro*.

A. JOHN

### Mycorrhizas

Field testing of container-grown Sitka spruce inoculated with different isolates of mycorrhizal fungi continued. Results were similar to those reported in previous years (*Report* 1988, p. 37). However, whereas in previous years, the *Thelephora terrestris* treatment in the older of the experiments at Dornoch Forest District had increased relative height differences, this year no such increase was attained. This indicates that the fungus may no longer be having a significant effect on growth when compared with naturally colonised controls.

Four new field experiments with mycorrhizas were established as part of a CEC-funded co-operative venture with INRA (France), IRTA (Spain) and the University of Surrey. Two of these sites were with Sitka spruce and two with Douglas fir. For each tree species, an experiment was established on new planting and restocking.

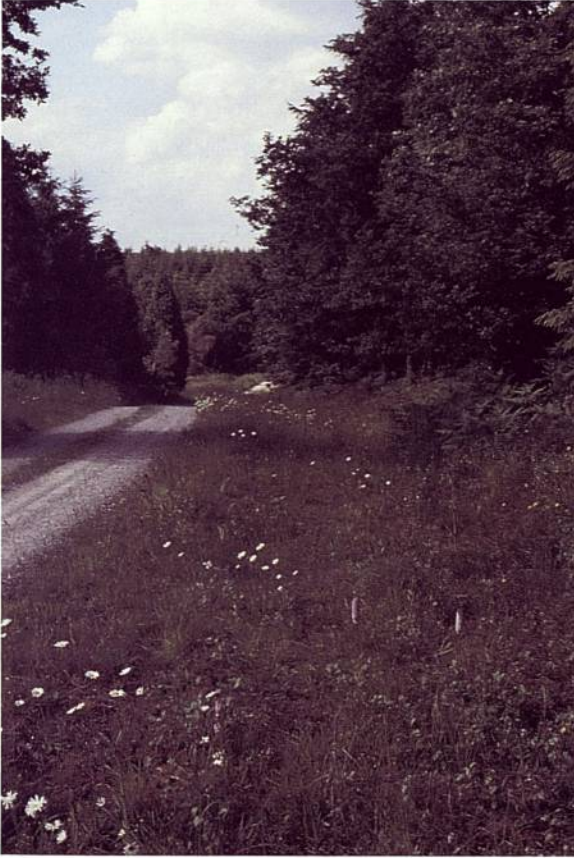
Work on nursery inoculation trials continued, with the co-operation of Silviculture (North) Branch. Trials were established at Wykeham nursery with Sitka spruce and Douglas fir. Preliminary results indicated that establishment of mycorrhizas is possible in the nursery by inoculating with a mycelial slurry, but cross-contamination has precluded further analysis.

C. WALKER

### Physiological quality of nursery stock

A new project was started to investigate physiological aspects of poor performance of nursery planting stock in the forest. One component of poor planting success is poor plant quality. The bulk of planting stock undergoes cold storage prior to planting, therefore the emphasis of the project initially is to understand the physiology of plants as they become dormant and the effects of lifting and cold storage. During the first year methods of determining safe lifting dates for transplants and undercuts of Sitka spruce and Douglas fir were examined. From October until April, physiological characteristics were measured which relate to dormancy status (frost hardiness, mitotic index, moisture content, root growth potential, and root elongation). These physiological indices will be correlated with the survival and growth of plants cold stored at intervals during October to April.

H. M. McKAY



*Plate 1.* Afternoon sunlight on the edge of a north-south forest road at Bentley Wood, Wiltshire. The herb-rich vegetation is enhanced by the Mendip limestone scalplings used in the formation of the forest road and the alternate year cutting of the edge sward. (*C. I. Carter*)



*Plate 2.* Tree establishment demonstration plots showing methods of weed control, with and without cultivation. Royal Agricultural Showground, Stoneleigh, Warwickshire. (*C. J. Potter*)





*Plate 3. Mounding for restocking with a Donaren moulder. (38727)*



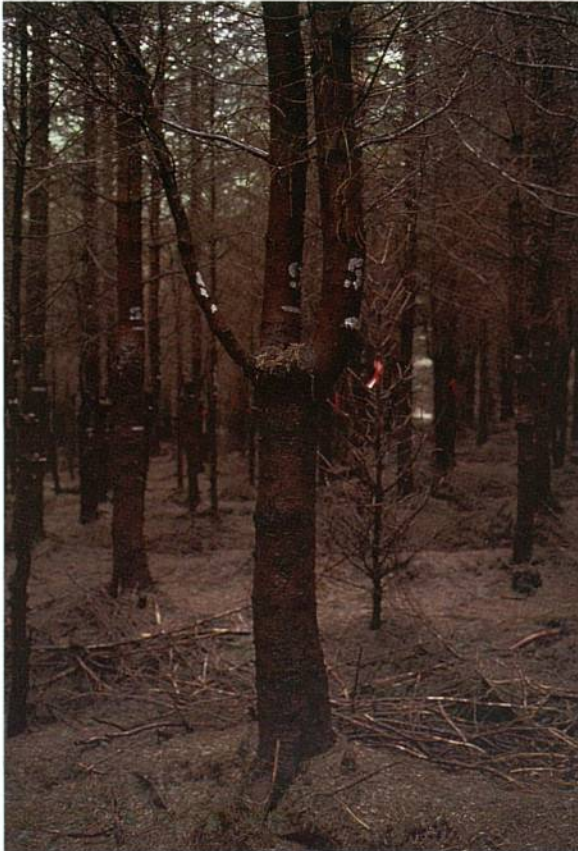
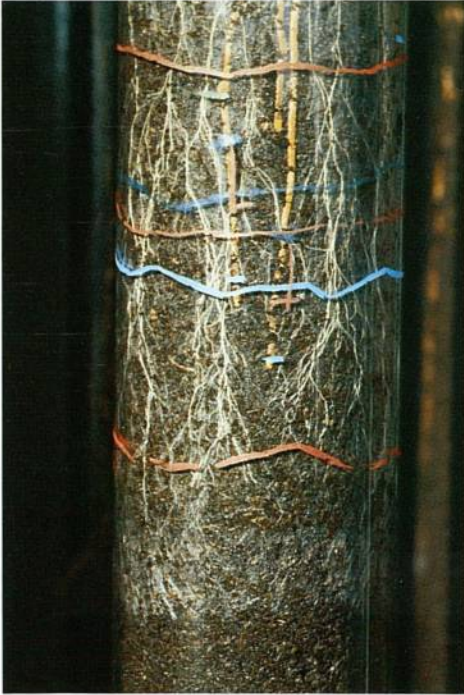
*Plate 4. Accelerated transplant system, transplanting at Wykeham nursery. Left module trays, background transplanter, right foreground transplanted beds. (J. Townend)*



*Plate 5. Aerial application of pelleted limestone to alleviate surface water acidity. (T. R. Nisbet)*



*Plate 6. Anemometer on a 10 m mast at Lussa Loch, Kintyre. A number of anemometers are being used to study airflow in complex terrain and to monitor windspeeds at various locations in upland forests. (C. Quine)*



*Plate 7 (top left).* Sitka spruce roots and the extra-matrical mycelium of the mycorrhizal fungus *Thelephora terrestris* growing in a perspex tube of peat. (Tube diameter = 7 cm).

*Plate 8 (top right).* Pigmented hyphae of *Leptographium wageneri* in tracheids of *Pinus sylvestris*.

*Plate 9 (left).* ‘Oceanic forestry’—regrowth of Sitka spruce after topping at 2 m.

## PATHOLOGY

Approximately one-third of staff time in the Pathology Branch is occupied in dealing with enquiries about diseased trees and in running the conservancy-based Forest Health Days which are now an established part of Forestry Commission activity. In February 1989 this work was subject to a detailed internal review and the various components were brought together formally in a project group entitled 'Disease diagnostic and advisory services'.

Preliminary accounts of a number of studies arising out of the effects of the October 1987 storm were reported last year as part of an inter-branch report (*Report* 1988, pp. 57–58). Work on these continued during 1988/89 and summaries are being published in Forestry Commission Bulletin 87.

Two special reports by C. M. Brasier, J. F. Webber and north American colleagues are presented in this year's *Report* following a sabbatical year spent at Oregon State University from March 1988–March 1989 (see pp. 48–50).

J. N. GIBBS

### Diagnostic and Advisory Services

#### *Scotland and northern England*

Weather was the most frequently recorded damaging agent during the year. Frost injury to young conifers occurred in several localities in spring 1988 and was especially severe in parts of west Scotland. Wind injury was also common, several of the cases deriving from a gale in late July which led to severe foliage browning of trees, particularly larches, in some areas. Toxic chemicals and cultural malpractices were also frequently diagnosed as causes of injury. Most of the losses arising from the latter were attributed to deficiencies in the methods of handling and storing forest transplants. Injuries by chemicals, though associated for the most part with herbicides or fertilisers, included a case in which smoke from burning coal-mining spoil caused severe foliage browning downwind in a Norway spruce plantation. This occurrence was noteworthy because of the much less severe injury sustained by Sitka spruce on the same site.

The most frequently investigated forms of biotic injury were mortality and butt-rot caused by the root pathogens *Heterobasidion annosum* and *Armillaria*. However, for the fourth year in succession, the poor condition of many Scots pine stands in northern forests gave rise to several enquiries. In most cases the damage was attributable to attack by *Lophodermium seditiosum* and *Brunchorstia pinea* with the pine shoot beetle having a secondary, though important, role. Most of the fungal damage appeared to have occurred in previous years though in some cases current dieback caused by *B. pinea* was evident. Also on Scots pine, browning of current needles by the pathogen *Lophodermella sulcigena* was noticed in several plantations in north-eastern Scotland.

Branch cankers and shoot diebacks of larches were unusually common sources of enquiry during the year. In most cases one or other of the two well known pathogens, *Lachnellula willkommii* and *Potebniamyces coniferarum*, was responsible but in some cases the culprit appeared to be an unknown *Cytospora* species. Another shoot pathogen, *Ramichloridium pini*, caused damage in several lodgepole pine stands and, for the first time in many years, the needle-cast pathogen of Douglas fir, *Phaeocryptopus gäumannii*, was recorded in a Scottish forest.

Of the diseases recorded on broadleaved trees, those caused by the two shoot and foliage pathogens of willow, *Pollaccia (Fusicladium) saliciperda* and *Marssonina salicicola*, were among the most common and damaging, as they have been in previous years. Twig dieback of rowan associated with *Nectria* species was an equally commonly reported problem, though one less well documented in previous records. An unusual disease of another member of the Rosaceae, foliage browning of hawthorns caused by *Diplocarpon mespili*, was recorded from Lanarkshire.

Two nursery diseases which appear not to have been previously described were investigated during the year. One caused a high incidence of severe stem and foliage deformation in beds of 1-year wild cherry seedlings growing in polythene tunnels. The circumstances under which the damage occurred made it extremely unlikely that the cause was abiotic but no living agent was in evidence nor did the symptoms clearly match those of any previously described disease of wild cherry. The distortions were, however, similar in some respects to those caused in various trees by species of *Taphrina* and the possibility that the damage was due to a member of this genus will be investigated further. More success was achieved with an investigation that arose from outbreaks, in two nurseries, of stem cankers on seedlings and transplants of ash. A *Phoma* species was consistently found on affected plants and preliminary results from inoculation trials indicate that it is indeed pathogenic. This appears to be the first demonstration of a *Phoma* species as a pathogen of ash nursery stock.

S. C. GREGORY, G. A. MACASKILL, D. B. REDFERN, J. E. PRATT

#### *Wales and southern England*

Winter-cold related diseases and disorders were absent following the mild and snow-free 1987/88 winter but the growing season brought a recurrence of most of the leaf and shoot diseases so common in 1987 with the addition of *Marssonina salicicola* on weeping willows and several other *Marssonina* leaf and shoot blights of broadleaved trees (though differing in the absence of reported cases of *Cristulariella depraedans*). As in Scotland, *Diplocarpon mespili* was recorded causing a severe leaf spot on *Crataegus oxyacantha* in the south of England and some trees were nearly leafless by late August. This disease has previously been recorded by us only on quince (*Cydonia oblonga*).

A second unusual occurrence was discoloration and defoliation of plantation larch by *Meria laricis*, a disease which is normally only found in nurseries. Material from two sites was examined: 10-year-old European larch in north Wales and 20-year-old Japanese larch from Gloucestershire. Similar damage has occurred in Scotland in recent years (*Report* 1988, p. 39).

During 1988, the discoloration and fall of 1987 needles of various species of pine infected by *Lophodermium* species and *Cyclaneusma minus* was commonly reported from the south and west, and *P. radiata* needles in a stand in southern England were found to be infected with both *C. minus* and *Rhizosphaera pini*, our first record for the latter.

In February 1989, *Dothistroma pini* (the imperfect state of *Scirrhia pini* and a serious pathogen elsewhere in the world) was found on severely browned 1988 needles of 13-year-old Corsican pine in south Wales. The disease has been recorded in this country only once before from plantation trees: in 1958, also on Corsican pine and very close to the present site. Since then it has been found only

twice (in 1966 and 1967), each time in the same Dorset nursery in which it was first found in this country in 1954 (*Report* 1967, p. 101).

The general severity of shoot killing in lodgepole pine plantations caused by *Ramichloridium pini* continued to cause concern in Wales and south-west England and in south Wales what is thought to be the first record of the disease on *Pinus peuce* was obtained.

June 1988 was the driest in England and Wales since 1976 and drought was presumed to be the cause of the premature yellowing and fall of inner (older) foliage on Leyland cypress and, less often reported, Lawson cypress and yew, mostly in the south-east.

Inoculations have shown the cause of a recurrent leaf and twig blight of a 4 m high specimen holly, *Ilex aquifolium* 'Aurea Marginata' in Sussex, to be a combination of attacks by *Phytophthora ilicis* (which seems to be the first record of this fungus from outside the USA (Buddenhagen and Young, 1957)) and *Coniothyrium ilicis* (apparently the first demonstration that this fungus is pathogenic).

Severe branch cankering of 50-year-old  $\times$  *Crataemespilus grandiflora* street trees by *Nectria galligena* was noted in Norfolk. Virtually nothing is known about the pathology of this intergeneric hybrid.

An unusually large number of requests for the identification of fruit bodies of *Meripilus giganteus* were received. This root-rotting fungus was also isolated from dead roots of a dying 100-year-old Monkey puzzle, our first record for a conifer.

A very large number of cases of lightning damage were investigated among both plantation and specimen trees. In two-thirds of the cases damage had occurred since the 1987 growing season, and most of these dated to the 1988 growing season; about two-thirds of these cases were from the eastern half of the region. Most of the damage in plantations was to pine and in the worst case well over a hundred 40-year-old trees had been browned or killed. Affected trees were scattered singly or in groups of two or three over some 10 ha. The damage to amenity trees involved nine different species, mostly broadleaves.

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

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### **Fomes root and butt rot**

#### *Prevention of Fomes in first rotation conifers*

Protection of conifer stumps against *Heterobasidion annosum* (*Fomes annosus*) was introduced in the early 1960s and has since been mandatory throughout the Forestry Commission estate. The material presently in use is a 20 per cent solution of urea, although the biological control agent *Peniophora gigantea* is used in pure pine crops.

A project was initiated in 1971 to provide information on the behaviour of *H. annosum* in lodgepole pine and Sitka spruce, particularly on upland soils which earlier research had suggested might be relatively unfavourable for disease development. Work has concentrated on elucidating the factors that affect the infection of stumps by spores and on the below-ground spread between infected stumps and healthy trees.

By 1985, inoculation experiments had shown that:

1. soils in the uplands vary markedly in the extent to which they influence the rate of disease spread (Redfern, 1984);
2. stumps of Sitka spruce are less susceptible to infection by spores of *H. annosum* than are those of lodgepole pine (Redfern, 1982);
3. spore infection of Sitka spruce stumps is extremely variable, both between sites and between stumps on the same site. Differences among sites might be related to rainfall (Redfern, 1982; Redfern, 1989).

In the light of these findings, Research Division was asked to consider the possibility that potential losses might be so low on certain sites that protection could be discontinued. Both the high cost of treatment and the likelihood that tree harvesters would soon be introduced on a large scale prompted this review. The method of working of these tree harvesters largely prevents manual treatment against *H. annosum* and considerable modification is necessary if they are to be fitted with automatic stump treatment devices.

A major part of the review consisted of an economic appraisal of stump treatment for Sitka spruce. To provide information on benefits (i.e. losses avoided by treatment) a model of disease development was devised and used to estimate losses which could be expected to occur over two rotations in the absence of protection. The model represented an attempt to summarise knowledge of the behaviour of the disease gained from experiments and from field observations on natural outbreaks (Pratt, Redfern and Burnand, 1989).

As a result of the review, the Forestry Commission's policy of mandatory treatment was re-affirmed in early 1989. A Utilisation Memorandum was written (UM2) for Forestry Commission staff and a general article aimed at increasing interest in stump protection in the private sector was also prepared (Pratt and Redfern, 1989).

D. B. REDFERN, J. E. PRATT

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### Dutch elm disease

#### *Elm regeneration*

The survival of English elm suckers in the wake of the Dutch elm disease epidemic has been monitored in southern England since 1977 (*Report* 1985, p. 35). In 1988 the incidence of new infections was the lowest since the observ-

ation plots were set up. In the main series of 21 plots there was no increase in the level of disease during the year, while in 12 plots where the suckers have been thinned out to leave individual trees the increase over 1987 was only 0.9 per cent. In both series of plots between 75 per cent and 80 per cent of the suckers are healthy and the largest trees are now over 13 m tall with a breast height diameter of 26 cm.

The low level of new infections is undoubtedly linked to the current low populations of elm bark beetles. In the past 3 years no maturation feeding wounds have been found in over 2000 twig crotches examined each year.

Despite the lack of new infections at present, it must be remembered that the young elms are genetically identical to the parent trees, and it remains very likely that they will succumb at some time in the future to new outbreaks of the disease.

B. J. W. GREIG

### Arboriculture: Department of the Environment contract

#### *Decay in amenity trees*

The evaluation of the fungus *Trichoderma* sp. as a biological control agent against decay fungi in pruning wounds continued with the inclusion of further tree species, bringing the total number to 14. The list of species is as follows: beech, pedunculate oak, gean, silver birch, Lombardy poplar, horse chestnut. The trial is designed to last 4 years, starting with the application of a *Trichoderma* spore suspension to freshly-cut wound surfaces, and ending with the dissection and microbiological sampling of the wood underlying the wound. The results should indicate whether this biological control agent is likely to be of use in the routine protection of pruning wounds. In the meantime, preliminary data have been obtained by plating out wood chips taken from wound surfaces one year after pruning.

The data in Table 10 show the percentage of wounds from which *Trichoderma* and basidiomycetes (decay fungi) were isolated in the 1-year sampling. The eight tree species in the table are those which have been assessed since the previous report on this experiment (*Report* 1987, p. 47). The high frequency of isolation

**Table 10 Preliminary sampling data from *Trichoderma*-biocontrol trial**

Tree species	Percentage of wounds yielding:			
	<i>Trichoderma</i>		Basidiomycetes	
	Sealant-only* control	<i>Trichoderma</i> inoculation	Sealant-only* control	<i>Trichoderma</i> inoculation
Sycamore	30	100	0	0
Norway maple	83	100	0	0
Lime	100	88	0	0
Hornbeam	100	100	0	0
Holly	77	80	0	0
Yew	75	100	0	0
Sallow	100	100	0	0
Horse chestnut	100	100	0	0

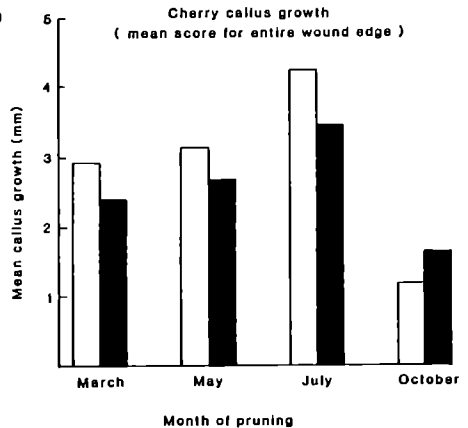
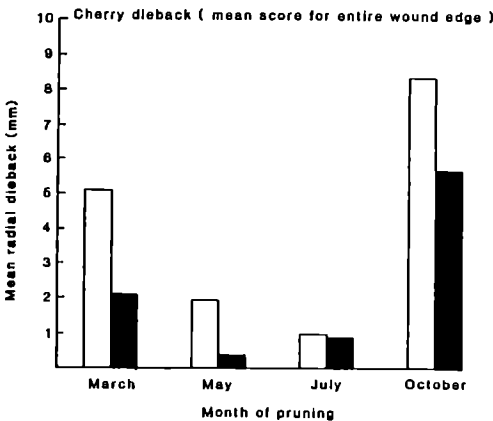
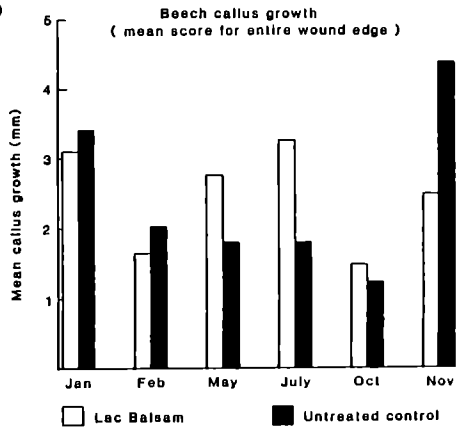
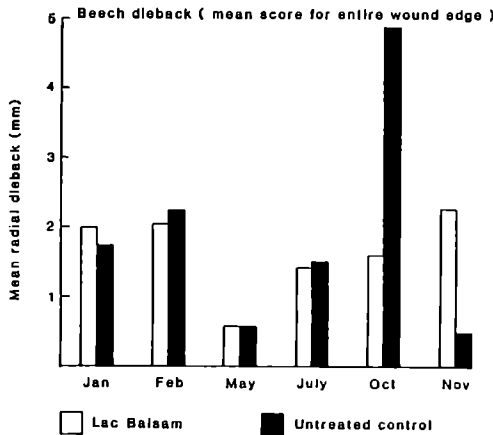
*Note:* Ten wounds per tree species were included in this preliminary sampling; *Trichoderma* isolation data refer to isolates of the same morphological type as the inoculant strain.

\*All *Trichoderma* treatments were supplemented with the sealant 'Lac Balsam' as anti-desiccant.



of *Trichoderma* suggests that it might be easy to establish it routinely in pruning wounds. It also appears that the 'background' occurrence of *Trichoderma* was high in these trials, since it was also isolated from a large percentage of wounds receiving the sealant-only treatment. The general frequency of occurrence of *Trichoderma* in tree wounds has, however, been much lower in other experiments where wounds were entirely untreated, and the present findings may reflect the ability of the sealant to enhance wood infection from natural inocula. The absence of basidiomycetes may indicate that *Trichoderma* is controlling their growth. In other experiments where the incidence of *Trichoderma* is low, it has been usual to detect basidiomycetes in up to 15 per cent of wounds.

Earlier experiments involving sealants without biocontrol agents have shown, at best, a delaying effect against the invasion of wounds by decay fungi, and their failure has been attributed largely to poor adhesion, durability or elasticity. Polyurethane-based sealants may offer improved performance in these respects and results were obtained from a 1-year trial on a 'slow curing' product of this type, primarily marketed for roof repairs. Throughout a series of 11 samplings



**Figure 8a** Cambial dieback and callus formation on wild cherry (gean) and beech following different times of wounding, and with and without application of the wound sealant 'Lac Balsam'.

**Figure 8b** Seasonal pruning experiment: dieback and callus formation on beech and wild cherry (gean) wounds created at different times of year.

over a 1-year trial, basidiomycetes remained entirely absent from beech wounds treated with this product, 'Isoflex'. Towards the end of the period, some very slight and shallow colonisation by other fungi and bacteria occurred.

The time of year of pruning appears to be important in determining the way in which trees respond to the injury itself and to the resulting exposure to microbial infection. During the currency of this report, interim data were collected from wounds which were created sequentially over 1 year on several tree species. Assessment included the measurement after 1 year of two inversely correlated processes; cambial dieback and callus formation. These data were derived from two of the species under test; gean and beech, and covered the periods March to October and January to November respectively. There were large differences in dieback and in callusing which related both to the time of year of wounding and also to the presence or absence of the inert sealant 'Lac Balsam'. The spatial patterns around the wound margins were also influenced by both variables. These data are summarised in Figure 8.

D. LONSDALE

## European oak decline

### *Identity of Ophiostoma roboris*

The serious decline of oak from central Europe to Azerbaijan is frequently attributed to a vascular mycosis complex involving various *Ophiostoma* species such as *O. roboris* and *O. kubanicum*, other fungi, and *Scolytus intricatus* beetle attack. In view of the often vascular wilt-like descriptions of the disease, its apparent spread from foci and on disease fronts, and reports of the pathogenicity of *O. roboris* and *O. kubanicum* to oak saplings in inoculation tests (e.g. Ivanchenko, 1957; Kryukova and Plotnikova, 1979; Guseinov, 1984), attempts have been made since 1979 to secure cultures of *O. roboris* and *O. kubanicum* for evaluation.

In 1987 a culture of *O. roboris* isolated by Dr E. S. Guseinov from *Quercus longipes* in Azerbaijan, USSR, was brought into the UK under licence with the help of the International Mycological Institute, Kew, and Soviet authorities. In a study at the IMI we found the isolate to be very similar in spore morphology and colony phenotype to isolates of *O. piceae*, a saprotroph commonly present on oak in Britain. When cross-mated it produced plentiful fertile perithecia and viable ascospores with an *O. piceae* isolate of appropriate mating type, but none with *O. ulmi* mating type testers. The perithecia and ascospores conformed to *O. piceae* in size and shape and gave rise to morphologically normal F<sub>1</sub> progeny of both mating types. The single *O. roboris* isolate studied therefore appears conspecific with *O. piceae*. Hence *O. roboris* might be the same taxon as the western European '*O. piceae*' or a closely related but more pathogenic sub-unit of it. Molecular studies, now in progress, and pathogenicity tests planned on oak seedlings under quarantine conditions, may further establish their degree of relationship.

### *Status of O. piceae on hardwoods and conifers*

The ubiquitous sapstain fungus *O. piceae* is currently considered to be both a hardwood and a conifer inhabitant (Hunt, 1956). The two sexual mating types were demonstrated among several *O. piceae* isolates associated with conifer beetle breeding galleries, and also among several isolates from sapstain and

scolytid beetle galleries in oak and elm. However, when paired together the conifer isolates did not mate with the oak/elm isolates. This indicates that the conifer and hardwood isolates of '*O. piceae*' are reproductively isolated and hence, although morphologically similar, may be sibling species of *Ophiostoma*.

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### Species susceptibility to black stain root disease

#### *Assessment of the threat to Europe*

The fungus *Leptographium wageneri* is a vascular wilt pathogen causing black stain root disease of conifers in western North America. Infection may occur through root contacts or insect vectors and the fungus exists as three varieties: one on Douglas fir throughout its range; one on pinyon pines in the desert south-west; and one on lodgepole and ponderosa (hard) pines in interior forests from California to British Columbia (Harrington and Cobb, 1986).

Despite being native to North America, black stain has become a steadily growing problem over the past decade, apparently as a result of intensified forestry practice (Hansen *et al.*, 1986). It is absent from Britain, but Hansen (1985) has suggested that *L. wageneri* could pose a considerable threat to the forestry industry if it were to be introduced here, especially as the susceptibility of European pines is completely unknown. During 1988-89, therefore, a collaborative study was conducted at Oregon State University to determine the susceptibility to the pathogen of some European and North American conifer species that are of commercial importance to Britain.

In these trials 3-year-old trees were wound-inoculated on the main root with agar plugs taken from cultures of hard pine or Douglas fir variants of *L. wageneri*. The inoculum was secured in place and the trees potted up and maintained outside in a nursery from May to September. Species assessed included lodgepole pine, Scots pine, ponderosa pine, Douglas fir, noble fir western hemlock and Sitka spruce.

Within 8 weeks both lodgepole pine and Scots pine showed some wilting, accompanied by a marked blue-black stain of the xylem. Longitudinal sections taken from stained regions revealed pigmented hyphae of *L. wageneri* extending along individual tracheids (Plate 8). The symptoms increased over time, and many trees had completely succumbed to the disease by the end of September. All the conifer species under test were affected by the disease to some extent, apart from noble fir (Table 11), and  $\chi^2$  contingency table analysis indicated significant differences in susceptibility between species ( $p < 0.001$ ). The tendency for the different forms of the pathogen to be host specific (Harrington and Cobb, 1984) was also confirmed; the Douglas fir form of the pathogen proving to be much more pathogenic to Douglas fir than to ponderosa pine ( $p < 0.05$ ).

**Table 11 Susceptibility of a range of conifer species to the pathogen *Leptographium wageneri***

	Percentage* of trees infected or killed following inoculation with <i>L. wageneri</i>	
	<i>L. wageneri</i> Douglas fir variant	<i>L. wageneri</i> pine variant
Douglas fir	73	10
Lodgepole pine	73	77
Ponderosa pine	30	26
Scots pine	70	50
Sitka spruce	13	13
Western hemlock	7	10
Noble fir	0	0

\*Three isolates inoculated into a total of 30 trees.

During November to February, a second experiment examined the susceptibility of Scots pine, lodgepole pine, ponderosa pine and Douglas fir to *L. wageneri* under greenhouse conditions. One previously untested conifer species, Austrian pine, was also included in this comparison. This second experiment confirmed the earlier results, and indicated that Austrian pine was moderately susceptible to the disease.

Clearly, these results reinforce the original suggestion of Hansen (1985) that the introduction of *L. wageneri* to Britain could have serious consequences, particularly as European pine species also appear to be susceptible to the disease.

As the fungus thrives under temperate forest conditions (optimal growth at c. 18°C), there seems little doubt that it would establish successfully in Britain. Moreover, insects with similar behaviour to known vectors of the disease in North America are already present in this country (e.g. *Pissodes* spp.)

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#### *Phytophthora* diseases

*Status of P. gonapodyides, P. drechsleri and P. cryptogea*

When isolates of a *Phytophthora* from remote forest sites in Alaska and Oregon and from roots of Douglas fir seedlings in Oregon and Washington, and attributed to *P. drechsleri* by Hansen *et al.* (1988), were examined, they were re-assigned (CMB) to the unusual and little known species *P. gonapodyides*. When compared with *P. gonapodyides* isolates obtained from roots of *Chamaecyparis*, *Prunus*, *Salix*, *Ilex* and other hosts in Britain since 1970, the Pacific north-west and British isolates proved very similar in cultural characteristics, soluble

protein patterns and mating behaviour, and are considered conspecific. *P. gonapodyides* may therefore be widely distributed both in North America and in Europe. Various mating tests including direct pairings, use of polycarbonate membranes and 'Trichoderma tests' indicate that *P. gonapodyides* induces selfing in A2 mating types of other *Phytophthora* species while itself being sterile. Antagonism by *P. gonapodyides* may be involved in this phenomenon.

*P. drechsleri* and *P. cryptogea* are common pathogens on roots of trees, ornamentals and herbaceous hosts worldwide including Britain. When 35 isolates representing both species from a wide range of hosts and international locations were compared, most showed a similar soluble protein pattern irrespective of original species designation, and fell within a broadly similar though variable range of colony phenotypes. Although a small number of isolates that grew at >35°C and differed slightly in other characters could comprise a high temperature ecotype, the results support the view (Bumbieris, 1974) that *P. drechsleri* and *P. cryptogea* are one taxon. A remainder of isolates (two groups) showed very different protein profiles, tended to be sexually sterile, and may represent interspecies hybrids.

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## ENTOMOLOGY

A new project has been initiated to study the impact of insects on tree growth. This is considering both mensurational effects as well as the ecological interactions between the insects and their host trees. Surveys for pine wood nematode continued; there were no nematodes present in the imported or British wood sampled. The survey is being expanded to include sampling of chipped pines throughout Britain.

H. F. EVANS

### Great spruce bark beetle, *Dendroctonus micans*

#### *Biological control of Dendroctonus micans*

During the year, 6700 *Rhizophagus grandis* were released amongst new *D. micans* infestations found during surveys of the peripheral zone. Studies of three permanent plots showed that, at one location, levels of attack by *R. grandis* rose from 56 per cent to 83 per cent of *D. micans* broods while, in the other two plots, attack levels fell from 66 per cent to 50 per cent and from 80 per cent to 63 per cent respectively. This was probably a result of the steep decline in *D. micans* brood numbers affecting the sensitivity of the sampling method.

Life cycle studies of *R. grandis* were concluded; these showed a peak of breeding activity from late April to July, resulting in the shortest life cycles when eggs were laid during this period. Both adults and larvae overwinter and incubation of pupae in the soil can be extremely protracted leading to life cycles in excess of one year. Other observations showed that *R. grandis* larvae predated heavily on the eggs of *D. micans*, could mine short distances through the bark and would migrate between prey broods.

Preliminary field experiments on predator impact were made on equal sized implanted *D. micans* broods. Predation was seen to be highly variable (range 0–100 per cent of *D. micans* larvae killed) with a mean consumption of at least 28 per cent. A new dispersal experiment showed that inundative release of *R. grandis* adults resulted in colonisation of 66 per cent of available *D. micans* broods, and establishment of predator breeding in 50 per cent of them, within 3 months of introduction.

C. J. KING, N. J. FIELDING

#### *Dispersal of Rhizophagus grandis adults*

Solvent extracts of *D. micans* larval frass, obtained from the Chemistry Department at Cardiff University, were tested for their attractiveness to *R. grandis* in both walking and flight wind tunnels. The most attractive fractions were those containing a number of host monoterpenes including  $\alpha$ -pinene (Report 1987, p. 50). Results suggest that a specific blend of host-tree monoterpenes in *D. micans* larval frass is most likely to be responsible for the specificity of attraction of the frass to *R. grandis* adults in the field.

D. WAINHOUSE, D. CROSS, T. WYATT\*, D. R. KELLY\*, M. BARGHIAN\*

\*University of Cardiff (M. Barghian is supported by a Forestry Commission Research Grant).

#### **The pine beauty moth, *Panolis flammea***

##### *Monitoring and control*

Pupal counts in autumn 1987 showed a possible need to treat a total of 987 ha in three blocks. Egg counts in May 1988 confirmed the need for treatment of 784 ha which was carried out by aerial application between 28 and 30 May. Two insecticides were used; the chemical Dicofen (fenitrothion) and a virus preparation produced on contract by the NERC Institute of Virology, Oxford. Dicofen gave excellent control based on autumn pupal counts before and after spraying and no significant defoliation occurred. The virus was applied as experimental treatments in an area with the highest populations but did not reduce damage satisfactorily and further development will be necessary.

The spraying system developed for use in 1987 was further improved by the fitting of more efficient electric motors to the X30 rotary atomisers and the equipment was trouble free throughout the spraying operation. Further work was done with the objective of improving the droplet spectrum emitted by the atomisers.

Routine pupal surveys in autumn 1988 showed no need for a control programme in 1989.

J. T. STOAKLEY, A. C. HENDRY

*Population ecology*

*P. flammaea* populations in lodgepole pine in the Elchies block of Moray Forest, continued to decline with only 0.05 pupae m<sup>-2</sup> being found. The average fecundity of the females was 22.4 eggs female<sup>-1</sup>, little different from the previous two years. Populations were low in all the plots and differences between fertiliser treatments and soil types were not distinguishable. Overall, larval mortality was higher in deep peat than in ironpan sites, but overwintering mortality of the pupae was greater in ironpan than in deep peat sites. Site factors, such as soil type, have little effect on population development but do have an effect on predators and parasites; they are less common in deep peat sites. This study has been completed but a new study to examine the effects of lodgepole pine seed origin on *P. flammaea* population levels has been initiated in the same forest.

Collaborative life table studies with Dr A. D. Watt (NERC, ITE, Edinburgh) at Elchies, North Dalchork (Sutherland) and Poulary (Fort William) are now in their fourth year and are beginning to reveal details of the major mortality factors affecting *P. flammaea* populations.

Laboratory investigations have shown that, although *P. flammaea* adults will lay eggs on non-pine hosts, even the least suitable pine (Alaskan origin lodgepole pine) is preferred. Larval growth and survival of *P. flammaea* is significantly affected by host plant species and seed origin, temperature and, to a lesser extent, larval density and intra-specific competition. Preliminary simulation modelling reveals highly significant seed origin effects on *P. flammaea* population dynamics, indicating that, even with significant larval predation, blocks of south coastal lodgepole pine would suffer from *P. flammaea* outbreaks once every 7 years. This is in close accordance with field experience. On the other hand Alaskan lodgepole pine, with a sufficient number of larval predators present, would not suffer a *P. flammaea* outbreak, even on a deep peat site. Further work is being carried out to elucidate the exact nature of the interaction between host origin and larval predation.

S. R. LEATHER

**Green spruce aphid, *Elatobium abietinum*: interactions with spruce**

In early 1988 instances of Sitka spruce defoliation by *E. abietinum* were widespread; attacks on Norway spruce were also reported to have caused damage to Christmas tree crops. Another increase in aphid numbers occurred during the generally mild and frost-free winter of 1988/89 as would be expected from previous studies on winter mortality (Carter, 1972).

Population monitoring has continued in the South Wales Coalfield study area on several site-types with trees of contrasting vigour using a shoot-sampling and extraction method that enables aphid numbers and aspects of their performance to be related to needle weight.

Less susceptible Norway and Sitka spruces, and other interspecific crosses involving Asiatic spruces, are being sampled and screened for chemical compounds in the foliage that have been correlated with resistance or reduced aphid performance (*Report* 1987, p. 54; Nichols, 1988). The development of a high pressure liquid chromatography system will enable quantitative analysis of the relevant amino-acids and secondary compounds in conifer foliage.

C. I. CARTER, J. F. A. NICHOLS

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**The European pine sawfly, *Neodiprion sertifer****Monitoring and control*

Surveys in spring 1988 showed high numbers of egg clutches within three blocks in Dornoch Forest District. Virox was applied from the air to a total of 1169 ha between 26 and 28 May but, compared with previous results from use of this product, it gave poor results in terms of early larval mortality and of minimising defoliation. However, counts of egg clutches in spring 1989 showed greater than 90 per cent reductions in numbers in treated plots compared with adjacent untreated plots which showed increases of as high as seven-fold between 1988 and 1989.

J. T. STOAKLEY, A. C. HENDRY

**The pine weevil, *Hylobius abietis*, and black pine beetles, *Hylastes* spp.***Chemical protection*

The treatment of transplants with permethrin using the 1988 modified Electro-dyn Sprayer Conveyor (ESC) was tested for efficacy, phytotoxic effects and persistence in field experiments. Results indicated that the ESC gave the same level of protection as dipping with insecticide, but reduced root growth compared with untreated plants. However, the ESC treatment was found not to have given adequate results in Conservancy plantings.

A wettable powder formulation of permethrin which may offer potential for cold-storage of treated plants, was tested for efficacy and phytotoxicity at various concentrations. It was shown that the levels of protection and phytotoxicity were the same as for emulsifiable concentrates of permethrin.

*Biology*

Laboratory studies, using photographic and radar techniques, were carried out on the effects of environmental factors and insect physiology on the behaviour and activity levels of *H. abietis* adults. Selection of resting sites by adult weevils was also studied. A significant preference for leaf litter or weed covered ground compared with mineral soil was demonstrated.

*Biological control*

An experiment to investigate the potential use of entomophilic nematodes to control *H. abietis* populations breeding in stumps was set up. Treatment of stumps significantly reduced the size of the developing weevil population ( $p < 0.05$ ).

Mobility and survival of infective nematode juveniles was studied in laboratory and field experiments. The laboratory studies demonstrated that most of the nematodes remained near the site of inoculation.

S. G. HERITAGE, S. COLLINS, T. JENNINGS, I. WATTS



**Pine looper moth, *Bupalus piniaria***

Pupal surveys were carried out in the same 38 areas surveyed in 1988. Counts were again low, the highest compartment means being  $6.4 \text{ m}^{-2}$  at Roseile (Grampian), an increase from 1988, and  $5.6 \text{ m}^{-2}$  at Cannock (Staffs) which remained the same as last year.

T. G. WINTER

**Advisory and taxonomic services**

As in the past 3 years there have been many enquiries relating to control of *Hylobius abietis* and *Hylastes* spp. resulting mainly from the changes in insecticide approvals and the increasing restocking programme.

There were fewer enquiries concerning defoliators with only a single case of *Tortrix viridana* damage to oak, although beech leaf mining by *Rhynchaenus fagi* was again widespread in southern Britain.

Aphid damage to spruce was widely reported and mainly involved *Elatobium abietinum* on Christmas trees. There was an unprecedented number of enquiries (74) concerning damage by *Cinara cupressi* to Leyland and Lawson cypress. The first symptom is a yellowing of the foliage, often at the base of the tree, which then turns brown accompanied by dieback of the affected branches. 'Castlewellan Gold' appears to be more susceptible than other cultivars of Leyland cypress. Damage was reported from southern England and south Wales north to Shropshire and Lincolnshire. Most cases were from late July onwards, possibly the result of a widespread immigration from southern Europe.

Forestry Commission plant health inspectors found fewer bark beetles on imports than in the previous year. *Orthotomicus caelatus*, *Scolytus laricis* (first record in Great Britain) and *Hylurgops rugipennis* were intercepted on Canadian imports of wood. The latter species was also attracted to a pheromone trap baited with a *Dendroctonus ponderosae* lure at Bristol. A *Crypturgus* sp. (probably *C. hispidulus*), together with *Ips typographus*, was intercepted on Russian wood imports. Larvae of the cerambycid beetle genus *Monochamus* were found in Somerset in timber imported from Canada; adults of this genus are potential vectors of pine wood nematode, *Bursaphelenchus xylophilus*.

T. G. WINTER, J. T. STOKLEY

**INTER-BRANCH REPORT:****ENTOMOLOGY AND WILDLIFE & CONSERVATION****Responses of insects to newly widened rides**

This study is being carried out within tall (220 m) P35 plantation beech in the West Downs Forest District, which is representative of many localities in the southern counties of England where shaded rides have excluded flowering plants and associated insects. Rides with different compass orientations have been widened for contrasting sunlight interception (see *Report* 1988, p. 48) to compare the responses of colonising insects and plant growth. The spectacular floral display of biennial plants in the summer of 1988 contributed to the five-fold increase from 1987 in the number of butterflies monitored in an otherwise

generally poor year. There is evidence that in one completely new ride 12 of the 16 newly acquired species are also breeding. In addition to this, ground invertebrate activity and aspect is being analysed using data from pitfall traps of three species of carabid beetles and two species of lycosid spiders.

C. I. CARTER, R. FERRIS-KAAN

## WILDLIFE AND CONSERVATION

The appointment of a plant ecologist has expanded research on managing lowland forests to increase species and structural diversity of vegetation on forest edges, under plantations and on unafforested sites. A change in emphasis in animal research will increase studies of the causes of damage and its long term economic impact and significance to timber trees and other plants. Historically, research has centred on 'pest control' aspects of wildlife management. A more balanced approach is now pursued incorporating the important conservation components of wildlife management and just over 50 per cent of resources are now devoted to such research.

P. R. RATCLIFFE

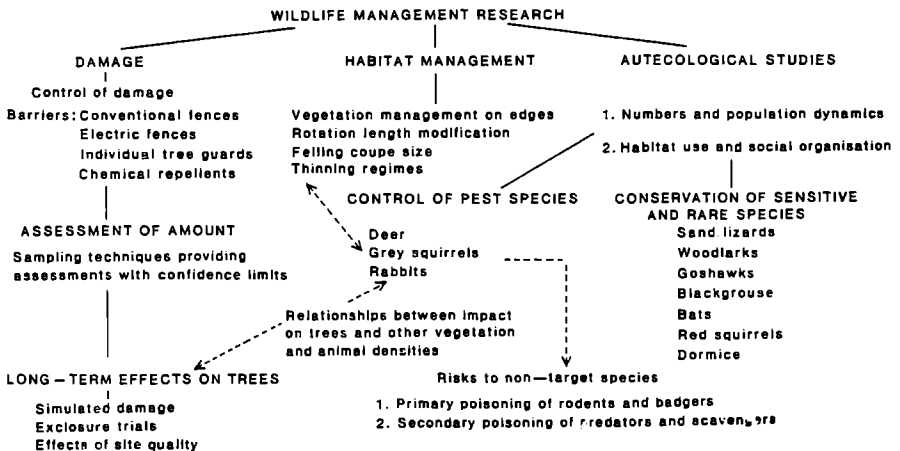


Figure 9 Wildlife management research.

### Vegetation management in upland forests

The retention of conifer stands beyond normal economic rotation length can provide many benefits to wildlife. Vegetation structure and species are being assessed in 16 stands of conifers which have been thinned and retained beyond normal rotation age. Methods are being tested which involve the introduction and establishment of plants characteristic of native pine forests, such as dwarf shrub species (*Vaccinium myrtillus*, *V. vitis-idaea* and *Empetrum nigrum*). Cuttings have been raised for planting in 1989 into plots offering varying conditions of light, soil disturbance and deer browsing. The establishment of juniper is also being investigated.

The removal of domestic livestock grazing from semi-natural habitats following afforestation can considerably reduce vegetation diversity, particularly on

species-rich flushes and pastures. In collaboration with the Nature Conservancy Council the effects of cattle grazing are under study in an unplanted riverside SSSI. Cattle are grazed between August and October: botanical changes are being assessed in grazed areas and in ungrazed enclosures.

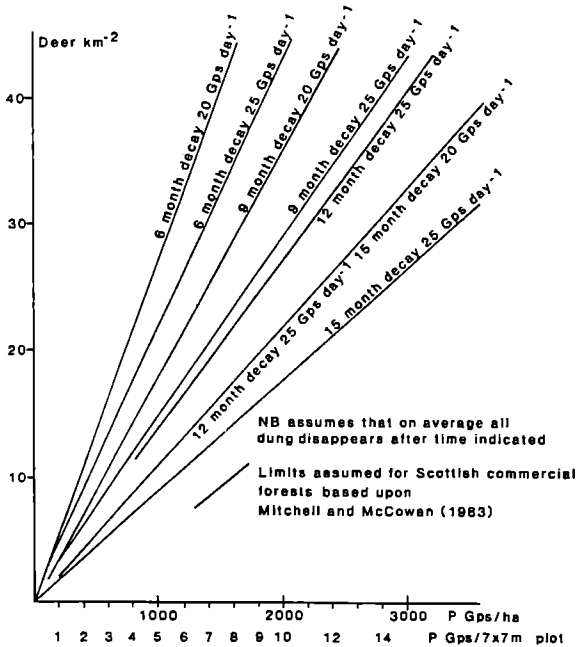
G. S. PATTERSON

**Deer**

The most difficult component of deer management remains the accurate estimation of population density. Though this has been largely solved for red deer in upland forests (Ratcliffe, 1987) new or modified methods based upon dung count dynamics offer a valuable means of estimating densities of all deer species in a variety of habitats. This is an important breakthrough especially for deer species occupying concealing habitats.

The method is discussed by Ratcliffe (1988) but is based on the fact that deer defaecate at random in space and time in specific habitats or structural types of forest. If defaecation rates and dung decay rates can be determined then, for a given density of deer, the distribution and density of dung pellet groups can be predicted (Figure 10). This relationship can be used to estimate deer densities from sampling pellet group densities.

P. R. RATCLIFFE



**Figure 10 Pellet group standing crop related to deer density for a range of conditions of defaecation and decay rates.**

*Roe deer*

Investigations into the population dynamics of roe deer have shown that some 98 per cent of all adult females (> 1 year) ovulate each year. In most populations *some* kids are sexually mature by the age of 3½–4 months. Ovulation, and subsequent pregnancy, is largely determined by the attainment of a particular body weight threshold, which varies between populations.

B. A. MAYLE

*Fallow deer*

The density and number of fallow deer at Cannock Chase were estimated by incorporating estimated fecundity and mortality, and known cull figures into a Leslie matrix model. This suggested a minimum population of 1593–1770 (45–50 km<sup>-2</sup>) compared with previous local estimates of about 1000. Estimates based on the pellet group method suggested 1648–2268 ( $p < 0.05$ ) (46–64 km<sup>-2</sup>).

P. R. RATCLIFFE

*Red deer*

Methods recommended for managing woodland red deer (Ratcliffe, 1987) have been incorporated into management training courses for three levels of managers. Branch staff will continue to contribute to this training, but increasingly it will become the primary responsibility of Education and Training Branch and North Scotland Conservancy. This approach to technology transfer is seen as a model for future training in wildlife management.

P. R. RATCLIFFE, A. H. CHADWICK

**Grey squirrels**

Further trials of plastic doors in poison hoppers have been entirely successful in ensuring that only squirrels and no other animals enter the hoppers. Of particular importance is the elimination of risks to common dormice (*Muscardinus arellanarius*), a species with restricted distribution in Great Britain and a 'schedule 5' species in the Wildlife and Countryside Act (1981). The exclusion of small mammals also considerably reduces costs by reducing bait take and topping-up visits. It also eliminates the risk of secondary poisoning to predators feeding on small woodland rodents.

H. W. PEPPER

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## MENSURATION

### Sample plots

The 1988/89 measurement programme was swollen by a number of plots requiring final measure after the storm of October 1987. Mensuration Branch staff assisted Forest Surveys with the workload, but some periodic measurements due in 1989 had to be deferred, and some windblown plots, including those at Bedgebury Pinetum, had to be abandoned without final measure. The EPSON portable microcomputer was used for collecting windblow data as well as periodic measurements in viable plots. Butt discs were retrieved from a windblown thinning experiment in Thetford Forest for dendrochronological studies. The results will be used to test the assumptions underlying current thinning practice and the choice of thinning intensity in the yield tables.

There was further windblow in North Scotland in February 1989 which destroyed another 17 plots. Final measurement of the majority of these will take place in the summer of 1989.

The sample plot database is being converted from the Rapport management system to Oracle. The advantages of Oracle are that it permits access by more than one user at a time, and it includes a Forms facility which enables the user to interrogate and update the database readily and without the need for programming.

G. KERR, J. M. METHLEY

### Measurement studies

The use and application of the many methods of abbreviated tariffing are being investigated. All Forest Districts have been circulated with a questionnaire to determine which systems are in use and how they are applied. The 60 forms returned have been analysed and a final report is in preparation.

Assistance was given to one Forest District requiring a local solid/stacked volume conversion factor. The photographic method described in the Mensuration Handbook (pages 33–35) was used, sampling across a range of products and species.

G. KERR, A. F. MARTIN

### Yield studies

Computer algorithms representing different methods of thinning have been written for use in forest growth modelling. The algorithms attempt to simulate the decision process involved in marking a plantation according to a chosen thinning regime. The exercise has helped to formulate clear definitions for traditional thinning grades. Low thinning treatments have been simulated, and it is intended to cover the full range of thinning methods including intermediate, crown and line thinnings. The algorithms require the approximate coordinates and sizes of individual trees within the plantation, detailed input requirements varying with thinning grade.

The construction of a traditional yield table requires families of curves to be fitted to the principal crop parameters, for example the top height–age curves in the existing yield tables. Computer methods have been developed for fitting anamorphic and polymorphic families of curves.

The Kershope respacing experiment, established to compare the performance of different respacing treatments for Sitka spruce, was the subject of a recent paper by Rollinson (1988). One of the objectives of this experiment was to compare mechanical respacing with the 'decapitation' method espoused by oceanic forestry. Plate 9 is a typical example of a decapitated tree from one of the oceanic plots. Side shoots, which have taken over from the main stem, have grown into the canopy and are seriously competing with crop trees. The consequence of this development for yield will be quantified by future measurements.

R. W. MATTHEWS, G. KERR

#### Reference

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#### Management services

Since the introduction of the microcomputer version of the Tariff checking and calculation program to Forest Districts, the Branch has continued to advise on tariffing queries, and has overseen a number of upgrades and amendments to the program. Most of the queries were concerned with the interpretation of computer output, and in response the Branch has written an additional chapter for the user guide which gives advice and recommendations.

One hundred and four assortment forecasts were run for Forest Districts, and over 3500 for Research and Headquarters projects. Results from assortment forecasts have been used to determine the percentage volume loss when cutting a range of non-standard log lengths to different top diameters.

A number of measurement seminars were given by Branch members to Forest District and Conservancy staff. This was in response to a direct request for help in maintaining standards of field measurement procedures.

G. KERR, J. M. METHLEY

## WOOD UTILISATION

#### Water-stored timber

A major experiment was established in June-August 1988, whereby selected logs of nine species were placed in a water-store at Thetford Forest (see Front Cover illustration). This store was initiated by East England Conservancy to alleviate problems in timber supply caused by the storm of October 1987. Logs in the store are being kept wet by sprinkling water at a rate in excess of 45 mm per day over stacks close-piled up to 3.5 m high. For three tree species, Corsican pine, Sitka spruce and beech, two variables are being examined; these are length of time in store and the length of time before logs were placed in store after felling. The other species included were Scots pine, Norway spruce, Douglas fir, Japanese larch, ash and sycamore. Each sample consisted of approximately 10 m<sup>3</sup> of logs 4.9 m length and minimum top diameter 18 cm overbark. All logs were obtained from windblow sources.

In February 1989 the first sample of 20 Corsican pine logs was removed from the store and sawn. The logs were found to saw easily and accurately with a wide

bandsaw. Nine of the logs had no visible blue stain. The remaining 11 had some stain which resulted in a flitch of wood being removed for analysis. The stain was always at the end of the log and was as common at the butt end as at the crown end. It was not possible to calculate the volume of wood that was stained but, even on the worst board, the stained area did not cover more than 6.2 per cent of the surface. On average, the amount of stain on the 11 boards amounted to less than 2 per cent of the surface area. A batch of 'filler' pine logs, which provided the bed for the experimental logs, gave even better results when sawn, with only 5 of 30 logs showing any stain.

Only in one instance did culturing from the stained areas regularly result in the isolation of a rapidly growing staining fungus (a *Leptographium*). It thus seems that the fungi are generally quiescent within the stored logs.

### **Physical damage in windblown Corsican pine**

Evidence collected between January and June 1988 from surveys and tests on Corsican pine timber produced from windblown material resulting from the gale in October 1987, did not demonstrate an increase in the proportion of battens shattering during and after sawing. A small sample of sawnwood was examined in detail by stress grading and showed little evidence of a higher than expected proportion of rejects. Three parcels from Rendlesham Forest were sawn to produce a single 4 m × 50 mm thick flitch from the centre of each of 208 logs. Sawing was carefully orientated in the direction trees were blown down. A high proportion of those pieces planed after sawing showed evidence of at least one area of compression creasing most commonly on the leeward side. Further investigation is continuing at the Building Research Establishment.

### **Beech pallet blocks**

Three treatments on 1 m × 95 mm × 95 mm sawn beech wood were compared with a control to see if development of stain and rot could be curtailed. The pallet industry often prefers green timber because this is easier to nail, however beech has a propensity to stain and rot when kept green. Samples of blocks amounting to one cubic metre each were hand dipped in either a 25 per cent solution of sodium orthoborate or a 3 per cent Copper 8 solution or a mixture of 25 per cent borate and 1½ per cent Copper 8. Results indicated that although the boron controlled internal fungal growth external appearance was poor. Copper 8 did appear to improve surface appearance but internal growth of fungus sometimes reached the surface. The mixture of the two chemicals gave the cleanest timber at the end of 6 months.

### **Effect of spacing on Sitka spruce**

Samples of Sitka spruce from a spacing experiment at Glenhurich (Strontian Forest District) was sawn, dried and graded at the Kilmallie Sawmill of BSW. Immediate comparisons between spacing treatments proved impossible because over 95 per cent of the battens graded out at SC4 on a commercial machine stress grader. Further assessments are being made at the Building Research Establishment.

## STATISTICS AND COMPUTING

### Statistics: Alice Holt

#### *Forest health*

Geostatistical techniques (Webster, 1985) have been employed in the analyses of forest health survey data in an attempt to discover the geographical range within which the observed plot health indices (i.e. crown density, total discoloration etc.) were spatially correlated. The semi-variances, calculated from differences between the values of the indices for all pairs of sites were plotted against the corresponding distances to give semi-variograms. The isotropic spherical model,

$$g(h) = c_0 + c_1[(1.5(h/a) - 0.5(h/a)^3] \quad \text{for } 0 < h \leq a, \\ = c_0 + c_1 \quad \text{for } h > a,$$

was then fitted to the semi-variograms for each index, where  $h$  is the distance between plots. The range,  $a$ , (the distance beyond which the correlation is zero), the nugget variance,  $c_0$ , and the sill,  $c_0 + c_1$ , are estimated by the model. Although, in most instances the percentage variance accounted for by the model was not high, estimates of the range appeared to be sensible for many of the indices. These range estimates were then used to limit the extent of interpolation when drawing contoured maps of the plot indices.

#### *Biomass estimation*

In short-term coppice experiments covering different sites, species, spacings and rotations difficulties were found in arriving at a consistent model for total biomass production based only on shoot diameter. Quadratic functions gave excellent fits within the range of the sample data but at one of the experimental sites did not provide acceptable values when extrapolated to small diameters. The solution adopted was to use a linear model through the origin up to the lower limit of the data and a concurrent quadratic above this point.

Analysis of an 8-year-old Nelder-design plot of poplar recently felled at Long Ashton Research Station gave interesting information on the relationships between plant spacing, dry weight production, mean diameter and tree height. For trees of this age the greatest dry weights per hectare were achieved in a small range of plant spacings at about 1 m while the greatest stem diameters occurred over a range of plant spacings from 2.0 m to 3.0 m.

#### *Roe deer*

Female roe deer skulls, collected from a number of English forests, were analysed for phenotypic similarities and distinct groupings. Eighteen cranial measurements, defined by Lowe and Gardiner (1974), were used in a multiple discriminant analysis in an attempt to relate phenotypic differences to the historical records of roe deer introductions. It is known that roe deer were introduced from several European countries including Austria, France, Germany and Ireland.

#### *Beech health*

The Cusum charting technique was used in the beech twig-growth survey to detect significant changes in residuals from expected growth curves and to date their onset. Sites had been chosen on a transect from Cornwall to East Anglia



in an attempt to cover a wide range of pollution zones, but no significant correlation was found between transect position and growth residual.

R. C. BOSWELL, T. J. HOUSTON, I. D. MOBBS, A. J. PEACE

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### Statistics: Northern Research Station

#### *Comparison of root plates*

In an experiment to compare the root systems of trees planted in three different ways, root angles and diameters were measured at 25, 50 and 75 cm from the centre of the stump. The 'centre of diameter', which is the mean position of all roots weighted by diameter, was calculated for each tree and used to compare planting treatments. Confidence intervals for the distance of the centre of diameter from the centre of the stem were calculated. The technique greatly simplified comparisons of complex root masses.

#### *Uniformity trial in a greenhouse*

To look for effects attributable to plant position in a greenhouse, the heights of seedlings grown during two summer months were examined for uniformity. Two-dimensional spectral analysis (Renshaw and Ford, 1983) was used to search for cyclic trends in growth as seedling location varied. Small effects were detected but did not correspond to any known factor affecting growth. Given similar conditions, completely randomised designs might be appropriate for future tests of experimental treatments.

#### *Genstat*

As Genstat 5 is not available under the familiar EMAS operating system, EMAS users have to transfer jobs between the NAS machine they work on and a VAX. A procedure in Job Control Language has been written to facilitate this. For correspondence analysis on large sets of vegetation data the package was found to be more convenient and flexible than some programs written specifically for ordination work. Suggestions for simple methods of fitting a time series model, which relates daily rainfall to borehole water levels, have been sent to the Genstat Newsletter.

#### *Statistical training for foresters*

Dr Trudy Watt of the Oxford Forestry Institute gave a successful course in statistics for field staff. She laid emphasis on practical problems of design, layout and basic analysis.

A. C. BURNARD, I. M. S. WHITE

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## Computing: Alice Holt

### *The computing system*

Systems for monitoring the load on the Prime and for charging customer branches for both statistical and computing services have been introduced to improve efficiency.

The two 96 megabyte disc units which had been part of the original installation in 1980 were replaced by a 496 Mb unit, bringing the total online disk storage to 1131 Mb. The memory was also increased from 4 Mb to 8 Mb. This has reduced the contention for memory at peak times and enabled some programs to run much faster.

The six Work Study teams and the HQ office are now able to dial into the Prime at Alice Holt. The success of these links has varied considerably between teams because of the variable quality of the public telephone network. Trials have therefore started to use the FC's data network between HQ and conservancy offices as a link to the Prime. The link between the Prime and the Joint Academic Network (JANET) is now available to users.

Word-processing equipment for typing staff has been standardised on the Opus V PC with Primeword, each typist having her own micro with access to a Laserjet printer.

Four new Microfin electronic data capture units have been supplied with a program to prompt users helpfully. After field trials this program will also be installed on three older units. A Psion Organiser II has also been used to record experimental data.

A Digithurst Microscale II R image analysis system was installed on an Opus V PC; the former has a resolution of  $512 \times 512$  pixels with 255 levels of grey scale. Functions are selected by a mouse from a menu displayed on the PC screen, or frequently used sequences can be built into a macro for semi-automatic processing of images. An initial evaluation of the system showed the inadequacies of the lens supplied, and the necessity of uniform object illumination. For the measurement of discrete areas of resin in bark (with Entomology Branch), the time taken for a single sample was between a fifth and a tenth of that using previous methods. Similar improvements are expected in many other applications.

B. J. SMYTH, R. C. BOSWELL, L. M. HALSALL, R. S. HOWELL

### *Programming*

A major revision was made of the Routine Seed Testing Database of the Seed Branch. The change of database management system from Rapport to Oracle provided the opportunity to restructure the tables of the database and allow the inclusion of several new features. The results of tests on deeply dormant seedlots can now be stored in the database and the allocation of seed tests has been automated; the computer identifies the tests, including weight and number of seeds, which need to be carried out. All seed test data will now be entered by means of formatted screens to allow faster and more accurate input of data.

For Wildlife Branch the canopy structure modelling system was modified by using the compartment grid reference in plotting areas by canopy type, and by writing a device driver to allow data to be captured using a digitiser.

G. J. HALL, L. M. HALSALL, A. J. PEACE

*Work study*

Time-study data are recorded on Microfin data loggers and can be processed immediately by the study man. A statistical analysis system based on Genstat programs called through a user-friendly Fortran interface, allows data selection by study number, tree type or product. Enhancements to the data checking system have continued throughout the year, one program being written to help in calibrating ratings.

Clearing up after the October 1987 storm required Work Study to produce quickly two output guides, whole-tree and end-product, for use with harvesting machines and motor-manual methods. End-product times were estimated from the population of broken and blown trees recorded in the studies, and also from the sub-population of whole trees. The ratio of the two end-product estimates was used to calculate times for processing windblown trees using whole-tree parameters from a tree-length analysis of the sub-population.

L. M. HALSALL, I. D. MOBBS

*Forest surveys*

The Subcompartment Database updating system was revised to ease further the burden of manual checking and to simplify the updating process. Many programs were written using the compartment grid reference data both for area summaries and volume forecasts. The forecasting programs were revised following the writing of two restocking programs to make such programs easier to produce. The database management system for the subcompartment database has been changed from Rapport to Oracle and the two are to be run in parallel until September 1989. The main input form and the system of model assumption have been revised.

G. J. HALL

**Computing: Northern Research Station***Data capture*

In pilot tests, assessment files from an FW60 data encoder were transmitted by telephone from the research outstation at Newton to the Edinburgh mainframe used by staff of the Northern Research Station (NRS). When a file was sent through an attached modem, the encoder's small screen handicapped the foresters, who were not fully conversant with operating systems, error messages, etc. If the file was first discharged to an Amstrad micro (which contained a modem board), the larger screen and use of the error-checking communication protocols of Kermit helped. (Usually, in practice, discs would be posted to NRS and the data transferred into mainframe computers over telephone lines that are faster and safer.) The planned distribution of micros to outstations will initiate a primitive research network; local demands for arithmetic and clerical procedures will provide other work for them.

*Program for incomplete blocks*

The program used by Tree Improvement Branch to do statistical analysis and summarise progeny tests was rewritten to accept incomplete block as well as ordinary randomised block designs. Work included tidying up and converting to a new format all the existing design files held on the computer for progeny

tests – a major task. The new program includes better data checking and error messages and can work if some of the values are missing.

#### *Experiment register database*

This database contains detailed descriptions of about 4000 forest experiments administered from the north. This year brief descriptions of about 1000 nursery experiments were added. Up-to-date information about the assessments previously made on any experiment is available using the specially developed EXPTINFO command. Efforts have been directed to reducing the number of different coding systems used in research and to standardising those retained.

#### *Grid reference in area*

An efficient 'point in polygon' program was written which allows checking the locations (land or sea) of GB Ordnance Survey grid references in a file. This will provide the basis of a program (for use generally and with the Experiment Register Database) which will give Forest District, Silviculture Outstation, county and other information for any grid reference.

R. W. BLACKBURN, K. P. DONNELLY

## INTER-BRANCH REPORT: STATISTICS AND COMPUTING (SOUTH) AND MENSURATION

Work on the model described in last year's *Report* (p. 64) has continued with three main developments.

Regression analyses of volume increment against measures of crown size have shown that the exposed surface area of the crown was the best predictor tested of volume growth rate in competing trees of Sitka spruce. This accords with the conclusions of Hamilton (1979) and has been incorporated into the growth model by making photosynthesis rate depend on crown surface area.

Competition from neighbours restricts crown size and this is built into the model by calculating the point at which crowns meet, assuming they are conical. The boundary between touching crowns is then used to calculate a polygon from which the ground area available to each tree, and its crown surface area, can be found as a step in calculating photosynthesis rate. The software to do this is based on a program supplied and described by Nance *et al.* (1988).

The current version of the model simulates an important feature of tree growth, namely that top-height is very sensitive to site factors but that the cumulative volume for any given top-height is similar for stands of widely differing yield class. In the model, this occurs because height and diameter growth both depend on the rate of new foliage growth; a given area of new sapwood is added for each kilogram of new foliage and height growth depends on the weight of new foliage and the crown surface area over which it is spread. So, height, basal area and hence stand volume depend on how much foliage there has ever been in the stand, not on how long it has taken to produce this foliage.

A. R. LUDLOW, G. KERR

#### References

- Hamilton, G. J. (1969). The dependence of volume increment of individual trees on dominance, crown dimensions and competition. *Forestry* 42(2), 133–144.
- Nance, W. L., Grissom, J. E. and Smith, W. R. (1988). A new competition index based on weighted and constrained area potentially available. In, *Forest growth modelling and prediction*, eds A. R. Ek, S. R. Shifley and T. E. Burke, Proceedings of a IUFRO Conference, August 23–27, 1987, Minneapolis, Minnesota, Society of American Foresters, Publication No. SAS 87.12, Vol. 1, 134–142.

## COMMUNICATIONS

### Library

Demand for information was similar to the previous year with 14 010 requests processed. The new CAIRS information retrieval system has been in regular use and with further development has enabled searching by visitors to Research Division and also by staff at NRS through the JANET system.

### Photography

Work has been concentrated in three areas of effort: photographs covering northern research, illustrations of urban forestry, and the development of computer graphics. This latter work, in co-operation with Publications Section's Graphics Officer, has produced over 500 slides for use in lectures and publications. A notebook video dealing with Forest Health Days was successfully completed.

### Visits, seminars and open days

Demand continues to rise for these highly effective means of communication and there was, once again, a marked increase in visits of parties and individuals. Of the 92 visits to Alice Holt involving 784 people, 30 were arranged as seminars dealing with 540 visitors. At NRS there were a further 44 visits involving 422 visitors.

B. G. HIBBERD

### Publications

To support the Government's initiative in encouraging alternative use for surplus agricultural land, two publications *Farm woodland planning* and *Farm woodland practice* were prepared in co-operation with the agriculture departments to provide technical information support for the Farm Woodland Scheme launched in the autumn of 1988.

The following titles were published during the year ending 31 March 1989.

#### *Report*

Report on forest research 1988 (£9.95)

*Bulletins*

- 75 The silviculture and yield of wild cherry, by S. N. Pryor (£2.30)
- 76 Silvicultural principles for upland restocking, by P. M. Tabbush (£3.50)
- 77 British softwoods: properties and uses, by T. Harding (£5.50)
- 78 Natural regeneration of broadleaves, by J. Evans (£3)
- 79 Forest health surveys 1987. Part 2: analysis and interpretation, by J. L. Innes and R. C. Boswell (£6)
- 80 Farm woodland planning, edited by H. Insley (£6.95)

*Handbook*

- 3 Farm woodland practice, edited by B. G. Hibberd (£7.50)

*Occasional Papers*

- 16 Forestry section proceedings (British Association for the Advancement of Science, Sept. 1986), edited by G. C. Barnes (£7.50)
- 17 Farming and forestry (proceedings of a conference, Sept. 1986), edited by G. R. Hatfield (£15)
- 18 Design of the census of woodlands and trees 1979–82, by K. Rennolls (£5)
- 19 The green spruce aphid and Sitka spruce provenances in Britain, by C. I. Carter and J. F. A. Nichols (50p)

*Miscellaneous*

Silviculture (South) Branch leaflet (free)

*Arboriculture Research Notes*

(Issued by the DoE Arboricultural Advisory and Information Service).

76/88/SSS Sewage sludge as a fertiliser in amenity and reclamation plantings, by A. J. Moffat.

The following revised Notes were issued:

- 2/88/PATH Breeding elms resistant to Dutch elm disease, by D. A. Burdekin and K. D. Rushforth (revised by B. J. W. Greig).
- 13/88/PATH English elm regeneration, by B. J. W. Greig.
- 21/88/SILS Coppice, by R. E. Crowther and D. Patch (revised by J. Evans and H. L. Davies).
- 27/88/SILS Herbicides for sward control among broadleaved amenity trees, by W. J. McCavish and H. Insley (revised by D. R. Williamson).
- 39/88/PATH *Coryneum* canker of Monterey cypress and related trees, by R. G. Strouts.
- 53/88/WS Chemical weeding – hand-held direct applicators, by P. B. Lane.
- 60/88/ENT Oak defoliation, by T. G. Winter.

*Research Information Notes*

- 133 Insects and storm-damaged broadleaved trees, by T. G. Winter.
- 134 Insects and storm-damaged conifers, by T. G. Winter.
- 135 Identity and nomenclature of vegetatively propagated conifers used for forestry purposes, by C. J. A. Samuel and W. L. Mason.
- 136 Conserving insect habitats provided in dead broadleaved wood by the wind damage of 16 October 1987, by P. T. Harding, K. N. Alexander, M. A. Anderson and D. Lonsdale.

- 137 The use of large scale ridge and furrow landforms in forest reclamation, by A. J. Moffat and C. J. Roberts.
- 138 Effects of the gale of October 1987 on sawn pine timber, by D. A. Thompson.
- 139 Forest health surveys 1988 – preliminary results, by J. L. Innes and R. C. Boswell.
- 140 Approved methods for insecticidal protection of young trees against *Hylobius abietis* and *Hylastes* species, by J. T. Stoakley and S. G. Heritage.
- 141 Provisional regimes for growing containerised Douglas fir and Sitka spruce, by M. K. Hollingsworth and W. L. Mason.
- 142 Use of containerised conifer seedlings in upland forestry, by W. L. Mason and M. K. Hollingsworth.
- 143 Early forest performance of Sitka spruce planting stock raised from cuttings, by W. L. Mason, P. Biggin and W. J. McCavish.
- 144 Inoculation of *Alnus rubra* seedlings to improve seedling growth and forest performance, by J. D. McNeill, M. K. Hollingsworth, A. J. Moffat, L. J. Sheppard and C. T. Wheeler.
- 145 Tree physiology and air pollution in southern Britain, by Gail Taylor, M. C. Dobson, P. H. Freer-Smith and W. J. Davies.
- 146 Carbon dioxide, global warming and forestry, by A. J. Grayson.
- 147 Application leaflet on the use of 'Gamma-Col' and 'Lindane Flowable' for pre-planting treatment of young trees against *Hylobius abietis* and *Hylastes* spp., by J. T. Stoakley and S. G. Heritage.
- 148 Liming to alleviate surface water acidity, by T. R. Nisbet.
- 149 Selection of superior oak, by R. Harmer.

E. J. PARKER

## PART II

### *Work done for the Forestry Commission by Other Agencies*

## SILVICULTURE

### **Nutrition and forest soils**

by M. F. PROE

*Macaulay Land Use Research Institute, Aberdeen*

Collaborative work with the Forestry Commission has continued into the establishment and early development of second rotation forest stands. At Culbin Forest, Moray, the long-term effects of nitrogen fertiliser on Corsican pine have been studied and consequences for nutrient cycling in the second rotation are currently being examined. Early results suggest a significant long-term effect on tree growth which may carry over into the second rotation as a result of the breakdown and release of nutrients from larger quantities of harvest residues. A significant decrease in soil pH has also been measured more than 20 years after the last fertiliser application was made.

An age series of Sitka spruce sites from pre-clearfell through towards canopy closure in the second rotation has now been selected for study at Kielder Forest, Northumberland. The physical and nutritional roles of harvest residues at different stages in stand development will be quantified over the next 5 years and potential consequences of whole-tree harvesting assessed for these sites.

The nutritional advisory service to Forest Nurseries continued to operate.

### **Herbicide evaluation for forestry uses**

by D. V. CLAY and J. LAWRIE

*Department of Agricultural Sciences, University of Bristol  
and Institute of Arable Crops Research, Long Ashton Research Station*

This project involves the evaluation of herbicides on forest crop and weed species in pot experiments, outdoors in the glasshouse. The objective is to find promising new herbicides and herbicide mixtures or new ways of using herbicides for forestry weed problems; these are followed up in field experiments by Forestry Commission research staff.

#### *Herbicides for seedbeds*

Eleven herbicides were applied to red alder and birch pre- and post-emergence. Most were very toxic particularly to birch. Chlorthal-dimethyl and isoxaben were the least damaging. Others were safe at low doses suggesting that repeated low-dose treatment may be a useful approach to seedbed weed control on herbicide-sensitive tree species. This was confirmed in an experiment on Japanese larch and birch where four applications of quarter doses of diphenamid and napropamide at 2-week intervals were as safe, or safer, than the full dose applied pre-emergence.



### *Herbicides for transplant lines*

Nine soil-acting herbicides applied post-planting were found to be safe on six broadleaf tree species at three times the recommended dose. Mixtures of some of these herbicides could form the basis of effective programmes for controlling annual weeds. The tolerance of broadleaf and conifer species to foliar-acting herbicides is now being assessed. Sulphonylurea herbicides of potential use against bracken did not damage Douglas fir when applied as root drenches but some foliar sprays in July inhibited regrowth the following year. Addition of surfactant to the sprays increased damage.

### *Herbicides for weeds of young plantations*

Glyphosate is often ineffective on some perennial grass species. Further work with adjuvants for glyphosate indicated some increases in activity particularly on *Molinia caerulea* but not the large-scale and reliable enhancement that is required on weeds such as *Deschampsia caespitosa* or *Holcus mollis*.

On *Rhododendron ponticum* the effect of sulphonylurea herbicides and imazapyr was increased by adjuvants such as Agral, Mixture B and Silwet L77.

There is a need for effective herbicide treatments to control natural regeneration of Sitka spruce. Imazapyr was more toxic than glyphosate at high doses. Activity was enhanced by adjuvants but mixtures of herbicides did not give much increase in toxicity.

## SITE STUDIES

### **Soil erosion on land cultivated and drained for afforestation**

by P. A. CARLING

*Institute of Freshwater Ecology,  
Windermere Laboratory, Ambleside, Cumbria*

Soil erosion in plough furrows has been monitored for over 1 year at three sites representing different lithologies, slope gradients and rainfall regimes. The erodibility of undisturbed soil samples has been tested in a laboratory flume using different gradients and water discharge rates. The results are being evaluated to determine the factors responsible for erosion and the spacing of cross drains which will minimise total soil loss from ploughed ground.

### **Effect of clear felling on stream sediment**

by R. I. FERGUSON

*Department of Geography,  
Sheffield University*

Suspended sediment concentrations (SSC) have been intensively monitored since mid-1987 in two neighbouring catchments, one about 50 per cent clear felled since December 1987 and the other a forested control. Mean and maximum SSC in the experimental stream were almost 10 times 1987 levels in January–March 1988, but since then SSC has averaged only 50 per cent higher than in 1987, mainly because SSC is higher at low flows. The initial increase may reflect disturbance during riparian operations but also coincided with exceptionally wet

weather during which mean and maximum SSC doubled in the control stream. There has been little change in bedload quantity or grain size.

### **The nature and pattern of soils under ancient woodland**

by B. R. WILSON

*Department of Soil Science,  
University of Reading*

Sampling was begun in three ancient woodland sites in Berkshire which stand on a calcareous gley soil and two acid gley soils respectively. These were compared with an area of cultivated agricultural land on the same parent material.

A number of soil properties were determined including carbon, nitrogen and organic phosphate. All the woodland soils showed significantly higher values for C, N and organic P than the agricultural soil, particularly in the surface layers. The magnitude of the variability of soil properties was also found to be consistently greater in the woodland soils. The spatial pattern of this variability of soil properties shows distinct trends beneath ancient woodland cover. The sampling strategy adopted reveals that variability of soil properties is closely related to the distribution of individual trees and the distribution of leaf litter.

This work will be extended to encompass woodland sites of different ages and sites with differing parent materials to develop an understanding of the behaviour of these properties in woodland soils through time.

### **Air pollution and tree physiology**

by G. TAYLOR

*Institute of Environmental and Biological Sciences,  
University of Lancaster*

Experimental work has shown that ambient air quality at Headley, Hampshire may significantly alter the physiology of young beech and Sitka spruce. For both species, exposure to air pollution present at the site, resulted in the production of roots which were longer than those grown in clean air. This is an interesting result since in many studies the impact of pollution on root growth has only been assessed by considering root dry weight, and yet it is well known that root length is far more important for the uptake of water and nutrients.

Shoot physiology was also significantly altered by exposure to air pollution, although both positive and negative effects were observed. For instance, for Norway spruce, needle length was significantly reduced by pollution at Headley; significantly increased at Chatsworth; while at Glendevon, pollution had no effect on needle length.

### **The role of the soil microbial community in areas reclaimed to forestry after opencast mining**

by J. A. HARRIS, H. BIRCH and P. BIRCH

*Environment and Industry Research Unit,  
Polytechnic of East London*

A research programme began in autumn 1988 to assess the importance of the microbial community for forestry in areas reinstated after opencast coal mining in South Wales. The size, composition and activity of the microbial community

including mycorrhizal relationships and assessment of nitrogen release from the microbial biomass will be related to tree growth and soil water relations in a parallel study being carried out by the Forestry Commission.

Preliminary results indicate a good correlation between increasing microbial activity in the shale and enhanced tree growth.

### **Effects of afforestation on water resources**

by J. R. BLACKIE and R. J. HARDING

*Institute of Hydrology,  
Wallingford, Oxon*

In the Balquhider catchments (Central Region, Scotland) increased sediment loads have been the dominant effects of the initial planting in the Monachyle and the progressive felling in the Kirkton since 1986, with loads now 4.5 and 1.5 times the pre-treatment levels respectively. Sources are the plough lines, now revegetating, and the roads in the Kirkton. Marginal evidence of decreases in water use by both catchments is now emerging. The studies of the water use of high altitude grassland were continued through 1988 (see *Report 1988*, pp. 71–72). Total water loss from the two lysimeters during the snow-free period was approximately 75 per cent of the Penman potential value.

### **Detection of any widespread and unprecedented changes in growth in European conifers**

by K. R. BRIFFA

*Climatic Research Unit,  
University of East Anglia*

This is a co-operative project being undertaken in conjunction with the Swiss Forest Research Institute, Birmensdorf, Switzerland.

During recent years, Dr F. H. Schweingruber of the Swiss Forest Research Institute has carried out an extensive programme of tree sampling from specially selected sites across western Europe. For each site, a suite of ring-width and wood densitometric parameters have been measured at Birmensdorf. The complete data bank has been transferred to the Climatic Research Unit. These data offer a valuable opportunity to study the links between tree growth and climate variability across both space and time.

The study will attempt to establish whether any recent changes in tree growth and wood density are unprecedented in a long-term context (*c.* 200 yr) and examine the spatial distributions of any such changes. The study will also examine to what extent any changes may be linked with climate or to other potential forcing factors, especially regional-scale pollution. So far over 70 sites have been selected on the basis of climatic data length, regional distribution, site density and species. Additional sampling has also been undertaken to increase the density of the network in central Europe (Switzerland and France) and this material is currently being processed at Birmensdorf. Meanwhile, data from the chosen sites have been processed to remove age-related trends in the individual series and the data averaged into site chronologies. A multivariate response function technique has been used to quantify the effects of regional scale temperature on total ring width and maximum latewood density variability at each site.

## PHYSIOLOGY

### Effects of nutrient deficiency on photosynthetic development in Sitka spruce

by J. CHANDLER

*Botany Department,  
University of Edinburgh*

The development of photosynthetic capacity and the effect of nutrient deficiency were studied in Sitka spruce seedlings during the 1988 season. Net photosynthetic rate, chlorophyll content and activity of ribulose 1,5-bis-phosphate carboxylase were measured under standard conditions in fully fertilised (control) trees and trees deficient in P, K, Mg, N or all nutrients. In controls, chlorophyll content increased until September, and ribulose 1,5-bis-phosphate carboxylase activity increased to 20 times its original value. The most significant reductions in all three factors occurred in the N-deficient and total nutrient-deficient plants. Application of fertiliser to deficient trees in these treatments caused a rapid 'recovery', with the variables reaching higher final levels than in controls.

### Physiology and anatomy of bud break, and rooting of cuttings, in oak

by R. A. STENNING, G. BROWNING, and K. A. D. MACKENZIE

*Institute of Horticultural Research,  
East Malling, Maidstone, Kent*

Experiments are proceeding to investigate the relationship between vigour, the chilling requirements of buds, and rooting of softwood cuttings of *Quercus robur*. A linear response to chilling, with great clonal variation in rate of bud break, was observed. Anatomical studies of cuttings taken from epicormic shoots showed that most rooting occurred at the beginning of secondary growth, when vascular bundles were in the process of joining to form a continuous cylinder. Root primordia arose from within the outer phloem region, with most activity in the gaps in the sclerenchyma sheath that lies adjacent to an interfascicular region

## PATHOLOGY

### Viruses in beech

by J. I. COOPER

*Department of Plant Sciences,  
University of Oxford*

Serological and biological assays have not revealed viruses in mature beech from Scotland or in 'declining' specimens in England. Evidence of compounds which lessen the reliability of these tests has been sought, but not found, in oak, beech or spruce. Virus-free (tested) beech seedlings (c. 200) have been inoculated with cherry leaf roll virus (CLRV ex birch) or arabis mosaic virus (ex lilac). Seedling beech have been intensively assayed to provide a baseline of knowledge concerning the directed double-stranded RNA species they contain (for comparison later this year with declining mature trees). CLRV has its genetic

information divided between two linkage groups (RNA-1 and RNA-2) which have different functions. Thus, RNA-2 specifies coat protein properties that are measured in serological tests and which are for this virus usually characteristic of the natural source. Unexpectedly, the RNA-1 and the RNA-2 of birch, rhubarb and walnut isolates of CLRV have one large segment (one quarter of their total length) in common. The replicated region is terminal and therefore particularly amenable to assessment as a broad spectrum detection aid. Non-radioactive procedures depending on nucleic acid hybridisation are being tested in the context of surveying broadleaved trees for these viruses.

## ENTOMOLOGY

### Genotype–environment interactions in the resistance of *Picea sitchensis* to the green spruce aphid, *Elatobium abietinum*

by E. J. MAJOR

*School of Agricultural and Forest Sciences,  
University College of North Wales, Bangor, Gwynedd*

The effect of water stress on Sitka spruce and the performance of *Elatobium abietinum* have been investigated. Trees were given three water treatments, intermittent stress, continuous stress and control.

Leaf water potential was measured and found to be significantly different between the water stress treatments. Aphids on intermittently stressed trees showed an increase in fecundity which was not found when trees were continuously stressed. Chemical analysis of the foliage from these trees revealed differences in two groups of secondary metabolites, the terpenes and phenolics.

### The arthropod fauna of coniferous plantations

by C. M. P. OZANNE

*Zoology Department, Oxford University*

Arthropods were sampled from the canopies of Scots pine, Corsican pine, Norway spruce and Sitka spruce during 1986 and 1987, using pyrethrin knock-down sprays. Pines showed high densities of Collembola in autumn 1986 while Sitka spruce supported a mean number of 11 186 *Elatobium abietinum* m<sup>-2</sup> in May 1987. Trees that were 10–15 years old had higher total populations than 25-year-old trees and arthropod numbers were generally greater in 1987 than in 1986.

A fertiliser trial was sampled in 1987. Analysis indicated that the abundance of Heteroptera, Lepidoptera, Collembola and Psocoptera responded to presence and absence of N, P and K.

A study, carried out during 1988, of the influence of patch size and 'edge effect' on Scots pine fauna showed that single trees supported higher populations and greater diversity of Coleoptera than 1 ha or 10 ha plots. Greater abundances in some orders were found on patch interiors than on edges; species richness was not found to be greater at the edges.

## WILDLIFE AND CONSERVATION

### **The pheasants and woodlands project**

by P. A. ROBERTSON

*The Game Conservancy Trust,  
Fordingbridge, Hampshire*

The objectives of this 3-year study are to examine the woodland habitat requirements of the pheasant in the winter and spring, to suggest management to improve conditions for this bird, and to assess the effects of such management on woodland conservation. Pheasants prefer woods with a high edge to area ratio and abundant low shrubby cover providing an abundance of natural food. Breeding populations are highest on land with 25–35 per cent woodland although 15–20 per cent is the optimum for effective shooting. Coppicing, rotational felling, use of conifer nurse crops, trees which cast light shade and the creation of wide rides all benefit this bird.

The provision of glades and wide rides for pheasants will result in an increased diversity of plants, songbirds and butterflies. Wood anemone, greater stichwort, pearl-bordered fritillaries, large skipper, white admiral, small white, ringlet are some of the species which benefit.

### **Nightjar ecology in Thetford Forest**

by C. G. R. BOWDEN

*Royal Society for the Protection of Birds,  
Sandy, Bedfordshire*

The aims of the project are to define nightjar breeding habitat requirements and to relate these to forestry management practices.

A survey detected 205 calling males in 1988 (10 per cent of the British population) on plantations less than 15 years old and revealed pronounced local differences in density within the forest. Radiotelemetry was used to establish feeding ranges and showed that birds regularly travelled up to 2 km, feeding mainly over the younger plantations but also using nearby heathland/pasture.

Techniques for comparing densities of moths (the main food) and for weighing adults before and after foraging bouts were developed so that comparisons can be made between the high and low density areas and between different management practices.

### **Mynydd Du: experimental forest management for bird conservation**

by K. BAYES

*Royal Society for the Protection of Birds,  
Sandy, Bedfordshire*

This project evaluates the impacts of management practices on bird communities in an established mixed species upland forest and will propose improvements of forests for bird conservation. Census work was undertaken during the winter (40 bird species recorded) and breeding season (57 bird species recorded) of 1988 defined bird communities and related bird densities to environmental and management variables. Proposals for forest improvement have been developed. The changes produced by management modifications will be compared with



## WOOD UTILISATION

### Research on British-grown timber

by J. W. W. MORGAN

*Building Research Establishment,  
Garston*

#### *Effect of thinning/growing space on structural wood quality of Sitka spruce*

The influence of growing space available to the tree throughout its life on the structural properties of the wood laid down, is being evaluated using trees from Brendon, Somerset. Forty-one trees from an experimental plot of P29 Sitka spruce with a recorded history of spacing and thinning have been felled and converted to battens, kiln dried and machine stress graded. The identity and position of the battens in the stem was retained during conversion.

A competition quotient has been devised, to examine the effect of within crop spacing on stem size and structural wood performance, based on the space available to a tree relative to its nearest neighbours in each of four quadrants. Work is now directed at identifying any relationships which may exist between this quotient and wood properties. The work is part of a co-ordinated European research programme on the wood quality of fast grown spruce.

#### *Effect of wood characteristics on machine grading of Sitka spruce*

A fuller understanding of the relative importance of wood characteristics on the performance of Sitka spruce in machine stress grading would assist growers in producing optimum yields of structural timber. Detailed data on density, slope of grain, knot size and position, microfibril angle and other growth features has now been recorded for 460 battens. These represent a range of quality and complete the database. All battens have been machine stress graded and a suite of computer programs has been devised (by Lancaster University) to examine statistical relationships. The raw data of measured characteristics were converted to 70 variables that might influence machine deflection and of these 11 were found to be significant.

Present indications are that the model should be able to predict properties for a population of battens but it is not precise enough to predict for an individual batten.

#### *Structural properties of windblown softwood*

Advantage has been taken of the storm damage of October 1987 to examine whether the structural properties of softwoods are adversely affected by (1) being windblown and (2) being water stored until used. Some work on the first aspect has been undertaken this year by examining boards taken from windblown Corsican pine. A substantial percentage of compression creases were found in the boards, but it is not known at this stage whether these are peculiar to windblown stems or are developed in the tree and are to be found in all material. Machine grading performance of the boards did not appear to be affected by the presence of the creases, but their significance for impact strength has yet to be assessed. Work on the mechanical properties of water stored timber will commence as material comes forward from the FC store at Thetford.



## **Drying and presentation of British-sawn softwood**

by C. J. GILL

*The Timber Research and Development Association,  
Hughenden Valley, High Wycombe, Bucks*

Forestry Commission/TRADA collaborative work has concentrated on investigating the prospects for drying at high kiln temperatures British-grown Sitka spruce to the moisture contents required of constructional timber. Although much carcassing and general purpose building timber is still supplied green or partially dried, it will be necessary to dry it to about 18 per cent both to compete with imported softwood (which is increasingly being dried at source) and to comply with the requirements of BS 5268.

High temperature kiln drying, i.e. at temperatures above 100°C, is, based on experience in Australia, New Zealand, USA and France, potentially attractive in terms of speed of drying, kiln capacity and avoidance of twist.

Preliminary trials carried out on small-scale equipment in France seemed to confirm that these benefits were available to British-grown Sitka spruce although virtually all commercial experience is with pine. The results did give cause for concern because the relationship between breaking strength and stiffness, on which machine stress grading is based, seemed to be upset by the high drying temperatures. Consequently a large-scale drying trial is in progress to investigate whether this effect is as significant for Sitka spruce as it has been found for certain other North American species.

Kiln loads of 3.6 m long timber grown in the Forest of Ae and chosen as representative of some UK-grown material have been dried at either conventional temperatures or high temperatures and their strength and stiffness compared. Before being dried, each piece was tested non-destructively for strength to allow the loads to be matched. After drying, each piece was machine stress graded and subsequently tested to failure in bending.

Not all the results are available but the early indications suggest that any effect of high temperature drying on strength is not of such significance as to inhibit the development of high temperature kilning techniques for British-grown Sitka spruce.

### *Comparison of Scots pine and Corsican pine*

The new transmission pole testing facility at TRADA is being used to compare the strength and stiffness characteristics of pole-length logs of Scots pine and Corsican pine. The objective is to determine the extent of any effect on the pole's strength caused by the presence of compression creases found in Corsican but not in Scots pine. If none then they can be ignored and the two species used interchangeably; if significant, it will be necessary to determine why such compression creases occur (maybe due to felling damage or wind) and how to eliminate them.

## **Timber preservation**

by R. J. MURPHY

*Timber Technology Group,  
Department of Pure and Applied Biology, Imperial College, London*

The work reported is conducted through a lectureship jointly sponsored by the Forestry Commission, the Timber Trades' Federation and the British Wood Preserving Association. A major research effort, with support from the Commission of the European Communities, has continued on development of improved methods of preservative treatment for British-grown Sitka spruce for use in high decay hazard situations. This has investigated further a diffusion treatment approach but has widened in scope to incorporate vacuum-pressure methods suitable for application to 'green' or partially seasoned material. A significant aspect of this project is the assessment of the efficacy of 'envelope' or 'shell' treatments in preventing microbial colonisation and decay of Sitka spruce in ground contact.

Gas phase treatment of wood-based board materials produced from home-grown timber has developed considerably since the previous report. Treatment schedules suitable for wood preservative application have been dramatically shortened and problems associated with board moisture content largely overcome. Gas phase treatment times in the order of 5 to 10 min have been achieved in a variety of wood based boards in laboratory studies. Application of this technology for flame retardant treatment is under active investigation. Further work using full sized 8 ft × 4 ft sheets of various boards in at pilot plant scale is planned.

Joint research with the Forestry Commission is also undertaken by Dr D. J. Dickinson in projects concerned with anti-sap stain treatments of British-grown softwoods and hardwoods and, in collaboration with the Electricity Council, on seasoning and treatment of British-grown poles for overhead lines.

## **DEVELOPMENT**

### **Value of user-benefits of forest recreation: some further site surveys**

by K. G. WILLIS and J. F. BENSON

*Department of Town and Country Planning,  
The University of Newcastle-upon-Tyne*

This work followed on from site surveys carried out last year by the Universities of Stirling and Newcastle. It involved collecting data on visitor numbers, values and other attributes, over a range of forests, in order to calculate the consumer surplus or net benefit generated from the free recreational opportunities provided in those forests. The sites were selected using cluster analysis, so that the complete set of sites (including those surveyed last year) represented types of Forestry Commission woodland showing the biggest differences from other types. The results for each site are set out in Table 12.

**Table 12 The total unmarketed benefit attributable to nine forest sites<sup>(1)</sup>**

Forest District main site	Consumer surplus per visitor, <sup>(2)</sup> £	Annual visitor numbers	Consumer surplus per site, <sup>(3)</sup> £
Cheshire (Delamere)	1.91	225 000	429 750
Ruthin, Clwyd (Moel Famau)	2.52	48 000	120 960
Brecon (Coed Taf)	2.60	41 000	106 600
New Forest (Bolderwood)	1.43	68 000	97 240
Loch Awe (Inverliever)	3.31	3 000	9 930
Lorne (Barcaldine)	1.44	10 000	14 000
Newton Stewart (Glen Trool)	1.61	70 000	112 700
Buchan (Bennachie)	2.26	84 000	189 840
Aberfoyle (David Marshall Lodge and Achray)	2.69	145 000	390 050

<sup>(1)</sup> At 1988/89 prices<sup>(2)</sup> Per visit<sup>(3)</sup> Per year

The results showed a significant appreciation of wildlife amongst forest visitors, with an average of 30 per cent of the value of a forest visit being allocated to the opportunity to see wildlife. The second most important factor was judged to be the facilities provided to improve access to the forest, including: roads, paths, car parks, toilets, and picnic places.

A very rough indication of the total recreational value of the estate generated from these figures, is £140 million per year. The final stage of this work will be to draw together the results from all the 15 sites surveyed over the last 2 years, and calculate a much more accurate estimate of total value, given the data on consumer surplus now available, and the visitor number estimates that are currently being collected.

### **Forest visitor numbers in Scotland, England and Wales**

by SYSTEM 3 and OMNIMAS

*independent market researchers*

As part of the work towards producing an estimate of the value of the whole forest estate for recreation, two market research companies have been hired to carry out questionnaire surveys on forest visitation. Rather than trying to count visitors in the forest, they are performing a household survey, asking respondents how many times they have visited a forest in the last 4 weeks. Further questions are aimed at identifying the ownership of the forests visited. This work has generated preliminary figures of 200 million forest visits per year, with about 72 million being identified as visits to Forestry Commission forests. This work is still underway, and it is hoped to have a final estimate by 1990, to tie in with the work described above.

### **Prices of broadleaved timber**

by G. R. WATT and D. MORRISON

*John Clegg and Co.,  
Edinburgh*

The management of the country's broadleaved resource, its replacement, and possible future expansion are important issues for many timber growers and hardwood-using industries. They are also subjects which are attracting a great deal of public attention. The Forestry Commission therefore decided that it was necessary to improve the information it had on prices of broadleaved timber. For this, it hired John Clegg and Co. in December 1988 to collect the data and assemble a database. These data will be used to generate price-size curves similar to those already derived for conifers. These will then be useful for evaluating the economic implications of managing existing broadleaved crops in different ways, and the expansion of broadleaved planting.

### **An input-output study of the forest industry**

by W. E. S. MUTCH

*Department of Forestry,  
University of Edinburgh*

Data have been collected for this project, covering every aspect of inputs and outputs to the forestry industry. Firms covered range from nurseries and growers to pulpmills and sawmillers. The project is now entering its second stage, where the information collected will be entered into the full national input-output model and used to explore the interactions between the forest and other industries, the local economy and rural employment. This is likely to be finished by 1990. As a planning tool it will be used to indicate, for example, the employment generated by forestry.

### **Economic security arguments for afforestation**

by A. MARKANDYA and D. W. PEARCE

*Pearce Sharp and Associates,  
Bedford*

A desk study was carried out in 1988 to evaluate the likely future costs of either an embargo or artificial price increase on UK timber imports. The results showed that uncertainty about future prices was a poor reason for justifying domestic forestry expansion, but that the risk of embargoes could lead to quite high welfare losses depending on the likelihood, scale and duration of future timber embargoes, and was therefore worthy of further investigation. The project showed that losses of between £3-100 million could be expected. It now remains for the Forestry Commission to evaluate how these expected future losses have been reduced by expansion of the forest estate.

## APPENDIX I

## Publications by Forestry Commission Staff

ALLEN, D. J. (1988). The measurement of unsaturated hydraulic conductivity using the instantaneous profile method in a forest soil. *Soil* 4, 84–100.

The soil moisture content and soil water potential of a stagnogley under a pine stand were measured using a neutron probe and sets of tensiometers in order to investigate the relationship between vertical hydraulic conductivity and water content. Data were collected to a depth of 1 m at regular intervals over a drainage period of 45 days. The method appears useful for determining the unsaturated conductivity of forest soils.

[BLOSS, H. E. and] WALKER, C. (1987). Some endogonaceous mycorrhizal endophytes in the Santa Catalina mountains of Arizona. *Mycologia* 79, 649–654.

This paper reports the results of an intermittent survey of endomycorrhizal species found in the encinal region of the Santa Catalina mountains of Arizona.

BRASIER, C. M. (1988). Rapid changes in genetic structure of epidemic populations of *Ophiostoma ulmi*. *Nature* 332, 538–541.

Current epidemic front populations of *O. ulmi* in Europe are largely clonal as judged by vegetative compatibility (vc) type, colony phenotype, and mating type (all B-type). A rapid change to heterogeneity then occurs in association with the appearance of the 'missing' A mating type. Preliminary evidence suggests that the frontal clones are more pathogenic than the emerging heterogeneous component, and that the rapid change to heterogeneity may be associated with the spread of mycoviruses (d-factors) in the pathogen clones.

BRASIER, C. M. (1988). *Ophiostoma ulmi*, cause of Dutch elm disease. In, *Genetics of plant pathogenic fungi*, ed. Sidhu, G. S., *Advances in Plant Pathology* 6, 207–223.

Reviews the current knowledge of genetic systems in *O. ulmi* including species structure, genetic markers, mating system, subgroup fertility barriers, vegetative compatibility system, growth rate, pathogeneity systems, subgroup evolution, d-factors and dsRNA, mitochondria and plasmids, developmental systems, ecological and population genetics.

[BROWN, K. A.,] FREER-SMITH, P. H., [HOWELLS, G.D.,] SKEFFINGTON, R. A. and WILSON, R. B.] (1988). Rapporteurs' report on discussions at the workshop on excess nitrogen deposition. *Environmental Pollution* 54, 285–295.

In the mid 1980s the idea that deposition of inorganic nitrogen compounds can damage natural ecosystems and forests has emerged. The mean wet plus dry deposition of nitrogen in the Netherlands is, for example, about 40 kg ha<sup>-1</sup> yr<sup>-1</sup>. The strands of evidence connecting nitrogen deposition with damage are tenuous and the issue remains controversial. This paper summarised the discussions which were based on 12 key issues raised at the workshop held at Leatherhead in September 1987.

[CANNELL, M. G. R. and] COUTTS, M. P. (1987). Growing in the wind. *New Scientist* 117 (1596), 42–46.

The impact of wind damage in upland forests is described, together with the mechanical effect of wind on tree growth.

CARTER, C. (ed.) (1988). *Summary of a workshop meeting on aphids and conifers*. Forestry Commission Research Division, Alice Holt, Surrey. (26pp.)

Summaries and discussions are given of 11 papers read at a meeting that brought together researchers engaged in, or aligned to, current investigations concerned with the association of aphids and conifers. The aim was to discuss recent developments in this field with representatives from the disciplines of silviculture and tree physiology.

CARTER, C. (1989). Woodland butterflies by the way. *Currant* 5 (1) January, 6pp.

An account of habitat enhancement for butterflies and flowering plants in even-aged coniferous plantations in Scotland. Suggestions are given for widening rides according to the crop height and orientation, and the benefits this will accrue for conservation and ride condition are discussed.

CARTER, C. I. and GIBBS, J. N. (1989). Pests and diseases of forest crops. In *Pest and disease control handbook*, eds. Scopes, N. and Stables, L., 619–634. British Crop Protection Council.

An account is given of pests and diseases of forest nurseries, Christmas trees and forest plantations and methods of control and management are described.

CARTER, C. I. and NICHOLS, J. F. A. (1986). The lime aphid, *Eucallipterus tiliae*. In *Insects and the plant surface*, eds. Juniper, B. and Southwood, T. R. E., p.342.

A summary of screening tests of European lime species for resistance to the lime aphid. Two types of resistance are identified from scanning electron micrographs of leaf surfaces. Some *Tilia* species have various types of stellate pubescence preventing aphids reaching their feeding site, other species have glandular structures along the leaf veins.

CARTER, C. I. and NICHOLS, J. F. A. (1988). *The green spruce aphid and Sitka spruce provenances in Britain*. Forestry Commission Occasional Paper 19. Forestry Commission, Edinburgh.

A comparison is made of the impact and recovery of a IUFRO provenance collection of Sitka spruce following complete defoliation in 1980 by *Elatobium abietinum*. Data on the phenological displacement of plant dormancy and bud break and the associated changes in foliar amino-acid concentration of old needles are presented and the influence this has on aphid population increase is discussed.

CARTER, C. I., [WOOD-BAKER, C. S. and POLASZEK, A.] (1987). Species, host plants and distribution of aphids occurring in Ireland. *Irish Naturalists' Journal* 22, 266–284.

Two hundred species of aphids are recorded from Ireland. This information has been compiled from recent collections and older material including museum specimens. All of the main family groupings of the Aphidoidea are represented in the Irish fauna except for the subfamily Pterocommatinae. All the species have been recorded previously from other places in northern Europe, although some of them cannot be native to Ireland as they are specialist feeders on exotic plants.

CHADWICK, A. H. and PEPPER, H. W. (1988). The electric element – still much to learn. *Forestry & British Timber* 17 (6), 29–31.

Electric fencing is widely used in agriculture and has been promoted for forestry as a low cost alternative to conventional deer fencing. This article describes experiences with electric fencing in four Forestry Commission forests. In addition a research programme is outlined which aims to test how effective electric fences are at excluding both red and roe deer from recently planted areas.

COOPER, J. E. and PETTY, S. J. (1988). Trichomoniasis in free-living goshawks *Accipiter gentilis* from Great Britain. *Journal of Wildlife Diseases* 21 (1), 80–87.

The goshawk *Accipiter gentilis* has recently been reintroduced to parts of Britain. In one population, 14 young from five broods died of stomatitis. This was the largest cause of chick mortality in 46 nests, accounting for 39 per cent of deaths between hatching and fledging. Post-mortem examination of three birds indicated that the deaths were due to trichomoniasis caused by *Trichomonas gallinae*. The reasons why these goshawks were so susceptible to this disease are discussed.

COUTTS, M. P. (1987). Development processes in tree root systems. *Canadian Journal of Forest Research* 17 (8), 761–768.

Root systems development is reviewed in terms of the formation and growth of certain primary roots on which the skeletal root system is built. Competitive processes within the root system are discussed and the physiology of tree root development is compared with that in herbaceous species.

COUTTS, M. P. and PHILIPSON, J. J. (1987). Structure and physiology of Sitka spruce roots. In *Symposium on Sitka spruce. Proceedings of the Royal Society of Edinburgh* 93B, 131–144.

The growth and development of Sitka spruce roots are reviewed, including responses of the roots to features of the soil environment such as aeration, mineral nutrition, temperature and water supply.

[CRANSWICK, A. M.,] ROOK, D. A. [and ZABKIEWICZ, J. A.] (1988). Seasonal changes in carbohydrate concentration and composition of different tissue types of *Pinus radiata* trees. *New Zealand Journal of Forestry Science* 17, 229–245.

Of all the carbohydrates analysed, starch showed the most consistent patterns of accumulation and depletion with seasons of the year in the 12-year-old *Pinus radiata* trees examined. Soluble carbohydrates (glucose, fructose, sucrose, cyclitol, quinic and shikimic acids) were present in high concentrations throughout the year, although these showed compositional changes with season and tissue type. Total non-structural carbohydrate contents were estimated to constitute some 2.8 per cent of the total biomass of a tree.

DAVIES, R. J. and PEPPER, H. W. (1989). The influence of small plastic guards, treeshelters and weed control on damage to young broadleaved trees by field voles (*Microtus agrestis*). *Journal of Environmental Management* **28**, 117–125.

Comparative trials of tree-guards, shelters and weed control showed that 250 mm or 300 mm tree-guards gave effective protection against damaging field voles.

[DEWEY, F. M. and] BRASIER, C. M. (1988). Development of ELISA for *Ophiostoma ulmi* using antigen coated wells. *Plant Pathology* **37**, 28–35.

Describes the development of a sensitive assay for rapidly screening large numbers of hybrodoma supermutants for monoclonal antibodies that recognise *O. ulmi* antigens in diseased elm tissue. The production by the diseased host or by the pathogen *in vivo* of a 'protein A' or 'lectin-like' molecule that binds non-specifically to immunoglobulins is postulated.

[DEWEY, F. M., MUNDAY, C. J. and] BRASIER, C. M. (1989). Monoclonal antibodies to specific components of the Dutch elm disease pathogen, *Ophiostoma ulmi*. *Plant Pathology* **38**, 9–20.

The potential of polyclonal antisera and monoclonal antibodies to differentiate the EAN and NAN aggressive subgroups of *O. ulmi* was explored. Polyclonal antisera crossreacted strongly with unrelated fungi and failed to distinguish EAN and NAN. Of 33 monoclonal cell lines, one-third were non-specific and 11 were specific to species or subspecies of *Ophiostoma*. Only quantitative differences were detected between the EAN and NAN aggressives, but two cell lines differentiated mycelial antigens of aggressive from non-aggressive. The approach promises a highly sensitive method for studying early frost/pathogen interaction, and most of the monoclonals appeared to have potential diagnostic value.

DOBSON, M. C. and FREER-SMITH, P. H. (1988). Ozone fluxes during short-term fumigations and their impact on the gas exchange of *Picea sitchensis* and *Picea abies*. In, *Second International Symposium on Air Pollution and Plant Metabolism: Workshop and poster presentation*, 51–52. GSF, Munich.

Exposure to ozone for 1 hour at concentrations of between 20–300 nl l<sup>-1</sup> significantly affected transpiration (E) and photosynthesis (A) of *P. sitchensis*. Prior to a two week cold period (min. temp. –10°C) E was increased, and after the cold period ozone decreased both E and A. For both species linear relationships between ozone uptake and exposure concentration were established.

EVANS, J. (1988). *Natural regeneration of broadleaves*. Forestry Commission Bulletin 78. HMSO, London.

The use of natural regeneration in managed broadleaved woodlands has been neglected. Opportunities for using such regeneration and silvicultural practices needed are described and practical recommendations made. Notes about individual species are included.

EVANS, J. (1988). Growing broadleaves successfully. In, *British Association for the Advancement of Science Annual Meeting, Bristol, 1986 – Forestry Section Proceedings*, ed. Barnes, G. C., Forestry Commission Occasional Paper 16, 43–44.

EVANS, J. (1989). Small woods, wasted asset – unmanaged woods can still have value. *Forestry & British Timber* **18** (3) 21, 22.

Many small woods in Britain contain a worthwhile crop of standing timber. Owners often remain unaware of this asset. Thinning, regeneration and enrichment of gaps are the silvicultural requirements most commonly needed.

FORREST, G. I. and SAMUEL, C. J. A. (1988). Monoterpene analysis of a diallel cross in Sitka spruce. *Silvae Genetica* **37** (3–4), 100–104.

Resin systems of main stems and of branch apical shoots were analysed in the proofing of crosses among seven trees, and in the parent trees and in half-sib open-pollinated families. For most components nearly all significant varieties were attributed to general combining ability, non-additive variation was significant for alpha-pinene in main stem cortical oleoresin.

FREER-SMITH, P. H. and TAYLOR, G. (1988). Abiotic factors leading to premature yellowing and other forms of necrosis. In, *Scientific basis of forest decline symptomatology*, eds. Cape, J. N. and Mathy, P., *CEC Air Pollution Research Report* 15, 107–125.

The biochemical changes associated with the yellowing and senescence of foliage are known for herbaceous plants; for conifers, they can only be assumed to operate in a similar sequence. For trees, the protein turnover and changes of membrane and pigment contents over successive years remain unquantified. Discoloration in response to abiotic factors other than pollution may sometimes contrast with natural senescence in the colour changes that occur. This suggests that different mechanisms are responsible for the biochemical changes when different stress factors are operating.

GARDINER, B. A. (1989). *Wind-tree interaction studies in Sitka spruce plantations*. Forestry Commission Research Information Note 150.

The physical process by which the wind's energy is absorbed by a forest canopy is being investigated in a series of field experiments which are intended to run over a 3-year period. Measurements of wind speed and turbulence above and within the canopy, along with measurements of tree movement, are being made in a number of different forests in SW Scotland. Some initial results, showing the strength of downdrafts over the forest, are presented.

GAY, J. (1988). Computer recording in the forest. *Timber Grower* 107, 32–33.

The Mensuration Branch at Alice Holt currently manages a national network of some 800 viable sample plots. Since 1985 the measurements from the majority of these permanent plots have been recorded on a portable microcomputer. The major benefit has been the increased speed of data processing, accuracy and consistency of data recording between measurements and regions.

GIBBS, J. N. (1988). Blue stain in windblown pine. *Timber Grower* 108, 31–32.

An account of the early stages in the development of blue stain in pine blown in the gale of October 16, 1987.

GOSLING, P. G. (1988). The effect of moist chilling on the subsequent germination of some temperate conifer seeds over a range of temperatures. *Journal of Seed Technology* 12, 90–98.

Pre-chilled and unchilled seeds of Douglas fir, Scots pine, and Sitka spruce, were incubated over a range of constant temperatures (10 to 40°C). Three weeks prechilling broadened the range of temperatures over which Douglas fir seeds could germinate, and for all three species improved the maximum percentage germination at some, if not most temperatures. None of the seeds ever germinated at 40°C. Pre-chilled seeds were always quicker to germinate than unchilled seeds. The results are discussed in relation to various authors' concepts of 'relative dormancy', and their practical significance to seed physiologists, plant producers, and geneticists is considered.

GOSLING, P. G. (1988). The storage and handling of tree and shrub seed. *Horticulture Week* 204 (21) Supplement, 5–6.

The majority of plants have seeds which can be dried without harm. These seeds are said to have 'orthodox' characteristics. However, some species, most notably the large-seeded broadleaves, possess seeds which are killed by drying. They are called 'recalcitrant'. Orthodox and recalcitrant seeds require very different handling and storage techniques. The optimum procedures for each type of seed are described.

GOSLING, P. G. (1989). The effect of drying *Quercus robur* acorns to different moisture contents, followed by storage, either with or without imbibition. *Forestry* 62 (1), 41–50.

Freshly harvested *Quercus robur* acorns were spread out two deep in trays, and dried/stored (at +2°C for a maximum of 28 days) to either 45, 40, 35, 30 or 25 per cent moisture content (fresh weight basis). Drying/storage significantly reduced the germination percentage ( $p$  is less than 0.01). The acorns at each moisture content were then either 'soaked' or 'not soaked', before immediate germination, or returned to the same cold store at +2°C, this time in loosely tied polythene bags. Soaking raised the acorns' moisture content, and also brought about a significant increase in germination capacity ( $p$  is less than 0.01). Regardless of the moisture content immediately before



soaking, 'soaked' acorns in loosely tied polythene bags stored better than 'unsoaked' acorns. All 'bagged' acorns (whether 'soaked' or 'unsoaked') stored better than acorns dried/stored in open trays.

[GRACE, J. C.] ROOK, D. A. [and LANE, P. M.] (1988). Modelling canopy photosynthesis in *Pinus radiata* stands. *New Zealand Journal of Forestry Science* 17, 210–228.

A model for simulating canopy net photosynthesis in stands of *Pinus radiata* has been developed from measurements of net photosynthesis on individual shoots and a radiative transfer model. Specific leaf area has been used to account for the variation in rates of photosynthesis due to the physiological and morphological state of individual shoots throughout the canopy.

GRAYSON, A. J. (1989). *Carbon dioxide, global warming and forestry*. Forestry Commission Research Information Note 148.

Assuming current industrial practices, a continued rise in the carbon dioxide of the atmosphere is likely and will in combination with other greenhouse gases cause a general warming of the atmosphere. Forest destruction, by contributing carbon dioxide, is part of the problem, forest creation can be part of its solution.

GREGORY, S. C. (1989). *Armillaria* species in northern Britain. *Plant Pathology* 38, 93–97.

Five species of *Armillaria*, *A. borealis*, *A. cepistipes*, *A. ostoyae*, *A. mellea*, and *A. lutea*, were identified among 145 isolates collected from sites in northern Britain. Most of the collection sites were in coniferous woodland containing dead or dying trees and *A. ostoyae*, a well-known pathogen of conifers, was the most frequently isolated species. Two species believed to be weakly pathogenic, *A. cepistipes* and *A. lutea*, were also commonly found; the former has only rarely been recorded in Britain before. The significance of the records is discussed.

GREIG, B. J. W. (1989). Decay in an avenue of horse chestnut (*Aesculus hippocastanum* L.) caused by *Ustulina deusta*. *Arboricultural Journal* 13 (1), 1–6.

A single tree in an avenue of horse chestnut was windblown in March 1986 and was found to have extensive root-rot caused by *Ustulina deusta*. In a survey of the avenue, fruit bodies of *U. deusta* were discovered at the base of more trees. After felling, extensive butt-rot was found in all these trees, averaging 2.5 m up the stem. There was evidence of clustering of the decayed trees along the avenue.

[HARDING, P. T., ALEXANDER, K. N.,] ANDERSON, M. A. and LONSDALE, D. (1988). *Conserving insect habitats provided in dead broadleaved wood by the wind damage of 16th October 1987*. Forestry Commission Research Information Note 136.

The storm of 16 October 1987 is having important consequences in south-east Britain for forest wildlife as well as for timber production. Some habitats have been damaged but others created. Sympathetic action during restoration will provide further habitat improvements at minimal cost. This note describes simple opportunities in conservation which landowners and managers may wish to take to reduce losses and maximise gains in a frequently undervalued wildlife resource: the dead wood of broadleaved trees.

HARMER, R. (1987). Epicormics in oak propagation. *Forestry & British Timber* 16 (5), 18–19.

Describes a method for the vegetative propagation of oak using epicormic shoots.

HARMER, R. (1988). Production and use of epicormic shoots for the vegetative propagation of mature oak. *Forestry* 61 (4), 305–316.

Partial girdling of *Quercus robur* at any time of the year will stimulate the development of epicormic buds during the following growing season. Shoots can also be grown on isolated sections of trunk placed in moist warm conditions in the nursery, those felled in summer form fewest shoots but production may be stimulated by a chilling treatment. Logs from trees felled in autumn can be stored for several months before use.

HARMER, R. (1989). *Selection of superior oak*. Forestry Commission Research Information Note 149.

Possible methods for the selection and propagation of improved oak are described. Recent work has developed methods for the vegetative propagation of juvenile and mature trees and studies leading to the development of a selection test have begun.

HIBBERD, B. G. (ed.) (1988). *Farm woodland practice*. Forestry Commission Handbook 3. HMSO, London.

The aim of this handbook is to provide information about establishing, managing and harvesting trees on farmland. It explains and describes forestry techniques and systems suitable for use on the farm.

HOLLINGSWORTH, M. K. and MASON, W. L. (1989). *Provisional regimes for growing containerised Douglas fir and Sitka spruce*. Forestry Commission Research Information Note 141.

A provisional regime for growing containerised Douglas fir and Sitka spruce is described. Seedlings are grown in a polythene greenhouse equipped with heating and ventilation. A plug-type container with a volume of 100–125 cc appears desirable. Growing medium, feeding and irrigation regimes are considered. The importance of inducing budset by drought-stressing or manipulation of photoperiod is emphasised.

INNES, J. L. (1988). Forest health surveys: a critique. *Environmental Pollution* 54, 1–15.

Most surveys of forest health are based on the assessment of crown density and crown discoloration. These assessments are subjective and serious errors can occur. In some cases, the sampling design that has been adopted is not the most suitable for the forest area under investigation. The blanket application of a systematic sampling design based on a 16 km by 16 km grid is particularly questionable given the variation in Europe's forests. Comparisons, either between regions or through time, may or may not be valid, depending on how the surveys are conducted.

INNES, J. L. (1988). Forest decline in urban areas – a comment. *Science of the Total Environment* 72, 227–233.

A paper by Benarie concludes that 'the hypothesis that air pollution is a cause of forest decline is untenable'. However, the arguments upon which this conclusion is based are suspect. Data from the forest damage inventory in the Federal Republic of Germany are misinterpreted. Major problems occur when comparing trees from urban and rural areas as a result of differences in environmental conditions and past pollution exposures. Pollution regimes in urban and rural areas are also very different.

INNES, J. L. (1988). Forest health surveys: problems in assessing observer objectivity. *Canadian Journal of Forest Research* 18, 560–565.

The quality of data collected in surveys of forest health depends on a subjective interpretation of tree condition. Many factors influence classification, including the observer's experience, the observer's bias, the weather at the time of the classification, and the appearance of the tree. The effects of some of these factors can be quantified and attempts made to reduce their impact. It may be possible to account for others during the analysis and interpretation stages of the inventory process.

INNES, J. L. (1988). The use of lichens in dating. In *Handbook of lichenology*, ed. Galun, M., Vol. III, 75–91, CRC Press, Boca Raton, Florida.

Lichenometry provides a possible means of obtaining a date for a surface. It is by no means universally applicable. Surfaces may be unsuitable for a number of reasons, including lithology, age and environmental conditions at the site. Many of the problems surrounding the technique have now been resolved, but several, detailed in this account, remain. Provided that the technique is applied correctly and with care, dates accurate to about 10 per cent of the surface age should be possible and, in some cases, it may be feasible to obtain more accurate dates.

INNES, J. L. (1988). Unravelling the acid rain story. *Forest Life* 4, 11–12.

The finding that the crown condition of Scots pine, beech and oak is best in areas with the highest levels of some types of pollution is unexpected. There are a number of possible reasons, but the separation of these is difficult. Climate and pollution are strongly correlated and the most likely explanation for the findings is that the trees are responding to better environmental conditions in high-pollution areas. An alternative is that the nitrate component of pollution is having a fertilising effect.

INNES, J. L. and BOSWELL, R. C. (1988). *Forest health surveys 1987. Part 2: analysis and interpretation*. Forestry Commission Bulletin 79. HMSO, London.

Distinct spatial patterns exist in the crown parameters of Scots pine, beech and oak. No patterns were identified for Sitka spruce and Norway spruce. The appearance of Scots pine, beech and oak deteriorates towards the north and west of Britain. The appearance of the trees is related to a wide variety of environmental variables. Some of the explanatory variables examined in the analysis are pollutant levels and there is a general increase in the crown densities of Scots pine, beech and oak with increasing levels of most pollutants.

INNES, J. L. and BOSWELL, R. C. (1988). *Forest health surveys 1988 – preliminary results*. Forestry Commission Research Information Note 139.

The preliminary results of the 1988 forest health surveys are presented. A total of 9211 trees were assessed in the two surveys, with the more detailed main survey involving 7411 trees. The results from both surveys suggest that there has been some deterioration in the crown density of Sitka spruce and Scots pine during the past year. Norway spruce and oak do not appear to have changed, whereas beech has clearly improved.

INNES, J. L. (1989). Why forests are dying. *Country Life* CLXXXIII (12), 23 March, 210, 214.

There is increasing evidence that early fears of an international decline in forest health were unfounded. A number of areas exist where decline is severe and tree death has occurred, but none of these are in Britain. However, the condition of forests in Britain, as judged by crown density, is about the worst in Europe. The causes for this remain unclear, although climate and adverse soil conditions are likely to be important. Given the condition of our forests, it is important to continue monitoring in case any deterioration occurs.

INNES, J. L., BOSWELL, R. C. and NEUMANN, H. (1989). Waldschaden und luftverschmutzung in Grossbritannien. *Der Forst und Holzwirt* 44, 10–11.

The main British forest health survey is organised on a different basis from similar surveys in the Federal Republic of Germany. This has enabled a different approach to the problem of the effect of air pollution on forest trees. Using a stratified random sampling design, it is possible to correlate tree condition with a number of environmental variables, including air pollution. There is no indication of an adverse effect of air pollution on trees; if anything, the data suggest the reverse.

[JENG, R. S., BERNIER, L. and] BRASIER, C. M. (1988). A comparative study of cultural and electrophoretic characteristics of the Eurasian and North American races of *Ophiostoma ulmi*. *Canadian Journal of Botany* 66, 1325–1333.

Using PAG electrophoresis wild isolates representative of the EAN and NAN aggressive subgroups of *O. ulmi* were distinguished on the basis of certain isozyme patterns, soluble protein bands and other physiological characteristics. One isolate previously designated an NAN was identified as an 'early' NAN/EAN hybrid. PAG has potential as a diagnostic aid in detecting the emergence of EAN/NAN hybrids in population samples.

JOHN, A. and MASON, W. L. (1987). Vegetative propagation of Sitka spruce. In, Symposium on Sitka Spruce. *Proceedings of the Royal Society of Edinburgh* 93B, 197–203.

A combination of two vegetative techniques is seen as a possibility for large-scale production of juvenile, rooted Sitka spruce cuttings of improved genotype. Tissue culture techniques, under development, would be used to produce large numbers of stock plants for stem cuttings production. Cuttings techniques, currently under commercial trial, would be used to produce the rooted plants for forest establishment.

JOHN, A. and PEARSON, D. J. (1986). Induction of vitrification in *Picea sitchensis* cultures. *New Zealand Journal of Forest Science* 16 (3), 328–342.

The flooding of *Picea sitchensis* cultures on hormone-free medium resulted in promotion of both apical extension and bud and shoot proliferation. Retreatment of vitrified and reverted cultures resulted in a further increase in bud and shoot proliferation. Rooting in vitro was higher in flooded cultures.

LEATHER, S. R. (1988). Insects on bird cherry. 2. The bird cherry–oat aphid, *Rhopalosiphum padi* (L). (Homoptera, Aphididae). *Entomologist's Gazette* **39**, 89–97.

A description of the life cycle and the biology of the aphid is presented, together with details of damage effects and control methods. A brief indication of where future research should lead is also given.

LEATHER, S. R. (1988). Size, reproductive potential and fecundity in insects. Things aren't as simple as they seem. *Oikos* **51**, 386–389.

It is clear that when dealing with insects, acceptance of the conventional tenet that big insects are more fecund than small ones is not a viable proposition, especially when taken from the laboratory to the field, unless one has a detailed knowledge of the other factors affecting fecundity. Much more attention should be paid to the longevity of the insects and the factors affecting it, e.g. in the field are big insects more susceptible to predation/parasitism than small ones, but on the other hand do big insects survive longer without a food source than small ones? Finally, how important is an index of potential fecundity when few if any insects live to achieve it?

LEATHER, S. R. (1988). Consumers and plant fitness: coevolution or competition? *Oikos* **53**, 285–288.

Insect feeding on bird cherry causes marked changes in plant architecture. However, there is no conclusive evidence that either *Rhopalosiphum padi* or *Yponomeuta evonymellus* have beneficial effects on their host tree. All the effects demonstrated would appear to be detrimental to plant fitness, especially in terms of productivity and reproductive success. It is possible that *Y. evonymellus* is less harmful to bird cherry than *R. padi*, and that natural selection favours those plants that are less suitable (nutritionally speaking) for the aphid, in that seed set and production is greater in *Y. evonymellus* favoured trees. Further observations may throw light on this question.

LEATHER, S. R., [WELLINGS, P. W. and WALTERS, K. F. A.] (1988). Variation in ovariole number within the *Aphidoidea*. *Journal of Natural History* **22**, 381–393.

Several different morphs from over 50 species of aphids were dissected and the number of ovarioles recorded for each. By using these results and published data, details of ovariole number in more than 125 species of aphid from seven families were analysed. Variation in ovariole number between generations was found in six of the seven families studied. Variation within a generation appeared to be restricted to certain subfamilies. Certain trends in variability of ovariole number appear to be linked with the morph of the aphid, migratory morphs (particularly within the *Aphididae*) having greater variability than non-migratory morphs. Heteroecious aphids tend to show greater variability than autoecious aphids which, in turn, show greater variability than anholocyclic aphids.

MASON, W. L. (1988). We neglect planting stock quality at our peril. *Forestry & British Timber* **18** (2), 29–33.

Existing systems of producing conifer nursery stock are reviewed. Bare-root transplant systems are thought to be less than ideal, and alternative techniques (e.g. precision sowing) offer the chance of major improvements in stock quality with savings on establishment costs.

MASON, W. L. (1988). Weeds in the wood. *Horticulture Week* **204** (15), October 7, 33.

Reviews results from herbicide and other research for forest nurseries. Mixtures of diphenamid with isoxben and with chlorthal-dimethyl have shown promise for pre-emergence control in seedbeds. Trials investigating the possibility of inoculating *Alder* seedbeds with *Frankia* have proved very promising and nurserymen are recommended to use this technique in future.

MASON, W. L. and BIGGIN, P. (1988). Comparative performance of containerised and bare-root Sitka spruce and lodgepole pine seedlings in upland Britain. *Forestry* **61** (2), 149–163.

Seedlings of Sitka spruce and lodgepole pine were grown in five different container types. The performance of the containerised seedlings was compared with bare-root transplants. Two to three years after planting, the bare-root plants were consistently superior in shoot growth to all containerised seedlings, with differences greater in Sitka spruce. The implications for future use of containerised seedlings in upland forestry are reviewed.

MASON, W. L. and HOLLINGSWORTH, M. K. (1989). *Use of containerised conifer seedlings in upland forestry*. Forestry Commission Research Information Note 142.

The potential role of containerised conifer seedlings in upland forestry is considered. Containers may be particularly useful for improving establishment of 'sensitive' species such as Douglas fir. Trials since 1986 have established that Douglas fir and Sitka spruce seedlings of plantable size can be produced within one year in a range of container types. Such seedlings have performed well in forest experiments suggesting that wider trials of this production method are warranted.

MASON, W. L. and KEENLEYSIDE, J. C. (1987). Propagating Sitka spruce under intermittent mist and other systems. *International Plant Propagators' Society* 37, 294–303.

The reasons for the recent interest in using stem cuttings of tree species to produce rooted cuttings for forest use are reviewed. In Britain, commercial developments are currently confined to Sitka spruce (*Picea sitchensis* Bong. (Carr.)). A prototype facility for rooting conifer cuttings is described. Results indicate that high rooting can be obtained in a wide range of media and under different propagation systems. Correct feeding of the mother plant is shown to be important in obtaining high quality cuttings. Future developments are reviewed.

MASON W. L., BIGGIN, P. and McCAVISH, W. J. (1989). *Early forest performance of Sitka spruce planting stock raised from cuttings*. Forestry Commission Research Information Note 143.

Forest experiments comparing bare-root Sitka spruce plants raised from cuttings with transplants raised from seed show that cuttings have as good survival as transplant stock of the same origin and grow as vigorously after planting. The stem form of cuttings is often poorer at planting, but an upright pattern of growth is rapidly assumed and differences do not persist. Root development after planting shows no difference between cuttings and transplant stock. The results indicate that Sitka spruce cuttings of improved genotype should be capable of realising their full potential genetic gains when planted in the forest.

McKILLOP, I. G., PEPPER, H. W. and WILSON, C. J. (1988). Improved specifications for rabbit fencing for tree protection. *Forestry* 61 (4), 359–368.

Trials of different mesh sizes and fence heights suggest more cost effective rabbit fences.

McNEILL, J. D., HOLLINGSWORTH, M. K., MASON, W. L., MOFFAT, A. J., [SHEPPARD, L. J. and WHEELER, C. T.] (1989). *Inoculation of *Alnus rubra* seedlings to improve seedling growth and forest performance*. Forestry Commission Research Information Note 144.

A collaborative venture has been established between the Forestry Commission, the University of Glasgow, the University of Surrey and the Institute of Terrestrial Ecology to investigate inoculation of *Alnus* seedlings with selected *Frankia* strains. Nursery experiments and subsequent field trials have given preliminary results of sufficient significance for the inoculation technique to be considered as a standard nursery practice. Although current research has been concerned primarily with inoculation of *Alnus rubra*, work with other alder species has shown comparable results. Methods of commercial production of inoculum are also to be promoted.

MOFFAT, A. J. (1988). Forestry and soil erosion in Britain – a review. *Soil Use and Management* 4 (2), 41–44.

Research on soil erosion under forest in Britain is reviewed. Erosion can increase as a result of afforestation in the uplands, sometimes with undesirable consequences for surface water quality. Published rates of erosion are usually close to 'natural' ones, at around 500 kg ha<sup>-1</sup> y<sup>-1</sup>. Of the forest operations that can lead to erosion, ploughing is the most important. Clear felling may also increase erosion, but little is known of its long-term effects. New developments in forestry may do much to reduce the risk of soil erosion, particularly the replacement of ploughing by subsoiling and the control of drain gradients.

MOFFAT, A. J. (1988). Reclamation remedies. *Horticulture Week* 204 (10), 19–21.

The Forestry Commission have been involved in reclamation for several decades, and has accumulated considerable experience in the afforestation of difficult sites. Most sites, if correctly prepared, can be planted with trees; an option considerably cheaper than end uses like public open space, recreation or agriculture.

MOFFAT, A. J. (1988). The distribution of 'Celtic Fields' on the east Hampshire chalklands. *Proceedings of the Hampshire Field Club and Archaeological Society* 44, 11–23.

Early field systems called 'Celtic Fields' have been mapped on the east Hampshire chalklands and related to site factors such as soil type, slope and aspect. The choice of early agricultural sites is discussed, and it is suggested that crop failure caused by acidity was probably why soils on clay-with-flints were avoided. Relatively little soil erosion occurred until Iron Age and Roman times when fields were enlarged and more efficient ploughs were used.

MOFFAT, A. J. (1988). *Sewage sludge as a fertiliser in amenity and reclamation plantings*. Arboriculture Research Note 76/88/SSS.

The potential for using sewage sludge as a fertiliser in amenity and reclamation plantings is outlined. It is concluded that on nutrient-poor sites, sewage may be a useful source of nitrogen and phosphorus. Sludge can be applied relatively easily to woodland sites, and there is little risk of pollution, toxicity or pathological problems provided that it is not severely contaminated with industrial effluent.

MOFFAT, A. J. (1988). Soil physical factors affecting tree establishment and growth at Pitsea landfill site, Essex. *Seesoil* 4, 66–83.

Investigations at an 11-year-old landfill site have shown that soil moisture was positively, and soil oxygen negatively correlated with temperature and methane generated by decomposition of the underlying landfill materials. The best survival and growth of five tree species occurred on plots where cover was 1.5 m thick, probably because these supplied enough soil moisture to negate large soil moisture deficits in the area, and soil levels were raised to non-toxic levels.

MOFFAT, A. J. and BIRD, D. (1989). The potential for using sewage sludge in forestry in England and Wales. *Forestry* 62 (1), 1–17.

The potential for using sewage sludge as a forest fertiliser on nutrient-deficient sites in England and Wales is evaluated. Most forest districts contain forests which are likely to benefit from sewage sludge application, mainly in the form of liquid sludge to thinned stands, but also before and just after planting. The environmental effects of sludge application are discussed, and it is concluded that there is little risk of toxicity or pollution.

MOFFAT, A. J. [and JARVIS, M. G.] (1988). The significance of gley features in soils derived from grey parent materials. *Journal of Soil Science* 39, 177–189.

Detailed observations of gley features in soils derived from grey upper greensand rocks have been compared with their moisture regimes as determined by water levels in dipwells. There was good correlation between the incidence of grey ped face and matrix colours of low chroma, prominent ochreous mottling within the matrix and duration of waterlogging. The wetness is due to the combination of low vertical permeability in the underlying rock, and moderate horizontal permeability in the overlying horizons.

MOFFAT, A. J. and ROBERTS, C. J. (1988). *The use of large scale ridge and furrow landforms in forest reclamation*. Forestry Commission Research Information Note 137.

Large scale (30 m wide × 1.5 m high) ridge and furrow landforms are commonly used in forest reclamation schemes in Britain to aid the removal of excess winter rainfall and improve rooting conditions. An investigation of soil physical and hydrological properties in relation to tree growth has shown that this system can succeed in producing land with reduced waterlogging and enhanced tree growth. The results support the use of the ridge and furrow system in areas where rainfall is high and soil moisture deficits low, but suggest that a modified system of lower amplitude may be warranted in drier areas.

NISBET, T. R. (1989). *Liming to alleviate surface water acidity*. Forestry Commission Research Information Note 148.

Research is being carried out to assess the effectiveness of different liming techniques for the alleviation of surface water acidity. Lake liming is relatively inexpensive and has been used successfully as a temporary measure to protect vulnerable fisheries and to restore previously fishless lakes. Source area liming appears to offer the best prospects for countering stream and river water acidity.

[PECK, T. J., EFTHMYIOU, P. N., FERREIRINHA, M. P.,] GRAYSON, A. J., [GREFERMANN, K., ROCCATI, R., STOCKMAN, L. and VAN WEELDEREN, W. H.] (1989). *Evaluation of the raw material programmes on wood and cork (1982-1985 and 1986-1989)*. Research Evaluation Report No. 35. Commission of the European Communities, Luxembourg. (144pp.)

Assesses the size of the forest industry of the EEC and expenditure on R&D, reviews objectives set for programmes, evaluates projects of 1982-85 programme and work proposed in 1986-89 programme. Identifies future research needs in forestry and forest products industry and proposes improvements to programme management.

PEPPER, H. W. (1988). Protection against animals and management for game. In, *Farm woodland practice*, ed. Hibberd, B. G., Forestry Commission Handbook 3, 46-57. HMSO, London.

Provides advice on protecting farm woodland crops against damaging vertebrates while maximising their game potential.

PEPPER, H. W. (1988). For easier joining. *Forestry & British Timber* 17 (6), 25.

The increased use of high tensile wire and the introduction of spring steel wire to fencing has dictated the need for improved methods of joining wire.

PETTY, S. J. (1989). *Goshawks: their status, requirements and management*. Forestry Commission Bulletin 81. HMSO, London.

The goshawk *Accipiter gentilis* is a large bird of prey which was reintroduced into Britain in the 1960s and 1970s. Goshawks are vulnerable to both accidental and wilful human disturbance when they are breeding. Recommendations are given for the management of nesting areas, together with a background of the history of goshawks in Britain, their requirements, population density and the legislation which gives them full protection.

PETTY, S. J. and ANDERSON, D. I. K. (1988). Ground nesting by long-eared owls *Asio otus* on restocked sites in upland forests. *Naturalist* 113, 73-74.

In upland Britain, the long-eared owl *Asio otus* is almost exclusively a tree nesting species. This paper describes a successful breeding attempt on a felled site in an upland spruce forest. The nest was situated on the ground, under dead branches from the previous crop. Breeding occurred in a year when field vole *Microtus agrestis* populations were high.

PHILIPSON, J. J. (1987). Promotion of cone and seed production by gibberellin  $A_{477}$  and distribution of pollen and seed cones on Sitka spruce grafts in a clone bank. *Forest Ecology and Management* 19 (1-4), 147-154.

This paper from a symposium proceedings describes the  $GA_{477}$  injection technique and presents data on enhanced coning, the distribution of cones on the tree and the effect of top-pruning. Seed quality of treated trees is measured as percentage germination and 1000-seed weight.

PHILIPSON, J. J. (1987). A review of coning and seed production in *Picea sitchensis*. In, Symposium on Sitka spruce. *Proceedings of the Royal Society of Edinburgh* 93B, 183-195.

Research on coning in Sitka spruce is reviewed and related to work on other conifers. Physiological mechanisms of cone-bud differentiation are discussed.

PHILIPSON, J. J. (1988). Root growth in Sitka spruce and Douglas fir transplants: dependence on the shoot and stored carbohydrates. *Tree Physiology* 4, 101-108.

When dormant Sitka spruce transplants were lifted from the nursery in March and transferred to favourable growing conditions in a controlled environment chamber, new roots emerged and elongated even when the plants were bark-ringed so that the roots could not receive metabolites from the shoot by phloem translocation. Carbohydrate analysis showed that starch reserves in the roots of the bark-ringed plants were depleted, indicating that these reserves provided the energy source for new root growth. This response is compared to that of Douglas fir and the findings are discussed in relation to the problems of establishing these species in forest plantations.

POTTER, M. J. (1988). Treeshelters improve survival and increase early growth rates. *Journal of Forestry* 86 (8), 39-41.

An introduction to the effects of treeshelters on early plant growth and synopsis of the benefits offered by this method of establishment.

POTTER, M. J. (ed.) (1988). *Broadleaves – changing horizons*. Proceedings of a discussion meeting. Institute of Chartered Foresters, Edinburgh.

A collection of papers presented as a contribution from the Institute of Chartered Foresters to the process of review of the government's policy for broadleaved woodlands.

POTTER, M. J. (1988). Exotic broadleaves. In, *Broadleaves – changing horizons*. Proceedings of a discussion meeting, ed. Potter, M. J., 17–29. Institute of Chartered Foresters, Edinburgh.

A review of the past, present and future roles of exotic species in British broadleaved woodlands.

POTTER, M. J. (1989). Treeshelters 10 years on. *Timber Grower* 110, 21.

This article looks at how far the technique of using treeshelters has advanced in the 10 years since their inception.

PRATT, J. E. and GREIG, B. J. W. (1988). *Heterobasidion annosum*: development of butt rot following thinning in two young first rotation stands of Norway spruce. *Forestry* 61 (4), 339–347.

Severe butt rot developed in two stands of first rotation Norway spruce on old agricultural land within 11 years of first thinning. At Site I, it is estimated that between 4.4 per cent and 6.6 per cent of potential volume was lost on clear felling. At Site II, 73 per cent of trees had butt rot; decay extended 3 m up the stems, and occupied significant areas of the butt. In both cases, the presence of butt rot in the crops led to premature clear felling, which resulted in additional loss of potential revenue.

RATCLIFFE, P. R. (1988). The management of upland commercial forests for birds and mammals. *Argyll Bird Report* 1987.

Discusses the birds and mammals present in different growth stages of upland forests with management options and habitat improvements aimed at maximising wildlife while maintaining the productivity of the trees.

RATCLIFFE, P. R. (1988). Roe deer management: the application of research. *Deer* 7 (8), 411–414.

Reports new developments in estimating numbers of roe deer within the context of constructing a deer management plan.

RATCLIFFE, P. R. (1988). Managing the woodland for wildlife conservation. In, *Farm woodland practice*, ed. Hibberd, B. G., Forestry Commission Handbook 3, 66–74. HMSO, London.

Provides advice on managing farm woodlands to achieve conservation benefits.

RATCLIFFE, P. R. and HINDE, A. (1989). Interactions between game management and commercial forestry in Strathspey. In, *Land use in the River Spey catchment*, Symposium No. 1, 6–8 November 1987, ed. Jenkins, D., 224–227. Aberdeen Centre for Land Use.

A discussion of the conflicts and benefits arising from the presence of game species in the commercial forests of Strathspey. Two species of deer represent a game asset, but they require firm control to regulate serious impact on vegetation and timber trees. Woodland grouse require conservation measures which preclude hunting.

REDFERN, D. B. (1989). The roles of the bark beetle *Ips cembrae*, the woodwasp *Urocerus gigas* and associated fungi in dieback and death of larches. In, *Insect–fungus interactions*, eds. Wilding, N., Collins, N. M., Hammond, P. M. and Webber, J. F., 195–204. Academic Press, London.

Two insect–fungus associations, that between *Ceratocystis laricicola* and the bark beetle *Ips cembrae* and that between *Amylostereum chailletii* and the woodwasp *Urocerus gigas*, are involved in a dieback disease of larches. In inoculation experiments with larches both fungi caused damage to bark and sapwood but *C. laricicola* caused more extensive injury than *A. chailletii*. The possible roles of the two associations in the development of dieback are discussed. It is proposed that trees are initially attacked by *I. cembrae* and that dieback occurs when lesions caused by *C. laricicola* coalesce and girdle the stem. *A. chailletii* is subsequently introduced during secondary attacks by *U. gigas* and its role is probably limited to that of a sapwood decay organism.



REES, A. A. and WEBBER, J. F. (1988). Pathogenicity of *Sphaeropsis sapinea* to seed, seedlings and saplings of some central American pines. *Transactions of the British Mycological Society* **91**, 270–277.

*Sphaeropsis sapinea* obtained from five tropical *Pinus* seed sources caused damage when inoculated on to seeds, seedlings and saplings of *Pinus oocarpa*, *P. caribaea* and *P. pseudostrobus*. Three isolates were appreciably more damaging than the remaining two and *P. pseudostrobus* seeds and seedlings and *P. oocarpa* saplings were most susceptible.

[ROGERS, H. J., BUCK, K. W. and] BRASIER, C. M. (1988). dsRNA and disease factors of the aggressive subgroup of *Ophiostoma ulmi*. In *Viruses of fungi and simple eukaryotes*, eds. Koltin, Y. and Leibowitz, M. J., 327–351. Marcel Dekker Inc., New York.

Discusses the molecular nature of cytoplasmic disease – the d-factor – in *O. ulmi* with emphasis on evidence that d-factors are dsRNA associated, including the number and size of the dsRNA genome in healthy and diseased isolates, parallel transmission of d-factor and dsRNA, association of specific dsRNA segments with d-factor function, evidence for separate transmission of dsRNA and mitochondria, and the phenomenon of d-factor latency.

ROOK, D. A., [BOLLMANN, M. P. and HONG, S. O.] (1988). Foliage development within the crowns of *Pinus radiata* trees at two spacings. *New Zealand Journal of Forestry Science* **17**, 297–314.

Needle production, development and abscission in *Pinus radiata* trees, 7 to 9 years old, were examined on branches of different ages and orders over an 8-month growing season. Trees of the more open stand consistently had three orders of branching and living branches up to 6 years old, while the close spaced trees had only two orders of branching and living branches up to 4 years old. The main period of needle emergence was from August to September. Generally needle elongation had ceased by mid-February in New Zealand.

SAMUEL, C. J. A. and MASON, W. L. (1988). *Identity and nomenclature of vegetatively propagated conifers used for forestry purposes*. Forestry Commission Research Information Note 135.

The genetic composition of two types of mixture of rooted cuttings is reviewed and the system which provides the identity and nomenclature for them is discussed. A similar system for identifying individual clones is also considered.

[STEWART, J. L. and] GOSLING, P. G. (1988). Seed pretreatment for *Guazuma ulmifolia* Lam. *Commonwealth Forestry Review* **67**, 187–190.

*Guazuma ulmifolia* is a tree species of Central and South America. It is widely used by farmers throughout its range, but seed germination is always variable and often poor. The most likely cause is a coat imposed dormancy, but seed handling is also made difficult by the seed's unusual characteristic of exuding relatively large volumes of a sticky gelatinous substance when moistened. A total of 13 different water and scarification treatments were applied to the seed and subsequent laboratory germination tested. The simplest method of obtaining the highest germination percentage was to pour five volumes of boiling water over the seeds and leave to soak for 30 seconds.

STOAKLEY, J. T. (1989). Forest insect pests and their control in relation to changes in land use and silvicultural practice. *Chemistry and Industry* **6**, 186–190.

Reviews the history of forests as a form of land use, discusses recent and evolving silvicultural practice and relates this to the status of the most important forest insect pests and the actual and likely future need for control.

STOAKLEY, J. T. and HERITAGE, S. G. (1988). *Approved methods for insecticidal protection of young trees against *Hylobius abietis* and *Hylastes* species*. Forestry Commission Research Information Note 140.

Damage done by *H. abietis* and *Hylastes* species and methods of control are briefly described. The two types of Approval for the use of insecticides which may be issued by the Pesticides Safety Division of MAFF under the Control of Pesticides Regulations 1986 and the use of 'Application Leaflets' to convey the conditions of 'off-label' approvals are explained. The current status, in terms of Approval, of various possible insecticide products and applications is detailed. This note serves as an introduction to 'Application Leaflets' on pre- and post-planting treatments to be issued as further RINs and stresses that these are issued in accordance with the statutory approvals.

STOAKLEY, J. T. and HERITAGE, S. G. (1989). *Application leaflet on the use of 'Gamma-Col' and 'Lindane Flowable' for pre-planting treatment of young trees against Hylobius abietis and Hylastes spp.* Forestry Commission Research Information Note 147.

This note describes the use of two formulations of lindane, Gamma-Col (ICI) and Lindane Flowable (PBI), as pre-planting treatments to provide protection of young planting stock – either bare-rooted or raised in Japanese paperpots – against *Hylobius abietis* and *Hylastes* spp. which are frequently destructive on felled conifer sites. It takes the form of an 'Application Leaflet', which has been approved by the Pesticides Safety Division of MAFF as a mandatory adjunct to the approval given for the described uses under the Control of Pesticides Regulations 1986. The need for specified protective clothing and detailed attention to safety procedures is emphasised throughout. The approval to which this publication refers expires on 31 December 1989.

TABBUSH, P. M. (1988). *Silvicultural principles for upland restocking.* Forestry Commission Bulletin 76. HMSO, London.

Plant and operational quality standards necessary to achieve high initial plant survival are given. Root growth potential, as an index of the physiological status of the plant, is used to specify dates for handling, storing and planting Sitka spruce and Douglas fir. Benefits from site preparation are explained for a range of site types. Recommendations by soil type are given for the use of site preparation machinery which is illustrated.

TABBUSH, P. M. (1988). Planting stock survival. *Scottish Forestry* 42 (2), 120–128.

Surveys of upland establishment sites in 1981 and 1986 revealed a tendency towards understocking, particularly on clearfelled sites. The most significant factor contributing to this was plant quality. Desiccation, physical shock and extremes of temperature are all damaging, particularly when experienced cumulatively. Provision of microsites favourable for early root development through site preparation reduces the risk of failure. If at least 90 per cent survival is not achieved at the first attempt, costs incurred will be punitive, estimated at up to £350/ha<sup>-1</sup> (£1987).

TAYLOR, C. M. A. [and BAYES, C. D.] (1988). *Use of sewage sludge as a forest fertiliser prior to replanting of clear-felled sites.* Water Research Report SDD 1773-M.

Previous work has shown that the early growth of Sitka spruce on sites of low nitrogen availability can be dramatically improved by the application of sewage sludge. This report describes the establishment of an experiment on a second rotation site and the technique of sludge application.

TAYLOR, C. M. A. [and BAYES, C. D.] (1988). *The use of sewage sludge in the afforestation of former opencast coal sites: Clydesdale forest trials.* Water Research Report SDD 1774-M.

This report describes several trials on applying sewage sludge to afforested opencast mine sites. These trials include preventive site treatment by incorporating large quantities of dewatered sludge prior to planting, and remedial application of liquid sludge after planting which had not received initial treatment.

TAYLOR, G., DOBSON, M. C., FREER-SMITH, P. H. and DAVIES, W. J. (1989). *Tree physiology and air pollution in southern Britain.* Forestry Commission Research Information Note 145.

The impact of air pollution on the physiology of spruce and beech was studied at Headley, Hampshire. Trees grown in the open-top chambers and exposed to ambient pollution showed different physiological responses from those grown in air free from pollution. For both beech and spruce, root growth and morphology were affected by pollution. These results suggest that air pollution in southern Britain may influence the growth and physiology of trees. Such effects may not always be detrimental, but may alter susceptibility to other environmental factors.

THOMPSON, D. A. (1988). Marketing chains for broadleaves. In, *Broadleaves – changing horizons.* Proceedings of a discussion meeting, ed. Potter, M. J., 64–79. Institute of Chartered Foresters, Edinburgh.

This paper reports on a study of the supply and utilisation of hardwoods during 1986 and 1987. It was based on a questionnaire survey of TGUK members in England and Wales. Subjects covered included tree species, quality, difficulty in selling and size of parcel. Suggestions are made for methods of increasing the utilisation of hardwoods.

THOMPSON, D. A. (1989). *Effects of the gale of October 1987 on sawn pine timber*. Forestry Commission Research Information Note 138.

Evidence collected between January and June 1988 from tests on sawn timber produced from pine windblown in October 1987 did not demonstrate an increase in the proportion of battens shattering during and after sawing. Similarly there was little evidence of a higher than expected proportion of rejects on stress grading. There is evidence of a number of compression creases in the one sample examined for this feature and investigations on this aspect are continuing.

[TURNER, D. J., RICHARDSON, W. G. and] TABBUSH, P. M. (1988). The use of additives to improve the activity of herbicides used for bracken and heather control. In, *The practice of weed control and vegetation management in forestry, amenity and conservation areas, Aspects of Applied Biology* 16, 271–280. Association of Applied Biologists.

Surfactant additives increased the phytotoxicity to bracken of asulam, glyphosate, sulfonylurea herbicides and imazapyr. Similar responses were observed in an experiment on control of heather by glyphosate, in which an interaction between additives and the application method occurred. Enhancement of phytotoxicity to bracken did not generally involve increased injury to grasses but some damage to Sitka spruce was observed. The use of appropriate surfactants may improve the selectivity of treatments on these weed species.

WAINHOUSE, D. [and GATE, I. M.] (1988). The beech scale. In, *Dynamics of forest insect populations: patterns, causes and implications*, ed. Berryman, A. A., 67–85. Plenum Press, New York.

A detailed review of the ecology and population dynamics of the beech scale.

WALKER, C. (1987). Sitka spruce mycorrhizas. In, *Symposium on Sitka spruce. Proceedings of the Royal Society of Edinburgh* 93B, 117–129.

A critical review of the current literature of Sitka spruce mycorrhizas is presented, and the need for more work directed at solving practical forestry problems is discussed.

WALKER, C. (1987). Identifying the endomycorrhizal *Endogonaceae*. In, *Programa e Resumos da II Reuniao Brasileira*, 83–97.

A review of methods and concepts used in identifying vesicular–arbuscular mycorrhizal fungi is presented.

WALKER, C. (1987). Current concepts in the taxonomy of the *Endogonaceae*. In, *Mycorrhizae in the next decade*. Proceedings of the 7th North American Conference on Mycorrhizae, 3–8 May, 1987, Gainesville, Florida, USA.

Current concepts in the taxonomy of the *Endogonaceae* are described and advice on how to identify specimens of this group of fungi is given.

WALKER, C. (1989). Friendly fungi poised to boost nursery growth. *Horticulture Week* 205 (1), January 6, 18–19.

An illustrated popular account of what mycorrhizas are is given and the potential for use in horticulture is briefly discussed.

WALKER, C. [and KOSKE, R. E.] (1987). Taxonomic concepts in the *Endogonaceae*. IV *Glomus fasciculatum* redescribed. *Mycotaxon* 30, 253–262.

A taxonomic redescription of this frequently mis-identified species is provided along with illustrations and a discussion of the difficulties in its identification.

[WATT, A. D. and] LEATHER, S. R. (1988). The pine beauty in Scottish lodgepole pine plantations. In, *Dynamics of forest insect populations: patterns, causes and implications*, ed. Berryman, A. A., 243–266. Plenum Press, New York.

The life cycle, biology and ecology of *Panolis flammea* are reviewed. The interactions between host plant, site factors and *P. flammea* population dynamics are highlighted. The effects of weather and natural enemies are discussed, and the possibilities of pest management using silvicultural and chemical methods discussed in relations to the strategies already used.

[WATT, A. D. and] LEATHER, S. R. (1988). The distribution of eggs laid by the pine beauty moth, *Panolis flammea*. (Deni and Schiff) (Lep., Noctuidae) on lodgepole pine. *Journal of Applied Entomology* **106**, 108–110.

The distribution of eggs laid by the pine beauty moth on lodgepole pine was investigated on 177 trees at two sites in northern Scotland in 1985–86. The average total number of eggs per tree was 1845. The average number of eggs per whorl rose from 15.8 on the leading shoot to 214.6 on the fifth whorl, then dropped gradually to 56.4 on the fifteenth whorl. The proportion of eggs laid on each whorl was independent of the total number of eggs laid on the tree, and the number of eggs laid per length of needle-bearing branch was greatest on the branches of the first three whorls.

[WATT, A. D. and] LEATHER, S. R. (1988). The impact and ecology of the pine beauty moth in upland pine forests. In, *Ecological change in the uplands*, eds. Usher, M. B. and Thompson, D. B. A., 261–272. Blackwell Scientific Publications, Oxford.

1. Outbreaks of pine beauty moth (*Panolis flammea*) have occurred in lodgepole pine (*Pinus contorta*) plantations since 1976. These outbreaks can destroy whole forest blocks within 2 years. 2. Large-scale control operations have been required in 6 years between 1977 and 1987. 3. Pine plantations vary considerably in their susceptibility to outbreaks. Factors contributing to this include pine species (Scots pine, *Pinus sylvestris*, has not experienced any outbreaks in Scotland), geographical region (most outbreaks have been in the Highland region of Scotland), soil type (plantations on deep peat are particularly prone to outbreaks) and age of lodgepole pine (so far, 10–27-year-old trees have had outbreaks). More surveys and research are required to confirm relationships between outbreaks and plantation size, tree species and age. 4. Relevant studies of the pine beauty moth's population ecology are summarised in the context of understanding further its impact on upland pine forests.

WEBBER, J. F. (1988). Effect of MBC fungicide tolerance on the fitness of *Ophiostoma ulmi*. *Plant Pathology* **37**, 217–224.

Isolates of *Ophiostoma ulmi* with mutations conferring high or low levels of tolerance to MBC-generating fungicides were selected in the laboratory. Comparisons between these tolerant forms and their wild type equivalents indicated that the acquisition of a mutation in the *Tol* locus was associated with decreased growth on agar medium. Pathogenicity and bark-colonising ability were also found to be significantly reduced, indicating that the fitness of tolerant individuals was impaired.

WEBBER, J. F. and GIBBS, J. N. (1989). Insect dissemination of fungal pathogens of trees. In, *Insect–fungus interactions*, eds. Wilding, N., Collins, N. M., Hammond, P. M. and Webber, J. F. Academic Press, London. (344pp.)

The insect vectoring of plant pathogens is discussed in detail. Case histories of several economically serious diseases such as oak wilt, Dutch elm, canker stain and black stain root disease are used to illustrate how biotic and environmental factors influence insect transmission.

WEBBER, J. F., BRASIER, C. M. and MITCHELL, A. G. (1987). The role of the saprophytic phase in Dutch elm disease. In, *Fungal infection of plants*, eds. Pegg, G. and Ayers, P. G., 298–314. Cambridge University Press, Cambridge.

This paper discusses the saprophytic phase of Dutch elm disease, and suggests that it provides a period of both intense inter- and intra-specific competition for the elm pathogen *Ophiostoma ulmi*.

WHITE, J. (1988). Westonbirt Arboretum. *Endeavour* **12** (2), 71–75.

An appraisal of the Forestry Commission's Arboretum at Westonbirt, its history, its site and the tree collection. Particular attention is given to the present objectives and working techniques. The 1987 land use survey is outlined. Westonbirt is constantly providing opportunities for research and education, and the future for trees and people is going to be as exciting as the past has been.

[WILDING, N., COLLINS, N. M., HAMMOND, P. M. and] WEBBER, J. F. (1989). *Insect–fungus interactions*. Academic Press, London. (344 pp.)

This symposium volume attempts to review the current state of knowledge in four principal areas of insect–fungus interactions: mycophagy, mutualism, insect spread of fungal plant disease and insect mycopathology.

WILLIAMSON, D. R. and MASON, W. L. (1989). Nursery herbicides update: FC's vital role in experiments. *Forestry & British Timber* 18 (2), 29, 33.

An effective weed control programme in the forest nursery is vital because weeds can compete with and damage tree crops especially at the seedling stage. Hand weeding is expensive, its effect is short lived and manual removal of weeds can damage small seedlings. Therefore, weed control using chemical herbicides has been generally adopted throughout the forest nursery industry.

WILLSON, A. and WADDELL, D. A. (1988). Influence of nutrition on the sensitivity of trees to air pollutants. In, *Air pollution and plant metabolism*, ed. Schulte-Hostede, S., 36–39.

Sitka spruce seedlings which were becoming nitrogen deficient were less sensitive to foliar injury caused by exposure to ozone than seedlings with adequate nitrogen. Ozone depressed the transpiration of all seedlings to the same extent.

WINTER, T. G. (1988). *Insects and storm-damaged broadleaved trees*. Forestry Commission Research Information Note 133.

Insect damage to windthrown broadleaved trees may be caused by several different beetles but with one exception will be restricted to the sapwood. The only insect that may damage the heartwood of oak, *Platypus cylindrus*, is rare. Beech is likely to suffer degrade due to fungal staining before insect damage is serious. No serious damage to the sapwood of logs arising from the storm of 16 October 1987 is likely before May/June 1989 when the populations of longhorn, powder-post and anobiid beetles may have greatly increased. Attack by various bark beetles will also occur but none of these are a threat to the remaining crop.

WINTER, T. G. (1988). *Insect and storm-damaged conifers*. Forestry Commission Research Information Note 134.

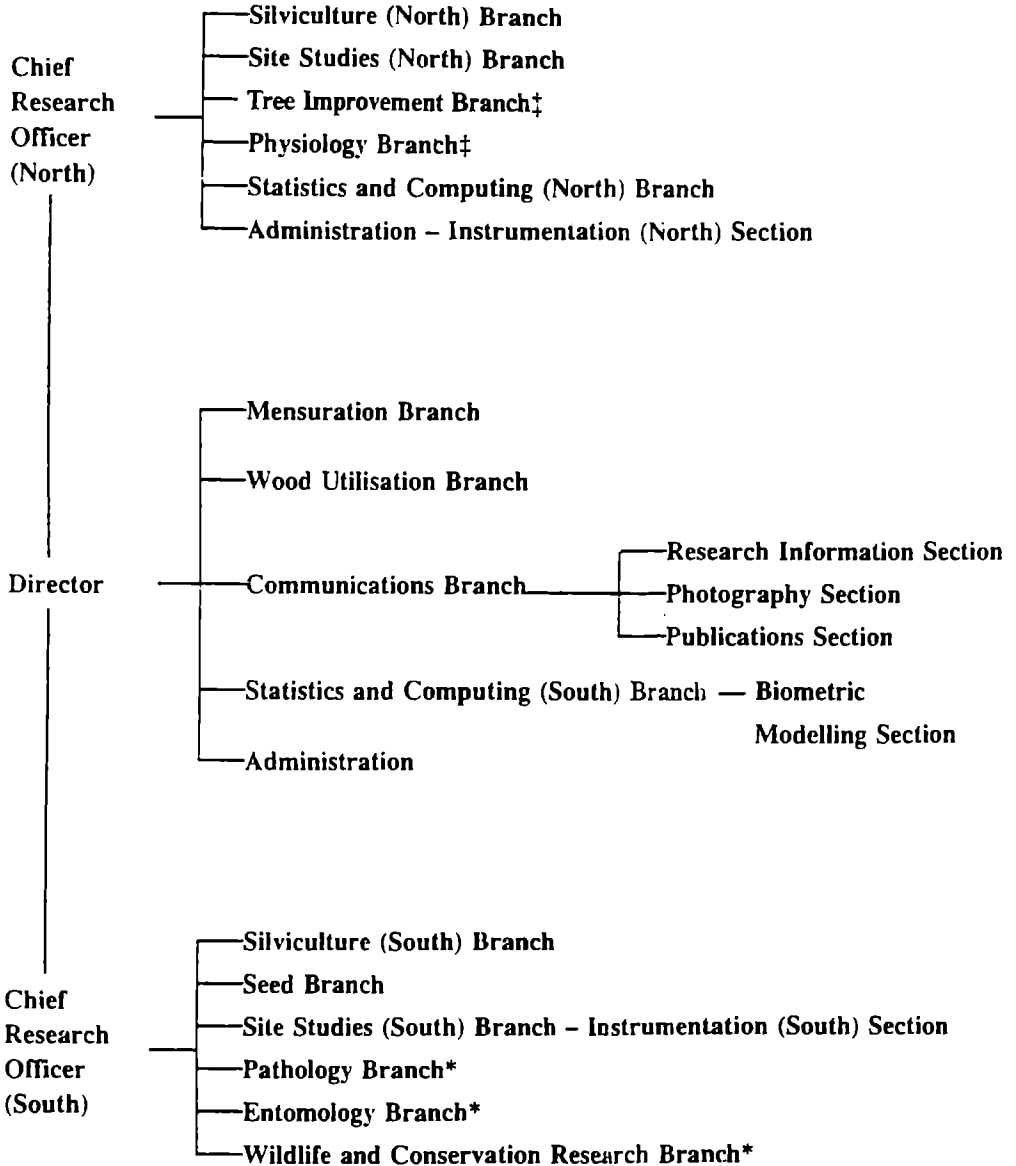
The main insect threat to conifers following the storm of 16 October 1987 is to pine, where attacks by bark beetles will be followed by blue stain. Severed trunks will be preferred by *Tomicus piniperda* for breeding and should be removed first. Scots pine will be attacked in preference to Corsican pine. There will be no danger of a new generation of *T. piniperda* emerging from logs before June 1988. Some degrade of larch left through the summer of 1988 is possible due to *Tetropium gabrieli* (larch longhorn). Recommendations are given for treatment of stacked produce to prevent attack by bark beetles.

WINTER, T. G. (1988). *Furcipes rectirostris* (Coleoptera: Curculionidae) in Scotland. *Entomologist's Gazette* 39, 187.

This weevil is recorded for the first time in Scotland from *Prunus padus* seed at Glen Urquhart. The species was first reported as British in 1981 some 350 km south in Cumbria.

## 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‡

<b>Seed</b>	<u>Project leader(s) at 31/3/89</u>
Research Service	P. G. Gosling, S. K. Jones P. G. Gosling
<b>Silviculture (South)</b>	
Plant production	R. L. Jinks
Species	M. J. Potter
Establishment	M. J. Potter
Weed control	D. R. Williamson
Farm forestry	C. J. Potter
Contracts: arboriculture advisory and information service	D. Patch
arboriculture research	S. Hodge
short rotation coppice	C. J. Potter
Dendrology	J. E. J. White
<b>Silviculture (North)</b>	
Plant production	W. L. Mason
Species	C. M. A. Taylor, C. J. Nixon
Planting (including weed control)	D. G. Nelson
Nutrition	C. M. A. Taylor
Cultivation	D. G. Nelson, C. P. Quine
Stability	B. A. Gardiner, C. P. Quine
Farm forestry	C. M. A. Taylor
<b>Site Studies (South)</b>	
Effects of trees on sites	P. H. Freer-Smith
Lowland production forestry	A. J. Moffat
Reclamation	A. J. Moffat
Hydrology: water quality	T. R. Nisbet
Air pollution	P. H. Freer-Smith
	J. L. Innes, A. Willson
Chemical analysis	A. Willson
Instrumentation	T. R. Nisbet
<b>Site Studies (North)</b>	
Clay soils	D. Ray
Deep peats	D. G. Pyatt
Ironpan soils	A. R. Anderson
Loamy gleys	A. R. Anderson, D. Ray
Hydrology	D. G. Pyatt
<b>Tree Improvement</b>	
Testing progeny and clones	S. L. Lee
Origin	A. M. Fletcher, C. J. A. Samuel
Production: clone banks and orchards	A. M. Fletcher, W. Brown
Stands: registration of seed sources	A. M. Fletcher, C. J. A. Samuel
Biochemical variation	G. I. Forrest
Biometrical studies	C. J. A. Samuel
Flowering	J. J. Philipson
Micropropagation	A. John
Rejuvenation	A. John, A. M. Fletcher
Propagation of broadleaves	R. Harmer

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

**Physiology**

Root growth and form  
 Bent top  
 Lowland restocking  
 Planting stock quality  
 Mycorrhizas  
 Development of rooting patterns

M. P. Coutts  
 M. P. Coutts  
 M. P. Coutts, H. M. McKay  
 H. M. McKay  
 C. Walker  
 C. Walker

**Pathology**

Disease diagnosis, damage monitoring  
 and risk assessment  
 Cankers and shoot diseases  
 Wilt disease  
  
 Root diseases  
 Stem decays and stain  
 Complex diebacks and chronic declines

D. B. Redfern, S. C. Gregory  
 R. G. Strouts, J. N. Gibbs  
 B. J. W. Greig, D. R. Rose  
 C. M. Brasier, J. F. Webber,  
 B. J. W. Greig  
 D. B. Redfern, B. J. W. Greig  
 D. Lonsdale, J. N. Gibbs  
 D. Lonsdale

**Entomology**

*Dendroctonus micans*

*Panolis flammea*  
 Beech bark disease  
*Elatobium abietinum*  
*Hylastes* and *Hylobius*  
 Advisory and taxonomic  
 Genetic variations

H. F. Evans, D. Wainhouse,  
 C. J. King  
 J. T. Stoakley, S. R. Leather  
 D. Wainhouse  
 C. I. Carter  
 J. T. Stoakley, S. G. Heritage  
 T. G. Winter  
 M. R. Jukes

**Wildlife and Conservation**

Red deer  
 Other deer (roe and sika)  
 Squirrels (red and grey)  
 Birds  
 Damage  
 Repellents (fencing and tree guards)  
 Bats  
 Vegetation management in lowland forests  
 Vegetation management in upland forests  
 Watercourse management in upland forests

P. R. Ratcliffe  
 P. R. Ratcliffe  
 H. W. Pepper  
 S. J. Petty  
 R. M. A. Gill  
 H. W. Pepper  
 B. A. Mayle  
 R. Ferris-Kaan  
 G. S. Patterson  
 G. S. Patterson

**Mensuration**

Sample plots  
 Measurement studies  
 Yield modelling  
 Management services  
 Data terminals

G. Kerr  
 G. Kerr  
 G. Kerr  
 G. Kerr  
 J. M. Methley

**Wood Utilisation**

Wood quality  
 Preservation  
 Utilisation of broadleaves

D. A. Thompson  
 D. A. Thompson  
 D. A. Thompson

**Statistics and Computing (South)**

Forest growth modelling

A. R. Ludlow



## APPENDIX IV

## Net Expenditure of Research Division 1988/89

Branch <sup>(a)</sup>	£000			
	Expenditure by Branch direct <sup>(b)</sup>	Net value of in-house services received less than those provided <sup>(c)</sup>	Commissioned <sup>(d)</sup> research	Expenditure attributable to Branch <sup>(e)</sup>
Seed	98	47		146
Silviculture (South)	809	51	21	882
Arboreta	397			397
Silviculture (North) <sup>(f)</sup>	1687	-216	26	1495
Site Studies (South) <sup>(g)</sup>	628	35	91	754
Site Studies (North)	151	66		217
Tree Improvement	671	243		914
Physiology	307	101	9	417
Pathology	462	77	34	573
Entomology	546	69	21	636
Wildlife and Conservation	380	71	133	584
Mensuration	268	47		315
Wood Utilisation	104	9	129	242
Statistics and Computing (South)	314	-243		71
Statistics and Computing (North)	228	228		—
Communications	351	-129		222
Total <sup>(e)</sup>	7401	456 <sup>(h)</sup>	464	7865

*Notes:*

- (a) Ordered as in text of this Report.
- (b) All directly incurred expenditure on wages and salaries, pension provisions, travelling and subsistence, materials, equipment, etc., plus office overheads of the Division of £1435 (000), plus Forestry Commission headquarters overheads for common services of £419 (000), net of income of £247 (000) for contract services provided to outside parties.
- (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 by Branches of other Divisions, namely Forest Surveys and Work Study, equals £20 (000).
- (i) Branches' work on behalf of Forest Authority Plant Health amounted to £84 (000).

## APPENDIX V

### Staff Engaged in Research

As at 31 March 1989

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#### 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 for silviculture and site studies in the lowlands, and throughout Britain for research in pathology, entomology, wildlife and conservation, seed, arboriculture, instrumentation and technical aspects of legislation relating to plant health.)

Chief Research Officer (North) . . . . . T. C. Booth, B.Sc., M.I.C.For.  
*(Northern Research Station)*

(Head of the Northern Research Station with general responsibilities for research north of the Mersey/Humber line and in Wales, with specific responsibilities throughout Britain for research in tree physiology and tree improvement, and for silviculture and site studies in the uplands.)

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STAFF AT ALICE HOLT LODGE

SEED BRANCH

P. G. Gosling, B.Sc., Ph.D., Head of Branch  
 Miss A. M. Bolster, S. K. Jones, G.I.Biol., M.I.Hort., Mrs P. J. Rigg, Mrs Y. K. Samuel, B.A.

SILVICULTURE BRANCH (SOUTH)

J. Evans, B.Sc., Ph.D., D.Sc., F.I.C.For., Head of Branch  
 D. Elgy, S. Hodge, B.Sc., M.Sc., R. L. Jinks, B.Sc., Ph.D., Mrs C. J. Potter, B.Sc., M.I.C.For.,  
 M. J. Potter, B.Sc., M.I.C.For., J. E. J. White (*Westonbirt*), D. R. Williamson, B.Sc., M.I.C.For.

	<i>Outstation staff:</i>	<i>Centre</i>
<i>East England Region</i>	A. T. Armstrong, S. M. Colderick, M.I.C.For. P. D. Howard, P. Marsh J. S. McIntyre	Alice Holt  Bedgebury Thetford
<i>West England Region</i>	T. D. Cooper, D. A. Hendrie H. C. Angus, P. A. Gregory, M.I.Hort., A. Russell D. G. Rogers, N. A. Smith M. W. Allen	Westonbirt Exeter Dean

ARBORICULTURAL ADVISORY AND INFORMATION SERVICE (Department of the Environment)

D. Patch, B.Sc., M.Sc., M.I.C.For., M.Arb.(RFS), F.Arbor.A.  
 F. R. W. Stevens

SITE STUDIES BRANCH (SOUTH)

P. H. Freer-Smith, B.Sc., Ph.D., Head of Branch  
 Mrs S. E. Benham, P. G. Crow, D. W. H. Durrant, B.A., J. L. Innes, M.A., Ph.D., P. C. Jokiel,  
 B.Sc., A. J. Moffat, B.Sc., Ph.D., T. R. Nisbet, B.Sc., Ph.D., C. J. Roberts, B.A.,  
 Mrs D. A. Waddell, E. Ward, B.Sc., M.Sc., A. Willson, B.Sc., Ph.D.

INSTRUMENTATION SECTION (SOUTH)

T. R. Nisbet, B.Sc., Ph.D., Head of Section

TREE IMPROVEMENT SECTION (of Branch at Northern Research Station)

R. Harmer, B.Sc., Ph.D., Mrs C. A. Baker

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., Mrs S. E. Brown, B.Sc., B. J. W. Greig, M.I.C.For.,  
 Mrs S. A. Kirk, D. Lonsdale, B.Sc., Ph.D., C. A. Palmer, Mrs T. C. Reffold, B.Sc.,  
 D. R. Rose, B.A., R. G. Strouts, Ms J. F. Webber\*, B.Sc., Ph.D.

ENTOMOLOGY BRANCH (with Section at Northern Research Station)

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

WILDLIFE AND CONSERVATION RESEARCH BRANCH

P. R. Ratcliffe, B.Sc., Ph.D., C.Biol., M.I.Biol., M.I.C.For., Head of Branch  
 A. Chadwick (*Cowal, Strathclyde*), R. Ferris-Kaan, B.Sc., Ph.D., R. M. A. Gill, B.Sc.,  
 Mrs B. A. Mayle, H. W. Pepper, S. J. Petty (*Cowal, Strathclyde*), G. A. Patterson, B.Sc.,  
 M.I.C.For. (*Northern Research Station*).

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

**MENSURATION BRANCH**

G. Kerr, B.Sc., M.I.C.For., Head of Branch

S. R. Abbott, A. F. Martin, B.Sc.(For.), R. W. Matthews, B.Sc., M.Sc., Mrs J. M. Methley, B.Sc.

**WOOD UTILISATION BRANCH**

D. A. Thompson, B.Sc., 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., A. R. Ludlow, B.Sc., Ph.D., M. A. Mellergaard, I. D. Mobbs, M.I.S., A. J. Peace, B.Sc., T. J. Randle, 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**

G. L. Gate, Head of Section

Miss M. Trusler

**PUBLICATIONS SECTION**

E. J. Parker, Ph.D., C.Biol., M.I.Biol., Head of Section

J. Williams (Graphics Officer)

**ADMINISTRATION**

HEOs: Mrs B. K. Bartlett (*Personnel*), R. Murray (*Accounts*)

EOs: Mrs J. C. Gates (*Office Services*), Miss J. R. Lacey (*Personnel*), Miss K. Beattie (*Accounts*)

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## STAFF AT NORTHERN RESEARCH STATION

## SILVICULTURE BRANCH (NORTH)

D. B. Paterson, B.Sc., M.I.C.For., Head of Branch

B. A. Gardiner, B.Sc., Ph.D., F.R.Met.S., W. L. Mason, B.A., B.Sc., M.I.C.For., D. G. Nelson, B.Sc., M.I.C.For., C. J. Nixon, B.Sc., M.I.C.For., C. P. Quine, M.A., M.Sc., M.I.C.For., C. M. A. Taylor, B.Sc., M.I.C.For.

	<i>Outstation staff:</i>	<i>Centre</i>
Special Projects	B. R. Reynard, M.I.C.For.	Northern Research Station
<i>North and Mid Scotland Region</i>	A. L. Sharpe	Newton, Grampian
North Scotland Area	W. G. Paterson, J. Boluski	Lairg, Highland
North-east Scotland Area (including Central Highlands and Islands)	A. A. Green, J. Davidson, B.A., M.I.C.For.	Newton, Grampian
West Scotland Area (including Mull)	D. R. Tracy, S. Stables, B.Sc.	Cairnbaan, by Lochgil- phead, Strathclyde
East Scotland Area	F. S. Smith, W. F. Rayner	Perth, Tayside
<i>South Scotland and North England Region</i>	J. D. McNeill	Northern Research Station
South-east Scotland Area	M. K. Hollingsworth	Northern Research Station
South-west Scotland Area (including Arran)	M. Riley, D. M. Watterson	Mabie
Borders Area	P. H. Priestley, P. W. Gough, D. Kerr	Kielder, by Hexham, Northumberland
North-east England Area	R. E. J. Howes	Wykeham, Scarborough, North Yorkshire
<i>Wales Region</i>	N. P. Danby	Brecon, Powys
Wales Area	S. J. Corcoran, B. A., N.D.F. M.I.C.For., S. A. Mead, B.Sc.	Brecon, Powys (Talybont-on-Usk from May 1989)

## SITE STUDIES BRANCH (NORTH)

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

A. R. Anderson, D. Ray, B.Sc.

## TREE IMPROVEMENT BRANCH (with Section at Alice Holt)

D. A. Rook, B.Sc., M.Sc., Ph.D., Head of Branch

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 I. M. S. White, B.Sc., M.Sc.

## ADMINISTRATION

HEO: C. K. Smith  
 EO: Mrs M. Farm

## INSTRUMENTATION SECTION (NORTH)

D. J. Brooks, Head of Section

## STAFF CHANGES

*Transfers in:* S. R. Abbott (Forest Officer IV) from Wales Conservancy to Mensuration, Alice Holt. R. J. D. Beveridge (Forest Officer IV) from West Scotland Conservancy to Silviculture North, Newton. Mrs M. Farm (Executive Officer) from Headquarters to Administration, Northern Research Station. D. T. A. Hendrie (Forest Officer IV) from East England Conservancy to Silviculture South, Theftord. A. C. Hendry (Forest Officer IV) from Mid Scotland Conservancy to Entomology, Northern Research Station. S. J. Hodge (Forest Officer II) from East England Conservancy to Silviculture South, Alice Holt. N. A. D. Muir (Forest Officer IV) from Wales Conservancy to Tree Improvement Branch, Northern Research Station. C. J. Nixon (Forest Officer II) from Wales Conservancy to Silviculture North, Northern Research Station. T. D. Russell (Forest Officer IV) from East England Conservancy to Silviculture South, Westonbirt Arboretum. C. K. Smith (on promotion to Higher Executive Officer) from HQ to Administration, Northern Research Station.

*New appointments:* R. Ferris-Kaan (Higher Scientific Officer) Wildlife & Conservation, Alice Holt. R. M. A. Gill (Senior Scientific Officer) Wildlife & Conservation, Alice Holt. J. L. Innes (Senior Scientific Officer) Site Studies South, Alice Holt. R. L. Jinks (Higher Scientific Officer) Silviculture South, Alice Holt. P. C. Jokiel (Assistant Scientific Officer) Site Studies South, Alice Holt. S. K. Jones (Higher Scientific Officer) Seeds, Alice Holt. C. M. McEvoy (Assistant Scientific Officer) Physiology, Northern Research Station. H. M. McKay (Scientific Officer) Physiology, Northern Research Station. T. J. Porter (Assistant Scientific Officer) Statistics & Computing, Alice Holt. D. A. Rook (Grade 6) Tree Improvement, Northern Research Station. Mrs J. Shipp (Typing Manager) Alice Holt. N. A. Straw (Higher Scientific Officer) Alice Holt.

*Transfers out:* H. L. Davies (Forest Officer I) from Silviculture South, Alice Holt to MAFF (ADAS, Bristol) on secondment. J. C. Keenleyside (on promotion to Forest Officer I) from Silviculture North, Newton to North Scotland Conservancy. S. E. Malone (Forest Officer III) from Silviculture South, Theftord to East England Conservancy. N. M. Proctor (Forest Officer) from Silviculture North, Lairg to South Scotland Conservancy. C. W. Shanks (Forest Officer III) from Silviculture South, Alice Holt to East England Conservancy. Mrs F. Snaith (Executive Officer) from Administration, Northern Research Station to HQ.

*Promotions:* B. J. W. Greig (Pathology, Alice Holt) to Forest Officer I. S. G. Heritage (Entomology, Northern Research Station) to Senior Scientific Officer. R. W. Matthews (Mensuration, Alice Holt) to Higher Scientific Officer. S. J. Petty (Wildlife & Conservation, Glenbranter) to Forest Officer II. Miss B. J. Smyth (Statistics & Computing, Alice Holt) to Senior Scientific Officer. E. Ward (Site Studies South, Alice Holt) to Higher Scientific Officer.

*Resignations:* M. A. Anderson (Higher Scientific Officer) Wildlife & Conservation, Alice Holt. R. J. D. Beveridge (Forest Officer IV) Silviculture North, Newton. Mrs V. Goodall (Assistant Scientific Officer) Physiology, Northern Research Station. J. C. G. Patterson (Forest Officer IV) Entomology, Northern Research Station. D. J. Pitt (Forest Officer) Silviculture North, Northern Research Station.

*Retirements:* E. Baldwin (Forest Officer II) Silviculture North, Mabie. I. J. M. Dawson (Forest Officer II) Silviculture South, Westonbirt Arboretum. R. Faulkner (Grade 7) Genetics, Northern Research Station. Mrs E. A. Walters (Typing Manager) Alice Holt.

*Death:* E. J. Fletcher (Forest Officer) Mensuration, Alice Holt.

## APPENDIX VI

### Addresses of Research Locations

#### MAIN CENTRES

Forestry Commission  
Research Station  
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Wrecclesham  
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GU10 4LH. Tel. 042022255

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 OUTSTATIONS

**Ardentinny** Wildlife  
Forestry Commission  
Wildlife & Conservation  
Research Branch  
Ardentinny  
Dunoon  
Argyll  
PA23 8TS  
Tel: 036 981 253

**Bedgebury** Silv(S)  
Forestry Commission  
Bedgebury Pinetum  
Bedgebury  
Cranbrook  
Nr Goudhurst  
Kent  
TN17 2SL  
Tel: 0580 211044

**Cairnbaan** Silv(N)  
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Research Office  
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Lochgilphead  
Argyll  
PA31 8SQ  
Tel: 0546 2304

**Dean** Silv(S)  
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Research Office  
Crown Offices  
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Coleford  
Gloucestershire  
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Tel: 0594 33057

**Exeter** Silv(S)  
Forestry Commission  
Research Office  
Bullers Hill  
Kennford  
Exeter  
Devon EX6 7XR  
Tel: 0392 832262

**Kielder** Silv(N)  
Forestry Commission  
Research Office  
Kielder  
by Hexham  
Northumberland  
NE48 1ER  
Tel: 0660 50235

**Lairg** Silv(N)  
Forestry Commission  
Research Office  
Ord Croft  
Lairg  
Sutherland  
IV27 4AZ  
Tel: 0549 2150

**Ludlow** Entomology  
Forestry Commission  
Entomology Office  
Whitcliffe  
Ludlow  
Shropshire  
SY8 2HD  
Tel: 0584 4542

**Mabie** Silv(N)  
Forestry Commission  
Research Office  
Mabie  
Troqueer  
Dumfries  
DG2 8HB  
Tel: 0387 52267

**Newton** Silv(N) &  
Tree Improvement  
Forestry Commission  
Research Office  
Newton Nursery  
Elgin  
Morayshire  
IV30 3XR  
Tel: 0343 3165

**Perth** Silv(N)  
Forestry Commission  
Research Office  
10 York Place  
Perth PH2 8EJ  
Tel: 0738 25344

**Shobdon** Tree Improvement  
Forestry Commission  
Research Division  
Uphampton  
Shobdon, Leominster  
Hereford HR6 9PB  
Tel: 056 881 8881

**Talybont-on-Usk** Silv(N)  
(formerly at **Brecon**)  
Forestry Commission  
Research Office  
Cefn Gethiniog  
Talybont-on-Usk  
Brecon  
Powys LD3 7YN  
Tel: 0874 87 444

**Thetford** Silv(S)  
& Entomology  
Forestry Commission  
Research Office  
Santon Downham  
Brandon  
Suffolk IP27 0TJ  
Tel: 0842 810271

**Westonbirt** Silv(S)  
Forestry Commission  
Westonbirt Arboretum  
Tetbury  
Gloucestershire GL8 8QS  
Tel: 0666 88220

**Wykeham** Silv(N)  
Forestry Commission  
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Wykeham, Scarborough  
Yorks YO13 9HQ  
Tel: 0723 862031

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