



**Forestry Commission**

**REPORT ON  
FOREST RESEARCH  
1988**

Forestry Commission  
**ARCHIVE**

REPORT ON  
FOREST RESEARCH

for the year ended  
March 1988

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**Front Cover:** Mixed broadleaved woodland adjacent to farmland in Buckinghamshire. The Government's Farm Woodland Scheme is giving rise to new initiatives in research directed towards the establishment and aftercare of trees on better land. (38502).

**Back Cover:** The noctule (*Nyctalus noctula*), one of Britain's largest bats, is almost exclusively found in tree holes and flies high above the tree canopy foraging for large insects. (Copyright: R.E. Stebbings)

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## INTRODUCTION

By A. J. GRAYSON

*Director of Research*

### Advisory Committee on Forest Research

Three visiting groups were established and reported during the course of the year. The first, on genetics, was led by Professor Peter Day, then Director of the Plant Breeding Institute, Cambridge, assisted by Professor E. C. Cocking, of Nottingham University, Dr K. Giles, then of Twyford Laboratories, Glastonbury and Dr J. Kleinschmit of the Lower Saxony Forestry Research Institute, Escherode, West Germany. Recent developments in plant biotechnology and the need to consider future organisation of tree improvement work in the Forestry Commission were the occasion of this review. The main recommendation was to strengthen the work of the Branch, which has subsequently been renamed Tree Improvement Branch, by integrating breeding and relevant physiology, and ensuring closer contact with scientists working in such areas as DNA characterisation, use of male gametocides and DNA methylation. The group confirmed that the classical approach adopted by the Branch had been successful and was justified, but wished to ensure that the contributions of other branches as well of new biotechnological techniques were more fully integrated into improvement work. The group also emphasised the desirability of achieving rejuvenation. These recommendations, which included the proposal to upgrade the head of an enlarged Branch to Unified Grade 6, have been accepted.

A second visiting group reviewed Entomology. This group was chaired by Dr T. Hussey, lately of the Glasshouse Crops Research Institute and included Professor A. F. G. Dixon, School of Biological Sciences, University of East Anglia and Professor M. P. Hassall, Department of Pure and Applied Biology, Imperial College, London. The group generally accepted the method of working and balance of projects undertaken by the Branch but recommended that particular attention be paid to the assessment of damage by major pests, whether causing death or sub-lethal damage, and the development of population dynamics studies, and drew particular attention to the desirability of adopting ecologically more appropriate management practices, rather than relying on control of pests alone. These recommendations were accepted by the Advisory Committee and I am implementing them and certain other proposals on organisation which were made.

A third group reviewed Site Studies (North) Branch and was headed by Mr Allan Robertson, lately of the Macaulay Land Use Research Institute, Aberdeen, assisted by Mr S. le Grice of ADAS. The group made a number of valuable recommendations, the bulk of which have been accepted. Although it has not proved possible to add to the Branch complement, recommendations concerning organisation of a multi-disciplinary group to co-ordinate work on tree stability, guides to forest drainage practice, emphasis to be given to studies of aeration and possible irreversible drying of deep peats under forest have been, or are being, implemented.

In reporting these visiting group activities, I wish to record my thanks to the chairmen and members concerned for the time so generously given to these enquiries and the preparation of balanced and penetrating analyses of Branches' work.



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

The Forestry Research Co-ordination Committee has continued its process of reviewing major fields of research in forestry. In the course of the year it received the report of a review group on farming and forestry in the uplands. Reviews of research activity in three other fields, arboriculture, economics and the physiology of stand growth are currently in progress. With these reports, the work begun in 1982 of assessing research requirements and performance in the main subject areas of forestry research will have been largely completed.

An important new initiative of the Committee was the co-ordination it undertook of farm forestry research. A sub-committee considered the priorities for research in this field against the background of current research in conventional forestry and the needs of farmers, and recommended to sponsors (principally the agriculture departments but also including the Agriculture and Food Research Council in respect of its 'Science Vote' money, the Natural Environment Research Council, the Economic and Social Research Council and the Forestry Commission) the groups of projects that should be funded. In the main these have now been agreed.

### **The gale of 15/16 October 1987**

This gale of an intensity estimated to have a return period of more than 200 years struck south and east England when most people were abed. Partly because of the time of day the loss of human life was smaller than it might have been. Damage to property was however heavy and estimated at £1 billion, while the devastation of the landscape of south-east England and eastern East Anglia was remarkable and horrifying. Fifteen per cent of the stock of trees in the six counties of Suffolk, Essex, Kent, Surrey, East Sussex and West Sussex were blown down. The physical wounds will no doubt be healed quite soon for all those who do not treasure the recollection of a particular piece of woodland or belt of trees. The restoration will call for careful choices of species blending tradition, beauty and profit with perhaps more than usual attention to security. The Division has been heavily involved in work aimed at minimising the possible loss of timber value through decay as well as provision of guidance on techniques of tree and woodland restoration.

### **Farm forestry**

The announcement of the Farm Woodlands Scheme provided an important stimulus to those with whom we deal on matters concerning farm woodland experimentation and communication of research results. Earlier in the year the Minister of Agriculture visited Alice Holt Lodge as did the President of the National Farmers' Union. Joint experimental work with the Agricultural Development and Advisory Service of MAFF has begun with site preparation for planting at the Experimental Husbandry Farm at Drayton, near Stratford. In addition, important new lines of work are in the course of being established in the Institute of Horticultural Research, Agriculture and Food Research Council.

One of these concerns studies of rejuvenation, a topic identified some years ago at a meeting organised by Professor Cocking for the Research Division and other interested parties as being of the highest importance, and also emphasised by Professor Day's visiting group. The value of being able to reproduce

vegetatively particular plants of tested stock arising from a breeding programme, instead of relying on new crosses of chosen parents and reproduction by seed with or without vegetative propagation thereafter, is calculable: it turns out to be very high. Attractive though the goal is for all tree breeders, the scale of research programme required to achieve it is also likely to be large.

### **Organisation of project work**

Experience with the special project team concerned with the development of improved methods of restocking upland areas with conifers has been altogether positive. Accordingly another project team, also designed to be of limited life, has been created to carry out research into lowland restocking where field practice is characterised by heavy failures and delayed establishment. The October 1987 gale in south-east England also led to the establishment of joint project work concerned with the central matter of reducing degrade of blown timber.

The writer has been privileged to observe a variety of organisational arrangements for research ranging from entirely discipline-based ones in some institutes to others in which work is divided up among task forces. The pervasive need in research, as in other walks of life, is to encourage and maintain the vitality needed to meet, and indeed create, new challenges. To some extent these can be expected to emerge from the science or technology under study, but equally they may on occasion be provided by changes in working arrangement. The employment of short-lived multi-disciplinary teams for tasks with a defined objective and target completion date provides one such stimulus.

### **Forest ecology and conservation**

Foresters have of necessity to be concerned with ecology because of the responsibility they bear for conservation of the growing stock of trees they manage. Forest researchers have increasingly been concerned with unravelling the underlying processes at work in forests as a means of managing woodlands more competently and with the aim of gaining better use of the environment in which trees exist. I am happy to report the formation in December 1987 of a Forest Ecology Group of the principal professional body of ecologists, the British Ecological Society. It is hoped that this new group will engage the interests of scientists and naturalists outside the normal associations of specialists in forestry research and will encourage more studies of both descriptive ecology and processes in woodland communities. The group may also be expected to provide a useful forum for exchanges of ideas on the problem of joint provision of wood and wildlife conservation.

### **Highlights**

The reader will make his or her own selection of material of particular interest within the body of this Report but a number of items are noted here in order to illustrate the relevance of this year's research to current issues:

- peat shrinkage and hydrology of deep peats in Caithness;
- root architecture in relation to cultivation and presence of stumps;

vegetative propagation of Sitka spruce as a working system and the testing of a widening range of plant production methods;  
the shaping of reclamation sites in relation to parent material;  
the design of ride edges in order to enhance interesting elements of the flora and associated fauna, especially butterflies;  
beech extension growth in relation to age, soil and climatic factors such as drought;  
the continuing work to assess forest health in major species and its regional distribution and associations with particular pests and diseases as well as pollutant loadings;  
methods of reducing degrade in timber blown in the October 1987 gale involving studies of insect and fungal attack, and protection of logs by water;  
control of *Dendroctonus micans* by *Rhizophagus* in the field.

### **Staff**

I regret to report the sudden death in November 1987 of Mr John Jobling who had served in Silviculture (South) Branch for 36 years and whose special knowledge of poplars in particular was greatly valued. The departure of staff of the Division who had been trained in forestry at the end of the war continued in the course of 1987: I would especially note the retirement of Dr W. O. Binns who has made outstanding contributions in nutrient diagnostics, the specification of operations required in the reclamation of man-made sites and, in the most recent 8 years, air pollution. The last subject has been the course of unprecedented media interest in trees and forests in the last 5 years of that period.

## PART I

### *The Work of the Forestry Commission*

#### RESEARCH DIVISION

#### SEED

##### Research

In species where up to *c.* 4 weeks moist prechilling is commonly needed to break dormancy, the International Seed Testing Association (ISTA) recommend 'double' germination tests be conducted, one with and one without pretreatment. We have devised a simple classification system to cater for all possible responses to pretreatment in 'double' germination tests, and over the past 3 years we have applied 'double' tests to 48 ISTA tree and shrub species instead of the recommended 23. Some of the additional species were deliberately selected as likely to suffer detrimental as well as beneficial effects from pretreatment since it is important for nurserymen to be aware of either response. Table 1 shows the classification system, and how it has been divided into 10 pretreatment response (PTR) codes depending on comparisons between pretreated and untreated germination rates and capacities. Column 4 shows the percentage frequency of each PTR code in the first thousand 'double' tests which have been analysed. It is clear that the most common PTR codes found in routine testing are 1, 4 and 5.

**Table 1** The classification of laboratory germination tests  $\pm$  pretreatment into pretreatment response codes

Maximum % germination after pretreatment	Interim % germination after pretreatment	Pretreatment response (PTR) code	Frequency of PTR code (%)
Significantly higher	Significantly faster	1	21.0
	Not significantly different	2	0.7
	Significantly slower	3	0.1
Not significantly different	Significantly faster	4	49.0
	Not significantly different	5	18.0
	Significantly slower	6	1.5
Significantly lower	Significantly faster	7	2.3
	Not significantly different	8	1.5
	Significantly slower	9	2.8
Higher, the same or lower	Alternately faster then slower or vice versa	10	3.0

This laboratory has also studied the germination over a range of constant temperatures, with and without pretreatment, of a number of seedlots which have fallen into PTR codes 1, 4 and 5 (see e.g. *Report 1984*, pp. 5–6). Prechilling has always brought about as high or higher germination over the full range of temperatures studied. It was therefore expected that a similar experiment on a Corsican pine seedlot exhibiting the germination profile shown in the inset in Figure 1 would show the same or lower germination

following pretreatment at each constant temperature. Figure 1, however, shows the actual results obtained. Clearly, the significantly detrimental effect of prechilling is only reproduced at constant temperatures of 15 and 20°C. At constant temperatures of 10 and 35°C prechilling actually becomes significantly beneficial. It is therefore possible that if nursery temperatures were consistently in the 10°C region, or if cloches were used to elevate seedbed temperatures to 35°C, then prechilling would significantly benefit field emergence. At intermediate seedbed temperatures prechilling would be significantly harmful.

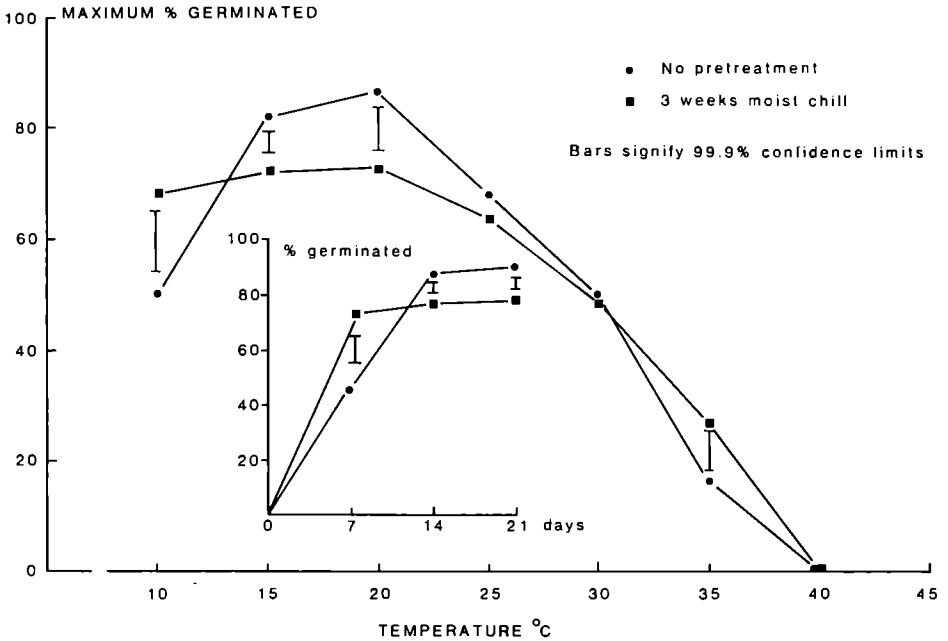


Figure 1. Maximum percentage germination at different temperatures of Corsican pine 80(4599) with (■), and without (●), 3 weeks moist prechill. (Inset shows course of germination in ISTA test.)

The results provide further evidence of why laboratory germination results obtained under one set of germination conditions are not easy to extrapolate to the field.

**Service**

The majority of staff time was again spent on official and advisory seed testing. A total of 613 tree seed samples were tested; 75 seedlots were received from seed merchants and nurserymen; 123 samples of tropical and sub-tropical species were tested on behalf of the Oxford Forestry Institute; and 415 tests were performed on FC seedlots.

## SILVICULTURE (SOUTH)

### Plant production

Two broadleaved species, ash and sycamore, were raised in paperpots as part of the research programme into agroforestry. Other container production in the polyhouse examined container types and compost regimes, and raising conifers in different containers and compost over a period of two seasons. A range of tree species and other plants were raised for use in pollution studies. The vegetative propagation programme largely concentrated on comparing rooting softwood cuttings of a variety of broadleaved species under conventional misting and a fogging unit. Rooted cuttings of elms were again supplied for Pathology Branch's investigation into Dutch elm disease.

A joint project with Hampshire County Council was carried out to provide rooted cuttings of *Tilia cordata* from ancient woodland sites.

D. R. WILLIAMSON, P. MARSH

### Lowland silviculture

#### *Treeshelters*

Since their inception in 1979 treeshelters have become an accepted and valuable tool for tree establishment, particularly of broadleaves in small planting schemes. Now that the efficacy of treeshelters has been demonstrated the research effort devoted to this project will decline considerably, though a few outstanding problems are still being investigated, such as the effect of the infestation of beech in treeshelters by *Phyllaphis fagi*. An experiment begun in spring 1988 will determine how treeshelters influence the survival of containerised forest planting stock when planting dates are extended beyond the normal season.

M. J. POTTER

### Agroforestry

The UK agroforestry research discussion forum has continued, and Silviculture (South) has planted one network experiment site (*Report 1987*, p. 17) at North Wyke, Devon in collaboration with the AFRC Institute for Grassland and Animal Production, North Wyke Research Station. Both ash and sycamore were planted in autumn 1987 at 5 m and 10 m spacing protected by 1.8m tall treeshelters and stakes, and at 2 m spacing in conventional plantations. A grazed open pasture control was also established.

Four experiments were established at North Wyke and Long Ashton to test methods of protecting young transplants against cattle using combinations of fencing and treeshelters. Although it is too soon to draw conclusions about the effectiveness of these protection methods, many interesting observations have been made leading to a better understanding of the management of animals in agroforestry. Contrary to expectations, only 17 out of 160 protected trees were damaged in the first year, out of these nine on one site involved welded wire mesh cages, usually used for protecting trees in urban streets.

After an untroubled 6 months, cattle started to get their ear tags caught up in the wire mesh and in the struggle to free themselves demolished the guards. Two further experiments were established at Long Ashton in collaboration

with the Long Ashton Research Station to test the benefits of different weed control strategies in an agroforestry system with pasture grazed by cattle. The first is a species trial with 12 species including one cider apple and one perry pear cultivar which have traditionally been grown in agroforestry systems. Here different chemical weed control strategies are tested with a non-weeding control. In the second experiment the effect of five different mulches which might be available on farms are tested against a chemical weeding control on the growth of ash and Douglas fir transplants. The mulches used were straw, straw with farmyard manure, wood chip and black polythene and felt mulches held down with a lorry tyre.

The black polythene mulch was torn out from beneath the lorry tyre within 2 weeks of introducing the cattle. This may have been due to using big bale silage bags which had previously contained silage, so the treatment was replaced with clean polythene. Again, the fresh polythene mulch was torn away very quickly, and this treatment was abandoned and replaced with wood chip contained within the lorry tyre.

One important factor found in all of the trials involving livestock was the need for an extra stake at the front of the treeshelter to stop the shelter being pushed around the support stake, so exposing the base of the young tree. This front stake need only be 15 cm above ground as long as it securely anchors the base of the treeshelter.

H. L. DAVIES, K. F. BAKER, D. G. ROGERS

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

#### *Plant production, establishment and maintenance*

A new contract began in January 1987 with some work on weed control and soil ameliorants continuing from the previous one. Four new projects were set up under the new contract; an investigation of plant quality in hardy ornamental stock, a study of growth rates in urban trees, the establishment of trees in hedges and the demonstration of results from tree establishment experiments.

#### *Weed control*

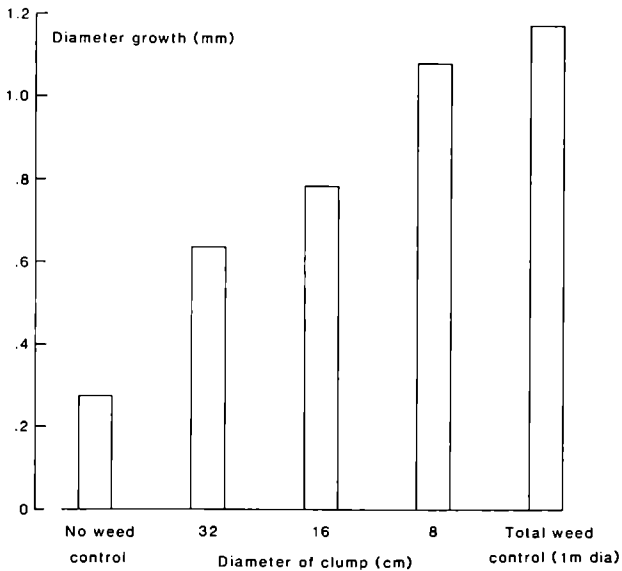
Two experiments were set up early in 1987 to investigate the effect of leaving different-sized clumps of weeds around the base of newly planted trees when applying herbicides. Preliminary results show that diameter increment in the first season increases with decreasing size of clump but that the only significant difference ( $p < 0.05$ ) at this stage is between no weeding and 1 m diameter spot with no clump (see Figure 2).

#### *Soil ameliorants*

Results given in the 1986 *Report* showed that there was no growth response to the use of any of the soil ameliorants tested. Trials on purely water-retaining polymer gels have been extended to include larger planting stock on sites where drought stress can be induced by the use of a mobile automatic rain shelter.

#### *Plant quality*

Several experiments were established to test the field performance of hardy ornamental stock raised under various nursery regimes at Luddington EHS.



**Figure 2.** Diameter growth of ash in different-sized clumps of weeds (May – November 1987).

First year results showed no significant differences between the treatments which were not considered to be very extreme.

#### *Urban tree study*

A study of the growth of common urban tree species was initiated this year with study sites being established throughout southern and mid England. A pilot survey was carried out during the summer, and data on shoot extension, health and vigour of the trees were collected, together with details of their immediate environment, especially the soil. The survey will be continued and expanded in 1988.

#### *Establishment of trees in hedgerows*

Work is concentrating on the establishment of trees into existing hedges, especially those which are regularly trimmed. Different methods of protection from hedge machinery and stock are under investigation, together with the effect of controlling competition from both the hedge itself and from weeds around the tree base. The planting of trees at the time of hedge establishment is also being included, with the use of black polythene mulch strips for weed control.

#### *Demonstration plots*

In order to communicate effectively the results of previous work on methods of tree establishment, demonstration plots were set up at four agricultural colleges (Askham Bryan, Seale-Hayne, Writtle and Pershore) and at the National Agricultural Centre Royal Showground, Westonbirt Arboretum and Alice Holt. Demonstrations include the effects of weed control, stock size and individual tree protection on successful establishment.



*Arboricultural Advisory and Information Service*

The continuing high demand for advice was increased further by the October 1987 storm. Over 2500 enquirers received replies from the Service. Many of the enquiries related to disposal and uses of garden and hedgerow trees, often of ornamental varieties. Techniques of site clearance and costs of operations also featured as enquiries. There were also the more usual enquiries about agents of damage to trees and the effects of tree roots on building foundations.

The subscription for Assistance with Arboricultural Reading inclusive of supply of photocopies proved extremely popular indicating the need for information transfer that exists in the industry. Arboriculture Research Notes continued to be in demand. Seven new titles were published during the year and three other titles were revised (see p. 68) and distributed to subscribers to the Service.

D. PATCH, F.R.W. STEVENS

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

The series of experiments to test the productivity of a range of broadleaved species as short rotation coppice is continuing. The number of sites being investigated has been reduced during this year from eight to four to concentrate effort on sites producing useful results. Harvesting has taken place at four sites this year to collect data on fresh and dry weight and nutrient content of harvested material. Material has been sampled from 4-year and 2-year coppice rotations at spacings of 1 m × 1 m (10 000 stools ha<sup>-1</sup>) and 2 m × 2 m (2500 stools ha<sup>-1</sup>).

The experiment in south Scotland (Aberfoyle 1) established in spring 1986 to widen the range of sites and climatic conditions tested was still not ready for its maiden cut owing to slow growth.

The survival and growth of poplar 'RAP' has been consistently good in all experiments, but the other species have not been as reliable. *Salix aquatica gigantea* has survived on most sites, but stocking in some plots is poor, and growth has been reduced due to weed competition and the early senescence and fall of leaves due to *Melampsora* rust on all sites except one. *Eucalyptus archeri* has been affected on most sites by silver leaf (*Chondostereum purpureum*) infection in the coppice stools, by winter cold damage, and suffered windblow badly in the storm of 16 October 1987 at Alice Holt. Further investigation into methods of control of silver leaf is being undertaken this season.

H. L. DAVIES

**Dendrology**

In the last year emphasis has shifted from collecting numerous measurements of trees to a more selective assessment of ultimate tree size according to geographical location. Results of this work will be of particular value to prospective planters anywhere in the British Isles. To take account of small ornamental specimens the strict definition of a tree has been altered to cover all woody perennials capable of reaching 5 m in height. New data added to the existing Forestry Commission National Tree Register make up the British Isles Tree Register (BITR).

Forty two estates and other areas were visited and 400 trees measured. Kirroughtree, Speech House, Dean, Brechfa and Vivod forest gardens were assessed. At Lough Ennell in central Ireland a previously unrecorded tree identified as *Sorbus hibernica* × *Sorbus aucuparia* was found. Liverpool University and the National Botanic Garden, Dublin are involved in its botanical authority. The tree register (BITR) and associated herbarium inventory have largely been put on a computer database held at Westonbirt.

J. E. J. WHITE

## Arboreta

### *Westonbirt Arboretum, Gloucestershire*

Six hundred and forty six trees were planted of which two hundred represent new taxa to the Arboretum. The main redevelopment work involved the opening up of a new pathway on to Palmer Ride and nearby into a neglected miniature conifer collection. Other remedial work involved removing overcrowded trees, pruning, bracing, stump removal and grass management. The propagation unit has been reorganised and its research role will increase. A special challenge was the need to propagate material from trees blown in the October 1987 storm in south-east England. Fortunately the storm did not affect the Arboretum, indeed no damage was sustained in 1987/1988.

Visitor numbers were lower than in the previous year owing to a wet summer and high rainfall in October. The education facilities were extended to provide an undercover workshop and eating area in response to increased demand.

H. C. ANGUS

### *Bedgebury National Pinetum, Kent*

The number of day visitors to the Pinetum increased during the 1987 season, despite a wet summer.

Activities became dominated by the effects of the storm of 16 October 1987. Rainfall recorded during the week prior to the storm amounted to 197 mm, (compared with an average October rainfall of 39 mm). This undoubtedly contributed to the instability of specimen trees in the collection. Linked to the clearing up operation, detailed damage assessment is largely complete. Twenty per cent of the specimen trees blew down or were seriously damaged in crown and branching. In addition, 20 per cent of the natural conifer and broadleaved shelter trees have been uprooted or damaged and represent a further loss to the Pinetum landscape.

The unique collection of 96 species in 138 individual Forest Plots was very badly damaged. Ninety per cent of the older plots, ranging from P20–P53, were completely destroyed. Sporadic damage occurred throughout the 36 young plots.

Preparations for replacing blown and badly damaged specimen trees are under way. Material for propagating has been retrieved from all blown cultivars of *Chamaecyparis lawsoniana* and *Thuja plicata*. Where possible, seed was collected from the Pinetum and Forest Plots. A selection of natural source seed has been received from several foreign arboreta.

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 herbicides for use in nurseries. Napropamide, a mixture of propham-fenuron-chlorpropham, and tank mixtures of diphenamid with chlorthal-dimethyl and of diphenamid with isoxaben were compared with a standard (diphenamid) and untreated controls for pre-emergent use on seedbeds. Three rates of each herbicide were used with Sitka spruce, Japanese larch, birch and common alder as crop species. The broadleaves were damaged by all herbicides; further work is required to develop safe regimes for these fine-seeded species. Results with conifers were promising since both napropamide and propham-fenuron-chlorpropham combined acceptable weed control with good crop safety. Field trials with these products are planned for 1988. The tank mixtures with diphenamid provided excellent weed control, but proved very damaging to the crop: further testing at lower rates is needed.

D. R. WILLIAMSON, W. L. MASON

#### Forest weed control

During 1986-87 14 experiments were laid down using terbuthylazine/atrazine (40/10 per cent a.i.) liquid or terbuthylazine granules (4 per cent a.i.). This material may well be an alternative to atrazine and application has been made for approval to the Pesticide Registration and Safety Division of MAFF.

Sitka spruce and hybrid larch were treated with up to 40 litres  $\text{ha}^{-1}$  of terbuthylazine/atrazine liquid (20 kg a.i.  $\text{ha}^{-1}$ ) or 500 kg  $\text{ha}^{-1}$  terbuthylazine granules (20 kg a.i.  $\text{ha}^{-1}$ ) at four dates (October, December, February, April). At no site was damage detected on Sitka spruce from any of the treatments at any rate or date of application. The terbuthylazine granules caused no damage to hybrid larch at any rate or date of application, but damage to hybrid larch caused by the liquid formulation increased with advancing date of application ( $p < 0.001$ ) and rate of herbicide ( $p < 0.001$ ).

Seven broadleaved species (see Table 2) were treated with up to 30 litres  $\text{ha}^{-1}$  of terbuthylazine/atrazine liquid (15 kg a.i.  $\text{ha}^{-1}$ ) pre- and post-bud burst. Generally these species tolerated pre-flush applications better than post-flush applications. From information now available the broadleaved species appear to tolerate the following rates of this formulation.

**Table 2** Terbuthylazine/atrazine herbicide tolerance levels for main broadleaved species

Tree species	Rate of terbuthylazine/ atrazine liquid tolerated litres $\text{ha}^{-1}$ (treated)
Oak, ash, sycamore	30 litres pre-flush
Beech	20 litres pre-flush
Birch	5 litres pre- and post-flush
Alder	5 litres pre-flush
Bird cherry	20 litres pre-flush

From observations made of the weed control achieved, comparable doses of terbuthylazine applied as a liquid appear to have greater herbicidal activity than the terbuthylazine granules, presumably as a result of contact activity. The soil type affected the activity of both formulations, with herbicidal effects being reduced by the presence of peat or a deep organic mat. The date of application affected the level of weed control achieved, with April giving the best results with the liquid formulation, while with the granules, winter application, October–February, gave the best results.

D. R. WILLIAMSON. P. M. TABBUSH

### **Farm forestry**

The current debate over land use and the need to reduce agricultural surpluses have raised the question of the planting of farmland with trees. The announcement of the Farm Woodland Scheme has led to increased interest in tree planting, particularly on arable and improved land. Much attention has been focused on the south of England where the prospects for establishing small woodlands for game shooting are particularly attractive but interest has been high throughout Britain.

Discussions have taken place with a wide range of research bodies in England, Wales and Scotland to identify possible collaborative research projects on tree planting on farmland. The first two experiments in a series of joint experiments with ADAS were planted at Drayton Experimental Husbandry Farm, Warwickshire. The first is a species trial of three conifer and six broadleaved species: the second is an experiment to test the effects of different cultivation treatments on early growth of ash and Corsican pine using both bare root transplants and containerised seedlings in Japanese paperpots (JPPs). The cultivation treatments were carried out by ADAS research staff using conventional farm equipment on a field which was previously grassland as a short-term ley in an arable rotation.

A range of sites for demonstration plots has been identified with ADAS and County Agricultural Colleges in England and the Scottish Agricultural Colleges. Demonstration plots are being established at Agricultural Colleges, Experimental Husbandry Farms and Agricultural Showgrounds. These are designed to be fairly simple demonstrations of such aspects of establishing trees on farmland as cultivation, fertilisation and intensity of weed control.

These effects are demonstrated on one conifer and at least two broadleaved species at each site and at some sites a range of other species suited to the particular locality are also included.

H. L. DAVIES, C. M. A. TAYLOR, M. W. ALLEN

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

### **Lowland restocking**

To complement the successes of the Upland Restocking Special Project Team, a Lowland Restocking Special Project Team was established in August 1987 to investigate the reasons for variation in the survival and early growth rates of second rotation planting in southern Britain and to recommend improved practices. The team is multi-disciplinary, being led by a silviculturist with core members from Entomology and Work Study Branches. Other specialists will join the team as and when appropriate.

Within the Forestry Commission the bulk of restocking in the lowlands involves the replacement of Corsican pine crops with the same species using Japanese paperpot (JPP) planting stock. The programme of such restocking has been considerably altered by the damage incurred during the storm in October. The prospect of utilising natural regeneration on appropriate sites will be examined. The team has reviewed previous work undertaken in this area and carried out a survey of current restocking methods and the related survival. The programme of future work is wide ranging. Plant production methods and planting stock standards will be closely scrutinised and the unique plant handling problems related to containerised forest planting stock will be examined in some detail.

Ground preparation methods for restocking are frequently time-consuming and expensive. Recent mechanical innovations have facilitated these operations considerably; the team will monitor new developments as well as examining the prospect of chopping brash ahead of scarifiers. The stumps of the previous crop can often provide good breeding conditions for *Hylobius* and *Hylastes* with consequent damage to the newly planted trees. The team will examine a variety of methods of limiting insect damage, including the use of insecticides and physical barriers such as mesh 'stockings'. Work investigating the phytotoxic effects of insecticides has already begun. Weed competition often exerts a critical influence on the survival of young plants. Current research clarifying weed control/site interactions is important in helping to prescribe restocking packages.

The team will continue its work for at least 3 years. It is intended that interim reports will include better defined standards for Corsican pine in JPPs for use in restocking, and an overall system prescription for restocking using containerised planting stock.

## SILVICULTURE (NORTH)

### Production of planting stock

#### *Vegetative propagation of conifers*

Investigations into the possibility of cold storing cuttings for long periods prior to insertion were continued at Bush Nursery (Lothian) (*Report 1987*, p. 20). Both cold (0° to +2°C) and freezer (-1°C) storage were compared. When cuttings of Sitka spruce and hybrid larch were inserted in March after periods of storage of up to 14 weeks, rooting percentage (95–90 per cent in Sitka spruce; 80–60 per cent in hybrid larch) showed no significant difference between storage treatments. A separate experiment compared rooting performance of cuttings of these species inserted in July after collection in late February. Cuttings of both species had very significantly ( $p < 0.001$ ) better rooting percentage and root volume after freezer storage. The differences were most pronounced in Sitka spruce (95 per cent rooted after freezer storage compared with 1 per cent after cold storage). The results are of commercial importance for two reasons. Firstly, cuttings can be stored for appreciable periods prior to insertion, thus making it possible for managers to spread peak workloads of collection and insertion. Secondly, if cuttings can be collected in spring and stored until summer without loss of rootability, it becomes possible to consider producing two crops of cuttings in one year, thus reducing the scale of investment required in propagation facilities.

The feasibility of raising Sitka spruce stock plants outdoors under less capital-intensive conditions was examined at Newton nursery (Grampian). The yield of cuttings from outdoor plants and their rooting performance was compared with that of cuttings from plants grown under standard polyhouse regimes. The outdoor plants were grown at three spacings ranging from 625 to 300 cm<sup>2</sup> per plant. Yield of cuttings from outdoor plants was considerably less (maximum of 43 cuttings/plant at the widest spacing) than for the standard regime (102 cuttings/plant). Rooting percentage of all treatments was high (100–93 per cent) with no major differences between outdoor treatments and the controls. Cutting quality was best on the widest spaced outdoor plants. When combined with earlier findings (*Report 1987*, p. 20), these results indicate that stock plants can be satisfactorily raised outside. However, the reduced yield of cuttings means that approximately twice as many stock plants will be required to support a given level of production.

The relationship between nutritional regimes in the season prior to collection and subsequent rooting of second cycle Sitka spruce cuttings (*Report 1987*, p. 20) was examined at Newton nursery. Four levels of a balanced NPK feed were compared with unfertilised controls and standard topdressing regimes. Differences in both rooting percentage and root volume were very significant ( $p < 0.001$ ). Best results were obtained from the controls or the lowest level of the balanced feed (100 and 99 per cent rooted respectively).

W. L. MASON, J. C. KEENLEYSIDE, A. A. GREEN, M. K. HOLLINGSWORTH

#### *Precision sowing and undercutting*

Following the successful performance of undercut plants in forest experiments (e.g. *Report 1987*, p. 21), the precision sowing and undercutting system has been introduced in a number of commercial nurseries. A provisional guide to

recommended nursery regimes has been produced (Sharpe *et al.*, 1988). Greater attention is now being paid to Japanese and hybrid larch, since it is clear that high quality stock of Scots pine, Sitka spruce and Douglas fir can be reliably produced with a precision sowing and undercutting system.

W. L. MASON, A. L. SHARPE

### *Containerised seedlings in upland forestry*

Earlier work investigating the production of conifer seedlings in containers was re-evaluated (Mason and Biggin, 1988). As a result, trials began in 1986 to consider the feasibility of producing 'sensitive' species (e.g. Douglas fir) in containers. The project has examined both growing regimes in the polyhouse and subsequent performance in the forest. An experiment at Bush nursery compared germination and height growth of Douglas fir grown in Ecopot 508 containers (volume 103 cc) in a range of peat-based media. Germination was significantly faster ( $p < 0.001$ ) in 'Shamrock Special 5', a standard compost used for growing Corsican pine at Thetford nursery, than in other treatments. However, seedlings grown in pure sphagnum peat or a 75:25 sphagnum peat:vermiculite mix were significantly taller ( $p < 0.05$ ) than those from other treatments at the end of the season.

One-year-old seedlings of Sitka spruce and Douglas fir grown in a range of container types (Ecopots, Styroblocks, Root-trainers; volume 100–200 cc) were planted in forest experiments and compared with two types of bare-root stock (Table 3).

**Table 3** First year survival (%) and height increment (cm) of Douglas fir and Sitka spruce bare-root and containerised seedlings

Experiment	Species	Characteristic	T	U	C	Significance
Aberfoyle 4 P87.	DF	Survival	53	100	98	$p < 0.001$
		Increment	1.5	8.7	9.8	$p < 0.001$
Aberfoyle 5 P87	SS	Survival	100	100	100	n.s.
		Increment	17.8	13.3	14.3	$p < 0.001$
North York Moors 20 P87	DF	Survival	63	87	84	$p < 0.001$
		Increment	3.5	5.4	8.2	$p < 0.001$

T = 1+1 transplant

U = 1u1 undercut

C = 1+1 containerised seedling (mean of four different container types)

The results indicate how benefits of containerisation may vary according to species. In Sitka spruce, there are no differences in survival, and bare-root transplants have better height increment than other types. By contrast, in Douglas fir, transplants are consistently poorer than either undercuts or containerised seedlings for survival and increment. There were no major differences between the container types, except that growth was better in the larger containers.

W. L. MASON, M. K. HOLLINGSWORTH

### References

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- Sharpe, A. L., Howes, R. E. J. and Mason, W. L. (1988). *Precision sown and undercut conifer planting stocks. II. Nursery regimes*. Research Information Note 132. Forestry Commission, Edinburgh.



*Plate 1* Extensive root-killing of English oak by the fungus *Collybia fusipes*. In this stand of 40 trees in Sussex, 32 were blown down in the hurricane-force winds of 16 October 1987. Twenty of the trees were infected by *C. fusipes*. All roots of the tree on the right were infected, most of them dead and many central sinkers decayed, yet in August the crown had been no poorer than that of the healthy tree on the left. (37979).



*Plate 2* The storm of 16 October 1987 in south-east England also provided an unprecedented opportunity for arboricultural researchers to investigate the root systems of blown street trees in towns. Here, the dense mat of feeder roots from a London plane had proliferated under the pavement, but had been unable to penetrate below the road. As a result of this physical barrier, the tree's anchorage became unequally distributed and thus the tree itself became unstable in the high winds. (37881).





*Plate 3* Storage lagoon constructed to hold sewage sludge before application to a restocking experiment on heathland at Teindland (Grampian Region). (C.M.A. Taylor).



*Plate 4* Application of sewage sludge to a restocking site at Gore Heath, Wareham, Dorset. (A. J. Moffat).



*Plate 5* Bräcke moulder and mounds prepared on a peaty gley soil at Kielder Forest (Northumberland). (D. G. Nelson).



*Plate 6* Effect of planting position on first year growth of Sitka spruce on a peaty gley soil at Kielder Forest. The variation in rooting conditions, often within the space of one metre, as illustrated by the variation in growth response of these three transplants, emphasises the need for attention to detail in site preparation. (D. G. Nelson).





*Plate 7* Checking sonic anemometers on a 30 m mast used to measure the vertical and horizontal air flow over a Sitka spruce canopy. (*I. Cameron*)

## Species

As part of a general investigation into species choice in Wales, the Division has started to undertake the management and measurement of species plots in two forest gardens – Brechfa (Dyfed) and Vivod (Clwyd). These contain a wide range of species, including a range of broadleaves, with the *Pinus*, *Abies* and *Picea* genera being particularly well represented. Long-term management plans are being drawn up to ensure that necessary maintenance work, such as thinning, is initiated. These forest gardens, augmented by other species trials, will provide an excellent nucleus for a comprehensive assessment of the range of species that can be successfully grown in Wales and their likely performance.

Assessments have been completed on some P53 broadleaved species plots at Brownmoor and Whitehills (Dumfries and Galloway), which provide useful information on the performance of oaks, lime, beech, sycamore, ash, cherry, *Nothofagus procera* and *N. obliqua* on better sites typical of those to be planted in the Farm Woodlands Scheme.

C. M. A. TAYLOR, D. B. PATERSON, E. BALDWIN, S. J. CORCORAN

## Nutrition

### *Modelling of growth response to application of fertiliser*

The computerised silviculture experiment database was used to categorise fertiliser experiments by species, type and quantity of fertiliser applied and to identify various parameters – soil type, lithology, rainfall and elevation. The response of Sitka spruce to the application of phosphate at planting was chosen as the first subject for investigation, for which 58 usable data sets were identified and compiled in a master file for analysis by multiple regression techniques. Significant relationships were found between soil type and lithology and growth response to fertiliser, which were then grouped to create a predictive model.

### *Sewage sludge*

Further experiments were established, in co-operation with the Water Research Centre, on site types identified as potentially benefitting from application of sludge (*Report* 1987, p. 24) – one on a clear felled heathland site at Teindland (Grampian) where liquid sludge was applied prior to restocking (Plate 3) and the other on a British Coal reclamation site at Clydesdale (Strathclyde), with sludge cake being applied in advance of planting. A field-scale trial was also carried out over winter, where Strathclyde Regional Council applied liquid sludge to 20 hectares of former open-cast land at Clydesdale. This followed the results from a trial established in 1986 (*Report* 1987, p. 24), where sludge-treated Sitka spruce have shown a 50 per cent growth response over the control.

A joint survey was carried out by the Forestry Commission and the Water Research Centre on the potential of sewage sludge as a forest fertiliser in Scotland. Accounting for suitable forest soils, crop types and distance from treatment works this indicated that approximately 8500 hectares of forest would be available annually, which could provide an environmentally acceptable outlet for 15 per cent of the sludge produced in Scotland (Taylor *et al.*, 1987).

### Reference

Taylor, C. M. A., Bennet, L. and Bayes, C. D. (1987). The use of sewage sludge in forestry; an assessment of the potential in Scotland. *Water Research Report* PRU 1707-M. (33 pp.)

*Investigation of interaction between genotype and nutrient use efficiency*

The first experiment investigating the response of 16 Sitka spruce clones to four levels of phosphate has been completed (*Report* 1987, p. 24). Preliminary results indicate that clones performing well with no phosphate also show the largest responses to application of phosphate. A new experiment has been established to test 16 clones, including three from the original experiment, at five levels of phosphate (one additional rate to give a more complete picture of the response pattern).

C. M. A. TAYLOR

**Cultivation, site preparation and drainage**

A review of past cultivation research has been carried out to consider current advice to managers and assess priorities for further research. The review recommended an intensification of rooting and borehole studies on existing experiments; and a small selective increase in experiments to provide a more comprehensive range of treatments and lithologies, with particular emphasis on subsoiling and mounding in afforestation. The need to integrate cultivation with plant-handling, herbicides and nutrition was also emphasised, particularly when considering growth in the establishment phase.

Little is known about the implications of mounding and dolloping on tree root architecture. In a preliminary study with Physiology Branch, root systems were extracted using a vertical tree-pulling technique from a restocking site planted in 1973 at Harwood Forest (Northumberland). The trees had either been flat-planted, planted on dollops, or planted at stump. Analysis is under way to quantify the differences in root architecture and to establish the implications for tree stability (see p. 36).

Results from borehole water level studies undertaken in conjunction with Site Studies (North) in afforestation cultivation experiments at Glendaruel (Strathclyde) (*Report* 1987, p. 25) and Angus (Tayside) have been analysed. Both experiments compare standard D45/T60 ploughing at 4 m intervals with mole-draining at 2 m intervals on a loamy peaty gley site. The mole channels have been formed at about 40 cm below the ground surface. Boreholes were placed at the planting position and also at the mid-point between the cultivation lines. Measurements were taken weekly to ascertain the depth to the water level from the original ground surface, and mean borehole water levels (b.w.l.) were then computed for each position within each treatment. On those occasions when the b.w.l. was greater than 40 cm, i.e. deeper than the mole channels or furrows, there was no consistent difference between treatments. At the planting position, when the b.w.l. on the ploughing was less than 40 cm, the b.w.l. was deeper on the moling by 3.6–17.3 cm at Glendaruel and 4.0–17.0 cm at Angus. At the mid-point position, when the b.w.l. on the ploughing was less than 40 cm, the b.w.l. was again deeper on the moling – by 1.7–12.4 cm at Glendaruel and 0.3–13.5 cm at Angus. The results suggest that moling gives more effective control of water level on loamy textured gley soils than does double mouldboard ploughing.

C. P. QUINE

**Stability***Windthrow*

Work has continued to locate the series of windthrow monitoring sites (*Report* 1987, p. 25). Further suitable blocks of forest have been identified in Kintyre

and Cowal (Strathclyde), Wester Ross (Highland), Speyside (Grampian) and Kielder (Northumberland). Site and stand characteristics will be recorded, and annual aerial photographs will be obtained to record onset of windthrow and its progress. Measurements of wind speed and direction are to be made to define the local wind climate and equipment was placed on a felled area adjacent to the Glentool monitoring site during the winter of 1987/88. Edge trees were also studied and a number of these were windthrown during a gale of 9 February 1988 when the highest 15 s average wind speed was  $21 \text{ m s}^{-1}$  (45 mph).

### *Exposure*

Exposure flags continue to be used to define plantable limits, to improve information on wind zonation, and to give researchers comparisons of experimental sites and treatments. At present 256 flags are sited at 34 locations ranging from Sutherland to Cornwall.

C. P. QUINE, B. R. REYNARD

### *Aeromechanics*

Two new aeromechanics research programmes, partially funded by the European Community, began during the year. The first programme, in collaboration with the Institute of Terrestrial Ecology (ITE), is investigating the interaction between trees within a forest and the atmospheric boundary layer and the mechanical response of trees to a turbulent wind field. A 30 m high mast has been set up at Rivox in Nithsdale Forest District (Dumfries and Galloway) in a Sitka spruce plantation with a mean height of 14 m, close to a site previously studied by ITE. The mast is being instrumented both above and within the canopy with a number of fast response anemometers capable of measuring the turbulent characteristics of the wind. In addition, displacement transducers have been attached to four trees to record their movement. One tree is being monitored at four heights so that the stem shape can be calculated during a strong wind. Data recording began in March 1988 and includes a gale when wind speeds were gusting to  $20 \text{ m s}^{-1}$  at canopy-top.

The second project is a wind tunnel study with the Wind Engineering Research Group, Oxford University, which will make use of their boundary layer wind tunnel. This carries on from previous work carried out by K. Miller and A. Papesch in which use was made of 'bottle-brush' trees. New model trees using plastic injection moulding techniques are being designed to simulate better the behaviour of full-size trees. A set of prototype trees in four different plastics has been produced and has undergone initial tests in the wind tunnel. To provide additional information on the characteristics of full-size trees, sway and bending tests are being carried out in the Lauder (Borders) and Rivox (Nithsdale) forests.

Initial analysis began on the Garcrogo data set (*Report* 1986, p. 21) which includes measurements of wind speeds and tree movement in normal and respaced plots of Sitka spruce. The analysis has demonstrated differences in the wind flow characteristics above the two plots.

B. A. GARDINER

### **Upland restocking**

Following its inception (*Report 1987*, p. 5), the restocking special project team has reviewed each aspect of establishment with the aim of recommending cost effective treatments and systems to improve early plant survival and growth. This has involved development work by Work Study Branch supported by experimental work conducted by several research Branches – Silviculture (North), Physiology, Entomology and Site Studies (North), all co-ordinated by team leader, P. M. Tabbush.

Scope of the research has covered plant production methods and plant quality; lifting and despatch dates; cold storage recommendations; packaging, plant handling and temporary forest storage; and site preparation specifications for various site types. Papers on these subjects have been submitted to Silviculture Division for distribution to Conservators and FC Bulletin 76 *Silvicultural principles for upland restocking* was in press at the year-end<sup>1</sup>. Seminars were held on location for managers in upland Conservancies and proved to be a good means of increasing awareness of best practice and also obtaining feedback on the problems of establishment.

The methods and chemicals tested for protection of *Hylobius abietis* and *Hylastes* spp. are discussed on page 14. A procedure for objective sampling of stocking density has been drafted in conjunction with Statistics and Computing (North) Branch.

P. M. TABBUSH, D. G. NELSON

<sup>(1)</sup> Published July 1988.

## INTER-BRANCH REPORT:

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

#### Farm forestry

Simultaneous with the liaison established with ADAS in England, discussions have taken place with a wide range of research bodies in Scotland and Wales to identify possible collaborative research projects on planting trees on farms in response to the increased interest following the announcement of the Farm Woodland Scheme. Liaison meetings were also held with the Scottish Agricultural Colleges and ADAS (Wales) to discuss establishment of tree planting demonstrations in Scotland and Wales. A range of likely sites was identified and three sites have been established – two in Scotland, attached to regional colleges, and one in Wales at Trawsgoed Experimental Husbandry Farm. These are designed to be fairly simple demonstrations of aspects of establishing trees on farmland, such as cultivation, protection, fertilisation and intensity of weed control. Two main species are demonstrated – one coniferous and the other broadleaved, with a range of six other species suited to the particular sites and demonstration of treeshelters also included.

#### Agroforestry

##### *Effects of agricultural rates of fertiliser on tree growth*

Three rates of fertiliser (0, 75 and 150 kg N ha<sup>-1</sup>) were applied to the respaced larch stand in Radnor (Powys) during the 1987 growing season (*Report 1987*, p. 18), with no obvious detrimental effect on tree performance or form. However, despite the relatively rough bark of these 10-year-old larch trees, bark stripping damage has occurred on unprotected trees.

##### *Agroforestry systems experiments*

In conjunction with the Macaulay Land Use Research Institute at Glensaugh (Grampian) and the Welsh Plant Breeding Station at Bronydd Mawr (Powys), systems experiments have been established (*Report 1987*, p. 17). These form part of the national network and include the nucleus of common treatments – sycamore at 5 m and 10 m spacing in grazed pasture and at 2 m in conventional forestry controls plus a grazing control. These two upland experiments include hybrid larch, at the full range of spacings, Scots pine and gean (Glensaugh) and ash (Bronydd Mawr) at 5 m spacing.

Early results from protection trials on the two sites indicated that each tree would require individual protection with a tree shelter, substantial main stake and small secondary stake to prevent turning. The trees are planted in a square spatial arrangement to facilitate systematic sampling and ease subsequent interpretation of results, with two trees at each position for later selection to ensure a good standard of well formed trees through the experiment.

##### *Effects of tree shading on grass growth*

The first full season's set of data is being processed for the joint experiment at Glentress (Borders) involving the Macaulay Land Use Research Institute (MLURI) and Edinburgh University. No noticeable effects were recorded on tree growth from the spacing treatment in 1986, although some trees have blown over and require guying. The early results from the monitoring of grass growth by the MLURI within the variously respaced stands indicate definite seasonal effects and the benefits of early pruning.



## INTER-BRANCH REPORT:

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

**Restocking project: mound temperature experiments**

Work on the effect of soil temperature on early root and shoot growth of Sitka spruce transplants continues (Tabbush, 1986); four new experiments were established in 1987. A battery-powered electronic data logger was used to measure the soil temperature at two depths below soil mounds of different size at three sites. The logging equipment was moved to each experiment in turn spending one week at each during the 1987 growing season. Accumulated hourly soil temperature above 4°C, 8°C and 16°C at 5 cm and 15 cm depth (Table 6) shows that mounds 20–50 cm high have a similar temperature regime early in the season, but were generally warmer than the 'no-mound' treatment (0 cm) in June and July.

Coutts and Philipson (1987) showed that higher soil temperature dramatically increased Sitka spruce root growth between 4°C and 25°C. Mounds provide warmer conditions favouring establishment of Sitka spruce. The average first year height increment of Sitka spruce from the three experiments improved as mound size increased with carefully handled but not with roughly handled plants.

The fourth experiment involved Douglas fir on a freely draining soil (no soil temperature measurements available). Results with carefully handled plants show that first year height increment and survival were greater in the screening 10 cm and 20 cm treatments than in the control (flat planted), 30 cm, 40 cm, and 50 cm treatments. Roughly handled plants had significantly less first year growth in all treatments. The best establishment was on 20 cm mounds, not on larger mounds; this result is thought to be due to water stress in bigger mounds on freely drained soil.

P. M. TABBUSH, D. RAY

## References

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 Tabbush, P. M. (1986). Rough handling, soil temperature, and root development in outplanted Sitka spruce and Douglas fir. *Canadian Journal of Forest Research* **16**(6), 1385–1388.

**Table 6 Degree-hour soil temperatures at 5 cm and 15 cm at three sites**

Site	Mound size (cm)	Threshold temperature (°C)					
		4		8		16	
		Soil depth (cm)		Soil depth (cm)		Soil depth (cm)	
		5	15	5	15	5	15
Site 1	0	605	*	82	*	5	15
5/4/87 to	20	514	332	93	6	0	0
16/4/87	50	473	374	89	15	0	0
Site 2	0	1593	1195	853	459	10	0
15/6/87 to	20	1522	1439	788	700	20	0
23/6/87	50	1518	1470	837	763	100	38
Site 3	0	1526	1343	854	671	8	0
17/7/87 to	30	1524	*	852	*	54	*
24/7/87	50	1484	1497	812	825	28	16

\* Signifies no data available.

## INTER-BRANCH REPORT:

### SILVICULTURE (NORTH) AND PHYSIOLOGY

#### Vegetative propagation of micropropagated Sitka spruce

The rooting performance of cuttings taken from micropropagated plants (*Report 1987*, p. 20) was compared with that of cuttings from control seedlings at Newton nursery (Grampian). Both controls and micropropagated plants were two years old (either from seed or from rooting *ex vitro*) at time of cutting collection. Cuttings were inserted in March and assessed after 22 weeks. There were no significant differences between treatments for either rooting percentage or root volume. Overall rooting percentage was 95 per cent for all treatments combined. The results suggest that micropropagation (e.g. John and Mason, 1987) does not induce maturation or other physiological changes that adversely affect rootability of cuttings.

W. L. MASON, J. C. KEENLEYSIDE, A. JOHN

#### Reference

John, A. and Mason, W. L. (1987). Vegetative propagation of Sitka spruce. *Proceedings of the Royal Society of Edinburgh* **93B**, 197–203.

## INTER-BRANCH REPORT: SILVICULTURE (NORTH) AND ENTOMOLOGY

### Effect of insecticide treatment and storage on root growth potential (RGP)

Earlier work (*Report 1987*, p. 26) has shown that insecticide treatments applied to the foliage can damage Sitka spruce (SS) and Douglas fir (DF) transplants during cold storage in polythene bags. Further experiments explored the effects of different forms and periods of storage on root growth potential (RGP) following a range of dipping treatments with various products in late February. Permethrin-based dips were much less phytotoxic than either cypermethrin or HCH (Table 4).

**Table 4** RGP of Sitka spruce and Douglas fir transplants treated with various insecticides and stored for 2 and 6 weeks

Treatment	2 weeks storage				6 weeks storage			
	Direct cold store		Canopy storage		Direct cold store		Canopy storage	
	SS	DF	SS	DF	SS	DF	SS	DF
Control (dipped in water)	15.3	5.7	16.4	5.1	13.0	6.5	21.4	2.3
0.5% permethrin as Permasect 25	11.4	1.6	8.9	1.4	15.6	7.3	12.0	2.0
0.5% permethrin as Permit	20.1	2.1	16.4	1.9	25.1	8.1	15.9	2.0
0.5% cypermethrin as Ambush C*	0.4	0.2	1.6	0.3	2.1	0.1	0.5	0
1.6% HCH as Gamma-Col*	0.8	0	0.6	0	0.9	0.1	0.2	0
Approximate S.E.D.	3.04	0.92	3.04	0.92	3.41	1.40	3.41	1.40

\*Results omitted from ANOVA.

After 6 weeks, direct cold storage was significantly better than canopy storage for both species, but the RGPs for DF are poor in all storage treatments.

SS lifted and dipped in early April and stored under canopy or in direct or humicold store had significantly lower RGP (Table 5).

**Table 5** RGP of Sitka spruce transplants lifted in early April treated with pyrethroids and stored for 2 and 6 weeks

Treatment	2 weeks storage			6 weeks storage		
	Direct cold store	Humicold store*	Canopy	Direct cold store	Humicold store*	Canopy
Untreated plants	9.6	5.7	10.3	11.3	0.1	1.5
0.5% permethrin as Permit	6.4	0.4	11.5	7.6	0	0.8
0.5% cypermethrin as Ambush C	8.3	0.2	4.2	7.1	0	0.4
Approximate S.E.D.	1.93	–	1.93	0.83	–	0.83

\*Results omitted from ANOVA.

After 2 and 6 weeks the humicold store had a very deleterious effect on both treated and untreated plants. Again, after 6 weeks, direct cold storage was significantly better than either canopy or humicold storage. RGP of plants lifted in April will usually be lower than for those lifted in February. Investigations will be undertaken into the physiology of plants in humicold storage to permit better interpretation of results after treatments.

P. M. TABBUSH, S. G. HERITAGE

## SITE STUDIES (SOUTH)

### Chemical analysis

Analysis for major nutrients was carried out on 4700 foliar and 1500 whole shoot samples during the year. The shoot samples were from the biomass experiments funded by the Energy Technology Support Unit of the Department of Energy. Fourteen hundred samples, mainly from Silviculture (North) and Physiology Branches, were submitted for analysis of starch and soluble sugars. Greater automation of the carbohydrate analysis has been achieved and 700 samples were analysed in 1987. Demands for analysis remain great and further developments of methodology are underway.

E. WARD

### Effects of trees on sites

A soil survey was undertaken at the long-term experiment at Gisburn Forest (*Report* 1982, p.13) which is examining the silvicultural and site-related effects of tree species, planted pure and in mixtures. The survey showed that many soil properties show non-random variation across the site, apparently unrelated to species plots. Some significant ( $p < 0.05$ ) differences were detected, mainly restricted to the upper soil layers (i.e. thickness of H and A horizons; loss-on-ignition), and are small in size. Canonical variate analysis showed some significant differences between mixed plots and their component species, especially in soil pH and horizon colour development. There was some evidence that oak and some mixed plots have promoted the formation of a gley, iron-deficient B horizon, while conifer and alder plots have inhibited it.

A. J. MOFFAT

### Reclamation

Work to examine the site conditions and tree growth on 30 m ridges on reclaimed gravel workings at Bramshill, Hampshire (*Report* 1986, p.23) has been extended to Woor Green (Dean) on open-cast coal spoil. Tree growth on these spoils is inversely related to soil waterlogging as indicated by dipwells: the best growth occurs on the upper parts of the ridges in contrast to those at Bramshill. Tensiometers and gypsum blocks monitored over the 1987 season suggest that drought is responsible for the reduced tree growth in these positions. In addition, examination of the rooting habit of Corsican pine at Bramshill has shown very poor rooting depths, especially at Bramshill Common where roots rarely penetrate below 0.3 m. High soil bulk densities (mostly  $1.7 \text{ g cm}^{-3}$ ) are considered responsible.

A. J. MOFFAT, C. J. ROBERTS, H. NEUMANN

### Impact of forestry on water resources

The effects of forestry on water quality have gained greater prominence during the last year. In particular, the association between forests and increased surface water acidification in sensitive areas of acid soils and geology has been accepted by many as proof of cause and effect, and used to restrict future afforestation in such areas. The evidence for such a causal relationship is currently being assessed.

As a result of the controversy, and its serious implications, advisory work on this issue has increased substantially. Liaison has been maintained with all organisations involved and particularly where research of the impacts of different forest practices on water quality, including the effectiveness of remedial measures, is being conducted. A research project has been planned on various aspects of how forests affect water quality and on how these effects can be ameliorated.

The Forest Management and Water Guidelines, drafted by a group drawn from the forestry and water industries to advise forest managers on working methods and measures to ensure that runoff from forests is of a satisfactory standard (*Report 1987*, p.30), are now nearing completion.

T. R. NISBET, W. O. BINNS

## **Air pollution**

### *Experimental studies*

During 1987, we repeated experiments investigating the effects of ozone events on the biomass distribution within tree seedlings and the seasonal variations of plant sensitivity.

Ozone decreased the root biomass of Scots pine giving similar effects to those seen in 1986 (*Report 1987*, pp. 30–31). The major difference between results in the 2 years of experimental work was the appearance of foliar injury in the 100 p.p.b. and 200 p.p.b. treatments. No damage was seen in 1986 in any of the ambient and filtered air treatments. In 1987 all the Scots pine suffered tip necrosis; the plants in the higher ozone treatment being most affected. None of the Sitka spruce showed foliar injury in the lower ozone treatment and only 25 per cent were slightly damaged in the higher concentration. The sensitivity of foliage is related to its developmental state and differs between individuals. However the different results for the 2 years suggest that the response to ozone also depends on climatic and other environmental variables.

We have also continued the investigation into the sensitivity of Scots pine, Sitka spruce and Norway spruce to 5 hour episodes at 600 p.p.b. ozone. The seasonal pattern reported in 1987 was seen again, although the climatic conditions during the two growing seasons were very different causing differences in the rate of phenological development. For example, in the QCI Sitka spruce wood ripening began in August 1986 while in 1987 this did not occur until mid-October. In 1986 the Sitka foliage became resistant to ozone in late August and in 1987 this occurred in early November. The dependence of sensitivity upon phenological condition and the variation between individuals within populations are now being investigated.

A. WILLSON, D. A. WADDELL, S. E. LEE

### *Biomonitors*

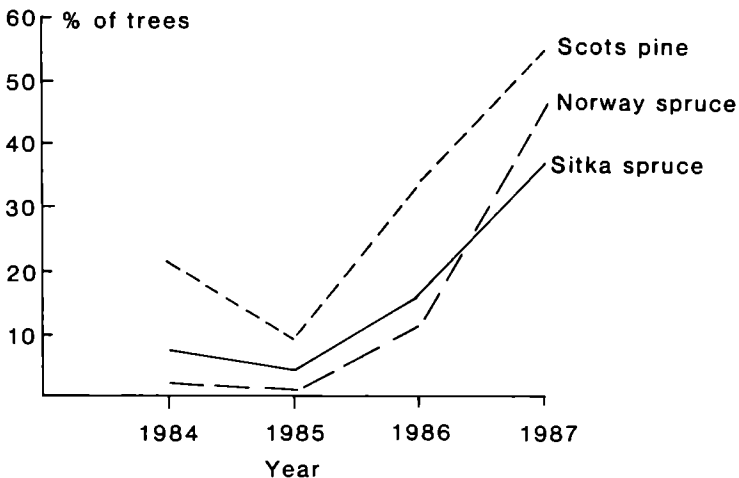
A number of poplars and other species known to be sensitive to specific pollutants were grown for 6-week periods in filtered and unfiltered air in the open-top chambers at Headley (Hants), Chatsworth (Derbyshire) and Glendevon (Tayside). In unfiltered air the responses were similar to those in earlier whole season experiments with leaves becoming chlorotic and early leaf fall seen within the 6-week periods. Chlorosis and leaf abscission were more

marked at Chatsworth where the ambient air is more polluted. During the same periods patterns of leaf senescence and loss were observed at 60 field sites covering east England and the Midlands.

D. W. H. DURRANT

### *Forest health surveys*

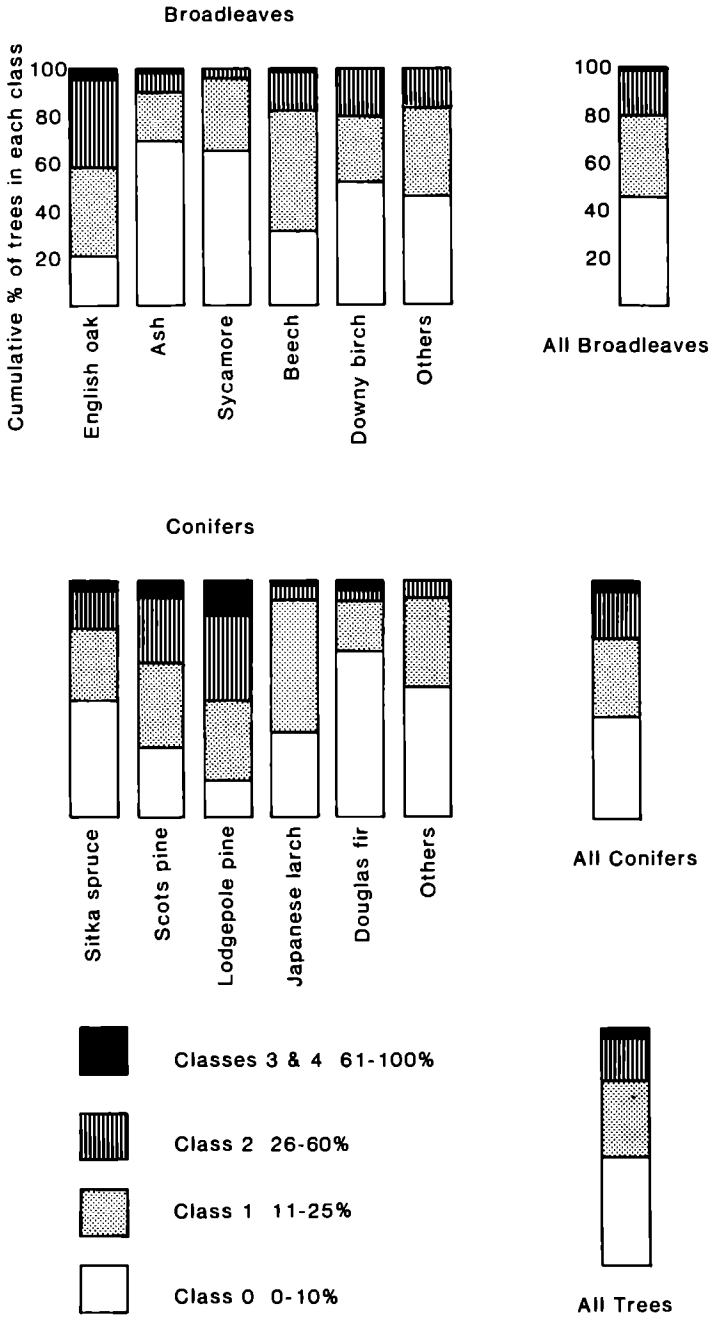
Two surveys of forest health were undertaken during 1987. The first was an extension of previous surveys (*Reports* for 1985, 1986 and 1987). Five species were covered: Sitka spruce, Norway spruce, Scots pine, beech and oak. A further decrease in crown density was recorded (Figure 3) in the conifers although whether this represents a real decrease or is an artefact of further changes in observer perception is unknown (Innes and Boswell, 1987). The overall figures (Table 7) are now similar to those reported from central European countries. A detailed examination of the data suggests that the major factor affecting the crown density of Scots pine, beech and oak is climate. Associations with pollution levels are generally positive: crown density *increases* with increasing levels of most pollutants.



**Figure 3.** Percentage of trees with more than 25% reduction in crown density over the four years of the survey. As stated in the text, differences in survey techniques mean that the data for 1984 and 1985 are not directly comparable with those for 1986 and 1987. The data refer only to those plots examined in all four years.

The second survey was undertaken as part of an EEC-wide survey of forest health. This survey is now a statutory requirement. It involves 75 sites in the United Kingdom, many of which are on private ground. All species and all ages of trees are included (Figure 4). This survey provides a broader picture of the condition of British forests and suggests that this is rather better than is revealed by the figures obtained in the first (main) survey. The results have been submitted to Brussels for further analysis and comparison with other European countries.

J. L. INNES



**Figure 4.** Distributions of crown thinning in the trees examined during the grid survey. In line with the EEC/ECE convention, the five most important broadleaves and the five most important conifers are shown, together with the totals.



**Table 7 Percentage distribution of trees by 10 per cent crown density classes, 1987; all plots**

	n	Crown density class									
		0	1	2	3	4	5	6	7	8	9
Sitka spruce (less than 50 years old)	923	20	27	28	15	7	2	1	0	0	0
Sitka spruce (more than 50 years old)	432	8	15	19	25	18	10	4	1	0	0
Sitka spruce (all trees)	1355	16	23	25	18	11	5	2	0	0	0
Norway spruce (less than 50 years old)	984	31	29	24	11	4	1	0	0	0	0
Norway spruce (more than 50 years old)	864	8	18	24	22	15	8	4	1	0	0
Norway Spruce (all trees)	1848	20	24	24	16	9	4	2	1	0	0
Scots pine (less than 50 years old)	907	17	23	27	19	9	3	1	1	0	0
Scots pine (more than 50 years old)	648	21	26	22	17	6	3	1	1	2	1
Scots pine (all trees)	1555	19	24	25	18	8	3	1	1	1	0
Oak (80-180 years old)	767	8	15	23	29	14	5	4	2	0	0
Beech (60-120 years old)	672	8	22	26	28	12	3	1	0	0	0

## Reference

Innes, J. L. and Boswell, R. C. (1987). *Forest health surveys 1987. Part I: results*. Forestry Commission Bulletin 74. HMSO, London.

**Meteorology**

The collection of meteorological data continues and an advisory and information service is provided for other research Branches, outstations, forest districts and outside bodies. The following records are available: the Meteorological Office monthly summary of all climatological and agro-meteorological stations in their network; daily measurements from Alice Holt (available on an expanded database) and soil moisture deficit data, which are available on microfiche and updated weekly.

D. W. H. DURRANT

**Advisory work**

Advice on tree planting on landfill sites has been sought, and a number of enquiries have been made on poor foliar colour and tree growth on soils over chalk or limestone.

The role of pollutant deposition as one of the factors responsible for forest decline in central Europe and the significance of pollutant inputs to forest health in Britain remain controversial, and advisory work in these areas has continued to be demanding. The European Year of the Environment has particularly highlighted the environmental impacts of pollutant deposition including enhanced pollutant capture by forests and the consequences of this for trees, soils and water, and there have been a number of presentations given on these subjects. We have fortunately been able to provide information of direct relevance as a result of our developing experimental work on these issues.

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

## SITE STUDIES (NORTH)

### Deep peats

At Rumster (Caithness) the experiment involving three depths of furrow-ploughing and three ditch spacings combined with the shallowest ploughing is now 20 years old. The progress of the drying of the peat beneath the trees is being examined by measuring peat water content in cores 90 cm long. We make the assumption that the water content is slowly reduced during dry summer spells, but during intervening wet periods, including the whole of the winter, the water content does not appreciably change.

The peat is driest near the surface where values as low as 1.5 kg water kg<sup>-1</sup> solids occur, and increases rapidly to 10 kg kg<sup>-1</sup> at the bottom of the rooted zone at 40 to 50 cm depth. The water content at 90 cm depth is about 12 kg kg<sup>-1</sup>. In the unplanted bog peat water content averages 13 kg kg<sup>-1</sup> near the surface and 15 kg kg<sup>-1</sup> at depth but is more variable with individual values in the range 10 to 20 kg kg<sup>-1</sup>. A small influence of the trees on water content of the peat outside the plots can be detected to a distance of 10 m.

Ground level within the plots of trees has subsided by 20–50 cm as a consequence of the peat drying. From about 10 m outside, the ground slopes towards each plot, the slope extending for a similar distance under the trees.

Depth to the water table has been measured weekly for 9 months in 144 boreholes which include 24 boreholes in unploughed unplanted plots. In the planted plots the water level was at about 50 cm depth (below the current ground surface) during summer, but during the winter of 1987–88 averaged 30 cm. In the unplanted plots the water level was at 5–10 cm depth in the summer and is at 0–5 cm in the winter.

There are no significant differences in borehole water level between the cultivation or drain spacing treatments, but a significant relationship exists between plot mean water level and ground slope across the plot. For example, a plot with a slope of 1.4 per cent has water levels some 30 cm deeper than a plot with a slope of 0.4 per cent, for the same treatment.

Although the depth and intensity of peat drying is also similar beneath the different cultivation treatments, the shallowest ploughing appears to give the best prospects for crop stability because the peat beneath the shallow (30 cm) furrows is noticeably dry, whereas the 60 and 90 cm deep furrows still lie wet. Assessment of root spread across furrows is required to verify this advantage of shallow ploughing in peat.

### Hydrology

Results of the water balance experiment on a peaty gley soil at Kershope Forest (Cumbria) (*Report* 1981, p. 28; 1982, p. 19; 1983, p. 24; 1984, p. 25; 1985, p. 26; 1986, p. 28) have been revised following a check in 1985 on the weir calibrations. For each of the four weirs the relationship between the rate of discharge and the head of water above the V-notch was found to have changed since the original calibration of 1981. Table 8 shows the results calculated using the old and new calibrations (first and second rows each year). We suspect that the old calibration was more accurate for the first two years and the new calibration for the last two years.

**Table 8** Water balance of four 2 ha plots of Sitka spruce planted in 1948

		Units are mm equivalent depth			
Year	Rainfall P	Mean of three plots felled during 1983		Control plot (not felled)	
		Drain discharge R	P-R	Drain discharge R <sub>c</sub>	P-R <sub>c</sub>
1981	1403	693	710	553*	850
		724	679	614*	789
1982	1568	764	804	705	863
		791	777	792	776
1983	1278	615	663	460	818
		651	627	498	780
1984	1259	832	427	430	829
		854	405	469	790
1985	1688	1121	567	757	931
		1174	514	866	822

\* Estimated from annual rainfall using a regression of R<sub>c</sub> on P.

The increase in runoff from the plots as a consequence of clear felling was calculated based on the relativity between runoff in the felled and control plots (R and R<sub>c</sub>). Using the old calibration the annual increase was 289 mm, using the new calibration it was 294 mm, so fortunately this major result was virtually unaffected by the revised calibration.

### Clay soils

The half of the Kershope drainage experiment which was felled for the hydrological study was restocked with an experiment involving conifer mixtures (*Report* 1986, p. 29). A new series of 216 boreholes was installed and water levels have been read weekly for 21 months. It is now some 5 years since felling took place and plot mean borehole water levels continue to be in the range 30–50 cm with little difference between summer and winter. Restocking sites elsewhere on peaty gleys and surface-water gleys in the Kielder Forest District seem much wetter than this and a 'Z' drainage experiment (see below) is now planned for such a site.

### Loamy gleys

A small, short-term drainage experiment has been set up in Angus Forest District on a loamy textured peaty gley. An area of less than one hectare has been drained with a zig-zag drain having three straight sections at angles of 45°, giving a continuous range of drain spacings from zero to 60 m. The contours of the site bisect the two angles of the 'z'. Boreholes were installed and water levels recorded every 6 hours for 3 months before the drain was dug so that water levels and their response to rainfall can be compared before and after drainage.

## GENETICS

### Forest progeny tests

A detailed study of the variation in crown width between open-pollinated Sitka spruce families in two different series of 6-year-old progeny tests confirmed the provisional result reported in the 1986 *Report* (p. 31) that crown width per metre of height decreases in the more vigorous families. The study showed this trait to be highly heritable (family  $h^2 = 0.8$ ); it could thus be exploited in clonal seed orchards. In future all clones selected for the Sitka spruce breeding population will subsequently be assessed for crown width in addition to stem straightness, which is already routine, in order to identify particularly narrow-crowned clones.

The relationship between 7th year and the 15th year stem-form assessments has proved to be more poorly correlated than had been hoped. Investigations suggest that the selection intensity at the earlier stage has been too high, and that clones originally rejected on the grounds of poor stem-form relative to the control are straighter at the later age as increased radial growth evens out earlier deviations from the vertical.

Results from the first Sitka spruce clonal tests established in Torridge Forest, Devon, in 1981 and 1982 with randomly selected clones from within a very limited number of open-pollinated families have indicated the huge amount of extra gain available for exploitation by taking advantage of the mainly non-additive genetic variance. Height gain relative to the Queen Charlotte Islands control was 10 per cent by selecting the best family, but 31 per cent by selecting the best clone within the best family. Further experiments to investigate the possible genetic gains to be obtained by selecting specific clones within full-sib families were started in spring this year.

Routine assessments continue. One hundred and thirty-six clones are now included in the Sitka spruce general breeding population. One hundred and fifteen single-pair matings within Alaskan origins of lodgepole pine were planted in three experiments over three sites in northern Scotland (two sites at Easter Ross and one in Dornoch). This continues the policy of both inter- and intra-origin breeding with this species.

Other progeny tests established include screening a further 179 Sitka spruce clones for the general breeding population; 22 European larch mother trees hybridised with a pollen mixture from selected Japanese larch trees, and two experiments to compare forest performance of full-sib families raised both as cuttings and seedlings.

S. J. LEE

### Pollinations

Flowering in 1987 of both larch and Sitka spruce was significantly better than in 1986 and the opportunity was taken to extend the pollination programmes for these species. In contrast flowering in both lodgepole and Scots pine was too poor to support a controlled pollination programme for the second year running. Demand for hybrid larch plants greatly exceeds supply and so advantage was taken of the heavy flowering in the seed orchard at Exeter (Devon) on which an extensive pollination programme (8500 flowers) was undertaken to produce hybrid larch seed for future use in vegetative propagation programmes based on bulked family mixtures. A wide range of

polycross and single-pair matings which required 15 000 flowers, was made in the larch clonal banks at Newton and Teindland (Grampian). The injection of GA<sub>4/7</sub> to all untested Sitka spruce clones and clones in the General Breeding Population in summer 1986 ensured good quantities of flowers in spring 1987; 26 000 female flowers were isolated. This exceptionally heavy flowering allowed most remaining untested clones to be polycrossed; additional GA<sub>4/7</sub> injections in 1987 should ensure that seed for all outstanding general combining-ability tests will be available in spring 1989.

### Provenance

There was a moderate crop of acorns on *Quercus petraea* in parts of south and south-west England. This coincided with attempts to organise an exchange of acorns amongst research workers in several western European countries on which to base an international series of forest experiments. Collections were made at four locations in northern France, seven in Germany, four in Ireland, one in Holland and eight locations in Britain. Acorns have been sown in a nursery experiment at Headley nursery (Surrey) to provide early comparisons in performance between the different 'home' and other European sources; these experiments will also indicate the amount of genetic variation both between and within populations of sessile oak.

A. M. FLETCHER

### Seed production

#### *Seed stands*

One hundred and twenty-eight stands were inspected, or reinspected as part of the quinquennial check. As a result a further 670 ha of seed stands covering 14 species, mainly Scots and Corsican pine, were added to the National Register during the year. Twenty-nine stands were withdrawn on account of fellings or windthrow. Thirteen applications for the registration of new sources were refused on the grounds of unacceptable quality or risk of serious contamination by pollen from nearby unsuitable stands of the same or compatible species.

#### *Seed orchards*

An additional 3.0 ha of clonal Scots pine and 2.3 ha of seedling lodgepole pine orchards were established in the Borders Forest District (Cumberland) and a 6.2 ha clonal Sitka spruce orchard in Marches Forest District (Hereford and Worcester).

The first 5.1 ha Scots pine orchard to be based on tested clones and planted during the period 1977–80 at Ringwood (Dorset) produced its first heavy crop of cones in spring 1988. Cone yields have risen steadily from 1.0 hl ha<sup>-1</sup> in 1984 to 6.9 hl ha<sup>-1</sup> in 1987 and yields of full seed per ramet from 290 to 3300 over the same period. Currently the orchard is producing sufficient seed to establish some 600 ha of new plantations. The percentage contribution of seed between the 40 component clones in the orchard is in the range 0.1 to 7.3 per cent.

R. FAULKNER

### Biochemical variation

The biochemical interactions between the pine beauty moth *Panolis flammea* and its host lodgepole pine are being studied in collaboration with Entomology Branch following an outbreak in the Poulary block of Glengarry Forest

(Highland Region). The resin chemistry of leaves and shoots has been analysed in trees which suffered varying degrees of defoliation, and chemical changes occurring during shoot development in the following year have been monitored. The tendency of the moth to oviposit on trees having relatively high ratios of  $\beta$ -pinene to  $\alpha$ -pinene in their shoot cortical oleoresin, previously found in provenance comparisons (*Report* 1986, p. 32), was even more marked in their selection of individual trees within the single South Coastal origin at Poulary. In trees of the highest defoliation class, the percentage of  $\beta$ -pinene in both the monoterpene hydrocarbon fraction and also of total terpenoids was maximal, both in stems and in leaves. Moreover, the levels of a number of other terpenoid constituents were also associated with degree of defoliation: presumably the moth responds to the overall sensory impact of a complex of volatiles rather than to an individual terpene.

In the new growth of the following year, these chemical differences between different defoliation intensities (in particular that of  $\beta$ -pinene) were in some cases no longer present; current year leaves of the most severely defoliated trees now contained by far the lowest  $\beta$ -pinene levels.

#### **Register of Forestry Commission seed sources**

G. I. FORREST

The development of a computer file recording details of all seedlots held in the Alice Holt store since 1956 is nearing completion. The register includes information on the identity, weight, origin, provenance and mixing history of each lot. This will form an important and easily accessible reference source for breeding work, seed research and testing, seed trading and general management.

C. J. A. SAMUEL

## **PHYSIOLOGY**

### **Flowering**

Naturally occurring gibberellins in Sitka spruce have been studied in relation to flowering ability in 6-year-old seedlings and in 4-year-old grafts from 16- and 48-year-old Sitka spruce ortets in a collaborative project with Dr Oden and other physiologists at the Swedish University of Agricultural Sciences. Using bioassay, radioimmunoassay and gas chromatography-mass spectrometry,  $GA_9$  and certain metabolites were detected from all ages of material,  $GA_4$  in the 6- and 16-year-old trees and  $GA_3$  and  $GA_1$  in the 48-year-old grafts. Flowering was examined using hot-dry inductive treatments and  $GA_{4/7}$  application. None of the 6-year-old seedlings flowered, even when  $GA_{4/7}$  was applied; the 16-year-old grafts flowered only when  $GA_{4/7}$  was applied, but the 48-year-old grafts flowered with the hot-dry treatment alone and additional  $GA_{4/7}$  application produced significantly more cones than on the younger material. Quantitative and metabolic studies are required before a natural role for gibberellins in cone-bud differentiation may be determined. Such studies were started during the visit of Dr Thomas Moritz to our laboratory, when radioactive GAs were applied to Sitka spruce. The material will be analysed in the laboratory in Sweden.

J. J. PHILIPSON

### Micropropagation

Cultures of Sitka spruce, growing on MS medium, have been stored in the dark at 2°C for extended periods. Survival of cultures after transfer to normal growth room conditions was 93 per cent after 2 months' cold storage decreasing to 14 per cent after 8 months' cold storage.

Infection of Sitka spruce cultures *in vitro* on MS medium with selected strains of mycorrhizal fungi failed either to produce mycorrhizas or to increase rooting and growth of the cultures.

Cultures have been established from specific cross hybrid larch seedlings raised in a growth room and a study has been undertaken of their growth and development *in vitro*.

### Rejuvenation

A joint project has been undertaken with Unilever Research to compare the morphological, physiological, and biological changes that occur as Sitka spruce and Norway spruce age. Preliminary results indicate that the decreases in the rate and level of rooting of Sitka spruce cuttings with increasing age (1–31 years) are not reflected in changes in the level of methylation of DNA cytosine in position 5.

A. JOHN

### Root growth and form

Analysis of 15-year-old excavated root systems of lodgepole pine and Sitka spruce, established on a ploughed deep peat site by planting bare rooted stock and by direct sowing, showed that root form was dominated by the effects of cultivation rather than by species or method of establishment. Root dry weight was concentrated in the plough ridge. However, lodgepole pine rooted more deeply than spruce, and had less symmetrical root systems (measured in plan view). Dissection to determine the origin of the five largest woody lateral roots per tree for Sitka spruce showed that on direct sown trees the roots mainly developed from the seedling radical. On transplants the two largest roots were usually of adventitious origin from the stem, whereas the 4th and 5th largest had grown from the nursery root system.

Studies on the formation and development of adventitious roots in Sitka spruce planting stock were initiated. A survey of Conservancy-planted trees in Dornoch Forest District (Highland Region) showed that by the fifth year after planting, many of the largest roots originated adventitiously from the stem, rather than from the original rooting system. Experiments were established to examine some of the factors that might induce or increase adventitious root production, and it was found that rough handling had no effect on their formation, whereas waterlogging caused a reduction in their numbers. Both field and laboratory experiments were established to investigate further the role of adventitious roots in the development of the structural root system of Sitka spruce.

Field observations show that lateral roots of Sitka spruce which emerge from ridges or furrows made by cultivation either continue to grow in their original direction, in which case the root tip normally dies resulting in branching further back, or they bend downwards in the litter or vegetation, in which they persist. These responses have been examined in greenhouse and growthroom, in

systems where the roots grew out from a vertical wall of moist peat, at angles close to the horizontal, into a space where light and relative humidity (RH) were regulated. At RH 98–99 per cent roots in darkness continued to grow without a change in direction but became sensitive to a reduction in RH, which killed the tip. Under these high humidity conditions the roots responded to light by bending downwards at a mean angle of 40°. At RH 93–95 per cent, in light or darkness, the roots bent back to the peat surface, where they survived and often grew. In much drier air the roots became dormant as soon as the tips emerged.

M. P. COUTTS, C. WALKER

### **Mycorrhizas**

The field experiments at Dornoch and Kielder Forest Districts (*Report* 1987, p. 40) were again measured. In the older of the two experiments at Shin, the height increase of Sitka spruce brought about by inoculation with *Thelephora terrestris* continued to be significant, the treated plants in their 4th year being 29 per cent taller than the untreated controls. Treatment with *Laccaria proxima* failed to induce height increases. However, in the second experiment, planted 2 years later, the *T. terrestris* treatment has so far failed to produce a significant response, while the trees inoculated with *L. proxima* now have a mean height approximately 12 per cent greater than the untreated controls. In Kielder, the same treatments have failed to yield a growth response in either of two experiments. These results suggest that there is a considerable site interaction affecting mycorrhizal efficacy.

C. WALKER

### **Propagation of oak**

The development of experimental methods for the selection of improved clones of oak has begun with a study of some characters which influence branching pattern and crown form. The supply of mineral nutrients influences apical dominance and shoot growth of both potted seedlings and 10-year-old trees in the field. Plants receiving large amounts of NPK flushed more frequently and produced longer shoots with more buds and branches than those given smaller quantities. Axillary buds associated with leaves in the terminal whorl of the shoots showed a greater tendency to flush than those on interwhorl sections of stem. During summer the terminal bud died on only 3 per cent of seedling shoots whereas mortality was 25 per cent after a period of winter dormancy. Up to 90 per cent of terminal buds died on trees in the field. Establishment of a new leader appears to be related to the initial difference in vigour between the new shoots produced.

R. HARMER



## **INTER-BRANCH REPORT: PHYSIOLOGY AND SILVICULTURE (NORTH)**

### **Restocking**

Safe lifting and planting dates have been recommended for Sitka spruce and Douglas fir following studies of root growth potential (RGP). These studies, however, used careful handling. Less careful handling during large-scale forest operations may alter the seasonal pattern of RGP. Further investigation showed that rough handling in January (when buds are dormant, with mitotic index of zero) reduced RGP by 45 per cent; i.e. from 51 to 28 new roots longer than 1 cm per plant. Rough handling in March and April was more detrimental, reducing RGP by 93 and 84 per cent respectively, to fewer than five new roots longer than 1 cm per plant. This increased susceptibility to damage probably reflects the beginning of physiological activity in the shoot (cell divisions in the bud, chilling requirement met) and the start of the root activity. The study suggests that the period when lifting plants from the nursery is safe may be less than was first thought and emphasises the need for careful plant handling and avoidance of late lifting.

J. J. PHILIPSON, P. M. TABBUSH

## PATHOLOGY

The great gale of 16 October 1987 had a major influence on the work of the Pathology Branch during the second half of the period covered by this report, and two items relating to that event can be found on pages 57–58.

### Advisory services

#### *Scotland and northern England*

As in previous years, the chief damaging agents were climatic adversity, cultural malpractice and misuse of chemicals. *Armillaria* spp. were the most frequently recorded pathogens but shoot and foliage diseases of Scots pine were also common. Although the severe outbreak of *Lophodermium seeditiosum* on Scots pine reported last year (*Report* 1987, p. 42) was not repeated, its effects continued to cause concern in the form of poor needle retention, reduced increment and, in extreme cases, dieback. Dieback caused by the shoot pathogen *Brunchorstia pinea* continued to be prevalent, especially in stands at high elevation. Appreciable mortality from the combination of these diseases, sometimes aided by attacks on weakened trees by pine shoot beetle (*Tomicus piniperda*), was found in some cases. Another needle pathogen (*Lophodermella sulcigena*) was also recorded on Scots pine in several plantations; this fungus is more commonly known in Britain on Corsican pine.

Severe damage to hybrid and European larch by larch canker (*Lachnellula willkommii*) was observed during the year at a few localities. Also on larches, and for the third year in succession, the nursery pathogen *Meria laricis* was found in plantations (see *Report* 1987, p. 43; 1986, p. 36).

Among broadleaves, beeches were found to be in poor condition in several areas. Some were still suffering from the effects of the 1984 drought while many others were, by contrast, badly affected by waterlogging as a result of recent wet summers. These causes, exacerbated in many cases by poor sites and root disturbance, appeared to be responsible for much thinning and yellowing of large tree crowns. Shoot dieback caused by *Nectria ditissima* canker, and foliage browning associated with attacks by *Apiognomonina errabunda* and insect pests, were also extremely prevalent on beech. There were some dramatic cases of foliage discoloration by disease in other broadleaves, most notably in sycamore (by *Phleospora aceris*, *Rhytisma acerina* and *Ophiognomonina pseudoplatani*), in oak (by *Gloeosporium quercinum*), in birch (by *Melampsorium betulinum*) and in willow (by *Melampsora* sp.). Another willow pathogen, *Pollaccia saliciperda*, was recorded causing severe foliage discoloration and withering of young shoots in *Salix alba* and *S. alba* 'Chermesina'. Similarly severe damage in aspen was caused by the related but less common fungus, *Pollaccia radiosa*, at two locations in north Scotland.

The wet summer (the third in succession) led to a number of root problems in nurseries. In some cases wet ground conditions alone were probably the main factor but in others root-disease fungi encouraged by the wet soil were responsible. In three cases the pathogen was a *Phytophthora* sp., a noteworthy incidence for a genus that has not previously been very damaging in northern forest nurseries. In one case an as yet unnamed *Phytophthora* sp. had killed pine transplants in a nursery in north Scotland. The other two cases involved *P. citricola* and occurred in a nurseries in south Scotland causing high losses among first year Sitka spruce, noble fir and grand fir seedlings.

### *Southern England and Wales*

Applications of de-icing salt to roads during the exceptionally cold, snowy period in mid-January 1987 resulted in much damage to roadside urban trees. This cold weather seems likely also to have been the trigger for a widespread outbreak of the mysterious and often fatal *Prunus* 'Kanzan' disease during the year (*Report* 1983, p. 31). Lesser outbreaks also occurred after the cold winters of 1985/86 and 1986/87. Attempts (with the help of MAFF and CMI bacteriologists) to confirm the supposition that this is a bacterial disease failed. Symptoms typical of bacterial canker (*Pseudomonas syringae* pv. *mors-prunorum*) were also often reported during the summer on various cherries (not including 'Kanzan').

Over much of the region, many ash trees were conspicuously sparsely foliated until well into June. The role of various agents including the ash bud moth (*Prays curtisellus*) and several pathogenic fungi is being examined as part of a current study on ash dieback, jointly funded by the Department of the Environment and the Forestry Commission.

May, June, July and, except in the south-west, August were generally cool, and June and July were also wet. This presumably accounted for the large numbers of leaf and shoot diseases reported, notably *Cristulariella depraedans* on sycamore (with a markedly westerly distribution), *Guignardia aesculi* on horse chestnut, *Sclerotinia laxa* on flowering cherries, *Venturia chlorospora* on willows (mostly *Salix alba* vars. and *S. matsudana* 'Tortuosa'), *Gnomonia leptostyla* on walnut and *Apiognomonium errabunda* on beech. Anthracnose of London plane (also caused by *A. errabunda* but on plane previously called *Gnomonia platani*) was also common. But, as in 1985, surprisingly no cases of anthracnose of weeping willow *Drepanopeziza sphaeroides* (= *Marssonina salicicola*) were brought to our notice. An exceptionally large amount of *Nectria* (presumably *N. ditissima*) cankering and killing of twigs and current shoots on beech was seen.

During 1987, much *Lophodermium* (mostly *L. seditiosum*) browning and fall of Scots and Corsican pine 1985 and 1986 needles developed in nurseries and plantations over the whole region, and from December onwards several similar cases were reported affecting 1987 needles. In two Scots pine cases, however, one involving 1986 and 1987 needles on 2-year-old nursery plants, the other 1985 needles on plantation trees, the principal fungus found was *Cyclaneusma minus*. The extensive browning of a noble fir Christmas tree crop seen in 1985 (*Report* 1986, p. 35) recurred in 1986 and 1987. It has now been established that this was due to the herbicide atrazine.

In the hurricane-force winds of 15/16 October, most of an English oak plot set up in West Sussex to observe the progress of *Collybia fusipes* root infections (*Report* 1979, p. 33) was blown down. Examination of the exposed root plates showed that twice as many trees were infected than was indicated by the presence of toadstools in 1984 and 1987, and that crown density was an unreliable guide to the proportion of dead roots in any tree (see Plate 1).

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

### **Pine stem rust**

Recent research by the Pathology Branch has shown that the 'pine to pine' rust *Peridermium pini* exists in two forms which can be separated on the morphology and cytology of the germinating aeciospores; the Scottish form

produces long aseptate germ tubes containing a pair of nuclei, while the Thetford form produces short septate germ tubes, each cell containing a single nucleus (*Report* 1986, p. 37; Gibbs, England and Wolstenholme, 1988). Occasional samples of aeciospores have been obtained from various southern pine forests which resemble the Scottish form of *P. pini* in germination but which could equally well correspond to the full cyclic rust *Cronartium flaccidum*. One such sample collected on 4 June 1987 from a Scots pine at Rendlesham, Suffolk Forest District, was inoculated on to the paeony cultivar 'Una Howard' at Alice Holt on 25 June. By 22 July concentric rings of pustules bearing uredospores were present on several leaves and in early autumn telial horns were also produced. The existence of *C. flaccidum* on pine in southern England as revealed by this result is consistent with sporadic reports of the rust on *Paeonia* or *Tropaeolum* in gardens south of a line from the Severn to the Wash. It is clear however that the damage to pine caused by *C. flaccidum* is insignificant when compared to that caused by *P. pini*.

## Reference

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

Gibbs, J. N., England, N. and Wolstenholme, R. (1988). Variation in the pine stem rust fungus *Peridermium pini* in the United Kingdom. *Plant Pathology* 37, 45-53.

**Dutch elm disease***Geographical origin of the disease: survey of China*

Surveys to investigate the centre of origin of Dutch elm disease and the directions of spread of the various forms of the pathogen, *Ophiostoma ulmi*, are continuing (*Report* 1987, p. 44). China and eastern Asia have been popularly assumed to be the origin of the disease owing to the diversity of the Chinese elm flora and the relatively high level of resistance of Asiatic elms. In August and September 1987, an elm survey was carried out in several parts of China with the kind assistance of Mr Shi Jin Lin (Shenyang) and the Ministry of Forestry, Beijing.

Investigations were conducted at Dandong, Dalian and Shenyang in Liaoning Province (north-east China), around Beijing, in western Xingiang (Central Asia/USSR border area), and around Xi'an. Most elms examined were varieties of the Siberian elm, *Ulmus pumila*, many forms of which are resistant to the disease. Scolytid beetle breeding was plentiful in all areas. Over 7500 cm<sup>2</sup> of bark containing active scolytid breeding galleries were sampled for *O. ulmi* via more than 1000 isolations. No positive isolations of *O. ulmi* were made, and no foliar or internal symptoms consistent with Dutch elm disease were seen whether on *U. pumila* (all areas) or on the susceptible elm species *U. laevis* and *U. densa* (Xingiang).

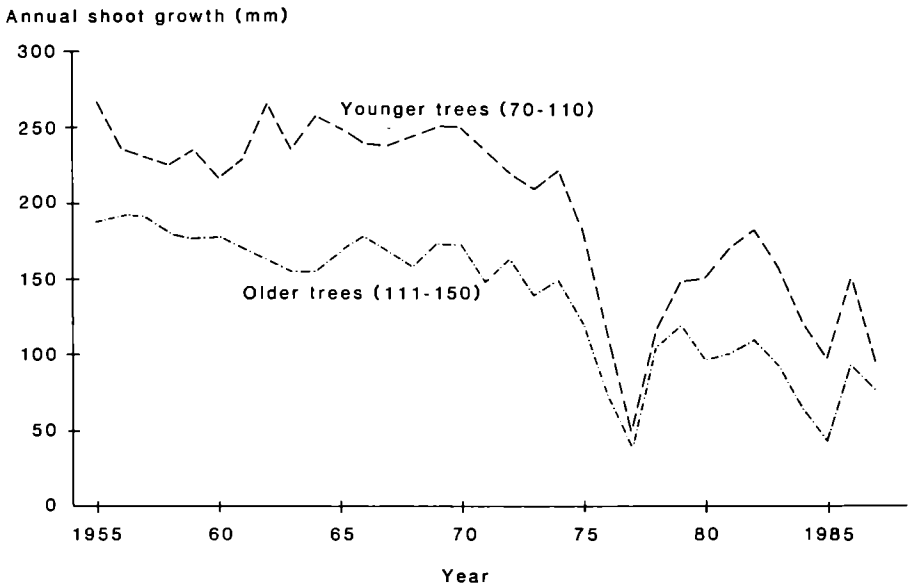
It is considered that Dutch elm disease is probably absent from the locations examined and, by extension, absent from most of China. It is, however, present and active in both its non-aggressive and EAN aggressive forms in parts of Soviet Central Asia close to Xingiang (*Report* 1987, p. 44). On the assumption that the disease does not occur in China, there appear to remain two possibilities as to its origin: (1) an origin in the Himalayas (a single record of the disease exists for Kashmir and the relevant *O. ulmi* isolate has unusual biological properties and could conceivably be an ancestral form); (2) an origin in Europe, including its possible recent rapid evolution as a serious pathogen under man's influence.

### Beech health study

#### *The use of shoot growth history to study the possible effects of air pollution*

This study involves the measurement of annual increments in shoot growth over the last 30 years. Roloff (1985), working in Germany, has found shoot growth to be a sensitive indicator of the past and present health of beech trees; more so than radial xylem increment. Knowledge that concentrations of certain pollutants vary across southern Britain suggested that this technique could be used in an attempt to determine whether beech health, as assessed over many years, has varied in response to pollution.

To this end, 15 sites along a transect running from East Anglia to Cornwall were selected using two criteria: the presence of woodland which included beech trees of 'sensitive' but not excessive age (70–150 years), and the absence of extreme environmental factors (other than pollution) which could have caused exceptional stress to the trees. The definitions of such factors comprised pH values outside the range 4 to 7.5; an estimated rooting depth <500 mm; exposure caused by adjacent clear felling and extreme topographic exposure to wind. A further restriction on site choice was the wish to exercise a preference for Forestry Commission stands so that permission for sampling could be obtained with reasonable ease. At each site a 30-year shoot growth history was recorded for five dominant or co-dominant trees by felling the trees and measuring the intervals between girdle scars on ten leading shoots per tree.



**Figure 5.** Beech shoot growth study: means of annual increments of leading shoots over the period 1955–87. Data are grouped for sites in two age groups.

As expected from earlier work, years following droughts showed reduced growth, very markedly so in the case of 1977 (Figure 5). More significantly,

normal growth (as estimated using the 1955–1970 period to generate an ‘expected’ growth curve) has not been re-established at most of the 15 sites. Furthermore, the depressions associated with the unexceptional droughts of 1983 and 1984 were much greater than that observed, for example, following the 1959 drought. (This must, however, be set against the greater age of the trees and the extremely unusual occurrence in 1975–6 and 1983–4 of droughts in consecutive years.) These sustained patterns may indicate the operation of some factor in addition to drought, since trees which are in generally good health might be expected to return to normal growth within 2–3 years of a drought (Roloff, 1985).

In the between-drought years, the difference between actual extension and that expected by extrapolation of the pre-1974 increment data was examined in relation to the estimated mean concentrations of  $\text{NO}_x$  and  $\text{SO}_2$  (Derwent, 1986 and personal communication; Perrin, 1986). No clear correlation was found, but it was noted (Figure 6) that some of the greatest differences occurred in south-west England where  $\text{NO}_x$  and  $\text{SO}_2$  concentrations are low. The frequency and intensity of episodes of ozone formation is not currently documented, but models of mean summer ozone concentrations show relatively high values for the south-west (R. Derwent and S. Metcalfe, personal communication).

Key to pollution zones

	N*	S*
A	<8	<2.5
B	8-10	<2.5
C	10-13	2.5-5
D	13-16	2.5-5
E	16-18	5-10
F	18-21	5-10
G	21-23	5-10
H	21-23	10-15
I	23-26	15-20
J	21-23	15-20
K	23-26	>20
L	21-23	>20
M	21-23	10-15
N	23-26	5-10
O	21-23	5-10
P	18-21	5-10
Q	18-21	2.5-5
R	21-23	2.5-5

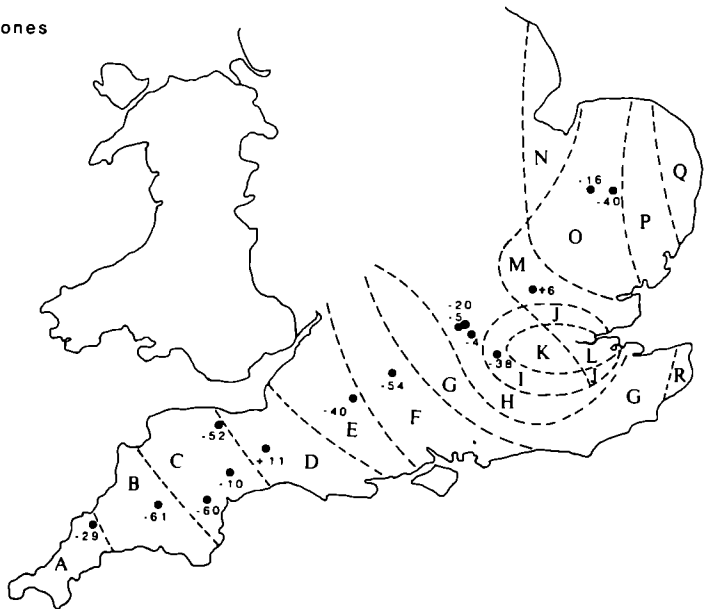


Figure 6. Beech shoot growth study: numerals indicate percentage deviations from expected growth (see text) over the years 1979–83 and 1986. Lettered zones refer to nitrogen deposition (N) and to mean atmospheric sulphur concentrations (S). \*Values shown in key are in  $\text{kg ha}^{-1} \text{yr}^{-1}$  for N and  $\mu\text{g m}^{-3}$  for S.

In spite of attempts to avoid sites where environmental extremes are likely to have generated excessive 'noise', the diverse nature of the conditions under which beech grows in Britain inevitably makes it very difficult to detect the possible effects of pollution. In view of this difficulty, work is now being conducted at one site within which soil conditions are very heterogeneous and where their possible influence can be studied within a uniform pollution climate.

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## ENTOMOLOGY

Studies of the mechanisms of resistance to insect attack were among the topics suggested for expansion by the Visiting Group to Entomology Branch in July 1987. This work, under the direction of Clive Carter, is being strengthened by purchase of an HPLC for chemical analysis and by links with Genetics Branch. Among the non-research activities of the Branch, surveys for pine wood nematode, *Bursaphelenchus xylophilus*, were carried out at ports and in pine forests. Although no nematodes were found, joint research work with European and Canadian Laboratories is being started in order to assess the potential risks posed by this pest which is devastating pines in Japan.

H. F. EVANS

**Great spruce bark beetle, *Dendroctonus micans****Biological control of Dendroctonus micans*

A total of 7100 *Rhizophagus grandis* were released into newly located *D. micans* sites on the periphery of the infested zone. Further sampling of three *D. micans* study plots showed that a mean of 68 per cent of *D. micans* broods contained the predator, double the previous level.

A study of the life cycle of *R. grandis* was started during the year. Interim results indicate that activity begins in late April and that few predators will have more than one generation per year. The shortest cycle was 105 days from insects which began to breed in June. Progeny from adults breeding in September remained in the pupal/young adult stage in the soil throughout the winter suggesting a total cycle in excess of 200 days.

The potential of high density, inundative predator releases was tested as an alternative strategy to the low density, inoculative introductions used throughout the main release programme. A batch of 2500 adult *R. grandis*, marked with fluorescent powder, were released in an isolated plot of Norway spruce containing 34 infested trees supporting 53 active *D. micans* broods. One month later, 30 per cent of broods contained marked *R. grandis*. The predators showed a preferential attraction to the older *D. micans* broods and had dispersed throughout the study plot up to 205 metres from source.

C. J. KING, N. J. FIELDING, T. O'KEEFE

*Interactions of D. micans and spruce*

Experiments on beetle oviposition behaviour in detached spruce bark showed that females often failed to complete gallery formation and oviposition in very highly lignified bark of both Norway and Sitka spruce. Bark thickness also affected gallery construction, the minimum thickness being around 3 mm.

Preliminary surveys in stands of spruce revealed considerable variability both within and between trees in the extent of lignification of bark. Of particular interest was the finding that, even on trees in which the bark of the lower bole was highly lignified, bark covering the main roots was relatively unligified and this may be a factor influencing the frequent occurrence of root attacks in this species.

D. WAINHOUSE, D. CROSS

**Attractants for *Rhizophagus grandis* adults in the frass of *Dendroctonus micans***

This co-operative project is aimed at isolating and identifying specific attractants for the predator *R. grandis* in the frass of *D. micans*. These 'kairomones' are used by the predator to locate its host in the forest. When isolated and suitably formulated for use in traps they could form the basis of a monitoring system following releases of the predator for biological control. Solvent extracts of frass were bioassayed in both walking and flight wind tunnels and the presence of attractive components demonstrated in several fractions. Work on the identification of these chemicals is in progress.

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**The pine beauty moth, *Panolis flammea****Monitoring and control*

Pupal counts in Autumn 1986 showed a possible need to treat 2600 ha (*Report* 1987, p. 50). On the basis of egg counts carried out in May 1987 a total area of 2265 ha was treated from the air between 30 May and 10 June 1987. Three insecticides were used: Dicofen (fenitrothion) on 1315 ha; Dimilin (diflubenzuron) on 709 ha and a virus preparation PfNPV on 241 ha. Dimilin was applied at the lower rate ( $17\text{ g a.i. ha}^{-1}$ ) tested in 1986 (*Report* 1987, p. 50). All applications gave more than 99 per cent reduction in populations based on autumn pupal counts before and after spraying; no significant defoliation occurred. Approvals for spraying were given under the newly effective Control of Pesticides Regulations (1986).

New rotary atomisers, X30s, designed to meet the requirements of ultra low volume application of chemical insecticides and virus formulations, were used for the first time. An improved spraying system was fitted to the helicopter; this provides for rapid and accurate calibration of flow rates using electronic sensors and a digital display. These developments involved close collaboration with the Scottish Centre of Agricultural Engineering and the helicopter operator, Fountain Forestry.

J. T. STOAKLEY



*Population ecology*

*P. flammaea* populations in lodgepole pine in the Elchies block of Speyside Forest (Grampian) declined again, only 0.07 pupae m<sup>-2</sup> being found. The average fecundity of the females was 18.6 eggs, resulting in only 0.43 eggs m<sup>-2</sup> being present in the spring. Larval mortality over the season was 57 per cent, no significant differences being found between deep peat and ironpan sites.

Field experiments at Poulary (Glengarry Forest, Lochaber Forest District) monitored soil and air temperatures, confirming and extending previous work on adult eclosion rates (*Report* 1986, p. 42; *Report* 1987, p. 51). Egg hatch was monitored at eight different locations throughout the forest and related to altitude and exposure. Collaborative field work with Dr A. D. Watt (Institute of Terrestrial Ecology, Edinburgh) over the first complete year of life table studies of *P. flammaea* at Elchies and North Dalchork continued. A third life table site was initiated at Poulary in autumn 1987. Laboratory investigations indicated that sex ratio had a significant effect on female fecundity and also on egg fertility, an imbalance in favour of females resulting in greater egg fertility. Larval survival is poorer as population density increases while previous defoliation in older trees has no effect on subsequent growth and survival of larvae.

S. R. LEATHER

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

Work continued, in conjunction with Work Study, to develop an alternative to dipping for treatment of plants with insecticide. Preliminary results indicate that the ICI Electrobyn sprayer shows great potential and will readily fit into a plant handling system.

*Physical barriers*

Two commercially available physical barriers were evaluated for cost and efficacy in a joint Work Study and Entomology project. The Teno Collar for bare root stock was found to be too expensive for Forestry Commission use. Vinetta Stockings for use with containerised stock gave an adequate level of protection when correctly applied. Further work on this barrier will continue.

*Hylobius damage survey*

All Forestry Commission restocking sites greater than 6 ha planted in 1985–86 were assessed by local staff for insect damage in order to establish the effectiveness of the standard techniques for plant protection. Over 4.5 thousand ha were assessed, 130 000 plants being scored for damage. The results show clearly that pre-planting treatment by dipping gave the greatest protection. Post-planting sprays gave poor protection. In most cases sprays were not applied prophylactically but in response to the occurrence of damage.

S. G. HERITAGE, J. T. STOAKLEY

**The European pine sawfly, *Neodiprion sertifer***

Surveys of pine sawfly defoliation in lodgepole pine crops in Caithness and Sutherland districts of Highland Region were carried out in 1986 and 1987. A random sample was chosen consisting of 16 per cent of all sub-compartments of

10 years old or less in Forestry Commission plantations, the same sample being assessed in the second year. For many individual sub-compartments the damage scores were different from one year to the next but on average the levels of damage were the same in both years. Thirty-three per cent of sub-compartments had some sawfly defoliation and 9 per cent had serious defoliation defined as loss of more than 60 per cent of the previous year's foliage. Heavy defoliation was associated with drier sites, trees of 1–2 metre height and inland provenances.

J. C. G. PATTERSON, J. T. STOAKLEY

### Genetic variation in insects

Isoenzyme electrophoresis was used to quantify genetic variation between *Panolis flammea* populations. Adult males were sampled from five English sites and one Scottish site by pheromone trapping. An additional two Scottish sites with high population densities were sampled for pupae, and the emerging adult males retained for analysis. Triturates of individual male moths were run on both polyacrylamide and starch gels. Following separation, the gels were stained for four enzymes selected for polymorphism and resolution from over 35 candidates. For each population, allele frequencies were scored at five polymorphic loci and preliminary analysis indicates significant genetic differences between all populations.

M. R. JUKES

### Pheromone trapping for exotic bark beetles

A further programme of monitoring was carried out in which pheromone lures for *Dendroctonus ponderosae*, *D. rufipennis*, *D. brevicornis* (all North America) and *Ips typographus* (Europe) were deployed at 25 locations (*Report* 1986, p. 53). One hundred and ten bark beetles of 12 species were caught. The most significant find was a single *I. typographus* at Goole Docks. Further investigation by York Forest District staff led to finding considerable numbers of *I. typographus* on bark covered spacers between steel plates imported from Norway.

D. A. BARBOUR, H. F. EVANS, T. G. WINTER

### Pine looper moth, *Bupalus piniaria*

Pupal surveys were carried out in 36 of the 39 areas surveyed in 1987 and also at Bawtry, Yorkshire and Wareham, Dorset. Three areas were omitted owing to damage from the storm in October. Counts were low, the highest compartment mean being  $5.6 \text{ m}^{-2}$  at Cannock (Staffs) an increase from 1987. However, Sherwood IV (Notts), dropped from  $24.4$  to  $3.6 \text{ m}^{-2}$ .

D. A. BARBOUR, T. G. WINTER

### Advisory and taxonomic services

As in the past two years, there was a larger number of enquiries concerning control of *Hylobius abietis* and *Hylastes* spp., reflecting the increasing scale of restocking and problems associated with changing practice.

Enquiries relating to sap-sucking insects, particularly *Cinara piceae* and, on Norway spruce Christmas trees, *Adelges abietis* and *Elatobium abietinum*,

increased for the second consecutive year; the latter also caused widespread and locally severe defoliation of Sitka spruce in England, north Wales and Scotland. Since 1981 several cases have occurred in southern England of extensive yellowing, browning and death of lower branches of Leyland cypress hedges. Usually the foliage has been covered with sooty moulds and in 1987 *Cinara cupressi* was found associated with such damage in Sussex. This aphid occurs on Monterey cypress in Britain but this is our first record of any aphid species on Leyland cypress. The eriophyid mite *Nalepella haarlovi* damaged spruce plants used for air pollution studies and the Sitka spruce bud mite, *Trisetacus grossmanni*, caused damage in Yorkshire.

Oak defoliation by *Tortrix viridana* was again widely reported in eastern England while in June *Operophtera fagata* severely defoliated birch in the central Highlands of Scotland. Damage to beech by the leaf-mining weevil *Rhynchaenus fagi* was noticeable in East Anglia, Dean and further north.

Apart from *Ips typographus*, Forestry Commission plant health inspectors found the scolytids *Orthotomicus proximus*, *Polygraphus subopacus*\* and *Phloeosinus bicolor*\*, from Europe; and *Dendroctonus pseudotsugae*\*, *D. rufipennis*, *Gnathotrichus sulcatus*\*, *Ips latidens*\*, *Pityogenes plagiatus*, *Scolytus unispinosus*\* and *Polygraphus rufipennis* from Canada.

\*Species not recorded previously in Britain.

T. G. WINTER, J. T. STOAKLEY

## INTER-BRANCH REPORT:

### ENTOMOLOGY AND WILDLIFE & CONSERVATION

#### Duration of daylight and levels of energy input to sunlit ridesides

Work on estimating the length of shadow cast on ridesides by trees has been extended to include calculations to give duration of sunshine for positions on rides of different orientations (see Carter and Anderson, 1987). An algorithm has been constructed which calculates the duration of daylight and the energy input for most heights of crop, ride widths and compass orientations at any time of year. We are indebted to Drs Yallop and Hohenkerk of the National Almanac Office at the Royal Observatory, Herstmonceux for the construction of the algorithm and to Mr Hendry who carried out the necessary calculations. Using these data, and the previously reported shadow lengths, it will be easier to decide on the best regime of ride-widening and subsequent management to favour plant growth and butterflies. Figure 7 shows the possible duration of bright sunshine at positions on forest rides at any date throughout the growing season; energy input can also be calculated the same way.

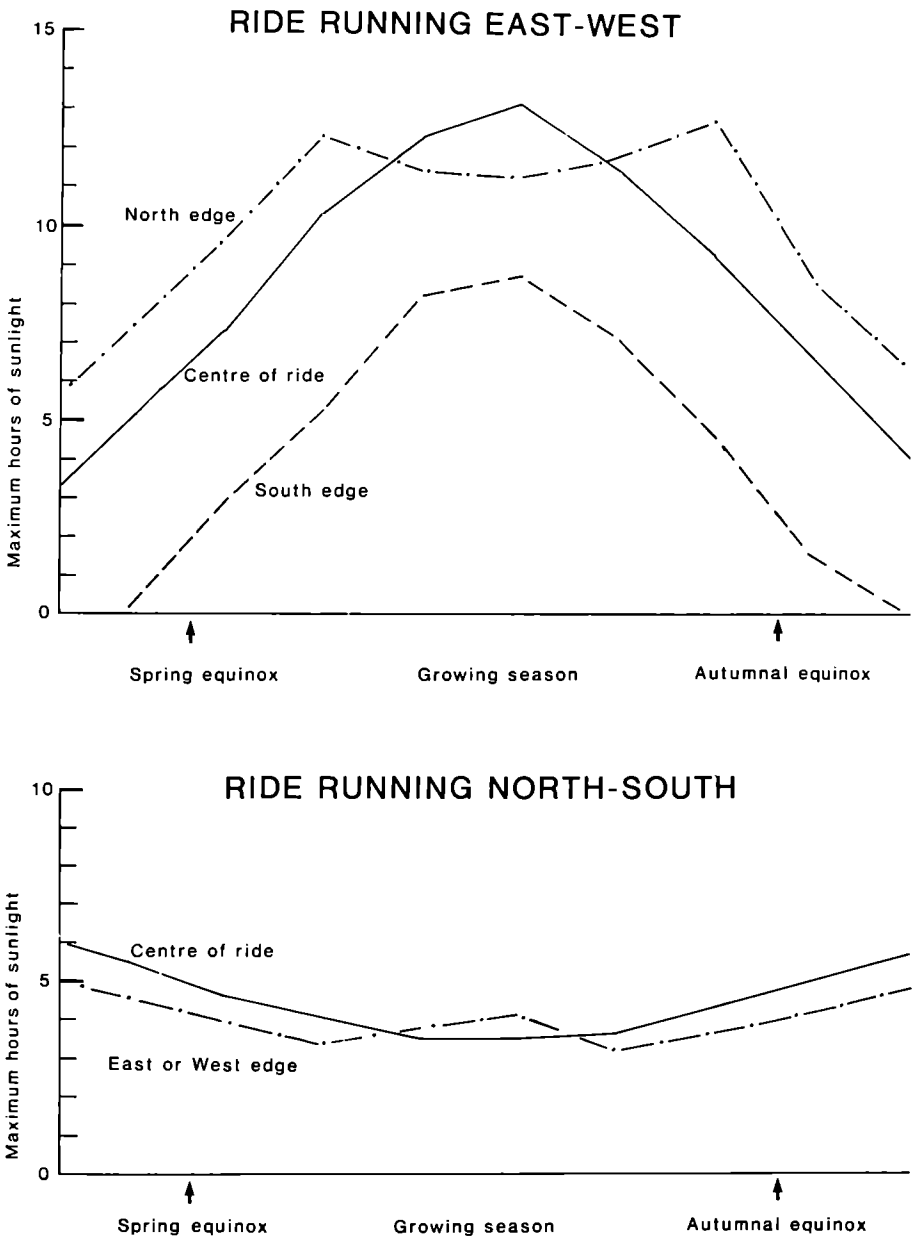
Efforts have begun to relate the forecast levels of light and heat to the requirements of some wayside plants and butterflies. This will permit prescriptions to be formed for precise rideside management to satisfy the needs of individual species.

The comparative rates at which newly widened rides are being used and colonised by various types of insects are being assessed using the national Butterfly Monitoring Scheme method (Hall, 1981) and with malaise and pitfall traps.

C. I. CARTER, M. A. ANDERSON

#### References

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**Figure 7.** A comparison of calculated potential daily values of uninterrupted sunshine falling on the ground in forest rides of opposing orientations in southern England. In both cases the ride width is equal to the crop height. Daylight hours on the brightest parts of the rides are almost equal in winter, but east-west rides offer a great advantage in the growing season.

## WILDLIFE AND CONSERVATION

### Vegetation management

New experiments have been established to compare the effectiveness of a number of rideside management practices in maintaining and encouraging edge plant communities and butterflies. The work seeks to find the best size of rideside bay or scallop cut into the surrounding crop (Anderson and Carter, 1988). The experiments are in both plantation and semi-natural woodland on rich soils. Assessments of the resulting vegetation structure and composition are being made under contract by Wye College, London University.

An investigation of the effect that a proportion of conifers has on the flora of a broadleaved crop has also been started in conjunction with Wye College. A survey of vegetation in pure and mixed crops will be carried out in lowland forests in 1988. This will be followed by a suite of experiments designed to test the results. It is intended that the final results will act as a guide to the fraction of conifers recommended as a nurse or as part of a mixed species crop.

A review of the successes achieved by non-government bodies in conservation management has been arranged with University College, London University. As a first step, trusts, societies and organisations who manage land to benefit wildlife are being asked to say which practices have been found successful and which failed. It is intended that a consensus summary of the findings will be published as an aid to choosing the best practices for conservation.

A new method is being sought to determine which plants are present as seed in woodland soils. Present methods rely on germination trials with soil samples in a cold greenhouse for 6 months. On many sites it is possible that other species may remain in the soil undetected because they fail to germinate. Chemical extractions, flotation and wet sieving are being tried as a means of uncovering hidden species. Early results suggest that the chemical methods are the more promising, 90 per cent of seeds of six specially sown woodland plants having been recovered alive and able to germinate after several months in the soil.

M. A. ANDERSON

#### Reference

Anderson, M. A. and Carter C.I. (1988). Shaping ridesides to benefit wild plants and butterflies. In, *Wildlife management in forests*, ed. D.C. Jardine. Institute of Chartered Foresters, Edinburgh.

In the uplands, commissioned work has begun on the dynamics of colonisation and succession of vegetation in coniferous forests (see p.75). Results will be used as a basis for predicting the effects of management practices on vegetation, and to develop methods of enhancing variety in the flora and encouraging self-perpetuating populations of woodland plants and the animals which depend upon them. This work will address problems within plantations and at the forest edge separately.

G. S. PATTERSON

The impact on plant communities of grazing and browsing by wild ungulates is difficult to control (Ratcliffe, 1988). Heavy grazing can cause the elimination of sensitive plants while the total exclusion of ungulates by fencing can cause the vegetation to become rank, again resulting in the exclusion of some species. Experiments are underway to determine whether controlled grazing by domestic stock can maintain or enhance plant diversity.

G. S. PATTERSON, P. R. RATCLIFFE

#### Reference

Ratcliffe P. R. (1988). The management of red deer populations resident in upland forests. In, *Wildlife management in forests*, ed. D. C. Jardine. Institute of Chartered Foresters, Edinburgh.

#### Bats

A review covering the current state of knowledge and conservation of bats in woodlands has been completed. The review highlights areas requiring further research: some work will begin in 1988. Contact has been made with all Forestry Commission forest districts involved in bat conservation and an experiment comparing two designs of bat-boxes has been started in Wales.

B. A. MAYLE

#### Deer

The collection of data on the population dynamics of roe and sika deer has continued. Almost 3000 female and 2000 male roe deer samples have been collected and the analysis of the data is in hand. Data collected during the past 20 years from a marked population of roe at Chedington, Dorset is being analysed under contract.

Preliminary results from vantage point counts of sika deer in Argyll and Peebles suggest densities similar to those of red deer.

P. R. RATCLIFFE, B. A. MAYLE, A. H. CHADWICK

#### Grey squirrels

Renewed emphasis has been placed on reducing the risks of poisoning non-target species. Two methods of preventing access to the 0.02 per cent warfarin bait by animals other than grey squirrels were tested. The first method used a modified 'Fuller' continual catch trap which was attached to the entrance of a standard type hopper. The second was the addition of a clear PVC door fitted to the inside of the square entrance tunnel of a Fuller hopper. Both hoppers were tested against standard hoppers in a broadleaved woodland over a two month period using unpoisoned red dyed wheat. The modified Fuller hopper effectively prevented small animals and birds from obtaining the bait ( $p < 0.001$ ), without significantly reducing the take by grey squirrels (Table 9). The modified continual catch trap reduced entry by small mammals but it also deterred squirrels. The modified Fuller hopper is now undergoing further field trials. Further work assessing the risks to non-target wildlife is being undertaken by contractors.

**Table 9** Comparison of bait taken by grey squirrels, rodents and birds from three hopper designs ( $\text{g wk}^{-1}$ )

Period	Standard hopper		Standard hopper with catch trap		Modified Fuller hopper	
	Open	Closed to squirrels	Open	Closed to squirrels	Open	Closed to squirrels
26.6 - 31.7.87	426	173	44	3	187	13
1.8 - 28.8.87	735	331	36	40	204	11

The possibility of making warfarin bait more palatable to squirrels was investigated by the addition of raspberry, strawberry and hazelnut flavours. Squirrels preferred plain, unflavoured wheat but male squirrels disliked strawberry flavoured wheat and females disliked hazelnut flavoured wheat ( $p < 0.5$ ).

### **Chemical repellents**

Four different repellents were tested. Real and synthesised lion dung tested against rabbits and deer produced an inconsistent repellent effect. Further trials of different formulations are continuing. Both Hoppit and Kunilent R-12 proved sufficiently effective to proceed with further trials whereas Narsty did not repel rabbits or deer.

H. W. PEPPER

## **MENSURATION**

### **Sample plots**

The storm of 16 October 1987 caused damage to 103 permanent sample plots. Damage was acute in 72 of these and they have had to be abandoned. This represents a loss of 9 per cent of the total viable plots nationwide. The main loss was Scots pine and Corsican pine. Other notable examples were: 65 species in the forest plots at Bedgebury and the *Nothofagus obliqua* at Micheldever, the latter being the fastest growing stand of this species in Great Britain.

Steps have been taken to renotify the sites of all sample plots. This followed a number of incidents of felling without consultation.

### **Yield modelling**

#### *Yield prediction on lowland sites*

With current changes in land use policy this is an important topic. A desk study was undertaken which highlighted the gap in knowledge on the subject: a project proposal for joint work with agricultural researchers has accordingly been prepared.

G. KERR

#### *Review of thinning experiments*

Mensuration Branch is responsible for the management of a large number of thinning experiments which are designed to aid the choice of economic thinning procedures. Thirty-eight unreplicated thinning trials and seven replicated thinning experiments are still in existence.

Last year the progress of thinning research was reviewed in order to decide on future data requirements and the establishment of the next generation of experiments. The conclusions of this study were as follows:

1. Previous data analyses have concentrated on the replicated experiments, and failed to exploit all the data available for a given experiment. A comprehensive analysis, employing data from the majority of experiments, is proposed.

2. Insufficient information is available for modelling the response of stand increment to thinning, making extrapolation to other treatments difficult. However, where an experiment is still in existence, the data required may be gleaned retrospectively from tree ring measurements. Stem analysis has therefore been introduced as a standard measurement procedure for all major experiments.
3. The range of thinning treatments covered by existing experiments is narrow and poorly defined. Future experiments will aim to extend this range, and also to provide data more amenable to extrapolation.

R. W. MATTHEWS

### **Management services**

The Tariff Checking and Calculation package has now been distributed to all forest districts. Training in the use of the package and interpretation of results was given by members of this Branch. Responses from users show that it is an effective management aid.

The Assortment Forecasting Service handled 130 runs. This was 33 per cent fewer than in 1986, despite the increased accuracy and flexibility of this system compared with forecasts of assortments using the Tariff Package.

G. KERR

### **Data terminals**

The Epson HX-20 has again been used for recording data from the majority of sample plots measured during 1987/88. More Forest Survey Branch teams have been trained in the use of the Epson and nine teams working throughout Great Britain used Epsons. In addition these machines and the data collection program are being used by Silviculture (North) staff for recording measurements in cultivation plots at Teindland.

The first machine was purchased by Mensuration Branch nearly 5 years ago. Numerous data capture devices/data loggers come on to the market each year. Although a more compact and rugged machine would be preferred, there is still not one available that provides these benefits in combination with the features and flexibility of the Epson necessary for sample plot measurement.

J. M. GAY



## WOOD UTILISATION

### Value enhancement of low quality hardwoods

A study of the market chain from woodland owner to consumer was undertaken in order to identify the most appropriate studies required to improve hardwood utilisation. The work was divided into four parts.

The first task was a survey of the volume of wood offered for sale by members of the Timber Growers (UK) Limited in England and Wales. This was a jointly run exercise with TG(UK) Ltd and involved sending a questionnaire. Approximately one third of those members with broadleaved woodland responded. Replies were categorised by size of holding and size of harvesting programme in the following 5 years. Proportions of species to be felled differed only slightly from those which might be expected on the basis of the 1979–82 census volumes with 3 per cent less oak, 2 per cent less sycamore, the same volume of beech and 7 per cent more ash.

The second task looked at volumes of hardwood trade in a sample area, Hampshire and East and West Sussex. This telephone survey of buyers and sellers showed a lower than expected felling of oak. This is associated with a reluctance on the parts of buyers to purchase the fuel and pulpwood assortment of this species. The difference between overall volumes for all species indicated by buyers and sellers appears to be largely due to direct selling of the significant volume of fuel wood. This survey provided evidence on quantities and qualities purchased by buyers many of whom were interviewed as part of the third task in this study.

TRADA was commissioned to examine the hardwood trade, with particular emphasis on sawmilling and downstream utilisation. The decline in hardwood sawmilling in Britain over the past 10 years mirrors declines in wood furniture manufacture and in the mining industry. There has been a notable increase over the same period in the volume of timber used for decorative or structural beams but the basic structure of the market has remained unaffected by the general decline. However, the introduction of tighter control on specifications for mining timber and palletwood is seen as a portent of the way all aspects of the market are likely to develop in the future.

The fourth task was also contracted to TRADA and involved an examination of those utilisation processes or final uses where British hardwoods might be used in increased volumes or substituted for imported timber or other material. This information will be used to formulate the next steps for the project.

### Advisory

Approximately one fifth of all enquiries in 1987/88 concerned roundwood; a similar proportion were on the subject of sawnwood. The single most common subject (28 per cent) was that of utilisation of residues, equally divided between bark and chipped forest residues.

## INTER-BRANCH REPORT:

# WOOD UTILISATION, FOREST SURVEYS, SILVICULTURE (NORTH), ENTOMOLOGY AND PATHOLOGY

## RESEARCH STUDIES FOLLOWING THE STORM OF 15/16 October 1987

### Meteorological aspects

The catastrophic damage to trees and woodlands in south-east England on the night of 15/16 October 1987 was caused by high windspeeds associated with the passage of a fast-moving depression. The centre of the depression (953–959 mb) tracked across southern Britain from the Bay of Biscay to the North Sea, passing over Exeter (2.00 am) and Hull (6.00 am) on the morning of the 16th. The strongest winds occurred on the southern edge of the depression, and particularly along the south and south-east Channel coast, and the coast of East Anglia.

Gusts in excess of 90 knots (104 m.p.h.) were recorded at a number of locations including Shoreham-by-Sea (100 kn), Langdon Bay (94 kn), and Sheerness (93 kn). North-west France was also affected and a gust of 117 knots was recorded at Pointe du Roc, Normandy. Gusts in excess of 80 knots occurred over an extensive area to the south-east of a line from Southampton to Kings Lynn, and this coincides with the zone of greatest woodland damage.

The windspeeds recorded during the storm are similar to those associated with previous catastrophic windthrow events in north-east Scotland (31 January 1953), central Scotland (15 January 1968), and mid-Wales and the Midlands (3 January 1976) (Quine, 1988).

However, the occurrence of such windspeeds in south-east England was particularly unusual and this is confirmed by return periods calculated for both the highest gusts and the highest hourly mean windspeeds. The return period of the winds that affected the area bounded by the line from Southampton to Kings Lynn is in excess of 200 years (Burt and Mansfield, 1988).

C. P. QUINE

### References

- Burt, S. D. and Mansfield, D. A. (1988). The great storm of 15–16 October 1987. *Weather* **43**(3), 90–114.  
 Quine, C. P. (1988). Damage to trees and woodlands in the storm of 15–16 October 1987. *Weather* **43**(3), 114–118.

### Damage assessment

Assessment of the damage to woodlands showed that of the almost 4 million m<sup>3</sup> of timber blown down half was conifer and half broadleaved species with about 70 per cent in private woodlands, 25 per cent in Forestry Commission managed woodlands and 5 per cent in hedgerows, parks and gardens. The worst affected counties were East and West Sussex, Kent and Suffolk.

**Table 10** Windblown volumes (000 m<sup>3</sup> over bark) by county

	Conifer	Broadleaves	Total	% original standing volume
Suffolk	510	230	740	13
Essex	10	100	110	4
Kent	230	330	560	18
E. Sussex	380	370	750	24
W. Sussex	350	480	830	19
Surrey	120	170	290	6
Hants	100	110	210	2
Others	230	190	420	
Total	1930	1980	3910	

In Table 11 the breakdown of species windblown highlights the volumes of pine and beech, both species which are liable to degrade more rapidly than other conifer and broadleaved species.

**Table 11** Windblown volumes (000 m<sup>3</sup> over bark) by species

	Pine	Other conifers	All conifers
Small roundwood	400	300	700
Sawlogs	850	350	1200
Total	1250	650	1900

	Oak	Beech	Other broadleaves	All broadleaves
Under 40 cm diam.	300	300	200	800
Over 40 cm diam.	500	400	300	1200
Total	800	700	500	2000

This windblow was remarkable for the high proportion of damage to private woodlands and for the high proportion of broadleaved timber blown. Ownership of the private woodlands is widely dispersed in many hundreds of estates. Not all these woodlands have been managed with timber production as a primary objective; significant areas have been managed for shooting and amenity and some have not been managed at all.

J. DEWAR

### Insects

The enormous quantities of potential breeding material that have resulted from the October windblow may result in very large increases in the densities of insects capable of exploiting such material. This is particularly the case for pine where a number of bark beetle species common in managed forests will undoubtedly respond to the sudden proliferation of wood suitable for breeding. Pine shoot beetle, *Tomiscus piniperda*, is regarded as the most serious of these and Entomology Branch staff have begun a study of the relative susceptibilities to this insect of blown and snapped Scots and Corsican pines.

H. F. EVANS

### Stain and decay in windblown pine

Within 2 months of the gale, a greenish-black discoloration was conspicuous on exposed pine sapwood surfaces – whether on broken material or on trees cut to clear the roads. Examination, during the period January–March 1988, of samples from Thetford, Suffolk and West Downs Forest Districts confirmed observations made after the gale of January 1976, namely that this discoloration was almost entirely due to the growth of the fungi *Botrytis cinerea* and *Epicoccum nigrum*, ubiquitous airborne ‘moulds’ which have never been regarded as the cause of significant sapwood stain. Incubation of a range of samples showed that in most cases these fungi had developed only 1–2 cm into the wood during a 2–3 month period; although occasionally they could be found up to 10 cm from the exposed surface. Only three examples of rapidly penetrating blue stain were found – one involving *Sphaeropsis sapinea* and the others involving *Ceratocystis coerulea*.

Previous experience in southern England has indicated that serious blue stain in pine will only develop following attack on the windblown material by bark beetles – most notably *Tomicus piniperda*. The processes involved will be followed in conjunction with studies on insect populations conducted by staff of the Entomology Branch.

Evaluation of the sapwood samples for stain revealed the presence in many of them of developing colonies of *Heterobasidion annosum* (*Fomes annosus*) and *Peniophora gigantea*. These had undoubtedly developed following infection of the freshly exposed sapwood surface by airborne basidiospores of the two fungi. Once established these fungi can grow through sapwood at rates of 5–10 cm per month, although it is many months before significant changes in wood quality occur. The presence of these fungi assumes a special significance where the long-term storage of pine logs is being considered.

J. N. GIBBS

### Parkland tree survey

In the 2 months that followed the gale, the Pathology Branch put in hand a survey of parkland trees to learn more about structural weakness and decay in a range of species. Twenty sites from mid Hampshire to central London were selected, and detailed information was collected on over 1000 significantly damaged trees. Species of *Aesculus*, *Fagus*, *Quercus* and *Tilia* together comprised 70 per cent of the sample, and Table 12 provides summary data on the point of failure in these four genera. It will be noted that *Fagus* and *Tilia* most commonly failed by blowing over at the roots while *Aesculus* and *Quercus* typically showed branch failure. The second part of the table shows for each genus the frequency with which appreciable decay was associated with the failure point. Decay was present in only 4 per cent of the failures in *Aesculus* but in 25 per cent of those in *Fagus*. In *Quercus* the overall incidence of decay was similar to that in *Fagus* but decay was less common in the failed roots and more common in the failed branches. A detailed analysis of the data is being prepared for publication.

The sites chosen were to the west of the area worst affected by the storm and approximately 80 per cent of the trees on each site did not exhibit significant damage. During January–March 1988 a follow-up survey of the remaining trees has been conducted so that some comparison can be made between the relative performance of different species. Data from this study are also in the process of analysis. This work was partly funded by the Department of the Environment.

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

**Table 12 Failure and decay in the four genera most commonly encountered in the parkland tree survey**

## (a) Position of failure point

Genus	No. of failures assessed	Percentage of the failure affecting			
		root	trunk*	stem	branch†
<i>Aesculus</i>	165	8	8	17	67
<i>Fagus</i>	124	52	7	19	23
<i>Quercus</i>	302	21	4	7	69
<i>Tilia</i>	206	66	11	11	13

## (b) Association between failure and the presence of appreciable decay at the failure point

Genus	Percentage of failures with decay occupying more than one third of the wood at the failure point			
	root	trunk	stem	branch
<i>Aesculus</i>	0	15	7	3
<i>Fagus</i>	25	78	30	7
<i>Quercus</i>	14	54	29	26
<i>Tilia</i>	6	70	43	7

\*Where the main stem was undivided it was recorded as a 'trunk'. Where two or more stems of equal importance were present the term 'stem' was used.

†Branch failures were only recorded if the branch exceeded 30 cm diameter at the point of failure or its diameter exceeded a quarter of the tree diameter at breast height.

**Other studies***Storage of timber*

A desk study on methods, practicalities and costs of water-immersion storage was concluded within a few weeks of the windblow with conclusions transmitted to the Forest Windblow Action Committee.

*Beech for pallet blocks*

A sample of beech sawn to 2.0 m × 95 mm × 95 mm was obtained to carry out a trial of anti-stain and anti-rot dipping treatments. A further sample was sent to a pallet manufacturer for evaluation of its performance during the manufacturing process.

*Strength testing of windblown Corsican pine*

Initial testing of a small sample of Corsican pine at the Princes Risborough Laboratory for stiffness and bending strength gave no reason to suspect a change from previously tested non-windblown material. Further samples have been collected to examine the relationship in strength between windward and leeward (tension and compression) sides of the trees and to look for evidence of splits, shakes and check. First indications suggest that the incidence of these defects is very small and unrelated to the performance in stress grading.

*Salvage of timber samples*

As reported elsewhere, 96 species in 138 Forest Plots at the Bedgebury Pinetum were 90 per cent blow down; in addition the gale blew down a large number of permanent sample plots at other locations. Many contain timber which is worth examining for one of two reasons. Timber from plots with unusual species would normally have been tested to learn the values of properties for British-grown sources. In some cases, as with *Nothofagus* spp., a more rigorous study of timber properties is now possible even though the trees blown down had not attained full maturity. The second reason concerns plots with good mensurational data which have been given various silvicultural treatments. Two sets of plots which compare thinning treatments of Corsican pine have been harvested and one of these already converted into battens for testing at the Princes Risborough Laboratory.

*Timber studies in relation to wet storage*

Preparations have been made to incorporate up to nine species in a wet storage area. It is proposed to examine the relationships between various factors in log preparation and storage parameters on ultimate timber quality.

D. A. THOMPSON

**INSTRUMENTATION**

A large number of jobs have been completed over the year for a range of research Branches including the construction of equipment for the open-top chamber programme, extraction ducts for laboratory mills and nursery ovens, the construction of several field instruments and tools, time-lapse photographic equipment, stretchers for carrying deer, and the installation of new pumps in the seed laboratory.

T. R. NISBET

**STATISTICS AND COMPUTING****Statistics: Alice Holt***Forest health surveys*

The programs to tabulate and summarise the forest health conifer survey were extended to include new assessments made on the trees, and new programs were written to summarise and tabulate the data from the broadleaf and EEC grid surveys. Modelled values of many pollutants were available for the first time this year from Harwell and Warren Spring laboratories and these were used in the analysis of the above health surveys, of an ash die-back survey and of a biomonitor study. Displaying the results of these investigations was improved by a program to colour 20 km grid squares over Great Britain according to the interpolated values of either the response or pollution variates.

*Beech twig growth*

An analysis of beech twig growth data over 20 sites showed drastic reductions of growth in the years following the 1976 and 1984 droughts. An exponential age-related decay function was fitted to the pre-drought data and linear regressions on years fitted to the residuals for each site. These were projected to provide growth 'forecasts' for the between-drought period. Differences between actual growth measurements and the forecasts were used to estimate mean differences, which could be assumed independent of tree age.

*Survey design for damage assessment*

Multistage sampling has been used to assess the amount of damage in the Chilterns Forest District caused by the edible dormouse, *Glis glis*. The sampling method, in which subcompartments are selected with probability proportional to size, has been applied separately to individual tree species/age class combinations. Subcompartments have been surveyed using the nearest neighbour method of Melville *et al.* (1983), and assessed for different types of *G. glis* damage.

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

## Reference

Melville, R. C., Tee, L. A. and Rennolls, K. (1983). *Assessment of wildlife damage in forests*. Forestry Commission Leaflet 82. HMSO, London.

**Statistics: Northern Research Station***Analysis of root weights in sectors*

Roots were collected from eight sectors, in circles of 1 m radius centred on trees, and their dry weights were analysed. Standard methods of analysis were not ideal for detecting treatment effects on concentration, or tendency to cluster in an unspecified direction. The method derived was an extension of the analysis of compositional data (Aitchison, 1982) and involved partition of the 'sector' and 'treatment  $\times$  sector' sums of squares into harmonic components, corresponding to clustering in equally spaced directions around the circle. Development of test statistics and their distributions assumed a circulant dispersion matrix for the sector root weights and a multivariate normal distribution for the log-transformed data.

*Ring width analysis*

Data from a fertiliser experiment were used to try to simplify the presentation of within-tree variation in ring width. For each of the 80 trees in the experiment, an additive model was fitted of the form

$$W = H_x + V_y + D_z, \quad x, y, z = 1, 2, 3 \dots,$$

where  $W$  was ring width,  $x$  and  $y$  were horizontal and vertical coordinates for the position of the ring within the stem, and  $z$  was the year of the tree's growth in which the ring was laid down. Because  $x$ ,  $y$  and  $z$  were linearly related, it was impossible to estimate all parameters

$$H_1, H_2, \dots, V_1, V_2, \dots, D_1, D_2, \dots$$

free from effects of aliasing. Omitting the term  $V_y$  overcame this however, and

$$W = H_x + D_z$$

gave almost as good a fit as the full model. This suggests that the sequences  $H_x$ ,  $x = 1, 2, \dots$  and  $D_z$ ,  $z = 1, 2, \dots$  might summarise the variation in ring widths more concisely than the type I, II and III sequences of Duff and Nolan (1953). For example, the type I sequences might be replaced by  $H_x$ ,  $x = 1, 2, \dots$ . While the technique is of limited interest to wood scientists and others for whom individual sequences are important (Denne, 1979), it may prove a useful tool for less demanding mensurational purposes, for example in detecting experimental treatment effects not apparent from analyses of height or diameter measurements.

### *Analysis of root angles*

Trees were grown in special boxes in which the bottom peat surface inclined at 30 degrees to the horizontal. The air humidity under this surface varied between boxes. The angles of roots in the peat and after emergence into the air below were measured and Mardia's (1975) rank test for spherical dependence was used to detect within-box correlation. The differences between angles in peat and air for each root were plotted around a circle. A grouped distribution, as for the low humidity treatments, indicated dependence, a uniform distribution indicated none. If Mardia's (1975) uniformity test showed that roots in the peat in a box were not uniformly spread, the direction of clustering was calculated.

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

### References

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- Duff, G. H. and Nolan, N. J. (1953). Growth and morphogenesis in the Canadian forest species. I. *Canadian Journal of Botany* **31**, 471–513.
- Mardia, K. V. (1975). Statistics of directional data. *Journal of the Royal Statistical Society B* **37**, 349–393.

### **Modelling: Alice Holt**

#### *Forest structure model*

The forest structure program written some years ago to study the suitability of forests as environments for wildlife was rewritten to reflect changes in the Forestry Commission forecasting program. It is a back-end program which produces an area summary for height classes for specified years in the presence of replanting of felled areas. These classes represent different habitats represented by the height range of the crop concerned. Predictions of the animal population are made, based on the abundance per hectare arrived at by field observations. The opportunity was taken to simplify the user interface by providing a file of parameters which can be edited and better specification of replanting is now possible. Graphical output of the structure through time is provided, and using the map references now available for compartments, a spatial representation is given of the structure of a study area for a given year.

#### *Coppice growth*

Guidance was sought from published material on useful parameters for modelling growth of short rotation coppice. It is likely that results from current Forestry Commission experiments will prove the most useful source of data for developing a biomass forecasting model.

G. J. HALL, I. D. MOBBS



### **Computing: Alice Holt**

#### *Access to the Prime computer*

Owing to the increase in demand for lines into the Prime a set of four contention units (Z-net boxes) has been introduced through which most users now enter the Prime system. This makes better use of the existing AMLC lines rather than adding further AMLC lines. So far the Z-nets seem effectively to have relieved the contention. By the end of the year three Work Study Teams (at Thetford, Ae and Inverness) had been supplied with suitable equipment to allow them to use the Prime remotely over dial-up lines. It is planned to install similar equipment for the remaining teams next year. Alice Holt has now been accepted into Janet (Joint Academic Network) by the network executive to allow the Prime to be attached to the network. The required software, Primeret and Isocept, has been purchased.

#### *Database management*

This year the database management system Oracle has been purchased as a replacement for the Rapport system after a detailed review of the needs of the station for a database system and of what available systems could meet these needs. Although some staff have been trained on Oracle courses, the transfer of databases from Rapport to Oracle is only proceeding slowly owing to the pressures of other demands.

The subcompartment database was expanded to include a national grid reference for each compartment. This located a point within a compartment to within a tenth of a kilometer. A validation system was programmed to check the data and to plot the compartment locations for each forest district. This system could only fault those references which were either not proper references or well outside the relevant forest district. The onus for accuracy within the forest district lies with local management. Another program was written to plot a circle centred on the reference for each compartment with area scaled to equal that of the compartment.

#### *Data capture equipment*

For Silviculture(S) Branch, data on about 200 experiments are maintained in a readily accessible form for updating and analysis. The increasing amount of data recorded from experiments and surveys by Site Studies Branch made it necessary to set up a data storage and retrieval system similar to that already used by Silviculture(S).

Evaluation of Psion Organiser II and Microfin units for electronic capture of field data resulted in three Microfin units being purchased by Silviculture(S) and Site Studies Branches. A program was written to prepare experimental data collected by these units for immediate analysis by Genstat programs. Although the Organiser II was rejected at this evaluation, new communications software now available allows it to be connected to an IBM PC, and its low cost makes further investigations into the potential of the device necessary.

#### *Use of microcomputers*

The use of micros has increased throughout the year, the most popular packages being for statistics with graphics, spreadsheets and wordprocessing.

Five new microcomputers have been purchased, all IBM compatible, for use by individuals or branches with special applications. The use of the IBM PC/AT, purchased a few years ago for general use, should now return to a reasonable level.

B. J. SMYTH, G. J. HALL, R. C. BOSWELL

### **Computing: Northern Research Station**

#### *Hand-held data encoders*

The Fieldworker FW60 hand-held data encoder was initially chosen for various features, including toughness, after consulting forest staff. First tests have been very successful. Programs in Basic have been written which enable it to be used effectively for assessing experiments in the polyhouse or the forest and for stocktaking in nurseries. The Fieldworker picks up data from Squirrel and Polycorder loggers (which are left recording on site) much faster than encoders previously employed and it can be operated as a terminal when collecting records from or programming a CR10 Automatic Weather Station. Various utilities have been provided to transfer the memory contents to other micros or to a mainframe. A newsletter is circulated to keep research foresters informed of progress and invite comment.

#### *Text processing*

Research project leaders have made increasing demands for text processing facilities to complement other software available to them. Most VDUs now have 'Fawn Boxes' attached, to allow screen editing of files on the Edinburgh University Computing Service mainframes. Micros equipped with the 'Newcastle Soft' terminal emulation program also allow this. For simple word processing on the micros Psion's 'Quill' has been selected.

#### *Miscellaneous work*

Considerable efforts have been devoted to rewriting, in association with geneticists, an analysis program for incomplete block designs; to choosing, installing and supporting the hardware and software of IBM compatible micros; and to further development of the Experiment Register Database which is beginning to prove its worth in answering queries.

R. W. BLACKBURN, K. P. DONNELLY

## **INTER-BRANCH REPORT:**

### **STATISTICS AND COMPUTING (SOUTH) AND PATHOLOGY**

#### **Expert systems**

It is often necessary to culture wood-rotting fungi for 6 weeks before enough diagnostic features are recorded to answer the questions in existing keys. Using an expert system it should be possible to make identifications earlier because questions can be answered in any order and unknown features skipped. A program was written in Snobol to simulate an expert system for this application

and the experience gained was used in designing a Prolog system. Mrs M. Heylin (Kingston Polytechnic) has developed a number of Prolog prototypes in collaborative work and we will soon have a system that tells the user which species have been eliminated, and which are the remaining possibilities, at any stage of the culturing process.

A. R. LUDLOW, G. J. HALL, D. R. ROSE

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

In its first complete year, the recently formed Biometric Modelling Section completed a critical appraisal of the pilot model developed by Rennolls and Blackwell (1986) and described in *Report* 1985, pp. 51–53. The main drawback of this model is that few of its parameters have clear biological meaning. There is thus no independent way of checking whether parameters take realistic values when they are estimated by fitting them to sample plot data.

The way out of this problem has been to build an alternative model in which all the parameters have biological meaning, so that estimates of their values, obtained by fitting the model to sample plot data, can be checked against field measurements. For example, diameter growth in the new model is calculated from the biomass of new foliage, assuming a constant sapwood area/foliage area ratio. When the model is fitted to diameter–growth data we can check how well it fits, and also whether the sapwood/foliage ratio needed to make it fit lies close to the values found by other researchers.

Alternatively, turning the fitting technique around, parameter values may be selected from the range of published values and output from the model can then be compared with sample plot data. In this way we have been able to test the sensitivity of the model to changes in particular values and to look for correlations between parameters.

The current version of the model describes forest growth at the stand level, beginning with the ideas of McMurtrie (1986), as discussed in the previous report. The work of Valentine (1985) and Mäkelä (1986) has also been incorporated and we have assumed that new foliage is accompanied by new sapwood, so that basal area growth is proportional to the weight of new foliage.

We have extended these models by making height growth a function of new foliage too, on the grounds that new foliage is added above the existing to cover the area available. Height growth, in the model, depends on the depth of new foliage which, in turn, depends on the area over which it is spread. Large crowns assimilate more carbon than small ones, and so generate more new foliage, but this is spread over a larger area and the two effects cancel out. Hence, height growth changes little when crown area is increased by thinning, while diameter growth is strongly affected. The model succeeds in describing diameter and height growth in Sitka spruce, but only when it overestimates mortality. If it gets mortality right, then it gets height and diameter growth wrong. The most likely reason is that, being a whole-stand model, it allows correctly for the number of trees dying, but not their size.

An individual-tree version is being developed to overcome this, and we calculate competition between trees in almost the same way as Grace (1980) did when developing her model. Like Grace, we assume that crown size and total photosynthesis will depend on how much of the tree can see the sky, instead of calculating how much of the sky each tree can see. This approach is supported by regression analysis of measurements from 12 sample plots at Dyfi which shows that crown surface-area is the measure of crown size which best predicts timber-volume growth-rate, and that it explains 83 per cent of variance. Crown size is readily calculated because height-growth in the model increases crown size, while shading by neighbours kills the lower branches.

The model incorporates software written by Nance *et al.* (1987) to calculate the area potentially available to the tree, and, when complete, will be used as the basis for preparing future yield tables.

A. R. LUDLOW, G. KERR, T. J. RANDLE, R. W. MATTHEWS

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## COMMUNICATIONS

### Library

Demand for information rose by 7 per cent compared with the previous year. Book loans were 1600, journal loans 6732, photocopies 3867 and outside (inter-library) loans 1284, totalling 13 483 responses to demand. The library acquired 315 new books. A new information system called CAIRS (Computer Assisted Information Retrieval System) for the library was installed and became operational at the end of the year. This provides an efficient library catalogue system and a means of incorporating literature reference material in a searchable database.

A widening audience concerned with matters such as farm woodland, urban forestry and storm damage restoration sought information from the library.

### Photography

The MICRO-CAIRS computer-assisted information retrieval system was installed in the section and work was started on transferring the photographic collection lists on to this searchable database. Other software purchased and installed during the year provided the Publications Section's Graphics Officer with computer assistance in generating photographic images for slides, overheads and book illustrations.

Equipment was installed which enabled computer images to be displayed instantaneously on an overhead projection screen, for lecture and display purposes.

Effort was devoted to expanding the collection of farm woodland photographs, in view of the increasing interest in this subject.

### Visits, seminars and open days

There was a marked increase (11 per cent on previous year) in visits of parties and individuals. Of the 83 visits to Alice Holt involving 745 people, 27 were arranged as seminars dealing with 510 visitors. Charges were made for seminars arranged especially for commercial organisations. At NRS there were a further 37 visits involving 463 visitors. Two Research Subject Days at Alice Holt on the theme of establishing trees in the lowlands attracted considerable attention from contractors, local authorities, private woodland and farming interests. Bookings for 345 visitors were recorded and this largely new audience responded well to the presentation of technology transfer.

A press day held at Headley Nursery provided information about the Commissions' research into possible effects of air pollution on trees and allowed journalists to meet and question project leaders.

B. G. HIBBERD

### Publications

Following a review of the Forestry Commission's technical publications' series, Booklets, Forest Records, Leaflets, and Research and Development Papers, will no longer be issued. From April 1987 the three main priced series are Bulletins, Field Books, and Handbooks. Bulletins supply detailed technical information to forest managers, growers, researchers, planners and students. Field Books contain essential data on day-to-day field operations for managers

and supervisors. These pocket-sized books will normally be printed on tough water-resistant paper. Handbooks, acknowledging the popular interest in some aspects of forestry, are aimed at a wider, less technical market, and are liberally illustrated. The new Handbook *Trees and weeds* has been particularly successful and well received.

A fourth main series of technical publications, the unpriced Research Information Notes, conveys research results and advice rapidly to the forest manager. Though these Notes are normally produced as low cost typeset A4 sheets, an alternative design carrying colour illustrations has been introduced to communicate technical information on subjects which lend themselves well to visual interpretation, and are intended for a wider audience than forest managers alone.

From the publications stand-point, the year was unusually productive with 43 new titles being issued of which 11 were new Bulletins and 17 were Research Information Notes.

The following titles were published during the year ending 31 March 1988.

### *Report*

Report on forest research 1987 (£8.95)

### *Bulletins*

- 64 The yield of sweet chestnut coppice, by T. J. D. Rollinson and J. Evans (£2)
- 65 Advances in practical arboriculture, edited by D. Patch (£8.50)
- 66 Choice of seed origins for the main forest species in Britain, by R. Lines (£5.20)
- 67 Population biology and control of the pine beauty moth, edited by S. R. Leather, J. T. Stoakley and H. F. Evans (£5.60)
- 68 Price-size curves for conifers, by D. C. Mitlin (£2)
- 69 Beech bark disease, by D. Lonsdale and D. Wainhouse (£2)
- 70 Air pollution and forestry, by J. L. Innes (£2.60)
- 71 The management of red deer in upland forests, by P. R. Ratcliffe (£2.35)
- 72 Predicting the productivity of Sitka spruce on upland sites in northern Britain, by R. Worrell (£2)
- 73 *Rhododendron ponticum* as a forest weed, by P. M. Tabbush and D. R. Williamson (£2)
- 74 Forest health surveys 1987. Part I: results, by J. L. Innes and R. C. Boswell (£2)

### *Field Books*

- 1 Top diameter sawlog tables (£2)
- 2 Thinning control, by T. J. D. Rollinson (£3.95)

### *Handbooks*

- 1 Forest insects – a guide to insects feeding on trees in Britain, by D. Bevan (£6.95)
- 2 Trees and weeds – weed control for successful tree establishment, by R. J. Davies (£2.70)

*Occasional Paper*

15 Evaluation of forestry research, by A. J. Grayson (£3.50)

*Research and Development Paper*

138 Champion trees, 2nd edition, by A. F. Mitchell and V. E. Hallett (£1)

*Miscellaneous*

Advice on establishment and tending of trees – with notes on choice of species, by R. E. Crowther and A. J. Low (free)

Guidelines for dealing with windblow in woodlands – marketing, sale and restocking in woods damaged by the storm of 16th October 1987. Issued by the Forest Windblow Action Committee. (Free)

List of periodicals held by the Forestry Commission, May 1987 (free, distribution restricted to libraries)

The recognition of hazardous trees, 2nd edition (free)

Wood as fuel – a guide to burning wood efficiently, 3rd edition, by G. D. Keighley (20p)

*Arboriculture Research Notes*

(Issued by the DoE Arboricultural Advisory and Information Service)

69/87/SILS Do soil ameliorants help tree establishment? by R. J. Davies.

70/87/SSS Surveys of tree health 1987, by J. L. Innes.

71/87/ARB Black polythene mulches aid tree establishment, by R. J. Davies.

72/87/ARB Sheet mulches: suitable materials and how to use them, by R. J. Davies.

73/87/PAT Treatment of storm-damaged trees, by D. Lonsdale.

74/87/ARB Protecting trees from field voles, by R. J. Davies and H. W. Pepper.

75/88/ARB Alginure root dip and tree establishment, by R. J. Davies.

The following revised Notes were issued:

18/87/PATH The detection of decay in trees with particular reference to the use of the Shigometer, by P. C. Mercer.

43/87/WILD Rabbit control – phostoxin, by H. W. Pepper.

63/87/SILS Treeshelters, by J. Evans and C. W. Shanks.

*Research Information Notes*

116 Audio-visual aids, by I. A. Anderson.

117 Surveys of tree health 1987, by J. L. Innes.

118 Safe dates for handling and planting Sitka spruce and Douglas fir, by P. M. Tabbush

119 Forest use of improved Sitka spruce cuttings, by W. L. Mason and W. C. G. Harper.

120 Technical publications issued during the year ending 31 March 1987, by E. J. Parker.

121 Experimental work on air pollution, by A. Willson, D. A. Waddell and D. W. H. Durrant.

122 New research and advice on plant conservation and vegetation management, by M. A. Anderson.

- 123 Information services provided by the Forestry Commission Research Division, by E. M. Harland and E. J. Parker.
- 124 *Rhizophagus grandis* as a means of biological control of *Dendroctonus micans* in Britain, by C. J. King.
- 125 Lodgepole pine seed origin and the pine beauty moth, by S. R. Leather.
- 126 Enhancement of lowland forest ridesides and roadsides to benefit wild plants and butterflies, by C. I. Carter and M. A. Anderson.
- 127 The storm of 16th October 1987, by B. G. Hibberd.
- 128 *Dendroctonus micans* – guidelines for forest managers, by H. F. Evans and C. J. King.
- 129 Precision sown and undercut conifer planting stock. I. Quality and performance, by W. L. Mason.
- 130 Timber measurement of windblown trees, by T. J. D. Rollinson.
- 131 Restocking after windthrow, by M. J. Potter.
- 132 Precision sown and undercut conifer planting stock. II. Nursery regimes, by A. L. Sharpe, R. E. J. Howes and W. L. Mason.

E. J. PARKER



## PART II

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

#### SILVICULTURE

##### **Control of shake in oak**

by G. S. HENMAN and M. P. DENNE

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

'Shakes' are radial or tangential splits which develop inside standing trees. Oaks (*Quercus robur* and *Q. petraea*) in many of Britain's woodlands are affected by this defect and, when severe, shake causes an important reduction in timber value.

Causes of weakness in the wood which could lead to shake have been investigated, and genetic (seed origin) influences on wood structure have also been studied. Since we suspect that internal growth stresses may be an important trigger of shakes, we planned a study of growth stress variation in oaks, using a non-destructive technique developed in France for large populations of beech. The technique uses diameter changes of increment cores to indicate the level of stress under which the wood has been held in the tree. Unfortunately, trial runs on our oak material showed up too many sources of error for the technique to be feasible with the samples available.

No strong associations have been detected between presence of shake and those anatomical features which can be easily controlled by genetic selection or silviculture. The soil type on which oak is grown continues to be the factor most strongly linked with the occurrence of shake. Highest shake incidence was found on stony soils derived from a variety of parent materials. The storm of 16 October 1987 has provided an opportunity for further surveys of shake incidence in 30 woodlands on different sites in the south and east of England. Soil samples from these woodlands are being analysed for pH, stone content and texture. Exchangeable cation contents (Ca, Na, Mg, Mn, K, Fe and Al) are also being tested; the Ca:Fe ratio is of particular interest, as previous work has suggested that low ratios are associated with high incidence of shake.

##### **Nutrition and forest soils**

by M. F. PROE

*The Macaulay Land Use Research Institute, Aberdeen*

Current investigations are focused upon the cycling of nutrients during establishment and early development of second rotation forest stands. *In situ* incubations of harvest residues, litter and soil cores are being used to determine nutrient transfers within the forest floor and rates of soil processes likely to affect nutrient availability. A sequential coring technique allows leaching and nutrient uptake to be quantified, the latter process being confirmed by destructive sampling. Work to date has concentrated upon restocked Corsican pine sites with contrasting first rotation fertiliser treatments. The nutrition advisory service to forest nurseries continues to operate.

## SITE STUDIES

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

by B. R. WILSON

*Department of Soil Science, University of Reading*

A three year project on ancient woodland soils in southern Britain began in 1987 with the aim of learning more of their properties and soil processes, and comparing the nature and rate of soil development with other site types. A desk study has examined the extent and location of ancient woodland in relation to soil type, particularly in Berkshire and Hampshire where Nature Conservancy Council information on ancient woodland distribution is good. In both counties there is a tendency for woods to occur preferentially on surface water gleys, though many occur on brown earths and brown calcareous earths. A sampling strategy for field work has evolved from this study, which concentrates on the most important site/woodland types.

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

by P. A. CARLING

*Freshwater Biological Association, Windermere Laboratory, Ambleside, Cumbria*

Forestry Commission and privately owned sites in mid and south Scotland were visited and some factors conducive to soil erosion in artificial channels were identified. These included soils of sandy texture with weak cohesion, high water tables, steep slopes and high rainfalls. To test field methodology, furrow erosion at two sites is being monitored for one winter and a computer-based data reduction system developed. It is intended that the effect on fisheries of the transport of sediment will be a part of the study.

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

by R. I. FERGUSON

*Department of Environmental Science, University of Stirling*

The new project aims to quantify the changes in sediment transport from an 80 ha catchment at Loch Ard, Aberfoyle Forest District (Central Region) during and after clear felling. Prior to any felling, the yield of suspended sediment in the stream was  $0.05 \text{ kg m}^{-2} \text{ yr}^{-1}$  expressed in terms of the catchment area. The yield of stream bedload was  $0.002 \text{ kg m}^{-2} \text{ yr}^{-1}$ . An adjoining 'control' catchment yielded far less suspended sediment and bedload; the reasons for this are not yet clear. After clear felling began in December 1987 both peak and median concentrations of suspended sediment increased tenfold.

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

by J. R. BLACKIE and R. L. HALL

*Institute of Hydrology, Wallingford, Oxon*

Continuing work on the Balquhiddier catchments (Central Region) has confirmed the mean annual water use of the heather/grass covered Monachyle and forest/grass covered Kirkton catchments as 634 mm and 425 mm

respectively, relative to a potential evaporation rate (ET) of 540 mm. The latter figure has been shown to be significantly higher than standard regional estimates, which underestimate ET for upland areas. To establish the effects on water resources of afforesting upland catchments, it is necessary to know the evaporation rates from the existing vegetation. Process studies have now established these for heather. Results emerging from a detailed study of high altitude grassland are confirming that previous estimates were erroneous, water use being lower than ET due to temperature restrictions on transpiration and growth. Tests of the new prediction models being developed from the process studies show improvements in prediction of both Balquhiddy and Plynlimon catchment results.

Provisional results indicate that the most immediate effect of the first stages of planting and clear felling has been to increase suspended sediment loads from both catchments by 3–5 times.

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

by G. TAYLOR, W. J. DAVIES and T. A. MANSFIELD

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

Work has begun to determine the mechanisms by which ambient levels of pollution may affect the growth and functioning of important tree species. The open-top chambers sited in Perthshire, Derbyshire and Hampshire will be used to provide three contrasting pollution climates and measurements will be made on beech, Scots pine, Sitka and Norway spruce. Intensive measurements of gas exchange (photosynthesis and transpiration), shoot development and the dynamics of root length development have already begun at the Hampshire site. This year, attention is being focused on beech and the hypothesis that summertime  $O_3$  and drought (which often occur together in south-east England) may interact and cause damage in this species is being investigated.

Air pollution often accelerates discoloration and ageing of leaves in deciduous species and, although discoloration of needles is also a common symptom of pollution damage, the consequences of this phenomenon are less well understood. In a laboratory-based study, the influence of  $O_3$  on leaf and needle expansion, maturation and premature ageing are being studied using clones of poplar and seedlings of Scots pine.

## **PHYSIOLOGY**

### **Growth of Sitka spruce needles**

by J. CHANDLER

*Botany Department, University of Edinburgh*

Growth of needles in Sitka spruce is being studied in terms of cell number increase and rates of needle extension, according to position on the shoot, in a range of trees of different nutrient status. Cell numbers in control needles increased from 5000 in primordia, to 200 000 at maturity. Cell division and cell enlargement ceased 5 weeks following budburst. A study of potted trees includes monitoring needle chlorophyll content, photosynthetic rates, and amounts and activities of ribulose 1, 5-bis-phosphate carboxylase in developing needles, to investigate how photosynthetic capacity is modified by nutrient deficiency.

## Physiology and anatomy of root and callus production in softwood cuttings of oak

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

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

In December 1987 sections of trunk from 10 trees of different crown classes were used to produce epicormic shoots for vegetative propagation. Some of the shoots were used in a study of the anatomical changes which occur during callus formation and the initial stages of root production. The remaining shoots were used to establish reliable methods of micropropagation and make preliminary studies of callus production in tissue culture. Good progress has been made and clonal material is in culture. Further experiments will be carried out on shoots taken from the stumps remaining.

## PATHOLOGY

### Viruses in beech

by J. I. COOPER

*Department of Plant Sciences, University of Oxford*

Possible inhibitors in foliar sap were assayed in order to provide background knowledge against which to judge the reliability of tests done to detect viruses in beech or oak. When extracted using liquid nitrogen, leaf sap from beech or oak tested in July or October did not diminish the infectivity of arabis mosaic or cherry leaf roll viruses assayed in *Nicotiana megalosiphon* or *N. tabacum* cv. Xanthi-nc. By contrast, fresh foliar sap at the same concentration and sampling time diminished the infectivity of these viruses as judged by comparison with assays done using water as a diluent.

Leaf sap from beech or oak was similarly tested in May–June or October to determine whether it contained material that interfered with virus detection using an enzyme-linked immunosorbent assay (PAS–ELISA). When cherry leaf roll virus was mixed with beech sap from leaves collected in May, the most concentrated extract (diluted 1:10) diminished absorbance values (A<sub>405nm</sub>) by 25 per cent but no interference with the assay was noticed either with beech or oak leaf sap that had been collected in June or October. Thus, PAS–ELISA tests done in August to detect cherry leaf roll virus in mature beech growing at Mickelour, Perthshire, or in Windsor Great Park, Berkshire, and which failed to reveal evidence of the virus in a total of 48 trees probably reflected a real scarcity of infection by this virus which has been reported from declining beech in West Germany.

## ENTOMOLOGY

### **Genotype–environment interactions in the resistance of *Picea sitchensis* to *Elatobium abietinum***

by E. J. MAJOR

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

In addition to assessing damage to selected provenances of Sitka spruce on contrasting field sites, three provenances were subject to water stress consisting of both drought and waterlogging at the beginning of the growing season. Once dormant, the trees were infested with *Elatobium abietinum* in a controlled environment and aphid performance monitored. No significant difference was found between mean individual aphid performance but population counts showed a more rapid increase in aphid numbers on the stressed trees. This effect was also demonstrated on trees that had been intermittently as opposed to continuously stressed. As an alternative method of stressing Sitka spruce, polyethylene glycol solutions were added directly into the soil. The moisture stress status of the trees was assessed by measuring leaf water potential using a pressure bomb.

### **The consequences of aphid induced changes in tree chemistry for *Cinara pini* L.**

by S. D. J. SMITH

*Department of Zoology, University College Cardiff*

The nature of an aphid induced change in host chemistry and its subsequent impact on the inducing species, *Cinara pini*, has been studied. Heavy aphid infestation resulted in significant changes in the nutritional status of the host tree with increases in the amino acids tryptophan and tyrosine, and decreases in GABA, glutamic acid and ornithine. There was also an increase in secondary metabolites with the production of two new groups of phenolic compounds.

Aphid performance was severely impaired as a result of prolonged feeding with lower relative growth rates and adult weights, and increased development times and mortalities. Aphid performance was closely correlated with concentrations of GABA. Histological changes previously found (*Report 1969*) persisted in following years.

## WILDLIFE AND CONSERVATION

### **Survey of Newborough Forest**

by M. O. HILL and H. L. WALLACE

*Institute of Terrestrial Ecology, Bangor, Gwynedd*

The survey set out to identify habitat types and management strategies that could enhance the conservation and recreation values of vegetation in Newborough Forest. The forest was divided into four major physiographic units: mobile dunes, fixed dune grassland, slacks and the marsh edge. Soil and vegetation were sampled from 42 locations, and included planted and unplanted plots and cultivated verges.

Sampling confirmed the distinctiveness of the major dune types; western mobile dunes contained more lime and were more alkaline than the eastern mobile dunes. Slacks were variable, some being leached. The marsh edge was mostly leached and acidic. Slight surface acidification had occurred under pines, but the major effects of tree planting were shading of the dune vegetation, lowering the water table and stabilisation of mobile dunes. Slacks and marsh edges have a denser and more varied vegetation. There was no distinction in vegetation on former fields or former unenclosed grassland. On the fixed dunes there was an invasion of woodland flowering plants under the heavily thinned and well-lit forest crop.

Many unplanted dune slacks have subsequently dried out and will acidify over the next 100 years unless they are treated with lime. Wide verges and slacks require special management alteration.

### **Nature conservation in upland conifer forests**

by J. GOOD

*Institute of Terrestrial Ecology, Bangor, Gwynedd*

This study aims to determine how forest management practices in an upland Sitka spruce forest can be modified to enhance plant diversity and improve wildlife habitats. A stratified random sample of 54 one kilometre squares was used to classify the vegetation in Kielder Forest (Northumberland). Planted parts of the forest are of low bryological interest due to topography and soil type. Bryophyte losses due to planting are likely to be few. Main losses are of small marsh and bog plants. Roadsides and quarries have provided rich new habitats for other species. Unplanted areas of forest edges, particularly rock outcrops near streams and relief woodlands, are important plant habitats. Recommendations for the preservation and enhancement of the flora include the conservation of these habitats. The study is continuing with a survey of invertebrates associated with the main vegetation types.

### **The conservation of red squirrels in relation to forest management**

by J. GURNELL

*Queen Mary College, University of London*

An extensive survey has shown that low densities of squirrels are distributed throughout Thetford Forest (Norfolk and Suffolk). This contrasts with previous impressions of small rather isolated pockets. Habitat use is being studied using radio-tracking, cone transect lines and live trapping. Grey squirrel habitat use and their interaction with red squirrels are also being studied. No spring breeding occurred in the grey squirrel population in 1986. Both species appear to feed on Scots pine seed until late May, switching their attention to the new green cone crop in mid-June. Serbian spruce was used for feeding during April/May when Scots pine seed was not available.

### **Re-introducing red squirrels: the stress factor**

by D. J. INKPIN

*Queen Mary College, University of London*

Red squirrels are declining in numbers over parts of their range. They are fully protected by law. Bark-stripping damage of conifers by red squirrels has led to

conflicts between forestry and squirrel conservation. The translocation of animals from areas where they cause damage to those where they are absent or scarce may help solve this problem. Traps with detachable nest-boxes reduce stress at capture. These familiar boxes help reduce stress and increase survival during transport and housing. Blood analysis, heart-rate monitoring and body temperature measurements give good indications of trauma. Squirrels must be housed for short periods only, prior to release, since long periods in captivity impair the movement of joints and cause problems in adapting to a new environment.

### **Blackgrouse ecology**

by P. HOPE-JONES

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

Blackgrouse are declining in number throughout much of their range. Study sites, in a range of habitat types in Gwynedd and Clwyd, were used to investigate demography and habitat use, and faeces were analysed to determine food preferences. The sex ratio was estimated at 1 male to 0.9 females, overall density was four birds  $\text{km}^{-2}$ . Density was greatest in afforested heather and lowest in open heather, grass or bracken. Diet varied according to sex, season and habitat type, but *Calluna* and *Vaccinium* were of greatest importance, being most important in winter, *Eriophorium* was important in the spring. Blackgrouse appear to require a mosaic of heather/bilberry, tall trees, open low grassland, and damp grassland.

### **Woodlark ecology**

by C. BOWDON

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

The woodlark has adapted to the reduction of its former habitat of breckland vegetation by colonising the younger stages of coniferous plantations. Thetford Forest supports an important part of the existing British population; 346 restocked compartments below 7 years of age were visited to assess presence of woodlarks. Breeding success was investigated by locating nests and monitoring progress of the eggs and chicks. Faecal analysis provided data on diet. Vegetation was recorded at each site.

Woodlark distribution was uneven, most pairs being found in the central area at a population density of about six pairs  $\text{km}^{-2}$ . Woodlarks showed a slight preference for unplanted and recently planted compartments. There was a preference for compartments with bracken, moss, other short vegetation and bare ground following the felling of a previous crop, and for compartments where atrazine has been used to control weeds. The mosaic of bare ground and tussocky cover provides foraging and concealing habitats in close proximity.

Most nests were found in April and May; of 27 nests found, most had clutches of four eggs, but only 18 nests fledged young. Management practices appeared to have no impact on nests. Predators destroyed seven nests. 69 nestlings were ringed. 3.62 young were reared/pair ( $n = 14$  pairs). Young dispersed up to 5 km from the natal site. Older compartments were less likely to retain their woodlarks. Woodlarks in Thetford have increased, but not proportionately with the increase in available habitat.

### **Woodland pheasants**

by P. ROBERTSON

*Game Conservancy, Fordingbridge, Hampshire*

Management of woodlands for pheasants is an important objective in lowland forests and likely to become more so with an increase in farm woodland. Four Hampshire shoots were visited in the winter and counts taken during 166 drives. Results showed that shrubby habitat is important to female pheasants. Male density was related to the number of feeding hoppers provided.

Radio-tracking and faecal counts indicated that females prefer mixed woodland in late winter. Use of edge habitats and fields increases throughout spring to summer when females with chicks feed exclusively in cereals. Nests are sited preferentially in cereal fields from mid-June. Males prefer edge habitats.

The effect of management for pheasants on other species of birds, mammals, vertebrates and plants is being investigated. Thirty-two woodland plots were censused and 65 per cent more birds were found in woods associated with pheasant feed rides in November/January; but only 2 per cent more birds were recorded in February/March. The number and species of other birds present are positively related to the amount of use by pheasants.

### **Afforestation and moorland birds**

by M. I. AVERY

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

This work, carried out in 1986 and 1987, was designed to assess the possibility that forestry plantations may have indirect effects on the birds of adjacent unplanted moorlands. No research on the direct effects of habitat loss due to planting was undertaken. Surveys of birds on areas adjacent to plantations were carried out at a total of 62 sites, each of 6.4 km<sup>2</sup>, in three areas of northern Scotland. Once the effects of vegetation differences were allowed for, there were no major effects of distance from the forest edge on the numbers of curlew, red grouse, dunlin and golden plover. An experimental investigation of predation rates was undertaken using chicken eggs placed at different distances from the forest edge. Predation rates were higher near to the forest edge than further away, but once the effects of vegetation differences were removed there was no remaining statistically significant effect of distance on predation rate. The results of these studies suggest that there are no edge effects of conservation importance (either positive or negative) around forestry plantations in northern Scotland.



## WOOD UTILISATION

### Joint research programme on British-grown timber

by C. TURNER

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

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

Having compiled evidence from a range of stands to examine the effects of planting distance on structural wood yields from unthinned crops, attention is being directed to the effects of thinning on structural wood quality. Thinned stands in a P29 Sitka spruce experiment at Brendon, Somerset, gave marginally higher yields of structural wood, particularly at SC4, than an adjacent unthinned stand; though with more numerous and somewhat larger knots. The thinned stands were of better form.

The effects of growing space on structural wood properties is being examined in more detail using the plot at Brendon thinned to normal Forestry Commission management table recommendations and for which, at each thinning, details of the trees removed were recorded. This work, part of an international study to examine the effects of modern forest practices on the wood quality of fast grown spruce, has obtained financial backing from the Commission of the European Community.

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

Development of a model to predict the effect of growth features on the performance of Sitka spruce in machine grading has continued. The database has been extended to contain information on over 6000 machine-graded 900 mm spans. More spans are currently being measured to increase the data representing weaker spans, i.e. spans with larger knots and low density. Measurements of microfibril angle are now being recorded and these will be amalgamated into the database to test their effect on stiffness. Initial statistical analysis has given encouraging results. Further analysis of the current database is being carried out under contract by Lancaster University to establish a valid statistical treatment and develop a predictive model.

#### *Conversion of British-grown timber*

Studies on sawing accuracy have continued. Moisture content of the timber, knots and variation in grain pattern have been found to affect sawing accuracy to a significant extent. Sawblade parameters have been identified which require special attention to minimise sawing variation when cutting British-grown spruce; tooth swage and blade tension are particularly important. These factors affect the within piece variation. Variation in dimensions between pieces continues to be of significance to British sawmills, but this can more easily be improved by the introduction of tighter quality control procedures. A report and guidance procedures to help British softwood sawmillers check their sawmill equipment and optimise their conversion accuracy will be published in the near future.

## Drying and use of British-grown timber

by C. J. GILL

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

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

Collaborative work with the Forestry Commission is in progress to improve the presentation and acceptability of sawn British-grown softwood destined for constructional uses. The main problem currently being tackled is to find the best strategy for producing a dry, twist-free product. The conclusions from a Department of Trade and Industry financed industrial survey mission to radiata pine sawmills in Australia and New Zealand indicated that drying in batch kilns at temperatures above 100°C was worth investigating. This is being done; three small kiln loads of Sitka spruce have been 'high temperature' dried in France for comparison with conventionally dried material. The results are promising in terms of drying speed and out-turn condition. Also there does not appear to be any significant reduction in strength properties resulting from the severe conditions used. Plans are being made to install experimental high temperature drying facilities in the UK so that trials to investigate further the method's potential and to optimise drying schedules for UK species can be undertaken. The work is being steered by a small joint Forestry Commission/Industry Committee.

The effect on twist of 47 × 97 mm Sitka spruce studs has been examined for two drying regimes, together with the effect of weighted loads, a distorted bed to cause pre-twist, and a conditioning treatment. Following kilning, the material was subjected to three exposures for 12 months, namely an outdoor/covered exposure, an outdoor/exposed exposure and an indoor exposure with partial heating. Results indicated the benefits of weighted loads, and distorted beds in reducing twist, using the high temperature (90°C) drying schedule. The distorted bed treatment has been discarded as impractical for actual kiln usage.

Further work is currently being undertaken to confirm the benefits of a high temperature drying schedule together with weighted loads.

An advisory leaflet on techniques for optimising the air-drying of timber has been drafted; its timing being particularly appropriate in relation to the large volume of timber becoming available following the storm of October 1987.

### *Markets for British-grown hardwoods*

TRADA was commissioned by the Forestry Commission to survey current markets for sawn hardwood and to speculate on potential new outlets for intermediate and lower grades. This forms part of a wider exercise with Timber Growers (UK) Limited aimed at improving the marketability of such materials.

### *Packaging*

Comparative test information has been obtained for British-grown Scots pine, Sitka spruce, Norway spruce, Corsican pine and Japanese larch. Representative samples of the species were conditioned and constructed into standard box panels which were then tested. All the testing has been completed and analysis of the results is in hand. The work is linked with, and will be used in, a revision of BS 1133 Packaging Code: Section 8 'Wooden boxes, cases and crates', which is being carried out concurrently.

### **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 project has concentrated on alternative methods of preservative treatment of British grown Sitka spruce for high decay hazard situations. Early results indicate that the timber is highly suitable for diffusion treatments owing to its high heartwood, as well as sapwood, moisture contents. A second major project concerns the development of gas phase wood preservative application systems suitable for wood based board materials produced from home grown timber. Gas phase systems offer many advantages over conventional liquid based systems for the treatment of manufactured boards, such as minimal swelling of boards, avoidance of solvent recovery/loss from boards, and rapid treatment times.

## **PLANNING AND SURVEYS**

### **Estimating the unmarketed benefits attached to Queen Elizabeth Forest Park**

by N. D. HANLEY and M. S. COMMON

*Department of Economics,  
University of Stirling*

A questionnaire survey carried out in the summer of 1987 set out to estimate the benefits associated with recreation, the landscape and the wildlife at Queen Elizabeth Forest Park. It was also designed with the aim of comparing the two main methods of evaluating recreational benefits, notably the Clawson or travel-cost approach, and the willingness-to-pay or contingent valuation approach.

Results indicate that there are considerable external benefits associated with this forest. The survey indicated that visitors would be willing to pay an average of 90 pence for the use of a wildlife hide, £1.60 for the use of the forest drive (where only £1.00 is currently charged), 80 pence to view the well-designed landscape behind David Marshall Lodge, and £1.25 for entry to the forest as a whole. It is hoped that such figures will provide an indication of the relative benefits of the wildlife, landscape and recreational services provided by this forest. They also indicate an overall valuation for the forest's unmarketed benefits in the region of £200 000 per annum. This is likely to be a low or minimum estimate. The travel cost has not yet, unfortunately, provided us with sensible results.

### Wildlife values of forest recreation

by K. G. WILLIS, J. F. BENSON and M. C. WHITBY  
*Department of Town and Country Planning,  
 University of Newcastle-upon-Tyne*

A survey of the distances travelled by visitors to six forests with a noticeable wildlife interest was carried out in the summer of 1987. From such data, an estimate of the consumer surplus, or total unmarketed benefits, gained by each visitor to the forest, was ascertained. This was then used to evaluate the recreational value of each forest site. The figures are set out in the table below.

**Table 13 The total unmarketed benefit attributable to six forest sites\***

Site	Consumer surplus per visitor†	Range of total consumer surplus from each site‡		
		Minimum	Average	Maximum
Thetford	2.51	205 820	256 020	306 220
Grizedale	1.26	80 640	100 800	120 960
Dalby	1.82	189 280	236 600	283 920
Hamsterley	1.55	151 900	189 100	226 300
Clatteringshaws	2.27	59 020	72 640	86 260
Forest of Dean	2.11	265 860	333 380	400 900

\* All figures are expressed in £ at 1987/88 prices

† Per visit

‡ Per year.

Visitors were then questioned about the importance they placed upon the different unmarketed benefits. Wildlife accounted for between 33 and 44 per cent of the benefit from each site. Conclusions about the other factors could not be made because of the difficulty in determining what is exactly meant by the landscape, etc. We hope to continue with more sites this year to draw general conclusions about the whole estate.

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

by W. E. S. MUTCH  
*Department of Forestry,  
 University of Edinburgh*

The purpose of this study, which began in September 1987, was to build up a regional input-output model of the forest sector, showing how it interrelates with other sectors of the economy. Elements such as downstream employment generation can be calculated from such a model.

This project has been jointly sponsored by the private sector, Forestry Commission and other Government agencies.

## APPENDIX I

### Publications by Forestry Commission Staff

[ADAMSON, J. K., HORNUNG, M.,] PYATT, D. G. and ANDERSON, A. R. (1987). Changes in solute chemistry of drainage waters following the clearfelling of a Sitka spruce plantation. *Forestry* **60** (2), 165–177.

In the first year after felling the export of potassium, nitrate, ammonium, phosphate and iron increased relative to the unfelled control. Except for ammonium, these levels were maintained in the second year. In terms of drainage water quality, the impact of clearfelling on this site is not great.

ALDHOUS, J. R. (1988). Background to the second draft: "Code of Practice for the use of pesticides in forestry". *Aspects of Applied Biology* **16**, The practice of weed control and vegetation management in forestry, amenity and conservation areas, Association of Applied Biologists, 5–7.

ALDHOUS, J. R. (1988). Bridging the gap – new forestry pesticides 'code' launched. *Forestry & British Timber* **17** (2), 24, 26.

An explanation of how forestry managers and contractors will be affected by the new pesticides legislation. A Code of Practice (see abstract above) has been prepared by the Forestry Commission.

ANDERSON, I. A. (1987). *Audio visual aids – the overhead projector*. Forestry Commission Research Information Note 116.

The overhead projector (OHP) has been in use since the 1930s but many lecturers continue to misuse it and fail to exploit its potential. This Note offers some basic guidance.

ANDERSON, M. A. (1987). The effects of forest plantations on some lowland soils. 1. A second sampling of nutrient stocks. *Forestry* **60** (1), 69–86

Nutrient stocks in whole profiles of three lowland soils are summarised. The results are for a wide range of species plots at two dates, one mid-way through rotations and one towards the end. High yielding conifers and some broadleaves are shown to have accumulated greatest stocks of N, P and K. Differences of nutrient concentration amongst the species plots were less at the rotations' end than at mid-way.

ANDERSON, M. A. (1987). *New research and advice on plant conservation and vegetation management*. Forestry Commission Research Information Note 122.

Forestry Commission information for woodland managers on topics of animal conservation has been extended to include applied plant ecology and vegetation management. Research will be done, and information given, on practical aspects of establishing and maintaining forest vegetation for the benefit the woodland plants and their associated creatures, great and small.

ANDERSON, M. A. (1988). Shaping ride sides to benefit wild plants and butterflies. In *Wildlife management in forests*, ed. Jardine, D. C. Institute of Chartered Foresters, Edinburgh, 66–80.

This introduces and summarises general approaches for managing forest edges to retain woodland and grassland inhabitants as well as true edge ones. Dimensions of edge belts of shrubs and swards are suggested. Practical means of overcoming problems of management are discussed. Species likely to benefit are listed.

BINNS, W. O. (1988). Forests, acids waters, and fish. *Timber Grower* **106**, 31–32.

The evidence that forest streams flowing over acid rocks have fewer fish than similar moorland streams is circumstantial. Tree crowns capture more acidic pollutants and forest drains may bypass natural channels and thus soil neutralising capacity. Stream management is part of the forester's job and guidelines, produced by the forestry and water industries, should be published in 1988.

BINNS, W. O., REDFERN, D. B. and RENNOLLS, K. (1987). Forest decline – the view from Britain. In *Effects of atmospheric pollutants on forests, wetlands and agricultural ecosystems*, eds. Hutchinson, T. C. and Meema, K. M., Springer Verlag, 69–81.

Norway spruce decline in West Germany in 1982 and 1983, with the implication of air pollution as one cause, made a precautionary survey in Britain advisable. The state of forest health in Britain was found to be satisfactory and instances of poor health could be explained without invoking pollution. Damage in winter 1983/84 to several species in north-west Britain appears to have been caused by rapidly fluctuating temperatures and strong winds.

[BLACKBURN, P., PETTY, J. A. and] MILLER, K. F. (1988). An assessment of the static and dynamic factors involved in windthrow. *Forestry* 61 (1), 29–43.

Critical windspeeds calculated by assuming static loading of trees greatly exceeded the windspeeds recorded during a gale that caused damage to the study site in the Scottish Borders. Perfect resonance was not observed in a comparison of tree movement and wind speed records but large oscillations were noted. The influence of sway direction and canopy contact was also studied. The results emphasise the importance of dynamic loading in the windthrow process.

[BLYTH, J. F.,] EVANS, J., [MUTCH, W. E. S. and SIDEWELL, C.] (1987). *Farm woodland management*. Farming Press, Ipswich.

All aspects of establishment, maintenance and harvesting farm woodlands are covered along with consideration of statutory land controls, taxation, planning and woodlands as part of the farm business. Sporting, amenity, conservation and recreational values of woodlands are highlighted.

BRASIER, C. M. (1987). The dynamics of fungal speciation. In *Evolutionary biology of the fungi*, eds. Rayner, A. D. M., Brasier, C. M. and Moore, D., Cambridge University Press, 231–260.

Explores the basis of speciation in the fungi in terms of the role of population structure and variation, natural selection and mechanisms for reproductive isolation. Discusses environmental influences on speciation including climate and host specialisation; problems in assessing apparent sympatric speciation processes; and evidence for emergence of biological species. Presents a theoretical model for rapid speciation in fungi under the influence of strong ecological disturbance (episodic selection) and considers the role of breeding and outbreeding in fungal systems.

BRASIER, C. M. (1987). Whither terminology below the species level in the fungi. In *Evolutionary biology of the fungi*, eds. Rayner, A. D. M., Brasier, C. M. and Moore, D., Cambridge University Press, 379–388.

Considers problems arising from the application of the current rules of fungal taxonomic nomenclature via the International Botanical Code, and the potential value of a more population orientated approach to defining sub-specific units in the fungi. Presents a scheme of terms and methodology as a basis for discussion.

BRASIER, C. M. and WEBBER, J. F. (1987). Positive correlations between *in vitro* growth rate and pathogenesis in *Ophiostoma ulmi*. *Plant Pathology* 36, 462–466.

*In vitro* radial growth rate was found to be positively correlated with pathogenicity in two experiments involving NAN aggressive isolates of *O. ulmi*. One of the correlations was detected in a sample of B mating-type, but not in equivalent A mating-type isolates. Another was detected in a sample of pathogenic phase, but not in comparable saprophytic phase isolates. The significance of these results for the vascular wilt syndrome and population biology of *O. ulmi* is discussed.

BRASIER, C. M. and WEBBER, J. F. (1987). Recent advances in Dutch elm disease research. In *Advances in practical arboriculture*, ed. Patch, D., Forestry Commission Bulletin 65, 166–179.

Discusses recent developments with shorter term disease control approaches aimed at treatment of high value amenity elms, including fungicide injection and experimental treatment with *Pseudomonas* and *Trichoderma*; and longer term research aimed at ameliorating the impact of the current epidemics, ranging from studies on the continuing changes in the pathogen population and beetle feeding preferences, to potential control by elm breeding and by viruses of the pathogen.

[CAPE, J. N., PATERSON, I. S., WELLBURN, A. R., WOLFENDEN, J., MELLHORN, H.,] FREER-SMITH, P. H. [and FINK, S.] (1988). *Early diagnosis of forest decline*. Institute of Terrestrial Ecology, Grange-over-Sands, Cumbria.

There is need for a predictive capability for the early diagnosis and objective quantification of the recent type of forest decline observed over large areas of Central Europe. This publication presents the results of an initial study to investigate diagnostic tests using material collected from several sites from southern Germany to north-east Scotland exposed to a wide range of pollution climates.

CARTER, C. I. and ANDERSON, M. A. (1987). *Enhancement of lowland forest ridesides and roadsides to benefit wild plants and butterflies*. Forestry Commission Research Information Note 126.

Wild plants and butterflies can be specially catered for in modern forests by widening and shaping the forest edge beside roads and rides. Rideside and roadside bays or glades provide alternatives to uniform widening. Recommended shapes and dimensions of these features have been worked out from calculations on the lengths of shadows thrown by adjacent trees during the growing season.

[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.

DAVIES, R. J. (1987). *Trees and weeds – weed control for successful tree establishment*. Forestry Commission Handbook 2. HMSO, London.

Landscape sites are often seeded with vigorous varieties of grass and legume species, which, while reducing soil erosion and giving an attractive green appearance may kill young trees or check their growth. Weeds compete with trees for moisture, nutrients and light; but they can also interfere by releasing toxins, modifying soil and air temperatures, and harbouring pests. The handbook guides the forester through the various methods of weed control – mowing, cultivation, herbicides, mulching and alternative ground-cover species.

DAVIES, R. J. (1987). *Do soil ameliorants help tree establishment?* Arboriculture Research Note 69/87/SILS.

Two experiments, one on sandy and one on clayey soil, tested a range of soil ameliorants, mixed into cultivated planting-pits. Seventy-five per cent of the Corsican pine planted into cultivated pits survived, compared with only 31 per cent in uncultivated soil; but the addition of ameliorants had no effect on survival or growth.

DAVIES, R. J. (1987). *Black polythene mulches to aid tree establishment*. Arboriculture Research Note 71/87/ARB.

Black polythene mulches greatly increase the survival and growth of young trees. Mulches should be at least 1 m square. Smaller mulches can be used to reduce the risk of herbicide damage which might occur when weeds close to the tree are sprayed.

DAVIES, R. J. (1987). *Sheet mulches: suitable materials and how to use them*. Arboriculture Research Note 72/87/ARB.

Many sheet materials make good mulches. To be effective they must be properly anchored and should remain intact for at least three years. The best materials are opaque and impermeable.

DAVIES, R. J. (1988). *Alginure root dip and tree establishment*. Arboriculture Research Note 75/88/ARB.

The effects of alginure root dip on tree establishment appear to be small. Under some conditions it was slightly beneficial but under others it was slightly harmful.

DAVIES, R. J. and PEPPER, H. W. (1987). *Protecting trees from field voles*. Arboriculture Research Note 74/87/ARB.

Field voles strip bark off the lower stem and roots of young trees, which are often killed thereby. Small plastic guards are usually cheaper and more effective than other methods of protection. Voles seem reluctant to cross bare ground, so weed-free trees suffer less damage than unweeded trees.

[DAVIES, W. J., METCALFE, J.,] TAYLOR, G. [and ZHANG, J.] (1987). Hormones as chemical signals involved in root-to-shoot communication of effects of changes in the soil environment. In *Hormone action and plant development – a critical appraisal*, eds. Hoad, G. V. Jackson, M. B., Lenton, J. R. and Atkin, R., 201–216.

It is suggested that roots are extremely sensitive to changes in the soil environment and that they may have the capacity to 'measure' soil water availability and to transfer this information to the shoot in the form of a chemical signal. Evidence is presented which suggests that ABA may be the chemical involved in this response.

EVANS, H. F. (1987). Sitka spruce insects: past, present and future. *Proceedings of the Royal Society of Edinburgh* **93B** 157–167.

The status of insects on Sitka spruce in Britain is examined in relation to the attributes of this tree as a widely planted exotic. Both time in Britain and particularly the area planted influence insect species diversity. The abundance and status of selected insects of pest importance are examined. Future trends receive attention, particularly in relation to potential importation of pest insects and this is examined for a number of species from Europe and North America.

EVANS, H. F. and ENTWISTLE, P. F. (1987). Viral diseases. In *Epizootiology of insect diseases*, eds. Fuxa, J. R. and Tanada, Y., Wiley, New York, 257–322.

Viral diseases of insects are described. Morphological, biochemical, biophysical and biological characteristics for all the major virus groups are included as well as a discussion on the evolutionary strategies adopted by viruses.

EVANS, H. F. and KING, C. J. (1988). *Dendroctonus micans – guidelines for forest managers*. Forestry Commission Research Information Note 128.

Gives symptoms of *D. micans* attack on spruce, the beetle's life cycle and status of *D. micans* as a forest pest. Also describes the measures that should be taken to control the insect.

EVANS, J. (1987). Management of broadleaved woodland in Britain. *Irish Forestry* **44** (2), 105–115.

Review emphasising need to manage neglected woodlands, thinning to improve stand quality, and development of better establishment techniques.

EVANS, J. (1987). Site and species selection – changing perspectives. *Forest Ecology and Management* **21**, 299–310.

An account of the changing criteria foresters must use when deciding choice of species for planting in tropical countries. The importance of involving farmers and local communities is stressed.

EVANS, J. and SHANKS, C. W. (1987). *Treeshelters*. Arboriculture Research Note 63/87/SILS (revised).

The technique of using treeshelters round recently planted broadleaved trees is now widely practised throughout Britain. Trees inside shelters grow much taller than unprotected trees. Shelters also provide protection from mammal damage, readily identify the planting position and permit easier weeding with herbicides. A shelter life of about 5 years is desirable.

EVANS, J. and WRIGHT, D. (1987). The Usutu Pulp Company – the development of an industrial forest. In *Sustainable industrial development*, ed. Carr, M., Intermediate Technology Publications, 151–171.

Economic and environmental effects of developing a 52 000 ha exotic pine forest in Swaziland as resource for Kraft pulp manufacture.

FAULKNER, R. (1987). Genetics and breeding of Sitka spruce. *Proceedings of the Royal Society of Edinburgh* **93B**, 41–50.

The species is highly heterozygous for many alleles. Phenotypic selection for vigour is therefore ineffective and therefore progeny and clonal testing is essential. The British improvement programme is based on the use of seed collected from superior plantation trees of desirable origin, later on from seed collected from clonal orchards based on clones tested for superiority in family tests. In the longer term highly superior seed is obtained from clones derived from a system of recurrent matings combined with family selection.



FORREST, G. I. (1987). A rangewide comparison of outlying and central lodgepole pine populations based on oleoresin monoterpene analysis. *Biochemical Systematic Ecology* **15**, 19–30.

The chemical diversity of interior populations was much higher than that of most peripheral populations. The chemotypic distributional data is discussed in relation to the recent history of the species and in particular to its relationship with Jack pine.

FORREST, G. I. (1987). Natural variation of native pinewoods. *Timber Grower* **105**, 39–41.

Biochemical techniques for 'finger-printing' individual trees have revealed the wealth of genetic variation which still exists within the present-day remnants of the ancient Caledonian forest.

FORREST, G. I. (1988). Finger-printing the Caledonian pine. *Curam* **4**, 14.

A brief description of the biochemical study of the Scottish remnant woodlands, and the conservation interest of particular populations.

FORREST, G. I. and LEATHER, S. R. (1988). It's biochemical warfare between 'Pine Beauty' and lodgepole pine. *Forestry & British Timber* **17** (3), 36–38.

The ability of the host plant to alter the chemistry of its resin is the key to an intriguing interaction between tree and insect.

FREER-SMITH, P. H. (1987). The responses of *Picea sitchensis* (Sitka spruce) to concentrations of SO<sub>2</sub> and NO<sub>2</sub>, experienced during dormancy and the implications for frost resistance. In *Direct effects of dry and wet deposition on forest eco-systems – in particular canopy interactions*, ed. Mathy, P., CEC Air Pollution Research Report 4, 201–209.

Pollutant exposures did not decrease plant dry weights, but exposure to NO<sub>2</sub> and SO<sub>2</sub> + NO<sub>2</sub> altered the plant water relations indicating that physiological effects occurred. There may be interactions in the effects of frost and winter pollutants which influence both bud (SO<sub>2</sub>) and needle (SO<sub>2</sub> + NO<sub>2</sub>) survival.

FREER-SMITH, P. H. (1988). Direct effects and dry and wet deposition on forest ecosystem – particularly canopy interactions. In *Air pollution and ecosystems*, ed. Mathy, P., D. Reidel, 217–224.

Considers mineral and nutritional status; interacting effects of SO<sub>2</sub>, NO<sub>x</sub> and O<sub>3</sub>; natural stress factors such as drought and frost; and the occurrence and effects of micro-pollutants on canopies.

FREER-SMITH, P. H. [and MANSFIELD, T. A.] (1987). The combined effects of low temperature and SO<sub>2</sub> + NO<sub>2</sub> on the new season's growth and water relations of *Picea sitchensis*. *New Phytologist* **106**, 237–250.

Seedlings were exposed to pollutants during dormancy in controlled environments, and were taken to 4, 0, –5, –10 and –15°C in a freezer in which temperature and humidity were carefully monitored. Poor bud break after exposure to SO<sub>2</sub> (45 ppb) resulted in the loss of the effectiveness of the chill requirement. Exposure to 30 ppb SO<sub>2</sub> and SO<sub>2</sub> + NO<sub>2</sub> led to slight but consistent increase in frost injury to needles.

GIBBS, J. N., [ENGLAND, N. and WOLSTENHOLME, R.] (1988). Variation in the pine stem rust fungus *Peridermium pini* in the United Kingdom. *Plant Pathology* **37**, 45–53.

*Peridermium pini* aeciospores from lesions on Scots pine (*Pinus sylvestris*) in Scotland and in Thetford Forest, East Anglia, differed in terms of germ tube morphology and cytology. Spores from both sources proved capable of causing infection of wounded Scots pine shoots. In addition, some Thetford spores caused infection on leaf discs taken from certain *Paeonia* cultivars. From these results it is concluded that two distinct forms of *Peridermium pini* exist in the UK.

GIBBS, J. N., GREIG, B. J. W. and HICKMAN, I. T. (1987). An analysis of *Peridermium* stem rust of Scots pine in Thetford Forest in 1984 and 1985. *Forestry* **60** (2), 203–218.

Five per cent of the 935 freshly felled trees were dead and 12 per cent had crown symptoms associated with girdling trunk lesions. Among the 775 trees with predominantly healthy crowns, it is estimated that 9 per cent would have died within 5 years, and 22 per cent within 20 years. By contrast 66 per cent had no disease at all, probably for genetic reasons. Information was also obtained on the rate of lesion development and the aspects of disease biology.

GILL, J. G. S. (1988). Juvenile-mature correlations and trends in genetic variances in Sitka spruce in Britain. *Silvae Genetica* 36 (5-6), 189-194.

Describes the value of early-testing in tree breeding programmes and introduces the concept of the coefficient of family variation. Two investigations into juvenile-mature correlations and trends in additive variance in Sitka spruce are described, one of which shows a decline in additive variance for vigour with age. Good correlations are shown between height at 3, 6 and 15 years.

GOSLING, P. G. (1987). Dormant tree seeds can exhibit similar properties to seeds of low vigour. In *Advances in practical arboriculture*, ed. Patch, D., Forestry Commission Bulletin 65, 28-31.

Several types of laboratory test are available to tree seed analysts. Recent evidence suggests that in the case of conifer and some broadleaved species, computer analysed comparisons between laboratory germination data obtained  $\pm$  pretreatment may provide a measure of the vague and illusive property known as seed vigour. The ability to detect this property could lead to a more accurate and reliable identification of seed lots whose field emergence will benefit from prechilling.

GOSLING, P. G. (1987). Report of the International Seed Testing Association 'Forest tree and shrub seed committee' 1983-86. *Seed Science and Technology* 15, 445-450.

The progress of the seven 'working groups' within the committee is reported for the period between the 1983-86 congresses.

GOSLING, P. G. (1988). Seed quality control. *Horticulture Week* 203, 16-17.

The role of the Forestry Commission Official Seed Testing Station is outlined and a brief description is given of the methods used in tree seed testing. The interpretation and application of laboratory results to field problems is discussed.

GRAYSON, A. J. (1987). *Evaluation of forest research*. Forestry Commission Occasional Paper 15. Forestry Commission, Edinburgh.

Three elements of research output are identified: those which apply to operations the results of which can be priced, those, largely with applications in the environmental field, for which monetary evaluation is currently impracticable, and those which have no direct application but add to knowledge and thus have scientific value. Application of this taxonomy to a range of Forestry Commission projects is described and methods of making the outputs commensurable outlined.

GREGORY, S. C. (1987). *Guidelines for monitoring and management of cold stores*. Forestry Commission Research Information Note 115.

Guidance is given on the monitoring and maintenance of temperature and humidity for overwinter storage of planting stock in directly, humidified and indirectly refrigerated cold stores. Advice is given on the avoidance of mould and on the timing of lifting for cold storage.

GREGORY, S. C. (1987). Honey fungus in gardens. *The Garden* 112 (11), 525-529.

This article gives an up-to-date account of the biology of *Armillaria* spp. in relation to their importance and control in gardens.

GREGORY, S. C. and REDFERN, D. B. (1987). The pathology of Sitka spruce in northern Britain. *Proceedings of the Royal Society of Edinburgh* 93B, 145-156.

In cases of damage investigated in north British forests and nurseries between 1971 and 1986, the most frequently diagnosed causes of injury to Sitka spruce were frost and the root pathogens *Heterobasidium annosum* and *Armillaria* spp. Two other root pathogens, *Rhizina undulata* and *Phaeolus schweinitzii*, and two needle pathogens, *Lophodermium piceae* and *Rhizosphaera kalkhoffii*, as well as several wound-infecting decay fungi were recorded in plantations. Only five other fungal diseases, those caused by *Botrytis cinerea*, *Phytophthora citricola*, *Helicobasidium purpureum*, *Sirococcus strobilinus* and *Pythium* spp. were recorded, all in nurseries.

GREIG, B. J. W. (1987). History of *Peridermium* stem rust of Scots pine (*Pinus sylvestris* L.) in Thetford forest, East Anglia. *Forestry* 60 (2), 193-202.

*Peridermium pini* has been present in Thetford forest on Scots pine for at least 40 years. Data are presented which show that there has been a dramatic increase in the disease between 1964 and

1979. The disease has apparently spread outwards from a central focus. An increase in disease from 28 to 46 per cent was recorded in 5 years, although only 1–2 per cent of the trees died. Limited data suggest that there has been no comparable increase in disease incidence in north-east Scotland.

GREIG, B. J. W. (1987). Aftermath of an epidemic. *Horticulture Week* **201** (26), 24–27.

In many areas devastated by the Dutch elm disease epidemic, English elms are producing prolific regeneration from coppice shoots and root suckers. The survival of this regeneration is monitored in a series of plots in southern England and to date around 80 per cent remains healthy. The future development of disease in the English elm regeneration is discussed.

GREIG, B. J. W. (1987). *Plectophomellea concentrica* on *Ulmus procera*. *Transactions of the British Mycological Society* **89** (3), 399.

*Plectophomellea concentrica* was described in 1981 causing cankers and shoot die-back on Wych elm in north-east Britain. This note reports the occurrence of *P. concentrica* on English elm in southern England.

[GURNELL, J. and] PEPPER, H. W. (1988). Perspectives of the management of red and grey squirrels. In *Wildlife management in forests*, ed. Jardine, D. C., Institute of Chartered Foresters, Edinburgh, 92–109.

The current state of squirrel management in Great Britain involving the conservation of red squirrels, and the control of both red and grey squirrels for protection against bark-stripping damage, is reviewed. Guidelines for more cost-effective and animal-orientated management tactics within the two broad strategies of conservation and control are discussed.

[HAND, S. C., ELLIS, N.W. and] STOAKLEY, J. T. (1987). Development of a pheromone monitoring system for the winter moth, *Operophtera brumata* (L.), in apples and in Sitka spruce. *Crop Protection* **6** (3), 191–196.

Winter moth (*Operophtera brumata*) can be an important pest both in top fruit orchards and in Sitka spruce plantations. Monitoring systems are required in both these crops to identify areas at risk and so to optimise the use of insecticide treatments. This paper is a report of work carried out to determine some of the requirements of a working monitoring system based on the recently identified pheromone (3Z, 6Z, 9Z)-1, 3, 6, 9,-nonadecatetraene. Experiments were carried out to discover the best trap design, pheromone dose level, lure change interval and trap height. Recommendations for the systems are made.

HARLAND, E. M. and PARKER, E. J. (1987). *Information services provided by the Forestry Commission Research Division*. Forestry Commission Research Information Note 123.

A comprehensive Forestry Commission scientific and technical information service for all those concerned with managing trees in Great Britain is based on the Forestry Commission Library at the Forest Research Station, Alice Holt Lodge, Wrecclesham, Nr Farnham, Surrey. A letter, telephone call, or personal visit (by arrangement) gives access to a wide variety of services.

HIBBERD, B. G. (1987). *The storm of 16th October 1987*. Forestry Commission Research Information Note 127.

The exceptional windspeeds of up to 90 knots (100 mph) experienced in the early hours of 16th October 1987 resulted in widespread damage to structures and trees in an area south and east of the line between Bournemouth and Kings Lynn. Many of the trees affected were broadleaved species in private and local authority ownership. This Note gives guidance for ordering priorities in the clearance, taking account of the possible deterioration of timber, insect damage and disease among remaining trees.

HIBBERD, B. G. (1987). Farm woodlands. *The Crondall Society News* (Autumn 1987) No. 30.

The Government's ALURE proposals are discussed in the context of Britain's need for wood and wood products. Changing land used in south-east England will enable greater diversity in the landscape, with opportunities for producing not only prime timber but also cover for game and habitats for wildlife.

INNES, J. (1987). *Surveys of tree health 1987*. Arboriculture Research Note 70/87/SSS.

Four surveys of tree health are currently in progress or about to commence, with emphasis on five of our most important species: Sitka spruce, Norway spruce, Scots pine, beech and oak. The surveys will provide information about the health of British trees which can then be related to environmental factors, both natural and man-made. Two of the surveys are being conducted by the Forestry Commission alone, the other two are co-operative ventures. In addition, the Forestry Commission is engaged in an analysis of the influence of environmental factors on shoot growth in beech.

INNES, J. L. (1987). Acid rain, air pollution and trees. *Quarterly Journal of Forestry* **81**, 191–193.

Current knowledge on the interactions between air pollution and forests in the United Kingdom is described. Surveys of forest health up to January 1987 revealed no evidence of a forest decline in the UK similar to that on the continent.

INNES, J. L. (1987) The interpretation on international forest health data. In *Acid rain: scientific and technical advances*, eds. Perry, R., Harrison, R. M., Bell, J. N. B. and Lester, J. N., Selver Ltd., London, 633–640.

The scientific basis of the surveys of forest health undertaken in Europe is questionable. Numerous difficulties are present and these frequently lead to the results of the surveys being misunderstood. A greater awareness of the limitations of the surveys is essential.

INNES, J. L. (1987). Dendroglaciological investigations in Norway. In *Applications of tree-ring studies*, ed. Ward, R. G. W., B.A.R. International Series 333, 107–119.

A dendroglaciological sampling network of over 40 sites has been established using Scots pine in Norway. At each site, at least 30 increment cores have been collected with ring sequences ranging from 100 to 450 years. This will provide a suitable database for reconstructing historic fluctuations in the sizes of glaciers in Norway.

INNES, J. L. (1987). *Air pollution and forestry*. Forestry Commission Bulletin 70. HMSO, London.

A full review of the role of pollution in forestry is presented. Both direct and indirect effects on trees are examined together with soil and water acidification. The various hypotheses of forest decline are examined: the most favoured hypothesis is related to the role of multiple stresses in forest decline.

INNES, J. L. and Boswell, R. C. (1987). *Forest health surveys 1987. Part 1: results*. Forestry Commission Bulletin 74. HMSO, London.

The results of the 1987 forest survey reveal that the overall crown densities of trees in Britain are similar to those in West Germany and elsewhere. As a result of changes in technique, it is not possible to say whether there has been any change in forest condition over the past four years.

INNES, J. L. (1988). Acid rain and other forms of air pollution – recent developments. *European Environmental Review* **1** (5), 38–45.

Recent developments in the 'acid rain debate' are summarised. There is an increasing amount of international legislation related to pollution control and this is described. The problems of determining cause and effect are examined in detail.

INNES, J. L. (1988). Forest health surveys 1987. *Forestry & British Timber* **17** (1), 40.

The results of the 1987 forest health survey are summarised in a format accessible to the British forestry industry.

INNES, J. L., BOSWELL, R. C. and NEUMANN, H. (1988). Waldschaden in Grossbritannien. Ergebnisse der Waldschadenserhebungen 1987. *Der Forst und Holzwirt* **43**, 64–66.

The results of the British forest health surveys are presented using the format adopted by West Germany to facilitate comparison between the results of the two countries.

KING, C. J. (1987). *Rhizophagus grandis as a means of biological control of Dendroctonus micans in Britain*. Forestry Commission Research Information Note 124.

Describes briefly the mass artificial rearing and release of *R. grandis* in Britain with methods used. Results of monitoring the progress and establishment of *R. grandis* in the field are also given. Some observations on the biology and dispersal of the predator are described.

KING, C. J. and FIELDING, N. J. (1987). Spruce beetle four years on – *Dendroctonus micans* – an update. *Forestry & British Timber* **16** (4), 21–24.

Describes the general strategy of *D. micans* control measures taken in Britain, including biological control using *Rhizophagus grandis* – its mass breeding, release and establishment. Also gives results of surveys to monitor population trends of *D. micans* and discusses the role of *D. micans* as a forest pest in the long term.

[KINLOCH, B. B., WESTFALL, R. D. and] FORREST, G. I. (1987). Caledonian Scots pine: origins and genetic structure. *New Phytologist* **104**, 703–729.

Monoterpene and isoenzyme loci, used as markers to study the genetic structure of native Scots pine in the relict Scottish populations, indicated the very high variability of all woodlands. Certain Wester Ross populations were distinct from all others and from each other. Results suggest the Caledonian race originated endemically from more than one refugium after the last glaciation.

LEATHER, S. R. (1987). *Lodgepole pine seed origin and the pine beauty moth*. Forestry Commission Research Information Note 125.

The pine beauty moth, *Panolis flammea* (D&S), appears to be able to distinguish between different seed origins of lodgepole pine (*Pinus contorta*), and egg laying is affected by the characteristic monoterpene profile of each origin. The origins preferred by the adult moths are those on which the caterpillars grow and develop best. Preferred seed origins are Central Interior, Southern Interior and South Coastal. Less preferred seed origins are from the North Coastal and Alaskan regions.

LEATHER, S. R. (1987). Pine monoterpenes stimulate oviposition in the pine beauty moth *Panolis flammea*. *Entomologia experimentalis et applicata* **43**, 295–297.

Female *P. flammea* did not lay their eggs at random on lodgepole pine needles treated with different concentrations of monoterpene solutions. Most eggs were laid on needles treated with a 3:1 B:K pinene solution. Very few eggs were laid on the control needles (equivalent to Alaskan lodgepole pine).

LEATHER, S. R. (1987). Lodgepole pine provenance and the pine beauty moth. In *Population biology and control of the pine beauty moth*, eds. Leather, S. R., Stoakley, J. T. and Evans, H. F., Forestry Commission Bulletin 67, 27–30. HMSO, London.

Female *P. flammea* show marked preferences for certain provenances of lodgepole pine on which to lay their eggs. Alaskan and north coastal provenances are avoided, south coastal and central interior provenances are preferred. Larval growth and survival are also affected by lodgepole pine provenance, those provenances that are preferred by the females being the most suitable for the larvae.

LEATHER, S. R. (1987). Generation specific trends in aphid life history parameters. *Journal of Applied Entomology* **104**, 278–284.

The mean number of ovarioles in successive generations of the aphids, *Rhopalosiphum padi* and *Myzus cerasi* on their respective primary hosts (*Prunus padus* and *P. avium*), declined with time and in proportion to the number of winged emigrants present. The apterous (non-winged) morphs had higher ovariole numbers than the alate (winged) morphs. Six sequential generations of *R. padi* were reared from the emigrant generation on oat seedlings at 20°C. Apterous offspring of apterous mothers in unbroken descent from the emigrants always had 10 ovarioles. Apterous which had an alate ancestor had only 8 ovarioles. Alate had a range of ovariole numbers (6–10) independently of their temporal distance from the original emigrant generation. The mean relative growth rates of apterous aphids with alate mothers were higher than those of apterous aphids with only apterous ancestors.

LEATHER, S. R. and BARBOUR, D. A. (1987). Associations between soil type, lodgepole pine (*Pinus contorta* Douglas) provenance, and the abundance of the pine beauty moth, *Panolis flammea* (D&S). *Journal of Applied Ecology* **24**, 945–951.

(1) Pupal numbers of the pine beauty moth, *Panolis flammea*, were highest in areas of deep unflushed peat and lowest in areas of peaty gleys and mineral soils. Soil suitability for lodgepole pine, *Pinus contorta*, was negatively correlated with number of pupae m<sup>-2</sup>.

- (2) There were many pupae associated with *P. contorta* from the north and centre of British Columbia. Few pupae were associated with *P. contorta* from the south coastal areas.
- (3) Within trees of the same provenance, higher pupal densities were associated with deep unflushed peat than with other soil types.
- (4) It is concluded that tree vigour (a consequence of soil type) is a major factor in the population dynamics of *P. flammaea*. It is likely that emphasis on the planting of less susceptible trees would lessen the dangers of outbreaks occurring in poor soil areas.

LEATHER, S. R. and BROTHERTON, C. M. (1987). Defensive responses of the pine beauty moth, *Panolis flammaea* (D&S) (Lepidoptera : Noctuidae). *Entomologist's Gazette* **38**, 19–24.

All stages of the life cycle of *P. flammaea*, apart from the egg, showed physical defence mechanisms against possible predator attack. These ranged from violent evasive actions in adults and larvae to ejections of body fluids in the larvae. The more pronounced the disturbance the greater the defensive response.

LEATHER, S. R. and BURNAND, A. C. (1987). Factors affecting life-history parameters of the pine beauty moth, *Panolis flammaea* (D&S): the hidden cost of reproduction. *Functional Ecology* **1**, 331–338.

Egg laying rates of *P. flammaea* were greater on some provenances of *Pinus contorta* than on others. The shorter the pre-reproductive delay, the greater the fecundity. Egg weights were negatively correlated with total and daily number of eggs laid. Eggs laid in poor quality hosts were larger than those laid on good quality hosts. Female lifespan was greatest on those hosts giving the greatest oviposition rate. Lifespan and fecundity were not correlated with adult weight.

LEATHER, S. R., STOAKLEY, J. T. and EVANS, H. F. (1987). *Population biology and control of the pine beauty moth*. Forestry Commission Bulletin 67. HMSO, London.

This contains a total of 14 papers presented at a workshop held at the Forestry Commission Northern Research Station, 17–18 December, 1984. All aspects of ecology, biology and control known to that date are presented.

LEATHER, S. R., WATT, A. D. and FORREST, G. I. (1987). Insect-induced chemical changes in young lodgepole pine (*Pinus contorta*): the effect of previous defoliation on oviposition, growth and survival of the pine beauty moth, *Panolis flammaea*. *Ecological Entomology* **12**, 275–281.

Significantly more eggs were laid by adult moths on previously undefoliated lodgepole pine saplings than on those which had been partially defoliated the previous year. Significant differences between the monoterpene profiles of the shoot cortical oleoresin of defoliated and undefoliated trees were linked to oviposition preferences.

LINES, R. (1985). Norway spruce in Romania. *Scottish Forestry* **39** (4), 282–287.

Describes a IUFRO meeting in Romania which included a tour of many fine seed stands. A description is given of Norway spruce in Romania and the methods used for seed collection. The best origins grow well in Britain, though too fast for use as Christmas trees.

LINES, R. (1986). Recent results from *Abies* provenance experiments in Britain. In *IUFRO Abies grandis provenance experiments: nursery stage results*, ed. Fletcher, A.M., Forestry Commission Research and Development Paper 139, 76–85. Forestry Commission, Edinburgh.

Recent results from forest experiments with *Abies alba* up to 10 years, *Abies grandis* (3 series) at 3, 6, and 10 years and *Abies procera* after one year in the nursery. With *A. grandis*, data from 17 sites show large differences due to seed origin in growth rate, flushing and frost damage. The tallest were from the north, east and south of the Olympic mountains of Washington.

LINES, R. (1987). Forestry in the Faroe Islands. *Scottish Forestry* **41** (2), 102–114.

The first plantation dates from 1904 and nine others were established on different islands before 1939. A wide variety of species has been tried and Sitka spruce and lodgepole pine have proved the most successful. It was surprising to find lodgepole pine, whose origin was the coast of Washington (47°N), growing well at 62°N. High wind speeds and low summer temperatures limit growth rate. A comparison is made with tree growth in Iceland and the northern isles of Scotland.

LINES, R. (1987). Seed origin variation in Sitka spruce. *Proceedings of the Royal Society of Edinburgh* **93B**, 25–39.

Describes 48 experiments planted between 1929 and 1975 which provide a good picture of the variation due to seed origin and the interaction with site factors. Differences in morphology and colour are slight and it is difficult to identify stands of unknown origin. Those from below 47°N grow fastest, but suffer more severe frost damage, particularly autumn frost in the nursery. They tend to have lower density timber than those from 53°N or above.

LINES, R. (1987). The changing form of Douglas fir. *Timber Grower* **104**, 12–13.

Poor stem and crown form in young stands is common and often blamed on inferior seed origins. Seed has always been imported from a variety of seed sources, though before 1951 about half as much came from British Columbia as from the USA. Since then only 8 per cent has come from British Columbia. Observations of the same plots over 30 years has demonstrated an apparent improvement in stem form, though grain distortion near the pith may lower wood quality.

LINES, R. (1987). *Choice of seed origins for the main forest species in Britain*. Forestry Commission Bulletin 66. HMSO, London.

This Bulletin includes recommendations for 12 conifers and 4 broadleaved species. They are based on results from large numbers of forest experiments. For each species the natural range, silvicultural characteristics, use in Britain and information from experiments is given, together with many literature citations for those interested in deeper study. For the practical forest manager a concise list of preferred origins is given and in some cases a warning against unsuitable ones.

LONSDALE, D. (1987). Prospects for long term protection against decay in trees. In *Advances in practical arboriculture*, ed. Patch, D., Forestry Commission Bulletin 65, 149–155. HMSO, London.

Due to the complexity and long-term nature of the decay process, evaluation of treatments remains incomplete. In short to medium term trials, commercial wound paints have at best delayed the colonisation of wounds by decay fungi, although more promising results have been obtained with the biocontrol agent *Trichoderma*. In contrast, the natural defences of the tree are of proven value, although they are often rendered ineffective by severe wounding and other avoidable damage.

LONSDALE, D. (1987). *Treatment of storm-damaged trees*. Arboriculture Research Note 73/87/PATH.

Gale damage to trees may leave them in a dangerous condition. It is important to make damaged trees safe as soon as possible, but immediate severe pruning may encourage the development of decay.

LONSDALE, D. and WAINHOUSE, D. (1987). *Beech bark disease*. Forestry Commission Bulletin 69. HMSO, London.

The development of the disease and its symptoms are described in relation to the ecology of the two organisms; the primary damaging agent *Cryptococcus fagisuga* (the beech scale insect) and the opportunistic fungal parasite, *Nectria coccinea*. Many features of the disease which have caused confusion are reviewed in the light of recent research. These include symptom variation, outbreak patterns, variation in the susceptibility of trees and the role of drought stress in lesion development.

LOW, A. J. (1987). Tree planting prospects in Shetland and Orkney. *Scottish Forestry* **41** (4), 282–296.

Growth in 32-year-old Forestry Commission trial plantations and in 15 to 30-year-old landowners' shelter blocks (and including the 70-year-old Kergord plantations) is described. Effective shelter planting is possible on a range of sites. Success requires careful site selection, adequate belt width, correct species choice, good site preparation, careful planting and tending and continued protection against damage. Wood production is unlikely to be economic but plantations have a high conservation value, providing roosts for large numbers of passerine birds during migration.

LOW, A. J. and WHYATT, J. G. (1988). Scarification as an aid to natural regeneration in the Glen Tanar native pinewood. *Scottish Forestry* **42** (1), 15–20.

Seedling development on 0.8 m<sup>2</sup> patch scarification by Leno single scarifier was monitored over 5 growing seasons on 0.8 ha felled unfenced site. After 5 years there was an average of 13 seedlings per scarified patch with tallest seedling height ranging from 3 to 35 cm. Results demonstrate the effectiveness of scarification as an aid to restocking managed eastern native pinewoods.

MASON, W. L. (1987). *Precision sown and undercut conifer planting stock. 1. Quality and performance.* Forestry Commission Research Information Note 129.

Since 1983, trials have been carried out at Wykeham nursery to develop a successful precision sowing and undercutting regime for a number of conifer species. Undercut plants generally are sturdier and have a more favourable shoot:root ratio than non-undercut transplants. Undercut stock also appears capable of withstanding cold storage better than transplants. In forest experiments, undercut plants generally show as good a survival rate as transplants and, in Douglas fir, performance is markedly better.

MASON, W. L. (1987). Gear up production. *Horticulture Week* 202 (9), 16–18.

Current commercial developments in the production of improved Sitka spruce cuttings are reviewed. Some 5–10 million plants per year could be produced by this method in the early 1990s. Cuttings offer an average genetic gain of approx. 10 per cent over conventional QCI stock. Costs of production are around twice those for conventional stock. Cuttings should be planted on stable sites in mixture with ordinary stock.

MASON, W. L. (1988). Trials with oxyfluorfen in northern forest nurseries. *Aspects of Applied Biology* 16, The practice of weed control in forestry, amenity and conservation areas, Association of Applied Biologists, 257–263.

Oxyfluorfen was tested for use on conifer seedbeds and transplant lines. It was also applied in mixture with propyzamide. It proved a safe and effective herbicide which should have considerable potential if marketed in the UK.

MASON, W. L. and HARPER, W. C. G. (1987). *Forest use of improved Sitka spruce cuttings.* Forestry Commission Research Information Note 119.

Reasons for commercial use of rooted cuttings of improved Sitka spruce are reviewed. Annual production should exceed one million by 1988 with further expansion in the 1990s. Cuttings come from bulked family mixtures offering an average of 10 per cent genetic gain over conventional stock. These should be planted on fertile, low windthrow hazard sites where Queen Charlotte Islands origins would normally be used. They should be planted in line mixtures with unimproved stock.

MASON, W. L. and HARPER, W. C. G. (1987). Improved Sitka spruce cuttings. *Timber Grower* 104, 11.

Implications of using surplus agricultural land for forestry are considered. Demand for forest plants could increase by 25 per cent. The present bare-root seedbed and transplant system has a number of defects and alternative systems such as precision sowing and undercutting, use of containers, and vegetative propagation are reviewed.

MASON, W. L. and WILLIAMSON, D. R. (1988). Recent research into weed control on seedbeds in forest nurseries. *Aspects of Applied Biology* 16, The practice of weed control in forestry, amenity and conservation areas, Association of Applied Biologists, 231–238.

Napropamide, metamiltron, isoxaben, a propham-fenuron-chlorpropham combination and various tank mixtures with diphenamid were tested for crop safety and weed control for pre-emergent use on seedbeds. Napropamide, metamiltron and propham-fenuron-chlorpropham were promising and warrant commercial trials.

MILLER, K. F., QUINE, C. P. and HUNT, J. (1987). The assessment of wind exposure for forestry in upland Britain. *Forestry* 60 (2), 179–192.

Several methods of assessing wind exposure on forest sites have been developed to aid the establishment and management of upland forests. These methods include the Topex system, based on the measurement of skyline angles, the measurement of attrition rates of exposed flags and the use of scaled topographic models in wind tunnel tests. A wind zonation of Britain for forestry applications is described. Refinement of methods is continuing.



MOFFAT, A. J. (1987). *The use of sewage sludge in forestry: an assessment of the potential in England and Wales*. Water Research Centre, Report PRU 1606-M.

The potential area of Forestry Commission forests in England and Wales which may be suitable for receiving sewage sludge is assessed. It is estimated that 219 km<sup>2</sup> could be treated, and would benefit from sewage application; most of this area is thinned, but a small amount of sewage could be applied after clearfell or before trees reached 5 years in age. 267 000 tonnes dry solid of sludge could be disposed over this area, with an additional 20 × 10<sup>6</sup> m<sup>3</sup> assuming reapplication at 5 yearly intervals.

MOFFAT, A. J. (1987). The geological input to the reclamation process in forestry. In *Planning and engineering geology*, eds. Culshaw, M. G., Bell, F. G., Cripps, J. C. and O'Hara, M., Geological Society Engineering Geology Special Publication No. 4, 541-548.

A geological understanding of a site is important if it is to be reclaimed successfully for a forestry after-use. Comprehensive site investigations before mineral extraction enable sensible decisions to be made concerning landform and drainage design, cultivation methods and species selection. Land given back to forestry is often of poor quality, and geological information helps to maximise the opportunities available. These points are illustrated with recent examples from British forestry practice.

MOFFAT, A. J. (1988). Land reclamation and forestry. *M & Q Environment* 2 (1), 18-19.

Over 71 155 hectares have been recognised by Department of the Environment (1974) as derelict in the United Kingdom. In fact, this figure appears to be increasing, despite strenuous efforts in recent times to restore and reclaim land in many parts of the country. Even in these days of agricultural surpluses, derelict land is undesirable: it gives no return and its appearance can inhibit regional investment. Invariably, derelict land can be restored to serve a useful purpose, whether it be for agriculture, forestry, amenity, housing or industry. But reclamation, as well as being a desirable end in itself, can also be an opportunity to create a new landscape and use land in different ways to that existing before dereliction took place. Forestry offers an exciting use of once derelict land, with many benefits in addition to the production of timber.

PARKER, E. J. (1987). *Technical publications issued during the year ending 31 March 1987*. Forestry Commission Research Information Note 120.

To keep readers abreast of recent information on forestry research, summaries are given of 11 priced and 3 unpriced technical publications issued in the past year. These, together with other currently available titles, are listed in the FC Catalogue of Publications 1987.

PATCH, D. (ed.) (1987). *Advances in practical arboriculture*. Forestry Commission Bulletin 65. HMSO, London.

A series of papers presented to a Seminar at the University of York, 10th-12th April 1985.

PATCH, D. (1987). Trouble at the stake. In *Advances in practical arboriculture*, ed. Patch, D., Forestry Commission Bulletin 65, 77-84.

A review of research into the effects of artificial support on stem development, reasons for supporting trees, and gives recommendations for modified practices of support.

PEPPER, H. W. (1987). Wildlife research for arboriculture. In *Advances in practical arboriculture*, ed. Patch, D., Forestry Commission Bulletin 65, 133-136.

Relatively little research has been undertaken specifically on wildlife problems in arboriculture because such problems are generally similar in all but scale to problems occurring in forestry, horticulture or agriculture. Research recommendations aimed at problems in these fields have been adapted to provide arboricultural solutions. Measurements of the field of wildlife enhancement for conservation have been neglected although small plantings are encouraged because of their potential wildlife value. Most advances have been made in the field of individual tree protection where most effort is now directed at reducing costs of materials and labour.

PEPPER, H. W. (1987). *Plastic mesh tree guards*. Arboriculture Research Note 74/87/ARB.

Light-degradable polyethylene plastic mesh tubes for use as tree guards to protect young trees vulnerable to damage by deer and rabbits are described. Their use in towns is also considered.

PEPPER, H. W. (1987). *Rabbit control – phostoxin*. Arboriculture Research Note 43/87/WILD (revised).

In rural areas rabbit control is essential if tree and shrub establishment is to be successful. Phostoxin may be used as an effective alternative to rabbit control by spoon-gassing with Cymag. It is also safer to handle than Cymag as it is a tableted formulation. The safety precautions which must be observed are listed.

PETTY, S. J. (1987). Breeding of tawny owls *Strix aluco* in relation to their food supply in an upland forest. In *Breeding and management in birds of prey*, ed. Hill, D. J., University of Bristol, 167–179.

In an upland forest in Northumberland, tawny owls *Strix aluco* fed mainly on field voles *Microtus agrestis*. The breeding success of 47–50 pairs of owls is given for the three years when field vole populations were high, declining and low respectively. The number of owl chicks fledged ranged from 142 in the high vole year to 7 in the low vole year. These results are discussed in relation to other studies.

PETTY, S. J. (1987). The design and use of a nestbox for tawny owls *Strix aluco* in upland forests. *Quarterly Journal of Forestry* 81 (2), 103–109.

The specification is given of a nestbox suitable for tawny owls *Strix aluco* in conifer forests. Boxes should be erected before December to obtain the highest occupancy in the following breeding season. In two upland forests, territories were situated along valleys where nearest neighbour distances ranged from 0.3–1.9 km. In 856 box years, 239 clutches were laid.

PETTY, S. J. (1988). The management of raptors in upland forests. In *Wildlife management in forests*, ed. Jardine, D. C., Institute of Chartered Foresters, Edinburgh, 7–43.

In upland forests, all raptors are solitary breeders and exhibit a regular spacing between pairs in suitable habitats. Their densities are governed primarily by food availability. Secondary factors such as a shortage of nest sites, interspecific competition and human persecution may also limit populations. Many simple management techniques are described which can be used to improve forests for this important group of birds. These practices are discussed in relation to current legislation.

POTTER, C. J. (1988). An evaluation of weed control techniques for tree establishment. *Aspects of Applied Biology* 16, The practice of weed control and vegetation management in forestry, amenity and conservation areas, Association of Applied Biologists, 337–346.

Weed control techniques that remove or kill weeds, thereby relieving root competition, result in improved survival and growth of trees. Trials of various mulching materials show heavy gauge black polythene to be the best. Weed control is most effective when it starts early in the growing season and produces a weed-free area with a diameter of at least 1 m. Growth benefits from weeding reduce after 3 years.

POTTER, M. J. (1987). *Restocking after windthrow*. Forestry Commission Research Information Note 131.

The storm of 16 October 1987 caused extensive windthrow in south-east England. This Note discusses the particular problems of restocking the wind damaged areas and advises on techniques.

POTTER, M. J. (1987). What future for *Nothofagus* in British forestry? *Forestry & British Timber* 16 (6), 31–32.

In the early 1970s *Nothofagus* was considered to have great potential as a timber producer but extensive losses during the hard winters of 1978/79 and 1981/82 dampened the enthusiasm of all but the most ardent supporters. Recent research has demonstrated that much of this problem could have been avoided with a better choice of provenance.

POTTER, M. J. (1987). Shelter questions and answers. *Forestry & British Timber* 16 (10), 28–29. This article provides answers to the most frequently posed questions concerning the use of treeshelters.

POTTER, M. J. (1987). Advances in treeshelter research and design. In *National Hardwoods Programme*, Report of the Seventh Meeting, ed. Savill, P. S., Oxford Forestry Institute Occasional Paper 34, 1-4.

As the use of treeshelters has expanded a number of problems have been experienced. These have generally been overcome by design improvements. Remaining difficulties are being examined in research projects associated with insect infestation and light relations.

POTTER, M. J. (1988). Vaekstror – sporgsmål og svar. *Skogen* 2, 72-73.

The background to treeshelter development is briefly explained and advice offered on the most frequent problems.

PYATT, D. G. (1987). The effect of afforestation on the water and oxygen regimes of stagnopodzols. In *North of England Soils Discussion Group Proceedings* 22, 93-108.

Stagnopodzols periodically have a perched water table and poor aeration in the layers above the thin ironpan. When a forest plantation is well established the waterlogging and aeration problems tend to be eliminated by the drying effect of the trees, but in some sites this process is aided by preliminary deep cultivation.

QUINE, C. P. (1987). Damage to trees and woodlands in the storm of 15-16 October 1987. *Weather* 43 (3), 114-118.

Details of the volume of timber windthrown from woodland and non-woodland trees in the October 1987 storm are summarised. Comparisons are made with the three previous storm events that have caused catastrophic damage to British forests since 1945, and differences in woodland composition between affected areas are noted. Similar damage to European forests is also reviewed and research investigations into both catastrophic and endemic windthrow are outlined.

RATCLIFFE, P. R. (1987). How many deer? *Timber Grower* 105, 20.

Describes methods of checking field estimates of deer numbers based upon the retrospective reconstruction of minimum populations using cohort analysis.

RATCLIFFE, P. R. (1987). *The management of red deer in upland forests*. Forestry Commission Bulletin 71. HMSO, London.

The Bulletin gives practical prescriptions for the management of woodland red deer populations based upon the collection of biological data.

RATCLIFFE, P. R. (1987). Red deer population changes and the independent assessment of minimum population size. *Symposium of the Zoological Society of London* 58, 153-165.

The growth of a red deer population is simulated using a Leslie-Matrix model. Census techniques seriously underestimated population size. The population has apparently increased from about 1500 in 1965 to about 4000 in 1986. Further simulations are used to consider present management options which suggest that a cull of about 20 per cent of total population is necessary to prevent further increase.

RATCLIFFE, P. R. (1987). The future of the red deer in Galloway. *Deer* 7, 134-136.

This paper summarises a more complete treatment (see abstract above). Although increased knowledge of the population ecology of deer in Galloway led to higher culls, the population continues to grow. This is likely to cause an increase in damage to commercial trees, increased impact on plant communities and a deterioration in the quality of the deer.

RATCLIFFE, P. R. (1988). The management of red deer populations resident in upland forests. In *Wildlife management in forests*, ed. Jardine, D. C., Institute of Chartered Foresters, Edinburgh, 44-53.

This paper summarises the practical prescriptions for deer management contained in Forestry Commission Bulletin 71. The optimum carrying capacities for trophies compared to venison production are different and the densities at which serious impact occurs are lower than both of these.

RATCLIFFE, P. R. and PEPPER, H. W. (1987). The impact of roe deer, rabbits and grey squirrels on the management of broadleaved woodlands. In *National Hardwoods Programme*, Report of the Seventh Meeting, ed. Savill, P. S., Oxford Forestry Institute Occasional Paper 34, 39-50.

Roe deer, rabbits and grey squirrels can severely reduce the productivity of broadleaved woodlands. The areas at risk and the predicted impact are described. The practical difficulties of control are discussed and solutions suggested.

REDFERN, D. B., GREGORY, S. C., PRATT, J. E. and MacASKILL, G. A. (1987). Foliage browning and shoot death in Sitka spruce and other conifers in northern Britain during winter 1983–84. *European Journal of Forest Pathology* **17**, 166–180.

A hitherto undescribed form of injury to Sitka spruce and other conifers occurred in plantations throughout northern Britain during the dormant season 1983–84. Damage consisted primarily of shoot death which was typically concentrated in a zone of variable extent below the upper few whorls of the tree. It occurred predominantly in forests in the west and was most severe in older crops at high elevation. Possible causes are discussed and it is concluded that the damage was probably climatic in origin.

REDFERN, D. B., STOAKLEY, J. T., STEELE, H. and MINTER, D. W. (1987). Dieback and death of larch caused by *Ceratocystis laricicola* sp. nov. following attack by *Ips cembrae*. *Plant Pathology* **36**, 467–480.

The bark beetle *Ips cembrae* acts as a vector for *C. laricicola* which it introduces into larches during breeding attacks. The fungus kills bark and cambium, and multiple inoculations resulting from numerous beetle attacks may cause dieback and death of trees. Trees damaged by *I. cembrae* and *C. laricicola* may be attacked subsequently by the woodwasp *Urocerus gigas* which introduces a sapwood decay fungus, *Amylostereum chailletii*. This is the first record of dieback caused by an association between *I. cembrae* and a species of *Ceratocystis* and the first record of dieback in larch caused by *I. cembrae* and *C. laricicola*. *I. cembrae* was introduced into Britain from mainland Europe and a similar association may exist there.

REES, A. A. (1988). Infection of *Pinus caribaea* seed by *Lasiodiplodia theobromae*. *Transactions of the British Mycological Society* **90** (2), 321–324.

Between 8 and 11 per cent of a *Pinus caribaea* seedlot from Nicaragua were infected with *Lasiodiplodia theobromae*. The infection was predominantly internal, so the pathogen was unlikely to be eliminated by surface sterilization.

[ROGERS, H. J., BUCK, K. W. and] BRASIER, C. M. (1987). A mitochondrial target for double-stranded RNA in diseased isolates of the fungus that causes Dutch elm disease. *Nature* **329**, 558–560.

The ten dsRNA segments in a mycovirus diseased or d-infected isolate of *O. ulmi* co-purify with the mitochondria. The mitochondria isolated from such diseased isolates are deficient in cytochrome oxidase aa3 (a mitochondrial respiratory enzyme). DsRNA segments 4, 7 and 10 may be responsible for the cytochrome deficiency. This seems to be the first report of fungal mitochondria as targets for deleterious effects associated with dsRNA segments or mycoviruses. Elucidation of the mechanisms which cause reduction of cytochrome oxidase aa3 in *O. ulmi* may help in the design of genetically manipulated d-factors suitable for the biological control of Dutch elm disease.

ROLLINSON, T. J. D. (1987). *Timber measurement of windblown trees*. Forestry Commission Research Information Note 130.

Timber measurement of windblown trees is likely to be extremely difficult and it is usually better to measure the timber *after* it has been extracted from the site. Measurement procedures for individual trees and stands of trees are given.

ROLLINSON, T. J. D. (1987). Quantifying the effects of damage on tree growth—some measurement problems. In *Development of thinning systems to reduce stand damages*, ed. Knutwell, H., Swedish University of Agricultural Sciences, Research Note 98, 64–72.

Studies of the effects of damage on tree growth are often based on comparisons of the growth of apparently healthy and damaged trees. Current measurement techniques and sample procedures are often inadequate. Measurement techniques for individual trees are discussed.

ROLLINSON, T. J. D. (1987). The yield of unthinned Sitka spruce in Great Britain. *Scottish Forestry* 41 (4), 265–272.

The measured volume yield to 7 cm and 18 cm top diameter overbark was compared with the predicted yield taken from published yield tables for 64 plots of unthinned Sitka spruce. There was no bias in the volume yield to 7 cm and the yield table over-estimated volume to 18 cm by 8 per cent on average. Yield tables may give reasonably accurate forecasts of production for a number of stands averaged over forests, but they may give inaccurate estimates for individual stands.

ROLLINSON, T. J. D. (1988). Respacing Sitka spruce. *Forestry* 61 (1), 1–22.

An experiment to test the effects of different intensities of respacing on the growth and yield of Sitka spruce was established in an 8-year-old stand; treatments applied gave stand densities of between 430 and 3190 stems per hectare. The relative magnitude of differences are discussed in relation to the subjects of growth and yield, wood quality, the selection of tree stands and tree stability. The possible use of respacing treatments in practice is discussed briefly.

ROLLINSON, T. J. D. (1988). *Thinning control*. Forestry Commission Field Book 2. HMSO, London.

A replacement for Booklet 54, printed on tough water-resistant paper.

ROSS, P. G. (1988). Herbicide use in British tree nurseries: problems and perspectives. *Aspects of Applied Biology* 16, The practice of weed control in forestry, amenity and conservation areas. Association of Applied Biologists, 245–248.

Current herbicide regimes at Bareagle nursery are described. Control of triazine-resistant weeds is a particular problem, but oryzalin and napropamide are possible alternatives if made available. Future developments in weed control are considered.

[SANDERS, C. P. R., PITTER, R. L.,] GARDINER, B. A. and HALLETT, J. (1988). An airborne precipitation cloud particle charge measurement device and analysis system. *Journal of Atmospheric and Oceanic Technology* 5 (1), 149–153.

A system is described for measurement and analysis of precipitation particle charge in the highly variable and harsh environment of a convective cloud.

SHARPE, A. L., HOWES, R. E. J. and MASON, W. L. (1988). *Precision sown and undercut conifer planting stock. II. Nursery regimes*. Forestry Commission Research Information Note 132.

Research trials since 1983 have developed a successful regime for the production of high quality precision sown and undercut conifer planting stock. The regime is based upon drill sowing at 150–400 seeds per m<sup>2</sup>, followed by intensive undercutting and wrenching in the second growing season. Additional nitrogen applications are necessary to prevent the stock becoming deficient. A good nursery soil and adequate irrigation are required.

[SIBBALD, A. R., MAXWELL, T. J., GRIFFITHS, J. H., HUTCHINS, N. J.,] TAYLOR, C. M. A., TABBUSH, P. M. and WHITE, I. M. S. (1987). Agroforestry research in the hills and uplands. In *Agriculture and conservation in the hills and uplands*, eds. Bell, M. and Bunce, R. G. H., Institute of Terrestrial Ecology Symposium 23, 74–77.

Description of a model on the potential of agroforestry in the uplands of Britain and the first experiment established to test certain aspects of the model.

[STAINES, B. W. and] RATCLIFFE, P. R. (1987). Estimating the abundance of red deer (*Cervus elaphus* L.) and roe deer (*Capreolus capreolus* L.) and their current status in Great Britain. *Symposium of the Zoological Society of London* 58, 131–152.

Direct censuses of deer are reliable in open habitats but not in dense woodlands. Recent developments in methods for assessing deer numbers in commercial forests are described. Red deer numbers are now in excess of 300 000 with densities commonly achieving values of 15–30 km<sup>-2</sup> and exceptionally 40 km<sup>-2</sup>. Roe deer continue to expand their range and densities of 25–30 km<sup>-2</sup> occur. There is every reason to believe that numbers will continue to increase in the foreseeable future.

[STAINES, B. W.,] PETTY, S. J. and RATCLIFFE, P. R. (1987). Sitka spruce *Picea sitchensis* (Bong.) Carr. forests as a habitat for birds and mammals. *Proceedings of the Royal Society of Edinburgh* **93B**, 169–181.

Sitka spruce *Picea sitchensis* comprises the largest single forest type in Britain and provides a vast reservoir for wildlife. Four major food categories are identified in Sitka spruce forests, and the abundance of each is discussed in relation to the growth stage of the forest, the birds and mammals utilising it, management strategies to improve its wildlife potential, and research requirements.

STOAKLEY, J. T. (1987). Pine beauty moth control: past, present and future. In *Population biology and control of the pine beauty moth*, eds. Leather, S. R., Stoakley, J. T. and Evans, H. F., Forestry Commission Bulletin 67, 87–90.

Reviews development of control methods, control programmes using fenitrothion, choice of spray equipment, alternative insecticides and cultural considerations. It is suggested that pine beauty moth infestation should be recognised as a silvicultural problem in the broadest sense.

TABBUSH, P. M. (1987). *Safe dates for handling and planting Sitka spruce and Douglas fir*. Forestry Commission Research Information Note 118.

Examination of seasonal changes in root growth potential (RGP), frost hardiness and dormancy, and consideration of the importance of soil temperature shortly after planting, have led to greater understanding of the effect of planting date on the establishment of forest trees. This Note describes the seasonal variation in RGP for transplants of Sitka spruce and Douglas fir, supplied directly or from cold stores, and gives guidance on safe dates for handling, storage and planting.

TABBUSH, P. M. (1987). Effect of desiccation on water status and forest performance of bare rooted Sitka spruce and Douglas fir transplants. *Forestry* **60** (1), 31–43.

Exposure of Sitka spruce transplants to drying conditions in March for 104 minutes had no effect on subsequent survival or growth, but exposure for 198 minutes reduced survival to 68 per cent. Douglas fir survival was much poorer for similar periods of exposure and started after shorter periods. Rewetting for 1 hour in the dark had no significant effect on survival or growth in either species.

TABBUSH, P. M. and WHITE, I. M. S. (1988). Canopy closure in Sitka spruce – the relationship between crown width and stem diameter for open grown trees. *Forestry* **61** (1), 23–37.

A highly significant linear relationship was found between crown width and breast height diameter (D) of Sitka spruce by measuring open grown trees. The relationship may be used to predict the time of canopy closure from a knowledge of the development of D with age for a given stand.

TABBUSH, P. M. and WILLIAMSON, D. R. (1987). *Rhododendron ponticum as a forest weed*. Forestry Commission Bulletin 73. HMSO, London.

A brief description is given of the biological characteristics of *R. ponticum*, a control strategy is suggested and control by physical and chemical methods discussed. Current recommendations on chemicals, rates, dates and methods of application are given.

TAYLOR, C. M. A. (1987). The effects of nitrogen fertiliser at different rates and times of application on the growth of Sitka spruce in upland Britain. *Forestry* **60** (1), 87–99.

Summary of the results from seven experiment sites in Scotland and northern England, indicating no difference in growth response between urea and ammonium nitrate or season of application. However, there were differences associated with rate of fertiliser, which varied according to the fertility of the site.

TAYLOR, C. M. A. (1987). *The use of sewage sludge in forestry: an assessment of the potential in Scotland*. Water Research Report, PRU 1707–M.

A joint desk study was undertaken by the Water Research Centre and the Forestry Commission based on sludge supply in 4 zones within 10 and 20 miles radius of forests, making assumptions of the crop site types which would benefit from applications. The potential area was 38000 ha or 8500 ha annually which would have provided an outlet for  $\frac{1}{3}$  of sludge production but economic radius of distribution to Forestry Commission forests would reduce this to 1300 ha annually and would consume nearly 14000 t ds of sludge. Including private forests, new planting areas and restored land, there is a potential for utilising 15 per cent of sludge production, mainly in E and NE Scotland.

TAYLOR, C. M. A. (1988). Agroforestry – you won't see the food for the trees. *Forestry & British Timber* 17 (3), 20, 23, 31.

Description of the background to research on agroforestry in the uplands, the problems to be solved and the experimental programme.

TAYLOR, G. [and DAVIES, W.] (1988). The influence of photosynthetically-active radiation and simulated shadelight on the control of leaf growth of *Betula* and *Acer*. *New Phytologist* 108, 393–398.

The growth rate of birch leaves is extremely sensitive to light intensity, with rapid leaf extension occurring in response to light intensity. Conversely, the growth rate of sycamore leaves is unaffected by rapid changes of PAR. A biophysical analysis of the intrinsic factors which govern the growth of leaf cells reveals that for birch, cell wall acidification and loosening occur in response to light, whilst for sycamore this mechanism is absent. This result may help to explain the relative abilities of the two species to tolerate woodland shadelight.

WAINHOUSE, D. (1987). Forests. In *Integrated pest management*, eds. Burn, A. J., Coaker, T. H. and Jepson, P. C., Academic Press, 361–401.

A detailed review of integrated pest management in European forests.

WAINHOUSE, D., GATE, I. M. and LONSDALE, D. (1988). Beech resistance to the beech scale: a variety of defences. In *Mechanisms of woody plant defences against insects*, eds. Mattson, W. J., Levieux, J. and Bernard-Dagan, C., Springer Verlag, 277–293.

The level of infestation of individual beech trees is largely determined by host defensive reactions, genetic variations in susceptibility and development of subpopulations of beech scale.

WATT, A. D. and LEATHER, S. R. (1987). Pine beauty moth population dynamics: synthesis, simulation and prediction. In *Population biology and control of the pine beauty moth*. Forestry Commission Bulletin 67, 41–45.

Simulation models showing the possible effects of weather and host plant provenance are presented. The possibility of pest management is discussed.

WEBBER, J. F. (1987). Influence of the  $d^2$  factor on survival and infection by the Dutch elm disease pathogen *Ophiostoma ulmi*. *Plant Pathology* 36, 531–538.

A particular form of mycovirus, the  $d^2$  factor, which attacks the elm pathogen *Ophiostoma ulmi*, was found to be extremely deleterious to this fungus both *in vitro* and *in vivo*. Most significantly,  $d^2$ -infected conidia were poor at persisting in feeding grooves, the usual infection court of the pathogen, and also showed a 50-fold reduction in successful xylem infection compared with their healthy counterparts. In addition, transmission of the  $d^2$  factor from diseased to healthy isolates of *O. ulmi* was found to take place in feeding grooves, indicating that the fungus exists in a mycelial phase prior to its invasion of the xylem vessels.

WILLIAMSON, D. R. (1988). Sprayer calibration is not so difficult. *Forestry & British Timber* 17 (2), 35–39.

The definitions of terms used in forestry herbicide application are explained. This is followed by a detailed look at the variables involved in the calibration of spraying equipment. Finally, an explanation of how to deal with the problems of applying herbicide to clumps or bushes is given.

WILLIAMSON, D. R. and TABBUSH, P. M. (1988). Forestry Commission experiments with terbuthylazine-atrazine mixtures for grass control in forestry. *Aspects of Applied Biology* 16, The practice of weed control in forestry, amenity and conservation areas, Association of Applied Biologists, 89–103.

Experiments are reported which tested terbuthylazine-atrazine liquid and terbuthylazine granules on two coniferous and seven broadleaved species. April applications appeared optimum for the liquid formulation but winter (Oct.–Feb.) application gave best results from the terbuthylazine granules. Sitka spruce was not damaged by any of the treatments but the liquid did cause damage to hybrid larch and the broadleaved species especially when applications were made after growth had started in the spring.

WILLSON, A., WADDELL, D. A. and DURRANT, D. W. H. (1987). *Experimental work on air pollution*. Forestry Commission Research Information Note 121.

We are investigating the effects of air pollutants on trees in rural areas by comparing growth in ambient air with growth in air with three levels of filtering. The trees are growing in open-top chambers at three sites in Britain. Initial results show effects on leaves of 18 cultivars representing four species of poplar, but no effects on Sitka and Norway spruces, while Hampshire ambient concentrations of ozone reduced the root biomass of Scots pine seedlings. Plant biomonitors will extend the studies to a wide range of sites.

WINTER T. G. (1987). Inland breeding of *Euproctis chrysorrhoea* (L.) (Lepidoptera: Lymantriiidae) in Hampshire and West Sussex. *Entomologist's Gazette* **38** (2), 124.

First record of brown-tail moth breeding in north Hampshire (v.c. 12) in 1986 and at other inland locations in south Hampshire (v.c. 11) and West Sussex (v.c. 13) well outside the usual seaboard distribution of this species.

WINTER, T. G. (1988). *Tremex columba* L. (Hym., Siricidae) imported into Britain in elm logs. *Entomologist's Monthly Magazine* **124**, 36.

Adults of this North American woodwasp emerged in a container of elm at High Wycombe, Bucks. The host range of this insect and the presence in Britain of a fungus which is closely associated with larval development suggest *T. columba* may be fitted to become established if fertilised females escape.

WINTER, T. G. (1988). Larvae of *Chyliza fuscipennis* (Robineau-Desvoidy) (Dipt., Psilidae) in coniferous resin. *Entomologist's Monthly Magazine* **124**, 73-76.

Larvae of an unidentified dipteran were found during *Dendroctonus micans* surveys in 1982 and subsequent years associated with resinous wounds on spruces and pines. An adult reared in 1985 was identified as *Chyliza fuscipennis*, a fly of which nothing was known of the immature stages or biology. The larva is described and figured together with notes on the life cycle and distribution in Britain.

WINTER, T. G. and BURDEKIN, D. A. (1987). The poem and the pest. *Quarterly Journal of Forestry* **81** (4), 234-238.

A 19th century sonnet by Charles Tennyson Turner (brother of Alfred Lord Tennyson) describes an insect epidemic in Germany which was probably an outbreak of *Ips typographus* in Bohemia (1869-75) of which details are given. This bark beetle is not indigenous to Britain but does sometimes occur in imported spruce. A brief history of such records is given together with current plant health measures to prevent its establishment in this country.

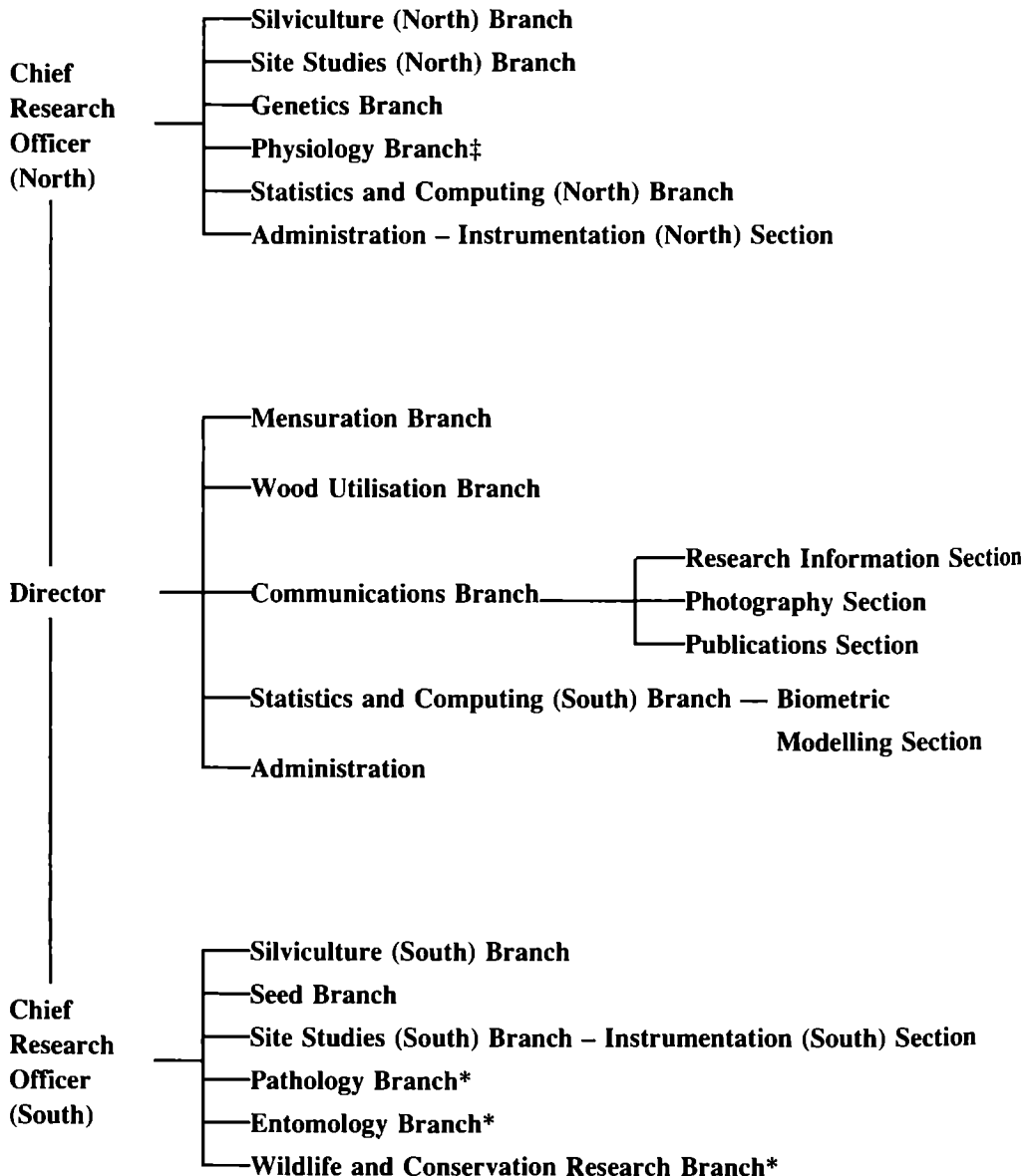
WINTER, T. G., STROUTS, R. G. and GIBBS, J. N. (1987). Getting to the roots of tree damage. *Turf Management* **6** (5), 53-54, 56.

Discusses in general terms damage caused to landscape trees by pests and diseases and that arising from the effects of drought, frost, herbicides and pollution.



## 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 31/3/88</u>
Research	P. G. Gosling
Service	P. G. Gosling
<b>Silviculture (South)</b>	
Plant production	D. R. Williamson
Species	M. J. Potter
Establishment	M. J. Potter
Weed control	D. R. Williamson
Farm forestry	H. L. Davies
Contracts: arboriculture advisory and information service	D. Patch
arboriculture research	C. J. Potter
short rotation coppice	H. L. Davies
Dendrology	J. E. J. White
<b>Silviculture (North)</b>	
Plant production	W. L. Mason
Species	C. M. A. Taylor
Planting	D. G. Nelson
Nutrition	C. M. A. Taylor
Cultivation	C. P. Quine, D. G. Nelson
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>Genetics</b>	
Testing progeny and provenances	S. J. Lee, A. M. Fletcher
Production: clone banks and orchards	A. M. Fletcher, R. Faulkner
Stands: registration of seed sources	R. Faulkner
Biochemical variation	G. I. Forrest
Biometrical studies	C. J. A. Samuel

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

**Physiology**

Root growth and form	M. P. Coutts
Bent top	M. P. Coutts
Upland restocking	J. J. Philipson
Flowering	J. J. Philipson
Micropropagation	A. John
Rejuvenation	A. John, A. M. Fletcher
Mycorrhizas	C. Walker
Development of rooting patterns	C. Walker
Propagation of broadleaves	R. Harmer

**Pathology**

<i>Heterobasidion annosum</i>	D. B. Redfern, B. J. W. Greig
Dutch elm disease	C. M. Brasier
<i>Armillaria</i>	S. C. Gregory
Beech health	D. Lonsdale
Contract: decay in amenity trees	D. Lonsdale
Advisory	R. G. Strouts, D. B. Redfern

**Entomology**

<i>Dendroctonus micans</i>	H. F. Evans, D. Wainhouse,
	C. J. King
<i>Panolis flammea</i>	J. T. Stoakley, S. R. Leather
Beech bark disease	D. Wainhouse
<i>Elatobium abietinum</i>	C. I. Carter
<i>Hylastes</i> and <i>Hylobius</i>	J. T. Stoakley, S. G. Heritage
<i>Bupalus piniaria</i>	D. A. Barbour
Advisory and taxonomic	T. G. Winter
Genetic variations	M. R. Jukes

**Wildlife and Conservation**

Red deer	P. R. Ratcliffe
Other deer (roe and sika)	P. R. Ratcliffe
Squirrels (red and grey)	H. W. Pepper
Birds	S. J. Petty
Damage	H. W. Pepper
Repellents (fencing and tree guards)	H. W. Pepper
Bats	B. A. Mayle
Vegetation management in lowland forests	M. A. Anderson
Vegetation management in upland forests	G. S. Patterson
Watercourse management in upland forests	G. S. Patterson

**Mensuration**

Sample plots	G. Kerr
Measurement studies	G. Kerr
Yield modelling	G. Kerr
Management services	G. Kerr
Data terminals	J. M. Gay

**Wood Utilisation**

Wood quality	D. A. Thompson
Preservation	D. A. Thompson
Utilisation of broadleaves	D. A. Thompson

**Statistics and Computing (South)**

Forest growth modelling	A. R. Ludlow
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## APPENDIX IV

## Net Expenditure of Research Division 1987/88

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	94	28	–	122
Silviculture (South)	691	76	25	792
Arboreta	336	–	–	336
Silviculture (North) <sup>(f)</sup>	1555	–149	23	1429
Site Studies (South) <sup>(g)</sup>	529	82	88	699
Site Studies (North)	114	62	3	179
Genetics	603	182	–	785
Physiology	264	75	7	346
Pathology	439	75	52	566
Entomology	488	54	30	572
Wildlife and Conservation	324	55	132	511
Mensuration	171	148	–	319
Wood Utilisation	75	30	177	282
Statistics and Computing (South)	504	–403	–	101
Statistics and Computing (North)	189	–189	–	–
Communications	378	– 80	–	298
Total <sup>(e)</sup>	<u>6754</u>	<u>46<sup>(h)</sup></u>	<u>537</u>	<u>7337</u>

*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 £1315 (000), plus Forestry Commission headquarters overheads for common services of £437 (000), net of income of £192 (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. The latter in particular are regarded as being more realistic than in earlier accounts.
- (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 £48 (000).
- (i) Branches' work on behalf of Forest Authority Plant Health amounted to £69 (000).

## APPENDIX V

### Staff Engaged in Research

As at 31 March 1988

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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 genetics, and for silviculture and site studies in the uplands.)

---

## STAFF AT ALICE HOLT LODGE

## SEED BRANCH

P. G. Gosling, B.Sc., Ph.D., Head of Branch  
Miss A. M. Bolster, Mrs P. J. Rigg, Mrs Y. K. Samuel

## SILVICULTURE BRANCH (SOUTH)

J. Evans, B.Sc., Ph.D., F.I.C.For., Head of Branch  
H. L. Davies, B.Sc., D. Elgy, Mrs C. J. Potter, B.Sc., M. J. Potter, B.Sc., M.I.C.For.,  
J. E. J. White (*Westonbirt*), D. R. Williamson, B.Sc.

	<i>Outstation staff:</i>	<i>Centre</i>
<i>East England Region</i>	A. T. Armstrong, S. M. Colderick, P. D. Howard, P. Marsh, C. W. Shanks J. S. McIntyre S. E. Malone, T. D. Cooper	Alice Holt Bedgebury Thetford
<i>West England Region</i>	H. C. Angus P. A. Gregory, M.I.Hort., D. G. Rogers, N. A. Smith M. W. Allen	Westonbirt Exeter Dean

## ARBORICULTURE 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  
P. G. Crow, D. W. H. Durrant, B.A., J. L. Innes, M.A., Ph.D., Miss S. E. Lee, 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

## PHYSIOLOGY 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, D. R. Rose, 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, T. Jennings, 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., 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  
M. A. Anderson, B.Sc., A. Chadwick (*Cowal, Strathclyde*), Mrs B. A. Mayle, H. W. Pepper,  
S. J. Petty (*Cowal, Strathclyde*), G. A. Patterson, B.Sc., M.I.C.For. (*Northern Research  
Station*).

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

MENSURATION BRANCH

G. Kerr, B.Sc., Head of Branch

E. J. Fletcher, Miss J. M. Gay, B.Sc., A. F. Martin, B.Sc.(For.), R. W. Matthews. B.Sc., M.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. Møllergaard, 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)

ADMINISTRATIVE Staff

HEO: Mrs B. K. Bartlett (*Personnel*), R. Murray (*Accounts*)

EOs: Mrs J. C. Gates (*Personnel*), Miss J. R. Lacey (*Accounts*), Miss K. Beattie (*Office Services*)

---

## 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. 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	Northern Research Station
<i>North Scotland Region</i>	J. C. Keenleyside	Newton, Grampian
North Scotland Area	W. G. Paterson, N. M. Proctor, B.Sc., J. Boluski	Lairg, Highland
North East Scotland Area	A. A. Green, J. Davidson, B.A., M.I.C.For.	Newton, Grampian
<i>Central Scotland Region</i>	J. D. McNeill	Northern Research Station
East Scotland Area	F. S. Smith, W. F. Rayner	Perth, Tayside
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<i>Borders and North England Region</i>	E. Baldwin	Mabie, Dumfries and Galloway
Borders Area	P. H. Priestley, P. W. Gough, D. Kerr	Kielder, by Hexham, Northumberland
South West Scotland Area	M. Riley, D. M. Watterson	Mabie
North East England Area	A. L. Sharpe, R. E. J. Howes	Wykeham, Scarborough, North Yorkshire
<i>Wales Region</i>	N. P. Danby, S. J. Corcoran, B.A., N.D.F., M.I.C.For., S. A. Mead, B.Sc.	Brecon, Powys

## SITE STUDIES BRANCH (NORTH)

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A. R. Anderson, D. Ray, B.Sc.

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## PHYSIOLOGY BRANCH (with section at Alice Holt)

M. P. Coutts, B.Sc., Ph.D., D.Sc., M.I.C.For., Head of Branch

C. Walker, B.A., Ph.D., Assistant Head of Branch

D. C. Clark, K. A. Clifford, B.A., Mrs V. Goodall, Mrs J. Harrower, A. John, B.Sc., Ph.D.,

B. Nicoll, B.Sc., Mrs M. O'Donnell, J. J. Philipson, B.A., Ph.D.



**PATHOLOGY SECTION (of Branch at Alice Holt)**

D. B. Redfern, B.Sc., Ph.D., M.I.C.For., Head of Section  
S. C. Gregory, M.A., Ph.D., Miss G. A. MacAskill, J. E. Pratt

**ENTOMOLOGY SECTION (of Branch at Alice Holt)**

J. T. Stoakley, M.A., M.Sc., D.I.C., F.I.C.For., Head of Section  
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Ph.D., I. M. S. White, B.Sc., M.Sc.

**ADMINISTRATIVE STAFF**

T/HEO: Mrs F. Snaith

**INSTRUMENTATION SECTION (NORTH)**

D. J. Brooks, Head of Section

---

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**FORESTRY COMMISSION NORTHERN RESEARCH STATION**

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Yorks  
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## STAFF CHANGES

*Transfers in:* H. C. Angus (Forest Officer III) from Rothbury Forest District to Silviculture South, Westonbirt. Mrs B. K. Bartlett (Higher Executive Officer) from M.O.D. London to Personnel, Alice Holt. Mrs J. C. Gates (Executive Officer) from East England Conservancy Office to Personnel, Alice Holt. Mrs C. J. Potter (Forest Officer II) from West England Conservancy Office to Silviculture South, Alice Holt. T. Jennings (Forest Officer IV) from New Forest to Entomology, Thetford. G. Kerr (Forest Officer II) from Dean and Three Counties Forest District to Mensuration, Alice Holt. A. S. Medhurst (Forest Officer IV) from Chilterns Forest District to Genetics, Shobdon. D. G. Nelson (Forest Officer II) from South Lakes Forest District to Silviculture North, Northern Research Station. C. A. Palmer (Forest Officer IV) from New Forest to Pathology, Alice Holt. D. B. Paterson (Grade 7) from Headquarters to Silviculture North, Northern Research Station. G. S. Patterson (Forest Officer I) from Fort Augustus Forest District to Wildlife and Conservation, Northern Research Station. N. A. Smith (Forest Officer IV) from Dorset Forest District to Silviculture South, Exeter. R. J. Sykes (Forest Officer IV) from Tay Forest District to Genetics, Newton.

*New appointments:* Miss K. Johnson (Personal Assistant to Director) Alice Holt. T. R. Nisbet (Higher Scientific Officer) Site Studies South, Alice Holt. P. H. Freer-Smith (Grade 7) Site Studies South, Alice Holt.

*Transfers out:* R. J. Davies (Forest Officer I) from Silviculture South, Alice Holt to Fort Augustus Forest District. I. T. Hickman (Forest Officer III) from Pathology, Alice Holt to Dorset Forest District. A. B. Lewis (Forest Officer III) from Silviculture North, Kilmun to Ayrshire Forest District. A. J. Low (Grade 7) from Silviculture North, Northern Research Station to become Assistant Conservator Operations (Grade 6), Mid Scotland Conservancy Office. S. A. Neustein (Grade 6) from Chief Research Officer, Northern Research Station to become Conservator (Grade 5), North England. T. O'Keefe (Forest Officer IV) from Entomology, Alice Holt to Corris Forest District. T. J. D. Rollinson (Forest Officer I) from Mensuration, Alice Holt to Headquarters or promotion to Grade 7. J. McA. Smith (Higher Executive Officer) from Northern Research Station to Headquarters. P. M. Tabbush (Forest Officer I) from Silviculture North, Northern Research Station to Llanrwst Forest District. Miss E. R. Wells (Executive Officer) from Personnel, Alice Holt to West England Conservancy Office.

*Promotions:* T. C. Booth (Chief Research Officer, Northern Research Station) to Grade 6. Miss A. C. Burnand (Statistics and Computing North, Northern Research Station) to Higher Scientific Officer. H. L. Davies (Silviculture South, Alice Holt) to Forest Officer I. K. P. Donnelly (Statistics and Computing North, Northern Research Station) to Senior Scientific Officer. Miss L. M. Halsall (Statistics and Computing South, Alice Holt) to Higher Scientific Officer. S. R. Leather (Entomology, Northern Research Station) to Senior Scientific Officer. D. Lonsdale (Pathology, Alice Holt) to Grade 7. Miss J. F. A. Nichols (Entomology, Alice Holt) to Higher Scientific Officer. A. J. Peace (Statistics and Computing South, Alice Holt) to Senior Scientific Officer. J. J. Philipson (Physiology, Northern Research Station) to Grade 7. M. J. Potter (Silviculture South, Alice Holt) to Forest Officer I. C. P. Quine (Silviculture North, Northern Research Station) to Forest Officer I. D. G. Rogers (Silviculture South, Exeter) to Forest Officer III.

*Resignations:* D. A. Barbour (Higher Scientific Officer) Entomology, Alice Holt. J. C. G. Patterson (Forest Officer IV) Entomology, Northern Research Station. M. L. Pearce (Forest Officer I) Silviculture South, Westonbirt. Mrs A. E. Walters (Superintendent of Typists) Alice Holt.

*Retirements:* I. A. Anderson (Chief Photographer) Alice Holt. K. F. Baker (Forest Officer III) Silviculture South, Exeter. W. O. Binns (Grade 7) Site Studies South, Alice Holt. D. S. Couatts (Forest Officer III) Silviculture North, Fort Augustus. Mrs V. O. C. Lampard (Personal Assistant to Director) Alice Holt. M. T. T. Phillips (Forest Officer III) Genetics, Newton. L. A. Tee (Forest Officer II) Wildlife and Conservation, Alice Holt. D. C. Wakeman (Higher Scientific Officer) Seeds, Alice Holt.

*Death:* J. Jobling (Grade 7) Silviculture South, Alice Holt.

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## GLOSSARY

*Latin names of trees cited by common name in this Report*

**Broadleaves**

Alder, common	<i>Alnus glutinosa</i>
Ash	<i>Fraxinus excelsior</i>
Beech	<i>Fagus sylvatica</i>
Birch, silver	<i>Betula pendula</i>
Cherry, bird	<i>Prunus padus</i>
wild (gean)	<i>P. avium</i>
Chestnut, horse	<i>Aesculus hippocastanum</i>
sweet	<i>Castanea sativa</i>
Elm,	<i>Ulmus</i> spp.
Siberian	<i>U. pumila</i>
Lime, common	<i>Tilia</i> × <i>europaea</i>
Oak, English (pedunculate)	<i>Quercus robur</i>
sessile	<i>Q. petraea</i>
Plane, London	<i>Platanus</i> × <i>hispanica</i>
Poplar	<i>Populus</i> spp.
Sycamore	<i>Acer pseudoplatanus</i>
Walnut	<i>Juglans regia</i>
Willow,	<i>Salix</i> spp.
weeping	<i>S.</i> × <i>chrysocoma</i>

**Conifers**

Cypress, Leyland	× <i>Cupressocyparis leylandii</i>
Monterey	<i>Cupressus macrocarpa</i>
Fir, Douglas	<i>Pseudotsuga menziesii</i>
grand	<i>Abies grandis</i>
noble	<i>A. procera</i>
Larch, European	<i>Larix decidua</i>
hybrid	<i>L.</i> × <i>eurolepis</i>
Japanese	<i>L. kaempferi</i>
Pine, Corsican	<i>Pinus nigra</i> var. <i>maritima</i>
lodgepole	<i>P. contorta</i>
radiata	<i>P. radiata</i>
Scots	<i>P. sylvestris</i>
Spruce, Norway	<i>Picea abies</i>
Serbian	<i>P. omorika</i>
Sitka	<i>P. sitchensis</i>

The second equation on this page was printed incorrectly, and should read:

$$\text{height} = \frac{a d}{b + d}$$

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