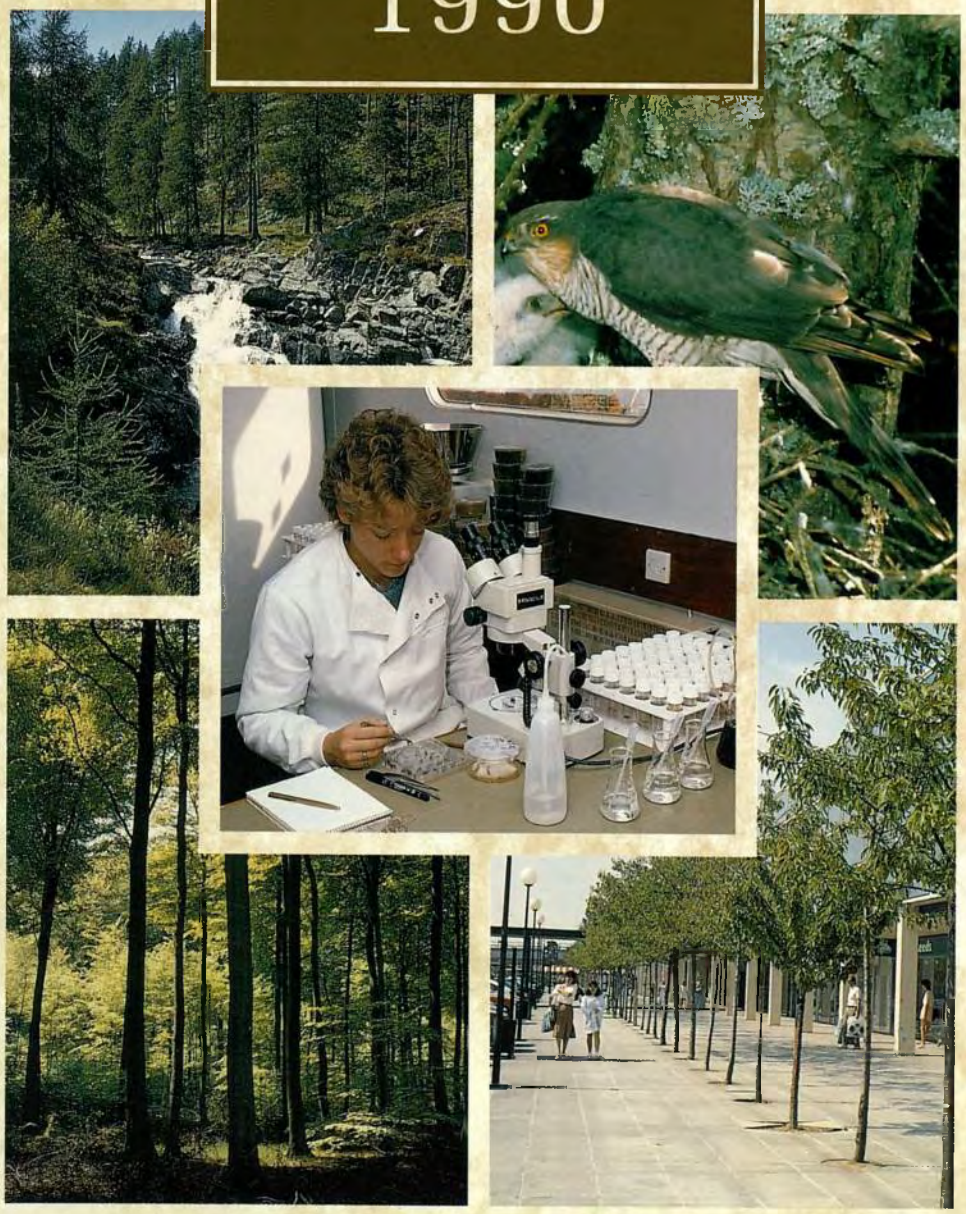
Forestry Commission

REPORT ON FOREST RESEARCH

1990



HMSO

REPORT ON FOREST RESEARCH

for the year ended March 1990

LONDON: HMSO

First published 1991

ISBN 0 11 710282 2
ODC 232.31:(021)
The abbreviated title of this Report is
Rep. Forest Res., Edin. 1990

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CONTENTS

INTRODUCTION

by D. A. Burdekin
Director of Research

Forestry research has, during the course of the year, maintained a high profile in both the public and the scientific spheres. Two areas have attracted particular attention, carbon fixation by trees and the effect of trees on water quality. Considerable progress has also been made in many other research areas and I draw attention to some of these below.

The public debate on global warming has focused on the control and containment of the emissions of 'greenhouse gases' especially carbon dioxide, methane and chlorofluorocarbons. The only identified anthropogenic activity that acts as a 'sink' for carbon dioxide is forestry. The Forestry Commission and the Research Division in particular have been publishing information on the rates at which trees sequester carbon dioxide. The proportion of total emissions (some 3–4%) of carbon dioxide absorbed by trees is small but not insignificant. Further planting of trees can help increasingly to ameliorate the position.

Fervours have been aroused by the water quality debate. On the one hand trees are blamed for causing acidity in our freshwater streams. On the other, foresters are vigorously defending their cause and point out that the acidity does not originate in the forest but in the fuel burning industries. It is hoped that the outcome of this will include a reduction in emissions (though there will be many reasons for these reductions), a treatment for severely affected areas, perhaps by liming, and a rational agreement on the critical loads of pollutants in acid-sensitive areas (which are of limited size in Britain) where trees may exacerbate the situation.

ADVISORY COMMITTEE ON FORESTRY RESEARCH

I regard the Advisory Committee on Forestry Research and the Visiting Groups that it establishes as a vital part of the monitoring and critique of the Research Division's activities. Two Branches were investigated during the year, the Pathology Branch and the Mensuration Branch. Dr Roy Burchill (Head of Crop and Environment Protection at the Institute of Horticultural Research Station at Wellesbourne) chaired the Pathology Visiting Group and other members were Dr D. H. Phillips (retired Forestry Commission Chief Research Officer) and Dr M. Griffin (Senior Officer, Plant Pathology, ADAS). The Group was particularly impressed by the research programme on *Heterobasidion annosum* but was concerned that the balance between advisory and research work based at Alice Holt was tilted too much in favour of the former.

Mr David Johnston (retired Director Research), together with Gavin Ross (Statistics Department, Rothamsted), chaired the Visiting Group to the Mensuration Branch. A total of 14 recommendations were made, perhaps the most important being the need to review the distribution of sample plots and also to incorporate data collected over the past 20 years into current and future yield models for use by forest managers.

HIGHLIGHTS OF THE RESEARCH PROGRAMME

I cannot state that the items below represent a comprehensive list of the activities of the Research Division, nor are they intended to be the most important achievements. They are merely a selection from the many items discussed in the body of the *Report* which perhaps give some flavour of the whole. I strongly commend those with interests that are not listed here to delve deeper into the following pages.

Weed control. The long-term interest in 'the need to weed' for the successful establishment of trees has continued in both lowland and upland research projects. For the first time, this year comparisons have been made between the effects of different weed flora including grass and herbaceous weeds. Both types had deleterious effects on the survival and subsequent growth of newly planted trees.

Farm forestry. Interesting weed problems have arisen on one of the farm forestry trials and a new experiment has been laid down to allow tractor access for the application of a trial range of herbicides.

Poplars. The poplar clonal trials established 3 years ago at Bedgebury (Kent) and Ampthill (Bedford) are already showing marked site differences, probably associated with the lower rainfall and greater droughtiness at Ampthill.

Water storage for sawlogs. Several species of both conifers and boadleaves have now been successfully stored under constant water sprinkling for more than 18 months with little sign of blue stain. All species continue to saw easily after water storage. Studies showed that delays of 9–10 weeks before water storage allowed blue stain fungi to gain entry before treatment.

The pine weevil. *Hylobius abietis* is a major concern in restocked areas. Treatment of transplants with permethrin using the Electrodyn Sprayer has been sucessful but there are still some situations where the treatment is not giving adequate control.

Windthrow prediction. The Windthrow Hazard Classification provides a means for forest managers to predict windthrow in their crops. A network of monitoring sites has been established to enable the hazard classification to be validated and refined.

Vegetative propagation. Two to three million cuttings of genetically improved Sitka spruce are being propagated annually in Britain. The feasibility of producing these rooted cuttings in containers is being investigated and shows promise.

Natural regeneration in upland oakwoods. The lack of natural regeneration in upland oakwoods is a matter of concern especially in Wales. A review of current knowledge has been completed and this will act as a base for future research.

Native pinewoods. A total of 35 genuinely native woods have been identified on the basis of shoot resin composition and have been included in the Native Pinewood Register of seed sources.

Statistics. A detailed analysis has been undertaken of data from logs and battens taken from a series of spacing experiments in order to determine if spacing affects wood quality. The analysis is providing a fascinating insight into the variability of the trees from which the samples were taken. At the same time more and more use is being made of data capture devices for recording data in forest experiments.

Growth models. Great strides have been made in the development of the Sitka spruce growth model. The model's parameters are being optimised to obtain the best forecast for particular sample plots.

Carbon storage. New and original models have been developed to simulate the absorption and release of carbon by forest plantations and forest products. This information has been published in Research Information Note 160 and further papers are in preparation.

Reclamation sites. One of the reasons why it is difficult to establish vegetation, including trees, on reclaimed land is the harsh chemical and physical environment in the soil. A study of spoils has shown that young unweathered material with a high pH is often associated with poor tree growth whereas spoils on older sites may have a lower pH and tree growth is better.

Water quality. Trials with pelletised lime at Llyn Brianne have led to a limited effect after 10 months on soil and drainage water chemistry.

Forestry Research Co-ordination Committee. The role of The Forestry Research Coordination Committee, chaired by Forestry Commissioner Roger Bradley, has been applauded by the House of Lords Select Committee on Science and Technology. An excellent example of coordination was pursued during the year in the form of a Special Topic on Farm Forestry. The Committee provided funds for a special topic on environmental and socio-economic aspects of farm forestry and as a result six research grants and six research studentships were awarded.

Total funding on forestry research in Great Britain has continued to increase and now totals some £21 million. This includes a large increase in research on tropical forestry by the British institutions as well as increases in research on environmental aspects of forestry and on wood sciences within Britain.

Two new review groups have been set up during the year, one on climate change and the other on forestry and conservation.

PART I

THE WORK OF THE FORESTRY COMMISSION

RESEARCH DIVISION

SEED

RESEARCH

Soaking and prechilling of noble fir seed

The effects of soaking and prechilling noble fir (NF) seed were investigated for seven commercially available seed lots owing to doubts over the efficacy of currently recommended procedures. Preliminary findings reported last year (*Report* 1989, p. 5) on one seed lot showed that whereas the laboratory method of prechilling small numbers of seeds (ISTA, 1985) was beneficial to subsequent germination, the preliminary soak phase universally applied by nursery managers prior to bulk chilling reduced germination from 61% to 17%. If similar damage is widespread among other NF seed lots, the recommendation to soak seeds for 48 hours at 4°C prior to bulk prechilling may need to be withdrawn.

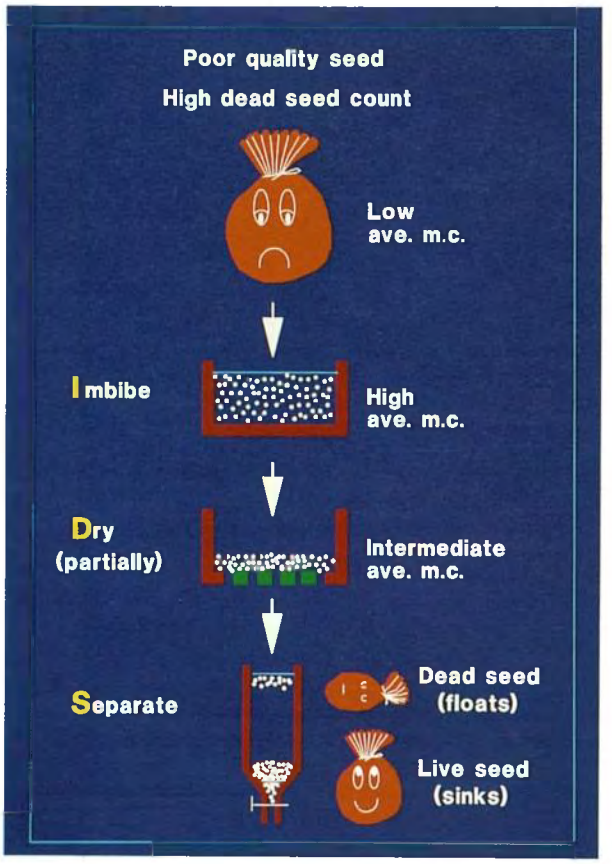
Samples of seven different NF seed lots were (1) untreated, (2) laboratory prechilled for 3 weeks, (3) soaked for 48 hours in water at 4°C, (4) soaked for 48 hours at 4°C, then laboratory prechilled for 3 weeks, or (5) soaked for 48 hours at 4°C, then bulk prechilled for 3 weeks. The seeds were then germinated for up to 42 days at an alternating 20/30°C (International Seed Testing Association germination conditions). The results are shown in Table 1.

For all seven seed lots the laboratory prechill method gave the fastest germination (not shown) and highest germination capacity at 42 days. For all seed lots except lot 4, soaking seed for 48 hours at 4°C significantly reduced the germination percentages compared with either untreated or laboratory prechilled seed. Soaking followed either by a laboratory or bulk prechill gave more variable results. In some cases the soaked seed recovered during the prechill period and in other cases the damage was made worse. However, the results prove that immersing NF seed in water for 48 hours at 4°C is harmful. The variable response of soaked then prechilled NF seed may help to explain the variable performance of NF seed lots in the nursery. Work on alternative methods of prechilling NF seed avoiding the damaging soak stage is underway.

S. K. JONES, P. G. GOSLING

Table 1. Germination percentages after 42 days at an alternating 20/30°C of seven different seed lots of noble fir. Treatment results within each seed lot that do not share the same letter are significantly different ($p<0.05$) from one another. Each seed lot was analysed separately.

Seed lot	*Untreated*	*Laboratory prechilled*	*48 hour soak*	*Soak + laboratory prechill*	*Soak + 'bulk' prechill*
1	51^{a}	50^{a}	38^{b}	28^{c}	$36^{b,c}$
2	58^{a}	62^{a}	46^{b}	31^{c}	42^{b}
3	28^{a}	$21^{a,b}$	16^{b}	9^{c}	10^{c}
4	35^{a}	36^{a}	$29^{a,b}$	$29^{a,b}$	25^{b}
5	32^{b}	43^{a}	23^{c}	33^{b}	$38^{a,b}$
6	41^{b}	51^{a}	28^{c}	38^{b}	40^{b}
7	32^{b}	51^{a}	16^{c}	49^{a}	46^{a}



An illustration of the IDS scheme (m.c. = moisture content).

IDS (incubation, dehydration, separation)

IDS was developed in Sweden to improve the germination of Scots pine (*Pinus sylvestris* L.) and lodgepole pine (*Pinus contorta* Douglas) seed lots by selectively removing the full, dead seed. As part of co-operative work with the Commission's Silviculture Division aimed at improving the quality of seed for container sowing, samples of Corsican pine (*Pinus nigra* var. *maritima* (Aiton) Melville) were subjected to either IDS or specific gravity (SG) separation. SG separation allows the separation of seeds on a density basis but does not selectively remove full, dead seed.

Using IDS, three-quarters of the 10 kg starting weight was raised from 72% to 84% germination. The remaining quarter, the 'dead' fraction, had 24% germination. If IDS were 100% efficient there would have been no germination among the 'dead' fraction at all.

Using SG, only one-tenth of another 10 kg sample could be raised from 72% to 85% germination. The germination percentage of the remaining nine-tenths dropped from 72% to 71%. So both fractions could still be used, but the poor quality seed only for broadcast sowing.

S. K. JONES, P. G. GOSLING, T. A. WADDELL

SEED TESTING

Official and advisory testing occupied c. 70% of staff time. Six-hundred-and-fifty-one tree seed samples were tested: 192 from seed merchants and nursery managers, 32 from the Oxford Forestry Institute and 427 of the Forestry Commission's own seed lots.

The main seed testing laboratory doubles as a research laboratory. During the last year it has been largely refurbished. A more comfortable working environment has been created, bench space for research has been improved and storage space increased.

P. G. GOSLING, Y. K. SAMUEL

SILVICULTURE (SOUTH)

PLANT PRODUCTION

Facilities for rooting softwood cuttings were upgraded during the year. A new propagation frame, equipped with mist and base heat and with a capacity for up to 5000 cuttings, was installed. The mist units and associated plumbing in the propagation glasshouse were completely replaced with new equipment. A new Conviron S10H growth cabinet was installed on the nursery for the determination of the Root Growth Potential of seedling stock.

Approximately 5000 softwood cuttings of 12 poplar varieties were rooted for clonal trials. Cuttings of several other broadleaved species were also rooted including oaks, beech, ash, sycamore, sweet chestnut and small-leaved lime. In addition, the research nurseries supplied 5000 hardwood cuttings and 54 000 bare root stock of poplar for experimental planting by other researchers.

Difficulties have been experienced in inducing bud set in seedlings of Corsican pine raised in 308 Japanese paper pots in polythene tunnels. The effects of short-days, drought and restricted nutrient supply applied for 4 weeks from late August were investigated. Since height growth had begun to decline naturally at this time, the treatments had no effect in further reducing height increment. However, 8-hour days and zero nitrogen in the liquid feed accelerated the rate of formation of terminal buds.

R. L. JINKS

LOWLAND ESTABLISHMENT

Research concentrates predominantly on broadleaved tree species with the aim of improving the quality and decreasing the cost of establishment. Past work on treeshelters and lowland restocking will be incorporated and more emphasis will be given to natural regeneration.

G. KERR

STAND SILVICULTURE

This is a new project focusing on broadleaved tree species with the immediate priority of reviewing past silvicultural research on the control of epicormics on oak, free growth thinning, and species mixtures.

G. KERR

LONG ROTATION COPPICE

Traditional treatment of sweet chestnut coppice (*Castanea sativa*, Mill.) in the Forest of Dean has been to cut it when there is a prospect of a financial surplus on the operation, usually 18–20 years. It is reported that French foresters believe the onset of shake to be age, rather than size, related, and has led to practices of early storing (thinning to 1–3 shoots per stool) with the aim of producing young large size, shake free timber. To check the validity of these observations an experiment has been established in the Forest of Dean to compare: storing at age 18, age 7 and a control treatment; this will be further replicated in the south-east of England in 1990.

G. KERR

FOREST WEED CONTROL

In 1988 an experiment was established to compare the effects of different sward types on the survival and early growth of wild cherry (*Prunus avium*) the object being to see whether managing growth and composition of a sward would be an acceptable alternative to normal weed control practice of killing competing vegetation.

Different swards were created through the use of selective herbicides: alloxydim sodium to remove grass; mecoprop + 2,4–D to remove broadleaved weeds; and growth regulators (mefluidide and maleic hydrazide).

Table 2. Survival of wild cherry in relation to sward composition

Treatment	*Percentage survival* (Prunus avium)	*Percentage broadleaved weeds*	*Percentage grass*	*Percentage bare ground*
Untreated control	42	17	73	10
Bare ground	92	13	0	87
Alloxydim sodium	38	48	33	19
2,4–D + mecoprop	44	2	88	10
2,4–D + mecoprop + maleic hydrazide	55	2	85	13
Maleic hydrazide	51	35	43	22
Mefluidide	24	32	50	18

The sandy, free draining site was covered by a sward containing approximately 73% grass and 17% broadleaved weeds and the following ground cover was produced: broadleaved weeds, grass, a mixed sward treated with growth regulators and a grass sward treated with growth regulators.

All these treatments were contrasted with a bare ground treatment and an untreated control.

Despite the dramatic differences induced in the sward (see Table 2) the only significant differences ($p<0.001$) at September 1989 in the health, height, survival, and stem diameter of the trees were between the bare ground treatment and all other treatments. Bare ground had significantly better values at each assessment.

This experiment suggests that on drought prone sites broadleaved weeds and grass which has been treated with a growth regulator can compete effectively with trees for moisture. This competitive effect can be sufficient to cause a considerable reduction in survival and growth of trees.

D. R. WILLIAMSON

FARM FORESTRY

As mentioned last year (*Report* 1989, pp. 13, 14) some of the trees in the species trial at Drayton Experimental Husbandary Farm (EHF) (Warwicks) suffered from lime induced chlorosis. These were removed and replaced with other species in spring 1990. Survival of all remaining species at the end of the second growing season ranged from 71.5% to 79.4%.

In the cultivation and plant type experiment at Drayton, at the end of the second growing season, there were no significant differences in the survival of ash between ground preparation or plant type. However, ash planted on ploughed ground or with polythene mulch had a significantly greater height and stem diameter ($p<0.01$) than ash planted on ridges or into uncultivated ground.

Corsican pine containerised plants had a significantly better survival than bare root plants ($p<0.001$).

Both plant types of pine had significantly better survival when planted under polythene mulch rather than on ridged or ploughed ground ($p<0.05$). Pine, notch planted into uncultivated ground, had significantly better survival than pine planted on ridges ($p<0.05$)

At Boxworth EHF (Cambs) trees all grew well in the species trial and survival at the end of the second growing season ranged from 96% to 100%.

Containerised Corsican pine performed better than bare root stock, while neither plant types of ash or ground preparation had any significant effect on survival.

Containerised oak had significantly better survival than bare root oak ($p<0.05$) and survival was significantly better on the ridges ($p<0.05$).

The experiments at Drayton and Boxworth are on fertile ex-arable land. A regime of minimum herbicide input has led to a serious arable weed problem. In response to this problem a further experiment has been established at Bridgets EHF (Hants) which will investigate different methods of managing the ground flora. This experiment has been laid out to allow tractor access between rows. Different management practices in the inter-row area are being tried including game cover, low productivity grass and wild flowers, maintainence of bare earth and mowing.

Trials are underway to screen arable herbicides over forestry tree species to determine crop tolerance.

D. R. WILLIAMSON

POTENTIAL PLANTATION SPECIES

A new project is being formulated to initiate and co-ordinate research into tree species that are not widely used in forestry at the present time, but could be of value for timber production in the future. This will incorporate existing studies on alder, *Nothofagus*, fast growing pines and *Eucalyptus*. Established exotic species plots, arboretum specimens, and some British native species (e.g. field maple) will be investigated.

J. E. J. WHITE

ARBORETA

Following a headquarters review and classification of Forestry Commission arboreta and forest gardens in 1989, research work has been concentrated on the most comprehensive collections. Eight sites have been designated as scientifically important. These are Bedgebury, Kilmun, Kirroughtree, Lael, Lynford, Speech House, Vivod and Westonbirt. It is intended that the inventories for all eight collections will be added to the International Transfer Format database at Westonbirt. In the past year progress has been made with the taxonomy of Vivod and much headway has been made at Lynford both in planting new species and increasing the size of the arboretum.

J. E. J. WHITE

DENDROLOGY

Acquisition of new data has been confined in the past year to specimens that are most likely to contribute to a register of important trees in Britain. The objective is to obtain enough measurements to give an indication of potential size for every species and variety of tree likely to thrive in the open air in this country. Fifty-seven new locations have been visited since the last update of the register.

J. E. J. WHITE

WESTONBIRT ARBORETUM

The high winds in January and February uprooted 320 large trees and a further 250 were damaged, many of these had to be felled. The arboretum was closed for 6 weeks while the most dangerous trees were dealt with. The majority of wind damaged trees had physical defects i.e. root and stem decay.

The propagation unit received seed and plants from many sources. Of particular interest was seed from wild sources in Japan and North America.

Our Education Unit had another successful year with over 11 000 school children participating in various programmes. Requests for the full day programme increased by 20%.

Visitor numbers were lower than average mainly as a result of poor weather conditions during October, when normally 50% of our visitors are expected.

High quality planting, using a combination of bark mulch and matting, was taken to be the reason for minimal losses during the prolonged dry spring of 1989. The drought caused many plants to flower and fruit in profusion.

H. C. ANGUS

BEDGEBURY PINETUM

Mopping up of the October 1987 gale damage continued throughout the summer. The summer was the hottest and driest for a number of years but few trees showed outward evidence of drought stress.

Two new genera were obtained for the collection, namely *Keteleeria davidiana* and *Fokienia hodginsii*, the latter being quite rare.

Unfortunately we suffered extensive damage in the storm force winds of January and February. As a result of this another 120 specimens were lost.

C. MORGAN

BEDGEBURY FOREST PLOTS

Three of the Ovington plots investigating long-term effets of trees on soil properties have been replanted and clearing work continues in other plots. Some single trees left standing after the October 1987 storm were damaged in the storms of January and February 1990. Coppice growth in the *Sequoia* plot is encouraging.

C. MORGAN

ARBORICULTURE: DEPARTMENT OF THE ENVIRONMENT CONTRACT

Plant quality at establishment

Spacing in the nursery has been shown to affect outplanting performance as well as stem diameter at planting. For 200 cm tall stock, spacings of up to 50 cm influence outplanting performance. Height growth after 2 years in one nursery experiment was 27.6 cm less at 10 cm compared with 50 cm spacing.

Research into the influence of nursery regimes on outplanting performance is being expanded to include nursery fertiliser and irrigation regimes.

Stock type for tree establishment in the lowlands

Genera such as *Quercus*, *Carpinus* and *Fagus* (coarse rooted species) suffer severe transplanting stress and high losses when planted as larger stock. Planting of species in these genera should be confined to transplants. Genera such as *Sorbus*, *Fraxinus*, *Prunus* and *Acer* (fibrous rooted species) establish more successfully from larger stock sizes. Species in these genera should be favoured when large stock sizes have to be planted.

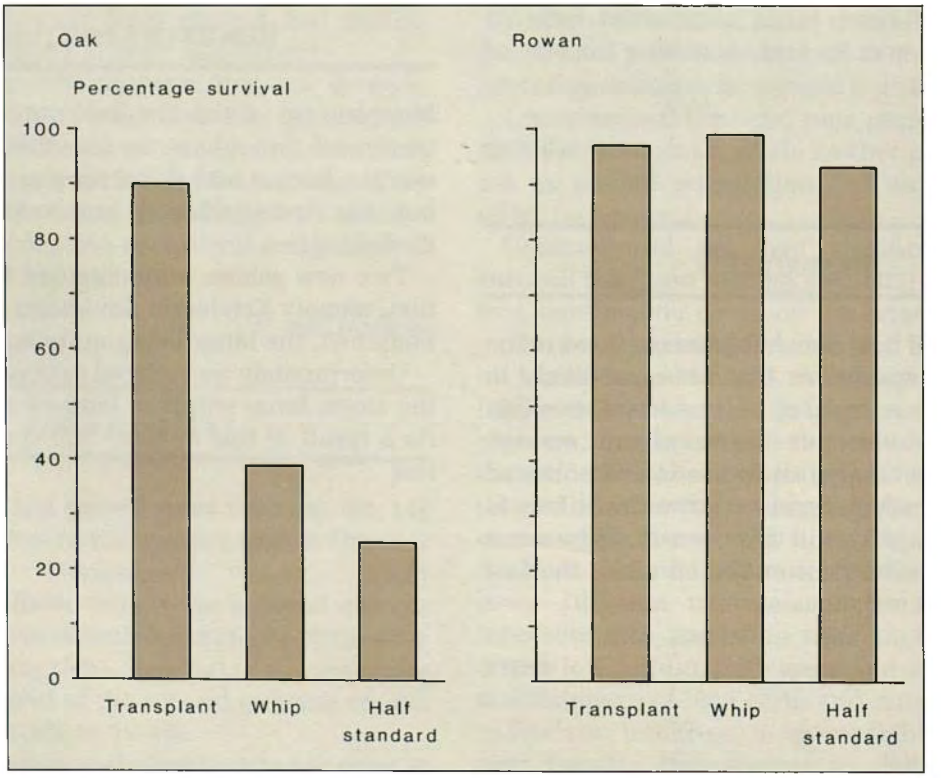
Work is planned to evaluate the new types of cell grown stock now available.

Site amelioration for tree establishment

Most organic and manufactured soil ameliorants have generally yielded no survival or growth benefit to pit planted trees in experiments on a range of sites. Super swelling polymers have been extensively researched and these products appear not to improve tree survival or growth during drought periods.

Establishment of hedgerow trees

Twelve experiments have been established. Nine are in existing hedgerows where planting was generally the most effective and economical means of establishing trees compared with hedge material or natural regeneration. Natural gaps in a



Survival of different stock sizes 6 years after planting.

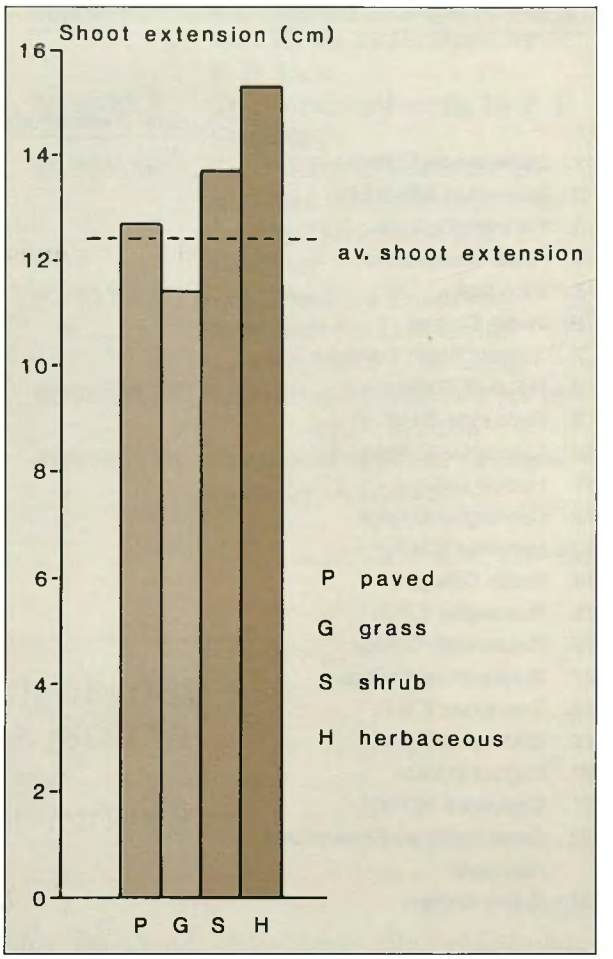
hedge can be planted. Alternatively, gaps of a minimum size required to allow access for planting and weeding can be created. Transplants protected with treeshelters have been shown to be beneficial especially when combined with mulch mats to provide a robust method of weed control.

The three experiments which involved planting new hedges have shown that weed control using polythene sheet mulch is the most effective means of establishing new hedgerows.

Study of urban trees

A survey of 3600 urban trees throughout England was completed and analysis of results has provided good evidence on the conditions and growth rates of urban trees in relation to soil and site factors. The intensive study of trees at selected sites chosen in 1987 has been completed and information from this forms the background to a new and more intensive study of the relationship between soil and site factors and tree performance at Milton Keynes. Development of the steel rod technique to determine soil aeration continues.

Excavation of the root systems of established urban trees is planned in 1990.

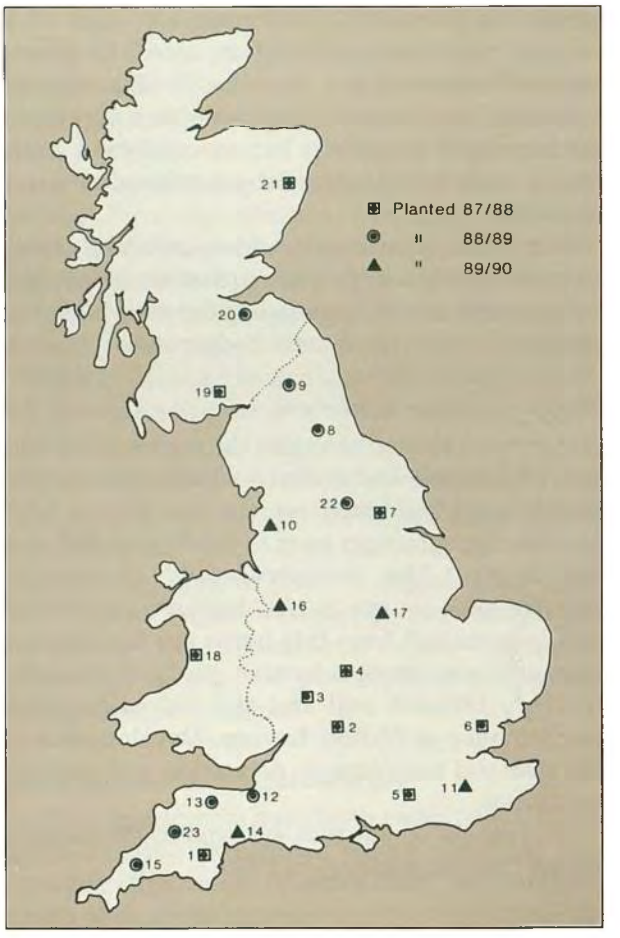


Urban tree survey 1989. Mean shoot extension for all species by planting position.

Steel rods used for soil aeration assessment.
Top. *Rod showing appearance before insertion into the ground.*
Upper. *Rod showing widespread rusting, indicating well aerated soil. Shiny patches indicate inhospitable soil.*
Lower. *Rod from poorly aerated soil – predominantly matt grey with flecks of rust.*
Bottom. *Rod from totally anaerobic soil indicated by matt grey surface.*

Location of tree establishment demonstration plots.

		Arboriculture	*Farm woods*
1.	Seale Hayne College	√	
2.	Westonbirt Arboretum	√	
3.	Pershore College	√	
4.	Royal Showground	√	√
5.	Alice Holt	√	
6.	Writtle College	√	√
7.	Askham Bryan College	√	
8.	Houghall College	√	√
9.	Redesdale E.H.F.		√
10.	Lancashire College	√	√
11.	Hadlow College	√	√
12.	Cannington College	√	√
13.	Liscombe E.H.F.		√
14.	Bicton College		√
15.	Rosewarne E.H.F.		√
16.	Reaseheath College	√	√
17.	Brackenhurst College	√	√
18.	Trawscoed E.H.F.		√
19.	Crichton WOSCA		√
20.	Boghall EOSCA		√
21.	Craibstone NOSCA		√
22.	Great Yorkshire Showground, Harrogate		√
23.	Duchy College		√



Tree establishment demonstration plots

Twenty-three demonstration areas have now been established across the UK and are freely accessible to interested parties. Local Forestry Commission Private Woodland Officers have been given the major role in promoting the use of these plots to those interested in planting trees.

S. J. HODGE, S. M. COLDERICK

Arboricultural Advisory and Information Service

During the review period the arboriculture research contract between the Forestry Commission and the Department of the Environment was completed and a new contract was agreed. The new contract, which includes research into plant production, establishment and management (p. 6) and decay and diseases in amenity trees (p. 55) is for 3 years 1990 to 1992. The Arboriculture Advisory Board, recently formed by the Department of the Environment, has convened a Review Group to make recommendations about the future development of the Arboricultural Advisory and Information Service. The Group should report by mid 1990.

The review period proved busier than any other year since the Advisory Service was established with over 3300 enquirers receiving answers to questions – an increase of 20% over the previous peak. Topics of concern continued to be damage caused to trees, damage caused by trees especially to dwellings, and management of mature trees.

Seven new Arboriculture Research Notes were published during the year. These are:

77/89/ARB	Stakes and ties, by D. Patch
78/89/PATH	Marssonina canker and leaf spot (anthracnose) of weeping willow, by D. R. Rose
79/89/PATH	Scab and black canker of willow, by D. R. Rose
80/89/ENT	Cypress and juniper aphids, by T. G. Winter
81/90/ARB	Ivy – boon or bane?, by J. E. J. White and D. Patch
82/89/SILS	Demonstration plots for amenity tree establishment and farm woodlands, by C. J. Potter, C. M. A. Taylor and S. Hodge
83/90/SSS	Survey of tree condition 1990, by J. L. Innes

In order to ensure that practitioners continue to have the most up-to-date information, ten titles

were revised and reissued. Many of the revisions were necessary to ensure that the recommendations for the use of chemicals did not infringe the requirements of the Food and Environment Protection Act 1985. The titles revised are:

12/89/SILS	Summer branch drop, by K. D. Rushforth
36/89/TRL	Tree roots and underground pipes, by G. Brennan, D. Patch and F. R. W. Stevens
40/89/ARB	Tree staking, by D. Patch
50/89/SSS	Nutrition of broadleaved amenity trees 1. Foliar sampling and analysis for determining nutrient status, by W. O. Binns, H. Insley and J. B. H. Gardiner
53/90/WS	Chemical weeding – hand-held direct applicators, by P. B. Lane
57/89/EXT	The brown-tail moth, by P. H. Sterling
59/89/ARB	The effects of weed competition on tree establishment, by R. J. Davies and J. B. H. Gardiner
61/90/PATH	Ceratotect – a fungicide treatment for Dutch elm disease, by B. J. W. Greig
68/90/PATH	Lightning damage to trees in Britain, by D. R. Rose
73/90/PATH	Treatment of storm-damaged trees, by D. Lonsdale

D. PATCH, F. R. W. STEVENS

INTER-BRANCH REPORT SILVICULTURE (SOUTH) AND SILVICULTURE (NORTH)

NURSERY HERBICIDES

Seedbeds

Nine herbicides (diphenamid, napropamide, oryzalin, propyzamide, isoxaben, chlorthal-dimethyl, metamitron, chloridazon and metazachlor) were tested at Bush (Lothian) and Headley (Hampshire) nurseries for post-emergence application to first-year seedbeds. Crop species were Sitka spruce and Japanese larch (both nurseries), birch and common alder (Headley only). Applications were made at one-quarter and one-half of recommended rates at 6-week intervals after sowing. Results indicate that herbicides which are damaging when applied pre-emergence (e.g. metazachlor, oryzalin) can be applied post-emergence in a repeat low dose regime to improve weed control without compromising crop safety (see Williamson *et al.*, 1990 for full details). Further trials are in progress to check the validity of this finding.

Transplant and undercut stock

Fourteen herbicides and herbicide mixtures were tested for crop tolerance on eight conifer and eight broadleaved species. The herbicides screened were oryzalin, clopyralid, cyanazine plus clopyralid, chloridazon plus chlorbufam, metazachlor, and mixtures of metazachlor with chlorthal-dimethyl, with clopyralid, with diphenamid, with simazine, with pendimethalin, with oryzalin and with lenacil. Simazine and diphenamid were included as standards. Crop species tested were Sitka and Norway spruce, Douglas fir, noble fir, Corsican and Scots pine, Japanese larch and western red cedar; oak, ash, sycamore, beech, wild cherry, birch, common alder and sweet chestnut.

The only crop damage was caused by metazachlor when applied singly or in mixture to pines that were undergoing active shoot elongation. Otherwise all herbicides proved to be widely crop-safe. The results indicate that there is a wide range of herbicides that can be used effectively on transplanted or undercut nursery stock depending upon growth stage and weed species.

D. R. WILLIAMSON, W. L. MASON

REFERENCE

WILLIAMSON, D. R., MASON, W. L. and CLAY, D. V. (1990). Repeat low dose herbicide application for weed control in forest nursery seedbeds. *Proceedings Crop Protection in Northern Britain*. SCRI, Dundee, pp. 187–192.

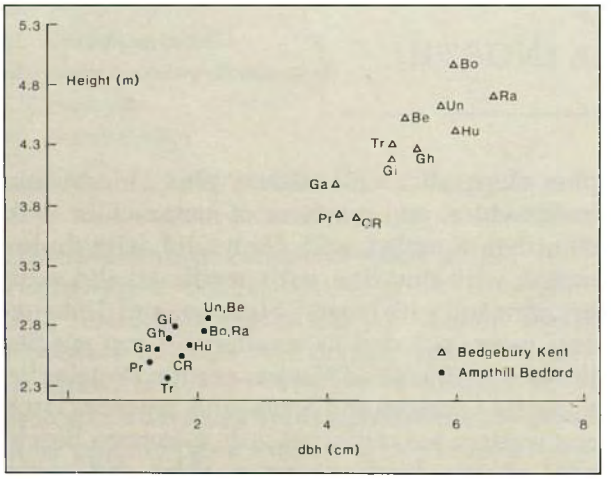
INTER-BRANCH REPORT: SILVICULTURE (SOUTH) SILVICULTURE (NORTH) AND SITE STUDIES (SOUTH)

POPLARS

Old clonal trials

During the summer of 1989 a student was employed to conduct a survey of poplar clonal trials planted in the 1950s. The survey included sites throughout Britain where a sufficient number of trees of selected clones still remained. Mensurational data and a detailed site description were collected and these will be used to relate the growth and yield of different clones of poplar to site type.

C. J. POTTER, C. NIXON



3-year mean height vs. dbh for the UNAL clones at Bedgebury and Ampthill.

UNAL clonal trials

Three-year height and diameter results for the poplar clonal trials at Bedgebury (Kent) and Ampthill (Bedford) are shown. Both trials were planted with rooted softwood cuttings (of 11 new clones) at 4 × 4 m spacing in early 1987. The marked difference in growth between the two sites can be explained largely by the available soil moisture which can be expressed in terms of the droughtiness of the site (See Table 3). Photographs illustrate the two sites.

C. J. POTTER

Silvicultural experiment

An experiment investigating the effect of pig slurry on the growth of poplars was established at Terrington EHF, Norfolk, in early 1990. Several rates of pig slurry and inorganic nitrogen will be applied to two poplar clones (*P. deltoides* × *nigra* 'Robusta' and 'Ghoy') established into cultivated or sprayed ground. Growth and nutrient status of the trees will be recorded and any effects on the site will be monitored.

The effect on poplar growth of interplanting with alder is being investigated in an experiment planted in spring 1990 at Fernhurst, W. Sussex. *P.* × *trichocarpa* 'Fritzi Pauley' was planted with varying proportions of *Alnus rubra* on a sandy loam. Prilled urea was also applied to half the plots.

C. J. POTTER, A. J. MOFFAT

Table 3. Soil moisture regimes at the UNAL clonal trial sites

Site	*Soil*	*Rainfall (mm)*	*Soil available water (mm)*	*Potential moisture deficit*	*Droughtiness (mm) (2) – (1)*
Bedgebury, Kent	Sandy loam Curtisden series	838	160	175	15 (slight)
Ampthill, Bedford	Brown sand, Frilford series	600	80	200	120 (very)

These figures are means for 1961–75 taken from the Soil Survey for SE England

UNAL poplar clonal trial site at Ampthill, Bedfordshire. (39413).

UNAL poplar clonal trial site at Bedgebury, Kent. (39414).

BIOMASS: DEPARTMENT OF ENERGY (ETSU) CONTRACT

The original contract ended on 30 June 1989 after 10 years' research. The end of contract report summarising yields and giving site details, was submitted to ETSU and will be published by Department of Energy in 1990. A new contract started on 1 January 1990 investigating the potential of several new poplar clones alongside the existing *Populus* 'RAP'. As in the previous contract, there are three experiments: at Alice Holt, Long Ashton Research Station and Mepal (Norfolk). Unrooted cuttings were planted in early 1990 at spacings of 1 × 1 m and 2 × 2 m. After an initial coppice cut at the end of 1990, the plots will be harvested every 2 or 4 years. Under the new contract, a further harvest of *Populus* 'RAP' was carried out in March 1990. Early indications are that the yields were lower than those for the previous cut (1987/8), probably due to the dry weather in both 1988 and 1989.

C. J. POTTER

INTER-BRANCH REPORT SILVICULTURE (SOUTH), PHYSIOLOGY, ENTOMOLOGY, WORK STUDY

LOWLAND RESTOCKING

Introduction

The Lowland Restocking Special Project Team was convened in August 1987 with the broad objective of 'recommending cost-effective treatments and systems to improve restocking in the lowlands'. In the 1989 *Report* it was stated that the membership of the group had been expanded to include specialists in plant production, herbicides and plant physiology. These specialists and core team members are now reviewing past research and drafting proposals for future work; a final report will be produced by the end of 1990 emphasising practical recommendations to forest managers.

G. KERR

Plant physiology

Experiments have been established to characterise cycles of activity and dormancy in Douglas fir and Queen Charlotte Island Sitka spruce and to compare the value of various direct measurements of the physiological status of plants at lifting as indicators of the plants' tolerance to cold storage.

Douglas fir roots were least active in mid-December but in the mild winter of 1988/89 there was a period of active root elongation and cell division in February and March. There was no period when Douglas fir roots could tolerate long-term (5 months) cold storage.

At lifting, root growth potential (RGP) was valuable in predicting differences in survival between species and plant types (1u1s and 1+1s).

Root deterioration during cold storage was closely correlated to survival after one growing season. It was measured by the rate of leakage of cell contents from fine roots.

Current experiments will establish dormancy cycles for Japanese larch and, we hope, will confirm results for Sitka spruce and Douglas fir. Indices at lifting and after cold storage will be evaluated for a second year.

These experiments will be extended to include more species (Scots pine and Oregon Sitka spruce) and earlier lifting dates for autumn planting.

H. M. McKAY

Plant type – Broadleaves

Rootrainer/Rigipot/Japanese paper pots (JPP), $\frac{1}{2}u\frac{1}{2}$ broadleaf comparisons are planned. Previous work suggests well handled bare-root plants perform as well as container-grown plants over most conditions and planting dates.

First year results of two container type experiments suggest that in the Rootrainer 'Sherwood', oak and beech perform marginally better than JPP 515 plants. Probable reasons include the wick effect of JPP paper, and higher density of JPP cells (cells m^{-2}) in the nursery producing plants with lower root collar diameter.

S. J. HODGE

Planting

There is a body of evidence in the literature to suggest that selection of a favourable planting position and good planting will produce significant survival and early height growth benefits for restocking. A number of experiments to confirm this for lowland conditions have been established.

G. KERR

Compartment costs of lowland restocking systems

During 1989 two areas in Midlands Forest District were set aside for Work Study trials into restocking methods. Site 1 (Cpt. 112) was an undulating site with slopes up to 40%, the area being approximately 7.8 ha. Site 2 (Cpt. 1563) was a flatter area where two-way working with machinery was achieved; this area was 1.7 ha. Eight different prescriptions were successsfully implemented on Site 1 which involve combinations of chemical weeding, windrowing, chopping slash, scarification and ploughing. Comparison of first year costs were made on the basis of total basic time expended per hectare. The full result will not be known until the end of all weeding treatments in 2–3 years, but results to date range from 10.77 hours ha^{-1} for pre-planting chemical weeding followed by planting through light brash, to 18.49 hours ha^{-1} for windrowing, ploughing and planting.

Three prescriptions were begun on Site 2 which did not include pre-planting weed control. Times range from 9.38 hours ha^{-1} for scarification plus planting, to 12.33 hours ha^{-1} for windrowing, ploughing and planting.

J. CLARKE

SILVICULTURE (NORTH)

PLANT PRODUCTION

Vegetative propagation of Sitka spruce

Between two and three million cuttings of genetically improved Sitka spruce are being propagated annually for use in British forestry. These cuttings cost two to three times more than seedlings, largely because of the high labour costs incurred during propagation. One possible way of reducing production costs would be to grow cuttings in containers and so eliminate the expensive transplanting phase. An experiment at Bush nursery (Lothian Region) looked at different aspects of propagation in containers and particularly at the feasibility of producing usable plants within one year. Tip cuttings were inserted in March 1989 in 175 cc containers and assessed after 20 and 30 weeks. The effects of various fertiliser and conditioning regimes (e.g. photoperiod manipulation) were considered. After 20 weeks 95% rooting was achieved with no major differences between treatments. The most important effects were on height growth where, after 30 weeks, use of a slow-release basal fertiliser improved height growth by 38% over the control ($p<0.001$) and ensured that the cuttings were of a suitable size for planting. Surprisingly, the use of liquid fertilisers did not achieve a similar effect. The results indicate that it is feasible to produce usable cuttings in containers provided the appropriate fertiliser regime is used.

W. L. MASON, M. K. HOLLINGSWORTH

Cold storage regimes for conifers

Over the last decade there has been a considerable increase in the cold storage capacity on British nurseries. It is estimated that over 30% of conifers are cold-stored for some period between lifting and planting. Two types of cold store are in common use. In direct-cooled stores, plants are stored in sealed bags to prevent root desiccation whereas in the newer type of humidified stores plants are stored bare-rooted at around 95% relative humidity. Casual observation had suggested that fine roots of plants seemed to be surface-dry after a month of humidified storage and this could damage the performance potential after outplanting. An experiment at Newton nursery (Grampian Region) examined the effect of three storage regimes on the forest performance of Douglas fir and Sitka spruce. Root growth potential (RGP) and fine-root moisture content (RMC) were measured monthly during the 4 months that the plants were stored. RMC was significantly lower after 1 month in store and RGP was reduced after 3 months (both $p<0.001$). Plants stored bare-rooted in humidified stores had significantly ($p<0.001$) lower survival and height increment than those from other storage regimes reflecting differences in RGP and RMC (Table 4). These findings show that bare-root storage of conifers in humidifed stores for periods of more than 4 weeks can seriously reduce performance potential.

W. L. MASON, A. L. SHARPE

Root growth potential of nursery stock

Based on work with Douglas fir and Sitka spruce, Tabbush (1988) recommended the use of root growth potential (RGP) to test physiological quality of nursery stock. Since 1988, we have been carrying out studies at Bush nursery (Lothian Region) to examine the yearly RGP cycle of a range of forest species. Table 5 gives preliminary results from the first year of this study including Sitka spruce, Scots, Corsican and lodgepole pines, hybrid larch and beech. Only Sitka spruce and lodgepole pine show the pattern of a pronounced mid-winter peak in RGP described by Tabbush (1988) and Ritchie and Dunlap (1980). Hybrid larch RGP appears higher in autumn and spring with lower values in winter. Scots pine values have comparatively little seasonal periodicity, but these are nearly always higher than those of Corsican pine. This would reflect the common perception of Corsican pine being a more difficult species to establish. RGP in beech is nearly always lower than in the conifer species. The results indicate that the patterns of RGP cannot be freely extrapolated from one species to

another and that standards of physiological quality may well need to be species specific. Further work is in progress to check upon RGP variation in other species, upon differences between provenances and to examine year-to-year variation (the winter of 1988/89 was noticeably mild).

W. L. MASON, D. G. NELSON, M. K. HOLLINGSWORTH

REFERENCES

RITCHIE, G. A. and DUNLAP, J. R. (1980). Root growth potential: its development and expression in forest tree seedlings. *New Zealand Journal of Forest Science* **10**, 218–248.

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

Table 4. First year survival (%), height increment, root growth potential and fine-root moisture content at planting, of Douglas fir and Sitka spruce planting stock after different cold storage regimes.

	Douglas fir			*Sitka spruce*			
	H	*HP*	*D*	*H*	*HP*	*D*	*s.e.d.*
Survival (%)	52	98	96	74	100	100	—
Transformed survival (%)	46	86	83	60	90	90	4.7
Height increment (cm)	1.6	4.3	5.6	3.4	5.4	6.1	0.9
Root growth potential	0.5	1.6	0.5	2.6	5.2	4.8	0.6
Fine-root moisture content	49	186	243	62	219	224	11.9

RGP and RMC values are the average of 20 plants. RGP values have been square-root transformed; squaring the values in the Table will give close to the actual figures. Survival data transformed by arcsine. Cold storage regimes are: H, bare-rooted storage in a humidifed store; HP, storage in black and white co-extruded bags in a humidifed store; D, storage in black and white co-extruded bags in a direct-cooled store.

Table 5. Root growth potential of transplants of different species. Data are shown after square-root transformation .

	Species						
Month	*Scots pine*	*Corsican pine*	*Lodgepole pine*	*Sitka spruce*	*Hybrid larch*	*Beech*	*s.e.d.*
5/88	2.2	1.6	2.3	2.3	1.0	0.2	0.3
6/88	3.2	2.4	2.3	1.9	1.8	0.8	0.4
7/88	0.7	0.9	1.3	0.5	0.8	0.1	0.3
8/88	1.7	1.4	1.9	2.1	2.4	0.2	0.3
9/88	1.1	0.9	2.5	1.6	2.7	0.0	0.3
10/88	2.0	1.1	2.9	3.5	3.6	0.4	0.4
11/88	1.7	1.3	3.3	3.9	1.0	0.3	0.5
12/88	2.4	0.8	3.8	5.3	1.9	0.1	0.5
1/89	2.3	0.9	4.4	5.9	2.1	0.4	0.4
2/89	1.6	0.6	3.2	4.8	2.8	0.7	0.4
3/89	1.9	0.5	3.5	5.0	2.7	0.2	0.3
4/89	1.1	0.3	1.6	5.0	4.0	0.9	0.3
5/89	0.7	0.3	0.6	1.5	2.3	0.0	0.2

RGP is defined as the number of white roots >1 cm after 14 days under test conditions described by Tabbush (1988). Data are the average of 16 2-year-old transplants per species. High values in 5/88 reflect recovery from transplanting in late April 1988.

Containerised seedlings in upland forestry

The 1988 *Report* (p. 16) discussed the increasing interest in the use of containerised planting stock in British forestry. By the spring of 1990 12 forest experiments had been established on a range of sites to compare the forest performance of containerised and bare-root planting stock. Fifteen different types of container were included in this series and species examined included Douglas fir, Japanese larch, Sitka spruce, Corsican pine and birch.

Early results generally show the performance of containerised plants to be similar to that of good-quality bare-root plants. However, there was no evidence that containerised seedlings were inherently superior to bare-root stock and they tended to be more susceptible to post-planting damage from weevils or fungal pathogens. Further work is in progress to examine the most appropriate conditioning regime for use with containerised seedlings, to look at effects of cold storage and to check on root architecture post-planting.

W. L. MASON

CULTIVATION AND ESTABLISHMENT

Restock establishment with Corsican pine

Undercut Corsican pines (1u1) were planted on a range of positions on mounding and disc trenching on a littoral sand in spring 1989 at Pembrey (West Glamorgan). Survival at the end of the first growing season is given in Table 6.

Table 6. First year survival of 1u1 Corsican pine from different planting positions on a cultivated littoral sand

	Survival (%)
On top of small mound (M)	78
On the 'duff' scraped away by the disc trencher (U)	23
At the top of the screef adjacent to the 'duff' (T)	32
Halfway down the screef (H)	42

Despite a drought over summer 1989, the plants on the mounds have survived very significantly better than the others. Growth has also been reasonable on the mounds and will be reported later. Foliage remained apparently healthy and little needle loss was experienced throughout the year.

D. G. NELSON, S. J. CORCORAN

Restock establishment with Douglas fir

A demonstration/experiment was established in 1989 in Wales to determine which combination of plant type plus handling and cultivation method gives the best survival and early growth of Douglas fir on upland brown earth after clear fell of Douglas fir. The experimental treatments are given below:

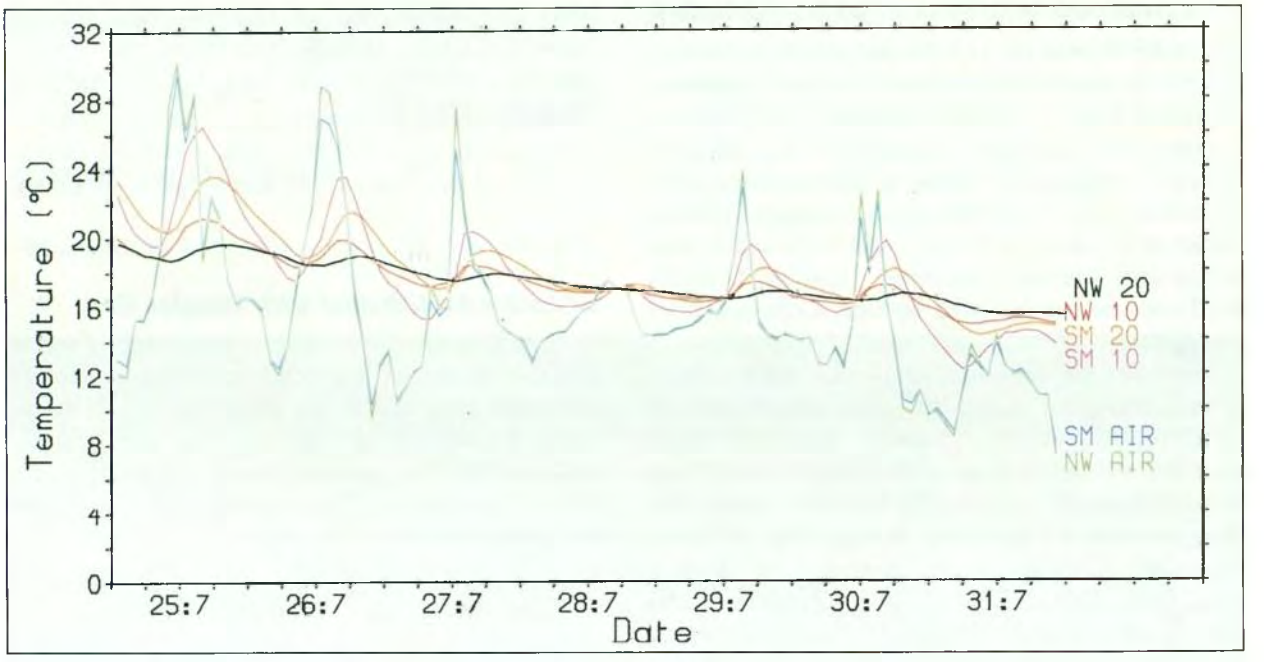
Plant type	– 1u1, 1+1s and containers – all ex research nursery
Handling	– well-handled (uplifted by research staff) – 'normal' delivery procedures
Ground preparation	– small mounds – disc trenching – simulated shallow ploughing – no cultivation, herbicide control of grasses – no cultivation, no herbicide

Despite a very hot and dry summer both survival and increment at the end of the first growing season are high (all plants treated with insecticide using electrodyne).

Survival over the range of treatments was 94.3% for well-handled and 92.6% for normal handling.

Further assessments are planned to assess deaths over the winter and in subsequent growing seasons.

Temperature. One year's measurements of soil temperature at two depths (10 and 20 cm) and air temperature close to the plant (10 cm above ground) have been completed. As an example, of the mounding treatment (SM) and the herbicide only (NW) treatment the temperatures during one week in July 1989 are shown in the graph. The seasonal temperature fluctuation on cultivated



Soil temperatures in late July 10 and 20 cm below and air temperatures 10 cm above the surface of a brown earth soil which is being restocked with Douglas fir. An area cultivated with small mounds (SM) is compared with an adjacent area which was not cultivated but was weeded (NW).

ground is, like the daily one shown, expected to have higher maxima and lower minima than uncultivated ground. These higher maxima will lead to enhanced root growth with cultivation. Air temperatures in all treatments were similar. These results will be reported in more detail later.

D. G. NELSON, A. R. ANDERSON

Restocking Review Group

The restocking special project team completed its 3-year term in April 1989 (*Report*, 1989). During this period, the main problems of weevil damage, plant quality, plant handling and inadequate cultivation have been clearly identified and tackled in a joint programme by Silviculture (N), Entomology (N), Physiology and Work Study, resulting in important guidelines to improved practice. Due to the ongoing nature of current research and development work, plus a continued unsatisfactory restocking success rate, a Restocking Review Group has been established with members from Research Division, Work Study Branch, Nurseries, and Silviculture Division. This group will continue to work at improving the success rate of restocking, concentrating on improved survival of Sitka spruce but also investigating the establishment of other important species such as Corsican pine, Douglas fir and the larches.

D. G. NELSON

Forest weed control

Grasses. In 1986, six experiments were laid down on a range of soil types to determine the optimum rate and date for application of terbuthylazine granules (4% active ingredient) for grass weed control, and to ascertain the crop tolerance of Sitka spruce, Norway spruce and Japanese larch. (See Nelson and Williamson (1989) for results from similar experiments with terbuthylazine and atrazine liquid.)

Application of 4.5, 7.5, 10 and 20 kg a.i. ha^{-1} on a 1 m diameter spot around the tree took place in October, December, February (1987) and April (1987). Additionally, atrazine/dalapon granules at 4.0 kg a.i. ha^{-1} and propyzamide granules at 1.5 kg a.i. ha^{-1} were applied as standards.

The degree of weed control achieved in the first year was variable. On thin peat, *Molinia* was not controlled by any product at any date. On a surface water gley, terbuthylazine at 5 kg a.i. ha^{-1} and above and the two standard treatments applied on the three earlier dates gave good control of *Deschampsia caespitosa* for one year, with atrazine/dalapon also effective when applied in April. On a freely draining mineral soil, control of soft grasses, including *Holcus mollis* and *D. flexuosa*, was poor. Only rates of 10 and 20 kg a.i. ha^{-1} gave acceptable control of these grasses, with control by the standard products surprisingly poor. At the end of the second growing season only the 20 kg a.i. ha^{-1} rate gave any lasting control and, where *H. mollis* was present, reinvasion was largely complete.

There was no damage to the spruce and only a slight blackening of some needles on the larch.

It is concluded that terbuthylazine granules are unsuitable for organic soils and give variable control on mineral soils depending on grass species and rate of application. There was no significant crop damage to sensitive species at these dates and rates.

D. G. NELSON, D. R. TRACY

REFERENCE

NELSON, D. G. and WILLIAMSON, D. R. (1989). *Gardoprim-A: experimental results on grass weed control and crop tolerances.* Forestry Commission Research Information Note 152.

Heather. A powder form of cyprazine was applied in solution through a Polyclair sprayer in 220 litres water ha^{-1} to control heather. A high degree of control was achieved with rates of 4 kg a.i. ha^{-1} in July and both 3 and 4 kg a.i. ha^{-1} in August (see Table 7).

Table 7. Percentage heather control and increment of Sitka spruce in first year after treatment with cyprazine

	Treatment	Heather control (%)	Increment (cm)
July	2 kg a.i. ha^{-1}	50	9.9
	3 kg a.i. ha^{-1}	58	10.7
	4 kg a.i. ha^{-1}	87	12.2
August	2 kg a.i. ha^{-1}	77	11.8
	3 kg a.i. ha^{-1}	92	11.2
	4 kg a.i. ha^{-1}	95	14.4
Control		—	5.8

There was no visible damage to the crop. This product has not been made available commercially.

D. G. NELSON

Bracken. Dense bracken on a recent Sitka spruce restock site was sprayed with asulam at half rate (3 litres product ha^{-1}) and full rate (6 litres product ha^{-1}), 36% glyphosate as Roundup at half rate (1 litre product ha^{-1}) and full rate (2 litres product ha^{-1}) and a 48% glyphosate solution as Roundup 480 at 1.5 litres product ha^{-1}, ± a range of adjuvants; namely:

Agral as 0.1% of total spray volume;
Mixture B as 1% of total spray volume;
Mixture B as 2% of total spray volume;
Galion as 2% total of spray volume;
Ethokem as 1% total of spray volume;
Silwett L77 as 0.5% of total spray volume.

Application by knapsack took place in July/early August. The results showed that:

1. The lower rates of herbicide do not give adequate bracken control even when adjuvants are used.
2. Adjuvants improved the degree of control achieved in nearly every case.
3. For an equivalent quantity of glyphosate applied ha^{-1}, Roundup 480 gave better overall control of bracken than the standard 36% product.
4. Without adjuvants, only asulam at 6 litres ha^{-2} gave adequate control. Taking 80% as the minimum acceptable level of control, the following combinations of currently approved products were effective, in descending order;

   6 litres ha^{-1} of asulam + Galion or Mixture B (2%)
   2 litres ha^{-1} 36% glyphosate + Galion
   2 litres ha^{-1} 36% glyphosate + Agral
   6 litres ha^{-1} asulam without adjuvant, with Agral or with Mixture B (1%).

D. G. NELSON, S. J. CORCORAN

RECLAMATION

Mineral sites

Recent experiments (P82–87) investigating various nutritional treatments of mainly Sitka spruce on upland mineral reclamation sites in Clydesdale and Kyle (Strathclyde) are now providing some useful early information and are of good demonstrational value. Treatments of spruce involving only inorganic nitrogen fertiliser need to be frequent to maintain acceptable and healthy plant growth. Top dressing with 'Biosol' (organic fertiliser), use of nutritional mixtures (with Japanese larch and alders) and sowing legumes ('Maku' – *Lotus pedunculatus*) generally improves colour of spruce but growth remains variable. The most significant growth response has come from sewage sludge application. Early trials (Kyle 18) and a later experiment (Kyle 19) have indicated a dramatic response lasting over two growing seasons from one application.

Peat dressed sites

The growth of Sitka spruce on re-distributed peat remains significantly superior to spruce on mineral sites. Applying inorganic nitrogen fertiliser, sowing legumes ('Maku') and using nutritional mixtures have not currently increased the performance over the controls which are growing well (Kyle 9 and 11).

J. D. McNEILL, M. K. HOLLINGSWORTH

NUTRITION

Sewage sludge

Experimental work, carried out in conjunction with the Water Research Centre, continues to confirm the early positive response of crops to sludge applications. Further work is being carried out to assess the environmental impacts of applications. This includes a survey of the ground vegetation under a Scots pine pole-stage crop before and after application, and an initial study of the effect of the heavy metals applied in the sludge on soil micro-organisms and hence nutrient cycling.

Copper deficiency

An initial survey of distorted trees at Harwood Forest (*Report* 1989, p. 18) was carried out by the Department of Forestry and Natural Resources at Edinburgh University. This confirmed that foliar copper levels were lower in the distorted trees than in the control trees, with the most distorted category of tree having the lowest levels.

An experiment is due to be established at the site this spring in which a range of treatments will be used to try to increase foliar copper levels. This will include a sludge treatment as results from a sludge application experiment at Ardross indicate that foliar copper levels are greater in the plots treated with sludge than in those receiving inorganic fertilser.

Sewage sludge application to a pole-stage Scots pine crop.

The establishment of pilot trials (*Report* 1989, p. 19) has continued, with five sites now receiving treatment. This has highlighted some operational difficulties associated with moving equipment within newly thinned crops. The announcement that sewage disposal at sea is to be banned by the end of 1998 has given impetus to the establishment of such trials and several more should commence this year.

Effects of earthworms and lime on N availability

Initial laboratory and field trials by ITE have demonstrated that earthworms can mobilise nitrogen (N) in peaty soils which have been amended with lime to increase the pH. In conjunction with ITE, two experiments have been set up in south-west Scotland to establish whether this effect can be reproduced on a larger field scale, and to quantify the response of the Sitka

spruce crop to any increase in N supply. It is hoped that if results are positive this technique may have potential for long-term manipulation of certain sites to improve nutrient status.

J. C. DUTCH

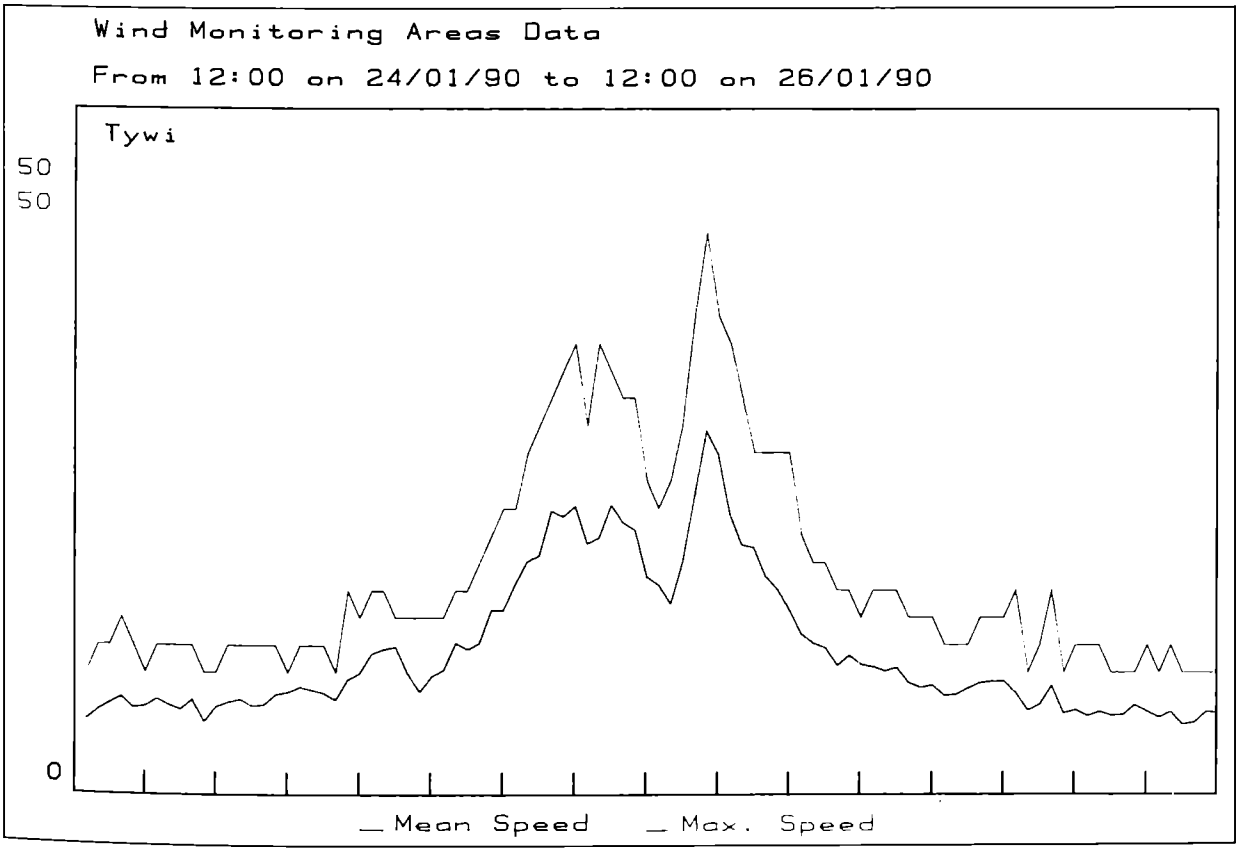
STABILITY

Windthrow

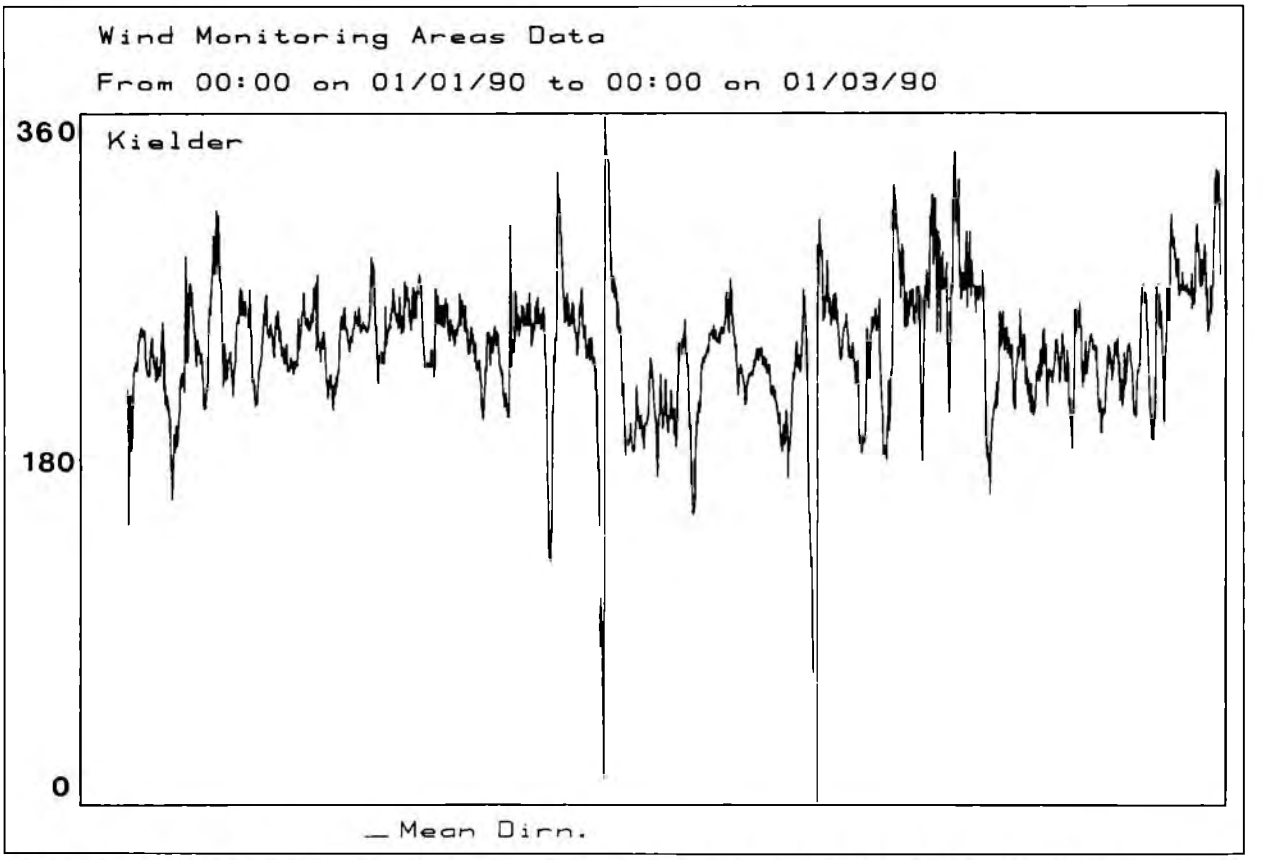
Work continues to be centred on the network of windthrow monitoring areas (*Report* 1988, p. 19; Quine and Reynard, 1990). There has been substantial progress in the ground survey to characterise site and crop factors, and the data gathered are being placed on a database; it is planned to use a geographic information system to carry forward the analysis and presentation of results. The network of anemometers and windvanes (*Report* 1989, p. 19–20) is giving valuable insights into the upland wind climate. However, the harshness of the environment has caused a number of equipment failures and one anemometer was destroyed by a lightning strike. Collaborative work with the Climatic Research Unit at the University of East Anglia has been initiated through the establishment of a CASE studentship to use our wind data to develop a model to predict windspeed for a range of upland sites.

The winter of 1989/1990 was noted for its windiness. Southern Britain was affected by a series of storms, the most notable being that on the 25 January when approximately 1.3 million m^3 of timber (4 million trees) were windthrown. Immediately after the storm preliminary Meteorological Office data were used to identify the main affected areas and this proved useful in responses to media enquiries and in guiding early damage estimates. The total damage and the proportion of broadleaved timber was less than in the October 1987 storm, but it is probable that this is largely due to lower windspeeds than to any leafiness factor (Quine, 1991). The windthrow monitoring site at Tywi was on the northern fringe of the main affected area but the wind record nevertheless indicates the main features of the storm. The maximum gust recorded was 41 m s^{-1} (80 knots, 92 m.p.h.), and the maximum hourly mean windspeed was 26 m s^{-1} (50 knots, 58 m.p.h.).

In northern Britain the winter was persistently windy, but the windspeeds were not as rare as those experienced in southern Britain. The predominance of the westerly airflow, representing a



Maximum and half-hourly mean windspeed (m s^{-1}) recorded at Tywi windthrow monitoring site from 12.00 on 24.1.90 to 12.00 on 26.1.90.



Mean half-hourly wind direction (0–360 degrees) recorded at Kielder windthrow monitoring area for the months of January and February 1990.

series of depressions, is well illustrated by the wind direction data recorded at Kielder. The strongest winds in many places in northern Britain occurred on 26 February; at Kintyre a maximum gust of 45 m s^{-1} was recorded, with a maximum hourly mean windspeed of 30 m s^{-1}, while at Kielder the maximum was 35 m s^{-1} and the hourly mean was 23 m s^{-1}.

Root architecture

Studies of root architecture aim to give managers guidance on the stability implications of different planting and cultivation methods. Following on from the work at Harwood which showed that old stumps had a detrimental effect on root spread of restocked trees (Quine, 1990), further work on restocking sites has been carried out in conjunction with Physiology Branch. A study at Kershope Forest recorded root spread in the presence of furrows remaining from the first rotation, as well as old stumps. Roots were exposed using a supersonic air knife, a new tool that uses compressed air to loosen and then blow away porous material. The technique proved extremely successful, and even fine roots remained intact after removal of litter and surrounding soil. The air knife is easier to work with

Supersonic air knife used to expose tree roots (C. P. Quine)

and is less messy than water jets, and is considerably quicker and less damaging than hand excavation. Initial observations indicate that roots can successfully spread across old furrows in the litter and brash accumulations. Similar studies on an afforestation site of the same type are now planned to provide a comparison.

Root systems have also been extracted by vertical tree-pulling from an experiment on a peaty ironpan site at Moffat (*Report* 1989, p. 19) which compared planting on spaced furrow ploughing, adjacent to deep ripped lines, and on complete ploughing. Surprisingly, there appear to be no significant differences in root system symmetry within 50 cm of the stem between the three treatments, although all showed enhanced root development upslope. Further analysis and interpretation of these results is underway.

Exposure

A detailed analysis of tatter flag results to date has indicated scope for a revision of windiness scores in the Windthrow Hazard Classification, including the introduction of an aspect score. The impact of these changes on classification of sites for Windthrow Hazard is currently being tested, and the revised scores will be published in the coming year. A total of 204 exposure flags are currently in use to provide estimates of wind exposure.

C. P. QUINE, A. L. MACKIE, B. R. REYNARD

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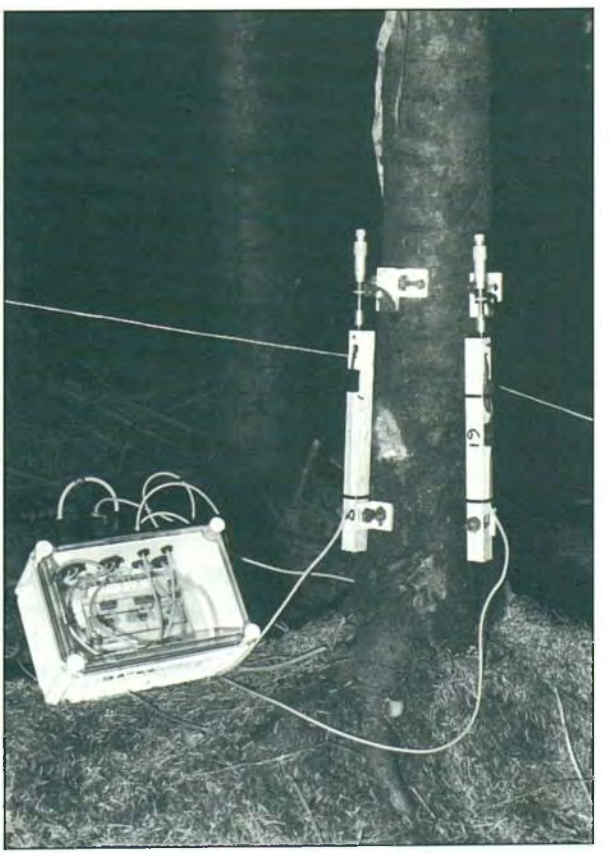
AEROMECHANICS AND AIRFLOW

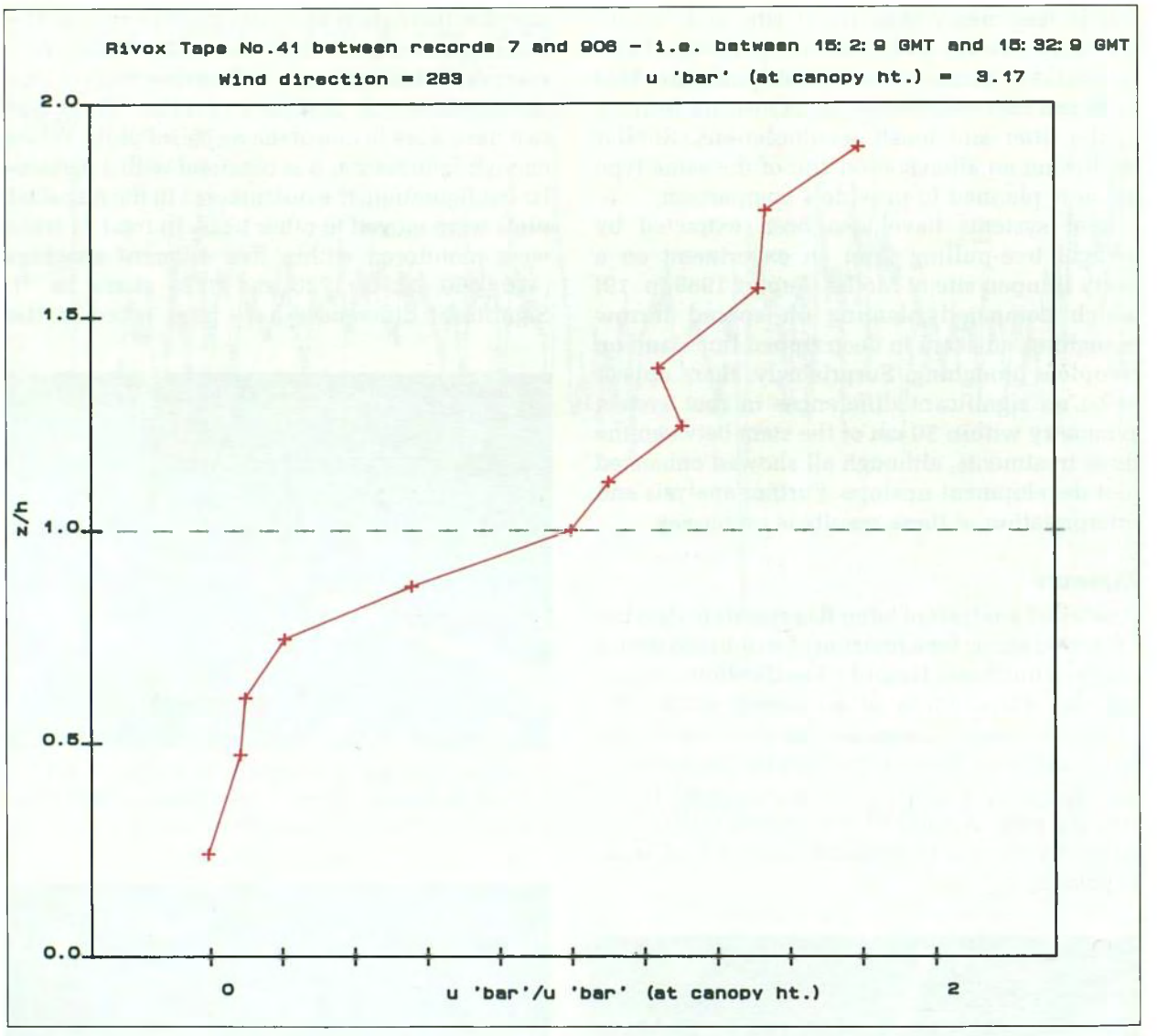
Wind/tree interaction studies

A new experiment was set up in a respacing experiment at Kershope (Borders Forest District) to test whether respacing has beneficial consequences for stability. A 16 m tower was erected in the centre of the experiment site within part of the untreated forest. Three-axis anemometers were placed at four heights on the tower to measure windspeeds above and within the canopy. Instruments were placed on three trees at a time to monitor their stem and root movement and the bending moment at their base. One of the trees was permanently chosen to be in the control plot (no treatment) to provide a baseline. The other two trees were in one of the respaced plots. When enough information was obtained with a particular configuration, the instruments in the respaced plots were moved to other trees. In total 11 trees were monitored within five different spacings (420, 880, 1250, 1720 and 3220 stems ha^{-1}). Significant differences have been noted in the

Sensitive three-axis anemometer for windspeed and turbulence measurements. (Constructed in the Forestry Commission Research Workshop.)



Bending moment sensors attached to the base of a tree. (Constructed in the Forestry Commission Research Workshop.)



Mean windspeeds at 12 heights within and above a forest canopy. All speeds are normalised to the speed at canopy top (canopy top is marked by the dashed green line).

root and stem movement and the basal bending moments of trees subjected to different respacings but the implications of these differences require further analysis.

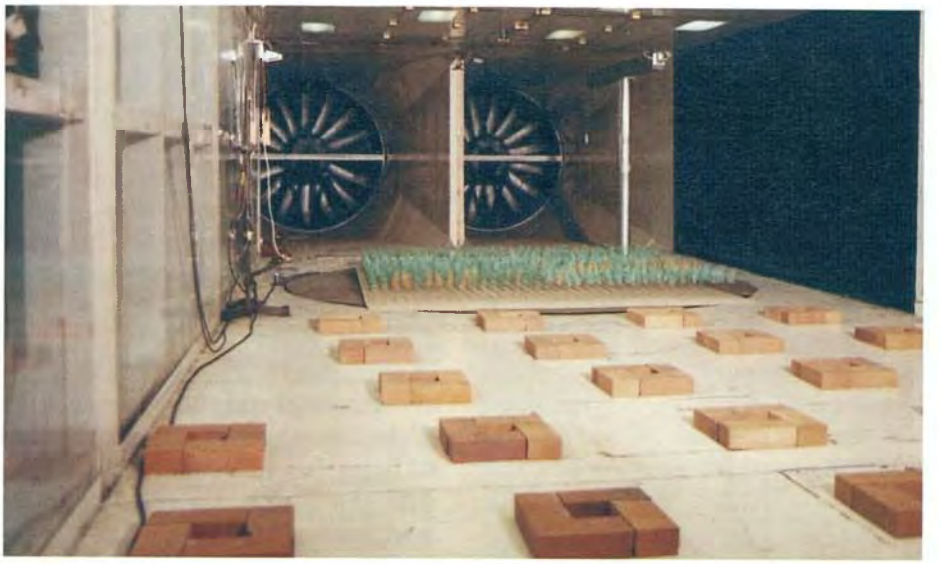
Analysis is also under way on the data obtained in the previous aeromechanics experiment at Rivox (Nithsdale Forest District) described in *Report* 1989. Information obtained from this experiment is revealing details of the structure of the airflow above and within forest canopies and the response of trees to the wind. The graph shows the mean windspeed at various heights from the ground up to almost twice canopy height and illustrates the very rapid increase in windspeed at the top of the forest canopy.

The Forestry Commission is collaborating on this project with the Institute of Terrestrial Ecology who are making additional measurements to those described.

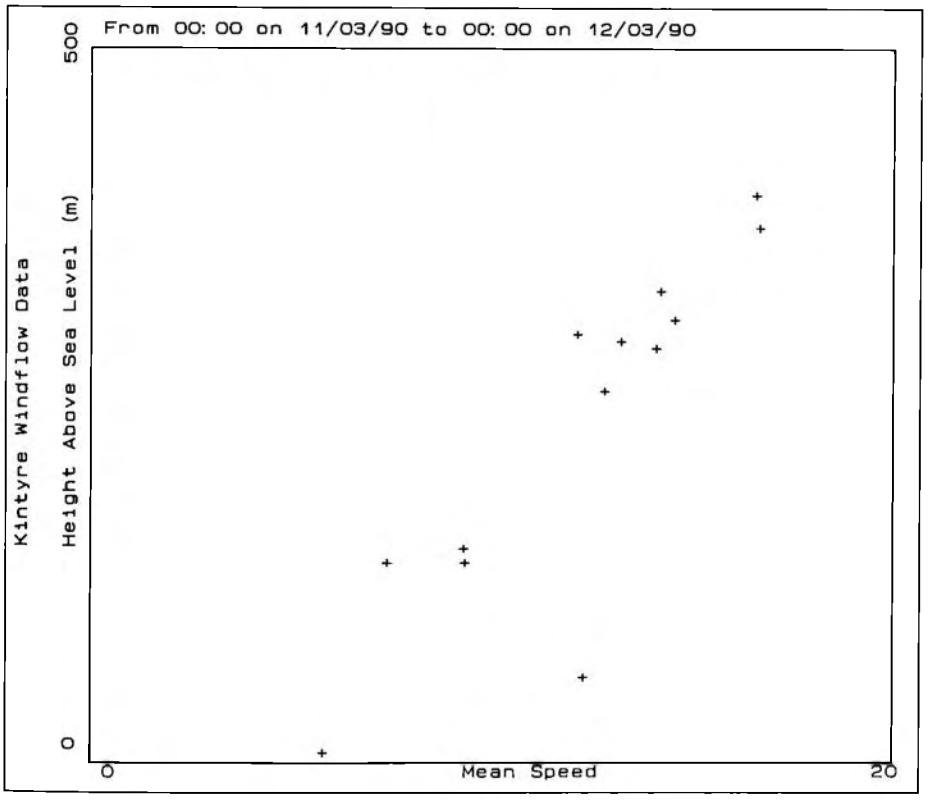
Wind-tunnel studies

The design of 1:75 scale model trees was finalised (Gardiner, 1989) and over 11 000 trees were constructed using plastic injection moulding techniques. This has enabled a model forest of 8 ft × 8 ft to be placed in the Oxford University wind-tunnel.

A number of forest patterns were identified for testing in the tunnel. These include various types of thinning, different planting densities and different clearing widths. The measurements to be made in the tunnel include windspeed and turbulence intensity above the canopy and the force on selected trees in the forest. Such information, along with the field experiments described above, will lead to a better understanding of airflow over forests and allow more precise judgements to be made of the impact of thinning, respacing or clear felling.



Model plastic forest located in University of Oxford wind-tunnel. The brick squares condition the airflow prior to it reaching the forest.



Variation of windspeed with elevation on the Kintyre peninsula.

This study is a joint effort between the University of Oxford and the Forestry Commission and is funded by the European Community

Airflow in complex terrain

This continuing collaborative project between the Forestry Commission and the University of Manchester Institute of Science and Technology involved a second period of field work in the Kintyre peninsula, Argyll. Windspeed and direction were measured at 14 sites across the peninsula during a 5-week period noticeable for the strength of the predominately westerly wind. The anemometer sites ranged in altitude from sea-level to 400 metres and the variation in windspeed with altitude is illustrated. In addition to the continuous measurements at ground level the University of Manchester light aircraft obtained windspeed, temperature and humidity information above the peninsula on several occasions. While the aircraft was operating more intensive windspeed information was also obtained at two locations on the ground to enable turbulence levels and shear stress to be calculated.

The data obtained over the past two field seasons are being compared with the predicted

Three-axis anemometers for obtaining turbulence information during the Kintyre airflow study.

windspeeds from various mathematical computer models (Inglis *et al.*, 1990). Development of the models will continue with the future aim of using them to determine the wind exposure of all but the most heavily indented terrain.

B. A. GARDINER, A. L. MACKIE, B. R. REYNARD

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NATURAL REGENERATION IN UPLAND OAKWOODS

Much concern has been expressed over the apparent lack of natural regeneration in many of Britain's native upland broadleaved woodlands. The progress of initiatives aimed at regenerating and extending such woods is hampered by a lack of detailed information on the factors that are important in influencing regeneration.

Substantial difficulties have been encountered in the regeneration of oakwoods. This is particularly important in Wales where 44% of the broadleaved woodland area is dominated by oak (26 000 ha).

Research into upland oakwood regeneration has been commenced with the preparation of a literature review by Dr R. Worrell under contract to Silviculture (North) Branch. This review forms a comprehensive reference of the present state of knowledge and has provided an invaluable baseline for the development of plans for further experimental and survey work to be carried out in Wales over the coming year. Potential experimental sites have been identified in collaboration with the Welsh Woodlands group Coed Cymru who have also been instrumental in securing funding for a joint survey of regeneration in the oakwoods of North Wales to be undertaken during the summer of 1990.

C. J. NIXON, N. P. DANBY

FARM FORESTRY

Following on from the pilot demonstration sites established in 1988/89, fully replicated farm woodland establishment experiments have now been set up in conjunction with each of the three Scottish Agricultural Colleges (SAC). The experiments include a wide range of coniferous and broadleaved trees with potential for use in upland farm woods. Tree growth responses to different intensities of weed control and cultivation will be assessed in detail across the three markedly different site types. Once established, the experiments will supersede the smaller demonstrations and will also be utilised for interpretation purposes.

C. J. NIXON

AGROFORESTRY

Collaborative work on two large-scale agroforestry experiments at Bronydd Mawr in Powys, Wales (Welsh Plant Breeding Station) and Glensaugh in the Grampian Region of Scotland (Macaulay Land Use Research Institute, MLURI) has continued with the collection of 2-year tree height and survival data (Table 8). The data for sycamore show reduced height growth in the open-grown forestry control plots (2500 stems ha^{-1}) compared with the sheep-grazed agroforestry plots (100 and 400 stems ha^{-1}) which were

Table 8. Mean height and survival of sycamore after two growing seasons

	Glensaugh		*Bronydd Mawr*	
Tree density	*Height (cm)*	*Survival (%)*	*Height (cm)*	*Survival (%)*
100 stems ha^{-1}	78	93	100	87
400 stems ha^{-1}	112	98	121	100
2500 stems ha^{-1}	41	99	34	79

established in treeshelters. They also exhibit a smaller mean height at the lower tree density.

The data indicate the advantage, at least in terms of height extension, of trees in shelters over those grown in the open. There also appears to be a greater number of trees lost at the lower tree density. This is probably due to the increased attention that each tree receives from the sheep. It is hoped that the installation of additional rubbing posts in the 100 stems ha^{-1} plots will help alleviate this problem.

In addition to this work, a research proposal has been submitted to the CEC DGVI research programme in the field of Competitiveness of Agriculture and Management of Agricultural Resources, in conjunction with MLURI. If funded, the work will aim to establish the potential for agroforestry in the EC with the research being carried out along with collaborators in France and Greece.

C. J. NIXON, S. J. CORCORAN, F. S. SMITH

SITE STUDIES (SOUTH)

CHEMICAL ANALYSIS

A total of over 6000 samples have been submitted for analysis of major nutrients during 1989 and of these 10% were from private forestry organisations. Starch and soluble sugars have been determined on 250 forestry samples using wet chemical methods. The new Dionex HPLC system has been used to determine (a) anions in water samples (Cl^-, NO_3^-, NO_2^-, PO_4^{3-}, SO_4^{2-}) and aqueous extracts of plant tissue and soils, (b) individual sugars in plant extracts. A project on salt induced damage to roadside trees has provided about 400 samples for chloride, acetate and other anions.

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

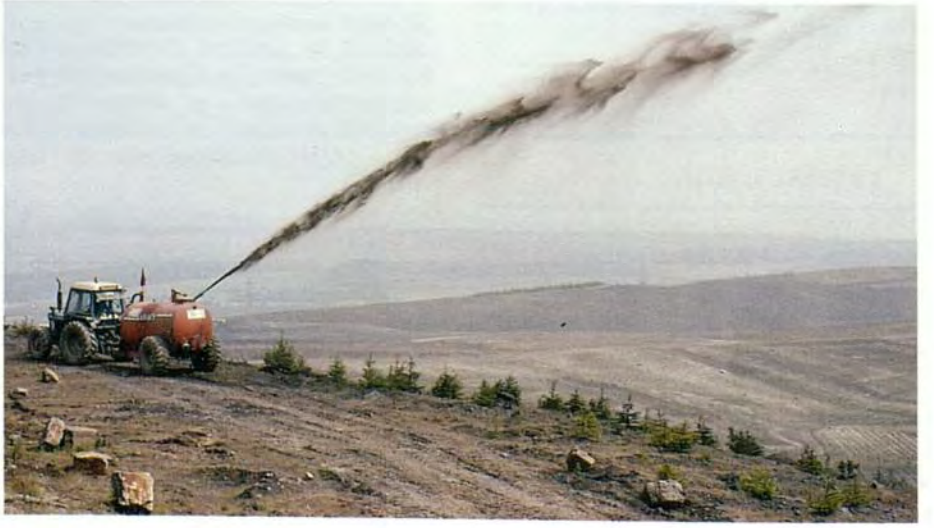
RECLAMATION

South Wales opencast spoil

Site factors affecting the performance of Japanese larch on restored opencast ground continue to be investigated under an extended 2-year contract from British Coal.

Variability in the performance of Japanese larch can be attributed to both soil chemical and physical conditions. Chemically young spoils of high pH (>7.2), conductivity and magnesium content are widely associated with poor growth. Spoils on older sites demonstrate the beginnings of soil forming processes with lower pH (<6.0), larger cation exchange capacities and organic matter contents. Growth on older sites, under favourable ground conditions, approaches that of adjacent undisturbed ground. Soil physical conditions differ widely between sites. Examination of rooting profiles suggests that shallow rooting is associated with spoils of a highly compacted nature (>1.7 g cm^{-3}), and where waterlogging conditions prevail. The presence of highly compacted spoil materials at shallow depth questions the efficacy of traditional ground cultivation techniques. Examination of the moisture status of spoil materials by means of tensiometers and gypsum blocks during the summer and autumn period of 1989, indicated that many spoils are also extremely susceptible to drought.

Experimental work has focused on the use of sewage sludge on afforested opencast ground. Experiments to examine both liquid and cake sludge have been established and monitored during 1989/90. At Tredeg opencast coal site



Liquid sludge application to opencast coal spoils and Maesgwyn. The tanker is capable of delivering nearly 100 l s^{-1} over a distance of 100 m. Treated spoil in foreground. (39424)

liquid sludge has been applied to Japanese larch at rates of between 75 and 250 m^3 ha^{-1}. Results after 1 year show increased foliar nitrogen and phosphorus contents of 83% and 187% respectively between the untreated and the 250 m^3 ha^{-1} treatment. At Maesgwyn opencast coal site, liquid sludge is now being applied routinely at 200 m^3 ha^{-1} over established trees to promote growth. Cake sludge applications of between 100 and 400 tonnes dry solid ha^{-1} have also been made on an experimental area, and the role of this material in improving soil bulk density, water retentivity and nutrition is being examined.

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

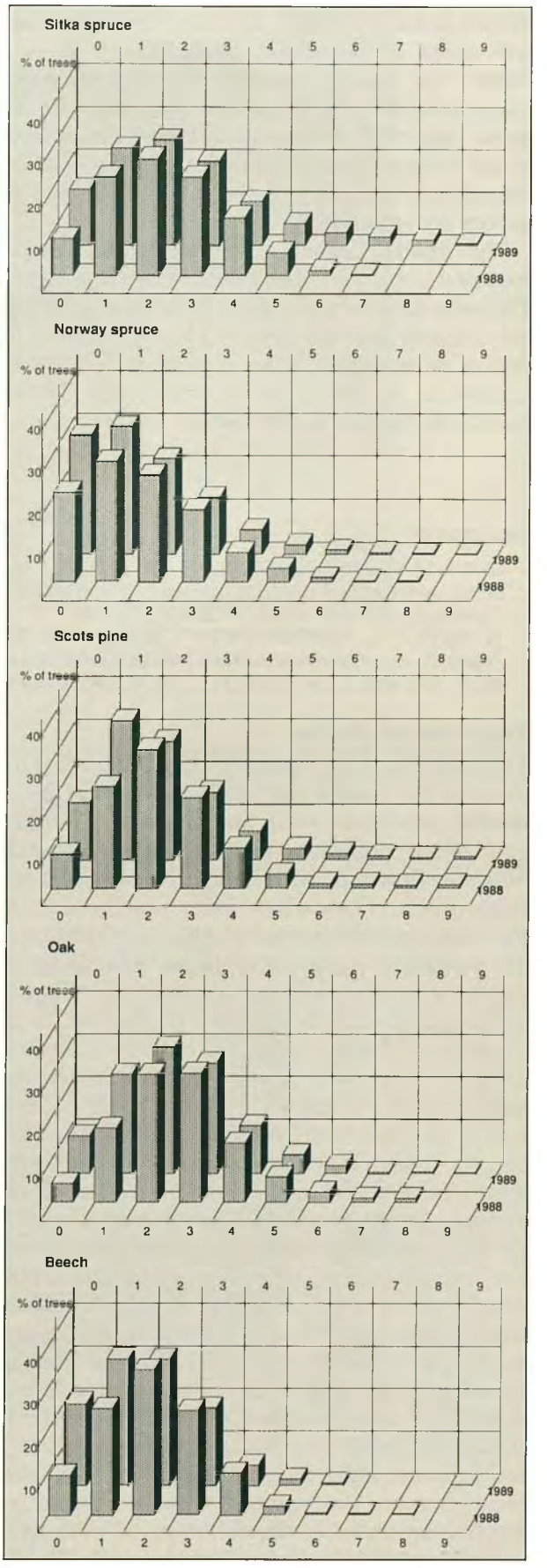
AIR POLLUTION

Monitoring of forest condition

The condition of forests in Britain continues to be monitored as part of an on-going research programme. Two surveys are undertaken, one on behalf of the Commission of the European Communities and a second, which is much more detailed, as part of the Forestry Commission's concern about the effects of environmental changes on the condition of forests. The latter is particularly concerned with assessing the impact of air pollution on trees.

The more detailed survey now involves a total of 7436 trees of five species: Sitka spruce, Norway spruce, Scots pine, oak and beech. Crown density and crown discoloration are both assessed together with about 35 other parameters of tree health. Consequently, a comprehensive assessment of the condition of each tree is now obtained. The different indices can be monitored through time, enabling trends to be identified. In addition, the emphasis that has been placed on observer consistency is now enabling regional assessments of forest condition to be made.

In 1989, all species showed an overall improvement, although the condition of some Sitka spruce deteriorated as a result of defoliation by the green spruce aphid (*Elatobium abietinum*). This was particularly severe in some areas and can be related to the mild winter of 1988/89. Norway spruce was also affected, but needle loss was much less severe. The improvement in the condition of most forest trees contrasts with many open-grown trees which suffered from drought stress during the summer of 1989. There is no evidence of the most important type of decline seen in Norway spruce in continental Europe, and the high levels of magnesium deposition that are currently experienced in much of



Comparison of 1988 and 1989 main survey results. Only sites assessed in both years are included. Ten per cent density classes are indicated along the horizontal axis of each histogram.

Britain makes it unlikely that this type of decline will occur (Binns *et al.*, 1980; Roberts *et al.*, 1989). The detailed assessments that are now undertaken have enabled the identification of many important differences between the nature of the crown thinness found in Britain and in continental Europe, suggesting that different factors are responsible.

The spatial patterns of crown condition recorded in 1987 and 1988 were repeated in 1989. The patterns are consistent with the general belief that climate and site quality play an important part in determining crown condition. There are exceptions to these general trends which can usually be related to site-specific factors.

J. L. INNES

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Experimental studies

The objective of the open-top chamber work is to monitor tree growth and metabolism under near-natural conditions, with and without the influence of air pollution. Growth, phenology and nutrient content of Sitka spruce, Norway spruce, Scots pine and beech have been monitored from the time of establishment (4/88) in ambient and filtered air chambers and in outside plots at Chatsworth, Headley and Glendevon (*Report* 1985, pp. 23–24). A synopsis of the results is presented in Table 9. Open-top chambers provide a sheltering and temperature-ameliorating environment. There is a 'greenhouse' effect where the increase in temperature within the chambers has a more significant effect on growth and phenology than the effect of filtered or ambient air. At Headley, where ozone provides the major pollutant input to the ambient chambers, growth appears to be favoured in filtered air. Analysis of variance identified statistically significant decreases of leader extension in Norway spruce and Scots pine in unfiltered air at Headley. Although differences can be seen at the other sites, these are not statistically significant. Data from the sites on quantities of pollutants, temperature, light and rainfall have been collected over the last year and will soon be available. Experiments in the forthcoming year will concentrate on more detailed photosynthesis and water relations measurements.

A. WILLSON, H. S. J. LEE, D. A. WADDELL, D. W. H. DURRANT, S. E. BENHAM

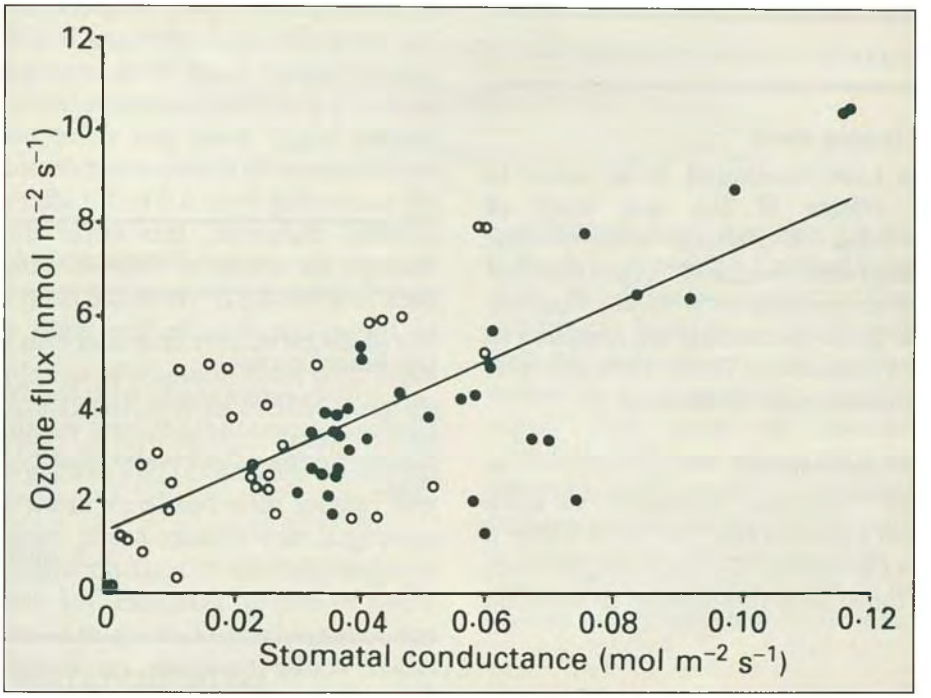
Table 9. Combined growth measurements from all three open-top sites

11/89	*Filtered*	*Ambient*	*Outside*
Norway spruce			
Height (cm)	40.9	40.6	37.3
Diameter (mm)	10.8	10.5	9.6
Leader (cm)	22.9	12.7	9.9
Dry weight (g)	45.8	46.8	32.2
Fresh weight (g)	103.7	106.3	71.0
DW/FW	0.44	0.44	0.45
Scots pine			
Height (cm)	50.1	52.8	47.7
Diameter (mm)	13.8	13.8	12.4
Leader (cm)	26.2	27.6	23.1
Dry weight (g)	53.8	64.6	37.2
Fresh weight (g)	149.9	158.5	105.4
DW/FW	0.36	0.41	0.35
Beech			
Height (cm)	60.4	58.0	50.5
Diameter (mm)	9.4	9.4	8.8
Leader (cm)	21.2	18.0	12.5
Dry weight (g)	16.0	15.6	13.4
Fresh weight (g)	68.4	78.6	47.4
DW/FW	0.23	0.20	0.28
Sitka spruce			
Height (cm)	44.7	47.8	32.2
Diameter (mm)	9.4	9.6	7.1
Leader (cm)	19.5	21.4	9.3
Dry weight (g)	22.7	23.2	10.3
Fresh weight (g)	53.2	56.6	25.6
DW/FW	0.43	0.41	0.40

Analysis of variance of the combined data for all three sites identified statistically significant effects of chamber but not of filtration.

To assess the possibility that air pollutants in southern England could be affecting trees, the concentration of nitrogen dioxide was measured using diffusion tubes at 68 rural sites during the growing season. The distribution of the pollutant is in general agreement with that predicted by trajectory models based upon emission inventories showing distinct concentration maxima in the vicinity of London and the Midlands. The measured concentrations over the whole area studied were higher than the models predict by up to a factor of three. The greatest differences between the observed and modelled values were found along transects connecting London with the industrial regions near the Solent and Severn estuaries. In all parts of the region studied, the concentrations were lower than that known to cause direct injury to trees.

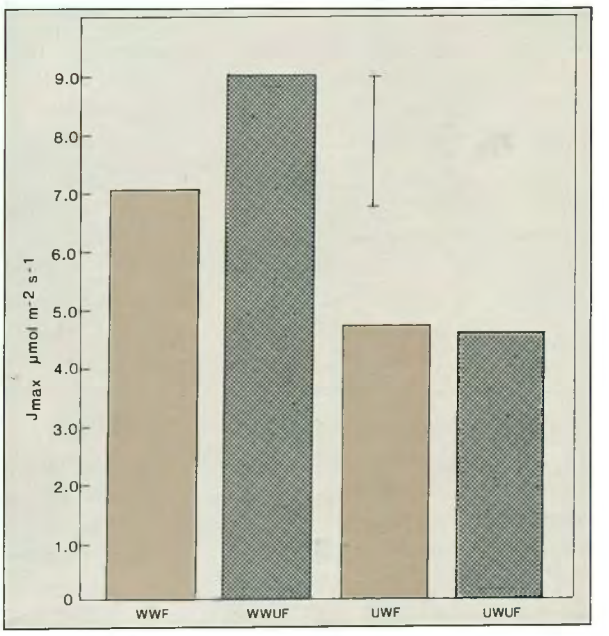
A. WILLSON, D. A. WADDELL, S. E. BENHAM, D. W. H. DURRANT



The effects of stomatal conductance on uptake rates of O_3 for watered (closed symbols) and unwatered (open symbols) Picea abies. *The fitted linear regression ($y = 6.22 x + 1.338$) accounts for 50.3% of the variance in O_3 flux and the slope is statistically significant ($p = 0.05$).*

Joint work with Lancaster University (see pp. 90–91 Part II, this volume) has identified interacting effects of water deficit and exposure to realistic episodes of ozone (O_3), and has allowed the physiological effects of air quality at the Headley open-top chamber site to be investigated. Mild water deficits resulting in physiological drought, as experienced at most UK sites during the summer months, have been imposed on Norway spruce, Sitka spruce and beech. Water deficit decreases the stomatal conductance and hence the O_3 uptake of Sitka and Norway spruce (data for Norway spruce illustrated). The characteristics of the photosynthetic apparatus of beech and spruce were altered by exposure to the ambient pollutants present at the Headley site, with maximum rates of photosynthesis (an indication of the rate of regeneration of reaction substrate RuBP) being increased for beech exposed to ambient pollution. For both beech and spruce these changes were accompanied by effects on leaf water relations, with polluted trees having higher solute potentials (less negative values). However, for all the parameters measured, mild or transient water deficit resulted in greater effects than those caused by air quality (see histograms). These results suggest that the responses of trees to current pollutant concentrations are subtle in comparison with the effects of other factors such as drought. The effects on stomatal and photosynthetic characteristics, and on water relations, indicate that the main significance of gaseous air pollutants may lie in their ability to alter physiology and morphology so that trees respond differently to other site and climatic factors.

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



The maximum rate of photosynthesis (J max in µmol CO_2 m^{-2} s^{-1}) of beech seedlings grown in the filtered (F) and unfiltered (UF) open-top chambers at the Headley site. Plants were well-watered (WW) or unwatered for 10 days (UW). For well-watered plants J max was greater in unfiltered air ($p<0.08$) and the LSD at $p = 0.05$ is shown.

HYDROLOGY : WATER QUALITY

Thetford wet timber store

Measurements have continued to be taken to monitor the effects of the wet store of windthrown timber on drainage water quality. Both water colour and biological oxygen demand have remained acceptable, with values fluctuating around the guide values that are specified in the European Community Water Directive (75/440/EEC) for normal water treatment.

Liming in acid catchments

The pelletised limestone treatment at Llyn Brianne has had a limited effect so far on soil and drainage water chemistry. The photograph shows pellets on the forest floor shortly after application by helicopter in 1988. Dissolution of the pellets has been slow and increases in pH and calcium concentrations have been confined to the near surface L and F soil horizons. Only in one of the treated boggy areas has there been a marked improvement in streamwater chemistry, with the pH increasing from 4.5 to 7.3 after a period of 10 months. However, this effect did not persist through the winter of 1989/90, with pH dropping back to around 5.0. There has been little response to the application in the main stream at the catchment outlet.

A collaborative study with the Water Research Centre to assess the optimum width of buffer strip for improving runoff water quality is planned for 1990.

T. R. NISBET, P. C. JOKIEL

Distribution of limestone pellets on the forest floor at Llyn Brianne following helicopter application in 1988. (39509)

INSTRUMENTATION

In addition to normal development and repair of research equipment the main jobs completed during the year were the construction of two large Conviron growth chambers for the Tree Improvement Branch, an instrument for measuring leaf cell-wall extensibility, a laboratory digestion block for foliar analysis and several control panels for regulating the environment within seed incubators. Development work has continued on designing an efficient animal poison bait hopper.

T. R. NISBET

ADVISORY

Water quality, long-term site monitoring and pollution effects remain areas in which there is a steady demand for advice. The joint Forestry Commission/Countryside Commission initiative on new Community Forests for city fringes has prompted a significant demand for advice on site evaluation, and preparation for tree planting. A survey of soil resources for the East London Community Forest was undertaken in July and August 1989. Advisory work on the possible impacts of climate change on forestry has increased with inputs being made to the Intergovernmental Panel on Climate Change, the DOE Review Group, joint ITE/FC workshop and to an FAO working group.

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

INTER-BRANCH REPORT SITE STUDIES (SOUTH) AND SILVICULTURE (SOUTH)

ALDER NODULATION

Following the previous experiment which examined the inoculation of common alder with *Frankia* after soil sterilisation with methyl bromide (*Report* 1989, p.31), a further experiment was set up to compare growth and nodulation on unsterilised beds or those sterilised with methyl bromide or dazomet. Shoot growth was largest on dazomet plots, and smallest on unsterilised control plots (Table 10). However, degree of nodulation was greatest on methyl bromide plots, and severely inhibited on dazomet plots. Foliar analyses reveal that inoculation with *Frankia* significantly increases nitrogen concentrations, but only on control and methyl bromide sterilised plots. These results suggest that dazomet is acting as nitrogen fertiliser, either directly (it contains 17% N), or indirectly by increasing mineralisation. As a consequence, nodulation is discouraged. This result is unwelcome because nodulation is more important than early growth for stock to be used on reclaimed land where indigenous *Frankia* populations may be low. An experiment examining the effect of varying the rate of application of dazomet on nodulation and growth of common alder has been set up.

A. J. MOFFAT, D. R. WILLIAMSON

Table 10. Height and nodulation of common alder, as affected by soil sterilisation and *Frankia* inoculation regimes

	Soil sterilisation		
	Unsterilised	*Methyl bromide*	*Dazomet*
Mean height (mm)			
Uninoculated	30.5	52.3	72.3
Inoculated at seed sowing	40.6	64.0	79.7
Inoculated at two leaf stage	35.6	50.8	85.8
Percentage trees nodulated			
Uninoculated	4.8	2.4	2.6
Inoculated at seed sowing	92.9	89.8	32.5
Inoculated at two leaf stage	13.0	24.4	14.4

Height is significantly different ($p<0.001$) between sterilisation treatments, but not inoculation treatments. Nodulation is significantly different between sterilisation treatments ($p<0.01$) and inoculation treatments ($p< 0.001$). There is also a significant sterilisation: inoculation interaction ($p< 0.01$).

SITE STUDIES (NORTH)

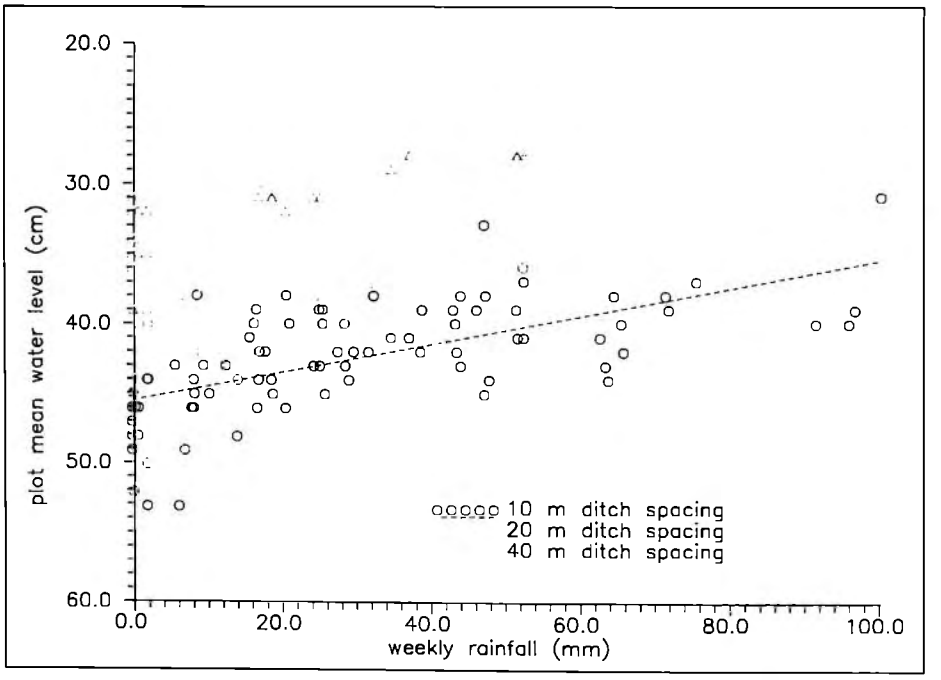
CLAY SOILS

Analysis of weekly borehole water levels and rainfall from the Kershope drainage/mixtures experiment (*Report* 1988, p. 32) has identified a ditching effect and a site slope effect on the water regime; scatter graphs of the plot mean water level (mean of 24 boreholes) against rainfall for 86 weeks in blocks 1, 2 and 3 respectively are illustrated. Blocks 1 and 2 cover an area of peaty gley soil, block 3 contains a surface-water gley on a steeper slope. Each dashed line presents the regression of plot mean water level on rainfall. In graph A data separate out by drainage treatment, with the 10 m spacing having more than a 5 cm advantage in lower water levels over the 20 m spacing and a 15 cm advantage over the 40 m ditch spacing. In graph B separation occurs but is less well defined, whereas in graph C there is no difference between spacing treatment water levels.

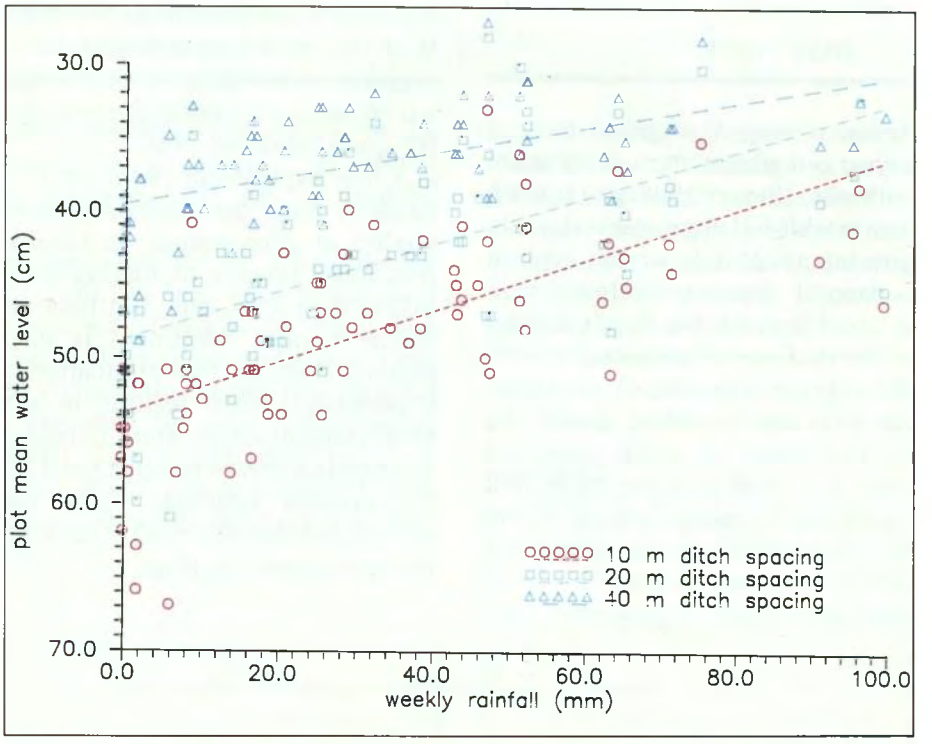
The results suggest that ditch spacings less than 40 m may give drainage benefits (which will be realised in deeper rooting and more windfirm stands) on gentle slopes, but that on more moderate slopes ditches should not be closer than 40 m spacing. We aim to verify these results at a drainage demonstration in Kielder Forest (see below).

At the drainage demonstration at Kielder the 'Z' or zig-zag design should allow ditch spacings from 5 m to 80 m to be compared (*Report* 1988, p. 32; 1989, p. 32 and this *Report*, p. 35 'Loamy gleys'). An instrument automatically measures and records water levels in 54 boreholes, and rainfall from a tipping bucket raingauge. We aim to characterise the water regime of the site prior to ditching by modelling the response to rainfall of each borehole (Rennolls *et al.*, 1980), and look for changes in the soil drainage status after ditching.

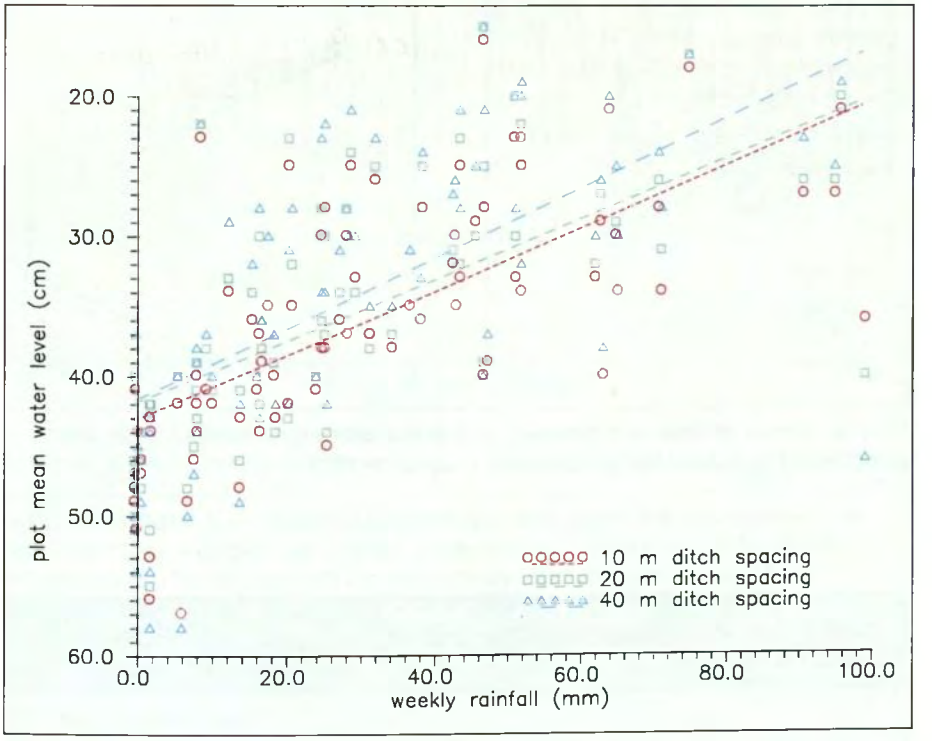
D. RAY



Weekly soil water level vs. rainfall on a slightly sloping (2–3°) peaty gley at Kershope.



Weekly soil water level vs. rainfall on a gently sloping (2–5°) peaty gley at Kershope.



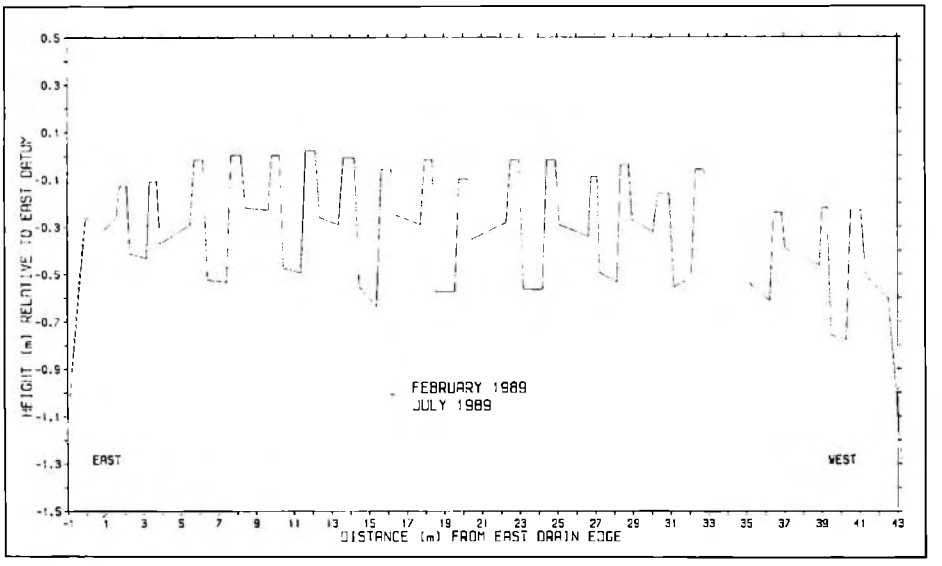
Weekly soil water level vs. rainfall on a moderately sloping (6–12°) surface-water gley at Kershope.

DEEP PEATS

Rainfall was below average throughout most of 1989 at the 22-year-old afforestation experiment at Rumster (Caithness) (*Report* 1988, p. 31; 1989, p. 32) and the water table fell more or less steadily from the beginning of March to the end of October. The deepest water table (maximum 70 cm) was as usual beneath the South Coastal lodgepole pine, the shallowest (maximum 53 cm) was beneath Sitka spruce. The intensity of drying of the peat was sufficient to extend greatly the cracking which had begun in recent years. An attempt to relate the weekly water table and rainfall data using the Rennolls–Carnell model (Rennolls *et al.*, 1980) developed for daily data was successful (84% of the variance in water table depth explained) after weekly evaporation was included as an additional independent variable. With this model we will look for changes in soil drainage status induced by the drain deepening which we carried out at the end of 1988 and/or by the cracking of the peat.

A new experiment (Rumster 17, P89) was laid down to study the effects on water quantity and quality of afforestation on blanket peat. Three treatments involve ploughing and planting with different species and fertiliser regimes and a fourth 'control' treatment is not ploughed or planted; there are four replications. Each plot has a peripheral ditch leading to a V-notch weir. Measurements of the ground level with respect to a datum rod driven through the 3–4 m of peat into the mineral substrate show the amount of subsidence that occurred in the months following ploughing and ditching.

D. G. PYATT



Ground surface profiles of a ploughed plot at Rumster experiment 17, P89, after ploughing in October 1988 and ditching in January 1989.

Table 11. Mean proportion of shallow and deep boreholes containing water, by cultivation treatment

	Deep	*Shallow*	*l.s.d.(5%)*
Uncultivated, unplanted rides	0.31	0.60	0.27
Standard double mouldboard ploughing (D45/T60 I 4.6 m)	0.14	0.42	0.14
Deep ripping under inverted ridge (T90 + inverted S45/T60 I 2.3 m)	0.09	0.44	0.32
Complete rotary mouldboard ploughing (RM60/T90 I 1.0 m)	0.07	0.08	0.16
l.s.d. (5%)	0.13	0.16	

IRONPAN SOILS

We have measured borehole water levels in the 7-year-old cultivation experiment at Moffat Forest (*Report* 1989, p. 32) for 18 months (Table 11).

The shallow boreholes do not penetrate the 30 cm deep ironpan; the deep ones penetrate it and extend to between 55 and 80 cm depth. The larger proportion of shallow boreholes than deep ones containing water in the uncultivated ground confirms the presence of some waterlogging above the ironpan. This waterlogging has been reduced by all three cultivation treatments and virtually eliminated by complete rotary mouldboard ploughing.

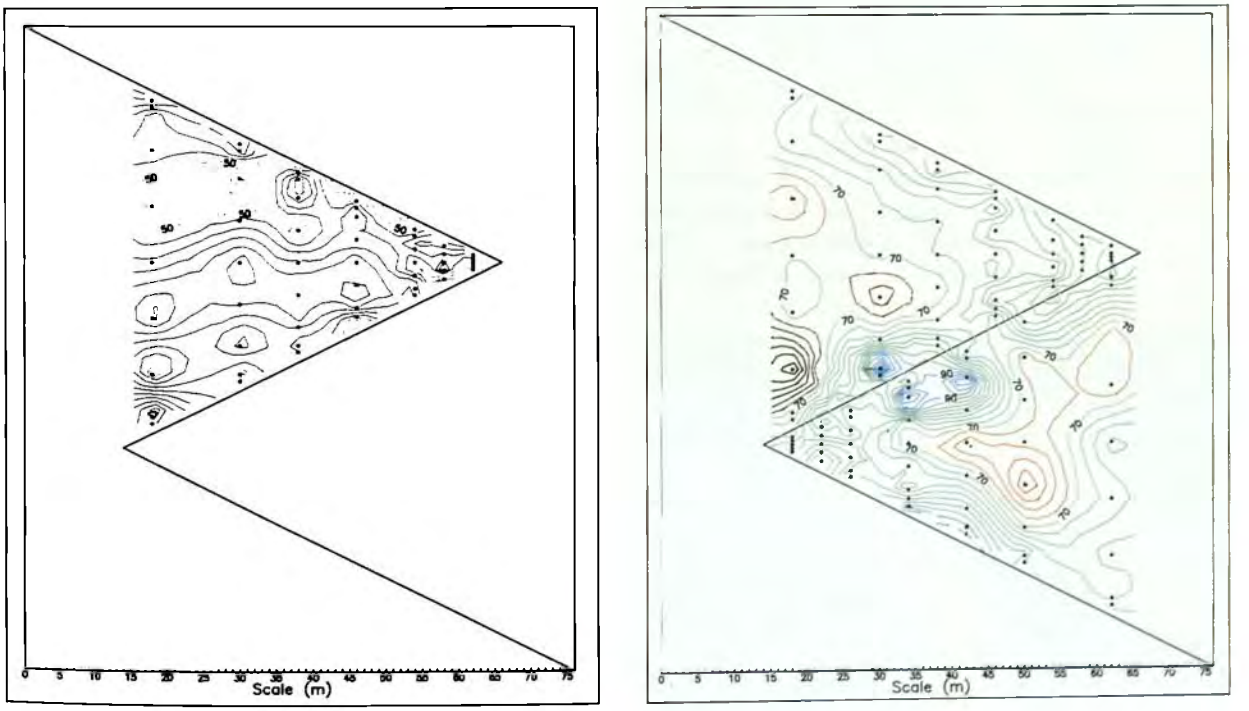
LOAMY GLEYS

Manual readings of borehole water level have been made in the 'Z' drainage experiment at Angus (*Report* 1988, p. 32; 1989, p. 33). They confirm that the water table has been lowered close to the ditch. Interpolation between boreholes was done by 'kriging', but other methods of contouring produce basically similar patterns.

A. R. ANDERSON

REFERENCE

RENNOLLS, K., CARNELL, R. and TEE, V. (1980). A descriptive model of the relationship between rainfall and soil water table. *Journal of Hydrology* **47**, 103–114.



Contours of water table depth before (left) and after (right) the zig-zag drain was dug. The colours purple, red, orange, green and blue represent depths of <30, 30–50, 50–70, 70–90 and >90 cm respectively. The contours are at 2.5 cm intervals.

TREE IMPROVEMENT

SEED STANDS

Following the introduction of the new native pinewood planting scheme and the revision of the grants for the extension of existing native Scots pinewoods, a large number of woods were surveyed. The woods were allocated to the regions as defined on the basis of variation in shoot resin composition (*Report* 1989, p. 36). A total of 35 woods have been included in the Native Pinewood Register. The main selection criteria used was 'nativeness' and an adequate number of trees per hectare to allow interpollination. The stands of course had to be isolated from foreign pollen and in some cases buffer zones had to be demarcated. Note that the Native Pinewood Register has no connection with the National Register of Seed Stands which is compiled under the Forest Reproductive Material Regulations.

Flowering was light in 1989 except for oak and the pine species so only a small number of new stands were added to the National Register. However advantage was taken of the flowering in oak to survey 43 of the 57 oak stands to recheck their purity. Twelve sessile oak stands were inspected and of those two will be reinspected in the next good flowering year as there appeared to be some doubt that more than 10% of the individuals were of pendunculate oak origin. These stands if confirmed to be of mixed species will have to be deleted from the National Register as they are not permitted under EEC Directive 66/404. In the case of the 31 pendunculate oak stands inspected, six are under consideration for deletion and 10 more will be checked further in a good flowering year.

A. M. FLETCHER, C. J. A. SAMUEL

SEED ORIGIN/PROVENANCE STUDIES

Douglas fir

Two of the IUFRO seed origin experiments with Douglas fir, located at the Forest of Dean and at Radnor, were measured at 16 years after planting. The assessments included d.b.h., basal area, height, volume and a number of branching characteristics. Greatest d.b.h. growth was observed on individual trees from southern Oregon and Californian origins, but survival was poorer than Washington and northern Oregon origins. Height growth, basal area increment per hectare and volume, based on height and mid-diameter, of the latter origins were greater than the former. Trees from the extreme southern origins were shorter with greater stem taper than trees of the more northern origins. Number of branches present in a fixed whorl showed significant variation between seed sources, but branch diameter and angle of the largest branch in the whorl were not consistent with latitude or regional groupings of the origins.

Grand fir

Combined analysis of height data from 11 seed origin experiments with *Abies grandis* at 6 and 10 years after planting has been completed. These experiments comprised 34 seed origins from a IUFRO collection. At both assessments, coastal origins performed better than those from inland areas. Greatest height growth was observed in the trees originating from coastal Washington, but those from Vancouver Island and coastal Oregon had above-average heights. Among the inland sources which normally had below-average performance, those from the east of the Cascades range in Washington and from the extreme eastern part of the state were superior in performance to their Oregon counterparts. Some origin × site interaction was noted, but is likely to be unimportant in Britain if only better quality sites are used for this species.

Noble fir

Third and sixth year height data from eight experiments comprising 15 IUFRO origins of *Abies procera* were analysed. This species has a more restricted natural range than *A. grandis* being concentrated along the upper slopes of the Cascades and the coastal range in Oregon. The most vigorous origin at both assessment dates was collection 13008 from Laurel Mountain, but another collection 13004 from the same area performed poorly. In the better represented regions, the Washington and north Oregon Cascades origins normally had above average rates of growth, while those from southern Oregon Cascades grew slowly except at the most productive sites. This latter material comes from the introgression area between *A. procera* and *A. magnifica*. Origin × site interactions were predictably less common in this species.

A. M. FLETCHER, C. J. A. SAMUEL

PROGENY AND CLONAL TESTING

As genetically improved Sitka spruce becomes available either from approved clonal seed orchards or through vegetative propagation, it is important that managers are aware of the financial benefits of this material relative to unimproved stock. Final volume gains are expected to be 15%. This is roughly equivalent to an increase of one yield class (2 $m^3 y^{-1}$). There are in addition improvements in form, estimated to be approximately 7% (see photographs).

Vegetatively propagated material is not recommended in Windthrow Hazard Class (WHC) sites V and VI since the truncated rotation lengths prevent realisation of the additional planting stock costs compounded to the end of the rotation. Improved seed from seed orchards to provide seedling planting stock is suitable for all sites, but again priority should be given to high yielding, lower WHC sites.

Trees with straight stems, fine branches and clear intervals are favoured.

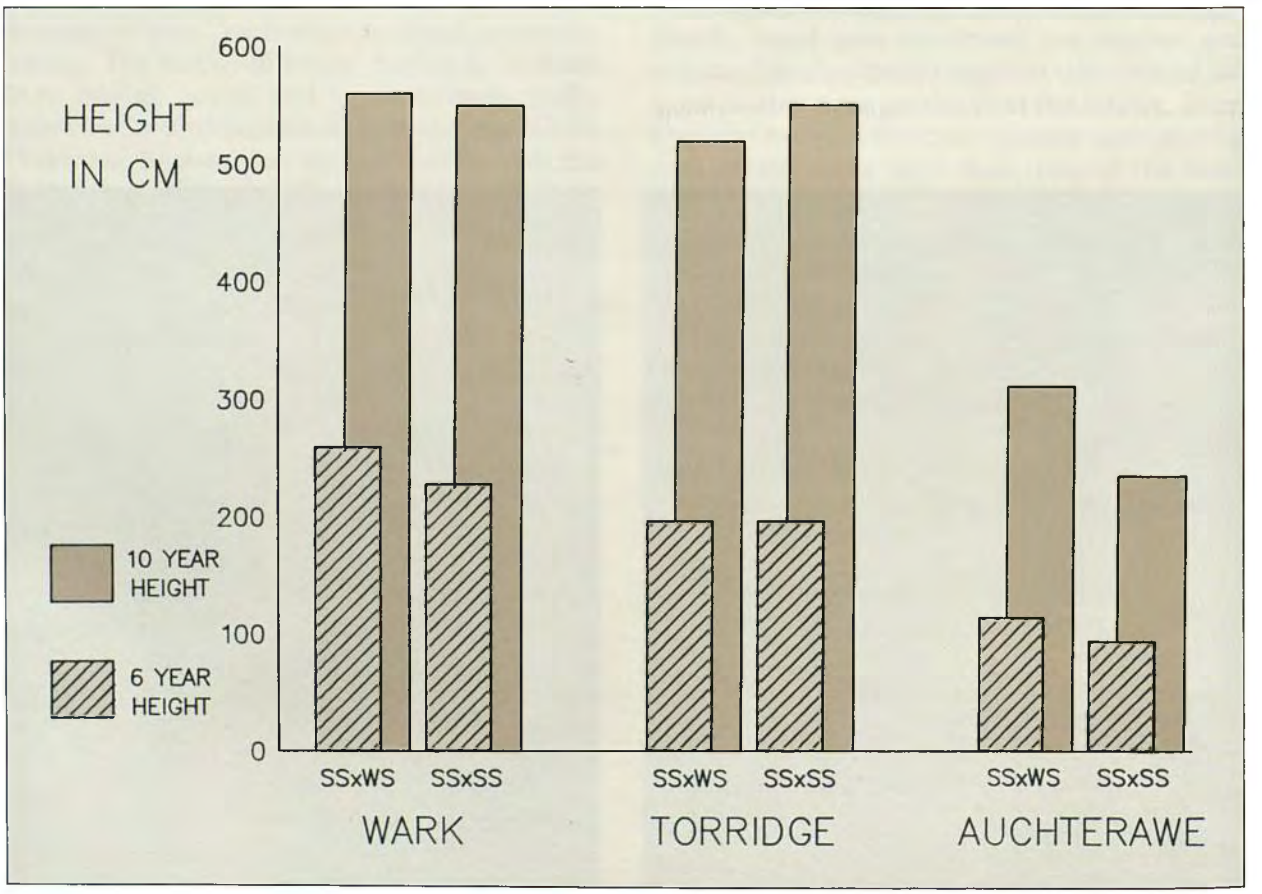
This tree is selected against as it shows bent stem and double whorling of branches.

Continual assessment of existing progeny tests has led to an increase in the Sitka spruce and Scots pine breeding populations by 16 and 33 clones to 152 and 149 respectively. The best available clones are used in the production population to supply the improved material for the next generation of forests.

There is keen interest in the Washington provenances of Sitka spruce particularly for Wales and south-west England and predictions of climate change would suggest possibly more northerly use for these provenances in future. Last year 24 Sitka spruce progeny tests were planted over four sites (Brecon, Clywd, Torridge and Kilmichael) to screen the genetic quality of 265 wind-pollinated families of Washington origin. One-hundred-and-twenty-eight of these families came from candidate trees selected in Scotland; the other 137 came from trees selected in the Republic of Ireland. Together with an additional 131 families collected from candidate trees in Washington (USA) due to go out to the field in 1991, it is hoped that sufficient clones of improved vigour and form can be identified to establish a Washington Sitka spruce breeding and production population within the next 10 years.

Ten-year height assessment of 13 Sitka spruce clones crossed with a white spruce pollen mixture compared with the same clones crossed with a Sitka spruce 'orchard quality' pollen mixture has shown a marked decrease in the superiority of the hybrids since height was measured at 6 years (*Report* 1985, p. 28) on all but the most testing sites (see Figure). The percentage mean superiority of the hybrid families relative to the pure Sitka spruce families at 10 years were (6 years in brackets) +2% (+14%) at Wark, −6% (0%) at Torridge and +32% (+21%) at Auchterawe. Other data from two 15-year-old experiments (Aultmore and Shin) confirm the suggestion that the vigour of the hybrid is short lived on all but the most exposed or frosty sites.

S. J. LEE



Comparison of Sitka spruce × white spruce pollen mixture and Sitka spruce × 'orchard quality' Sitka spruce pollen mixture. Height at 6 and 10 years.

FLOWERING

It is now well established that treatment of container-grown Sitka spruce grafts with gibberellins A_4/A_7 and drought in a polythene house can enhance cone production but the quality of the pollen and seed produced under these conditions needed to be investigated. After inductive treatments grafts overwintered outdoors and remained outdoors except for a 16-day period in the polythene house, beginning in late April, to facilitate pollinations. These grafts produced 233 μl pollen per cone, of 80% viability, and 113 full seed per cone, of 72% viability. Thus the cone induction techniques are yielding good quality pollen and seed for tree improvement programmes.

Placing grafts in a heated greenhouse in mid-January to force early pollen production advanced pollen shedding by 3 months compared with controls but reduced the yield of pollen and seed. Cytological studies with Dr J. N. Owens, University of Victoria, showed that no meiotic irregularities were observed in the forced pollen mother cells although these have been reported in other species. However, abnormalities were observed in later stages of pollen development, including failure of the tetrads of microspores to separate and degeneration of immature pollen. Poor seed-cone development was associated with retarded development in the distal ovules, which adversely affected pollination and fertilisation. Forcing grafts in an unheated polythene house later in the year, in mid-March, advanced pollen shedding 3 weeks compared with controls and did not significantly reduce yield of pollen or seed.

In this experiment all the grafts were removed from the polythene house in early May, seed cone development continued outdoors and seeds were extracted in September. In earlier trials grafts which remained in the polythene house all summer yielded poor quality seed and Ross (1985) reported that elevated temperatures are detrimental to seed development in spruce.

J. J. PHILIPSON AND M. O'DONNELL

REFERENCE

ROSS, S. D. (1985). Promotion of flowering in potted *Picea engelmannii* (Perry) grafts: effects of heat, drought, gibberellin $A_{4/7}$, and their timing. *Canadian Journal of Forest Research* **15**, 618–624.

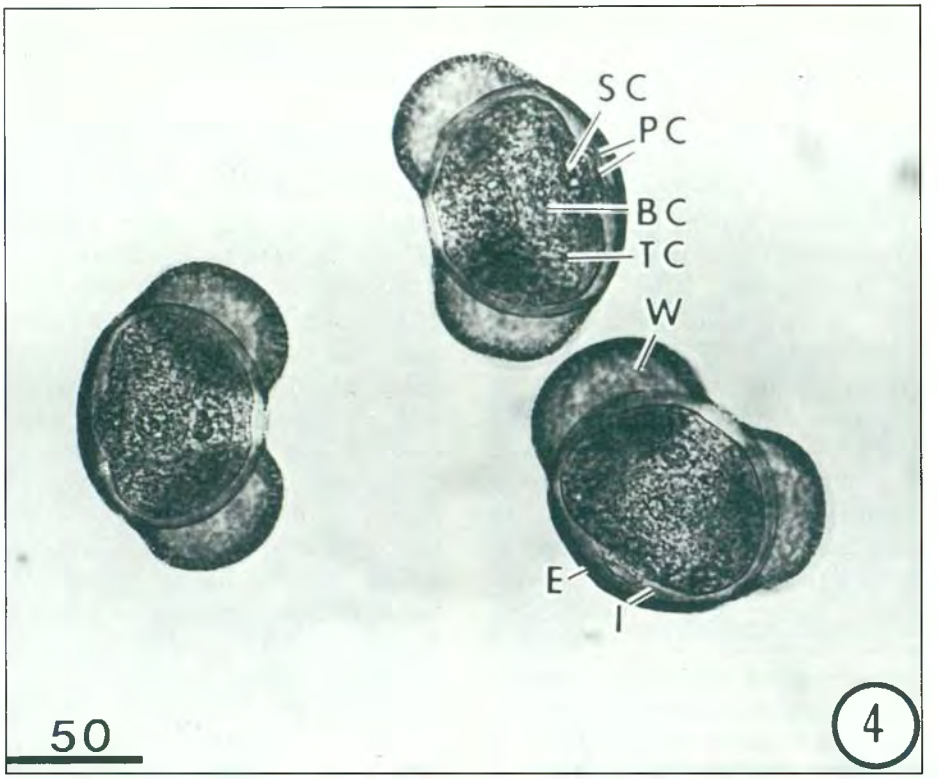
BIOCHEMICAL VARIATION

Improved gas chromatography facilities have been acquired (Perking-Elmer 8700, with both capillary and packed column capability), and collaboration with other laboratories having GC–MS facilities has enabled the identification of a number of terpene components. Increased emphasis is being placed on two main applications: the use of biochemical parameters in the characterisations of origins, families, and clones; and the relationship between terpene composition and pest or disease resistance.

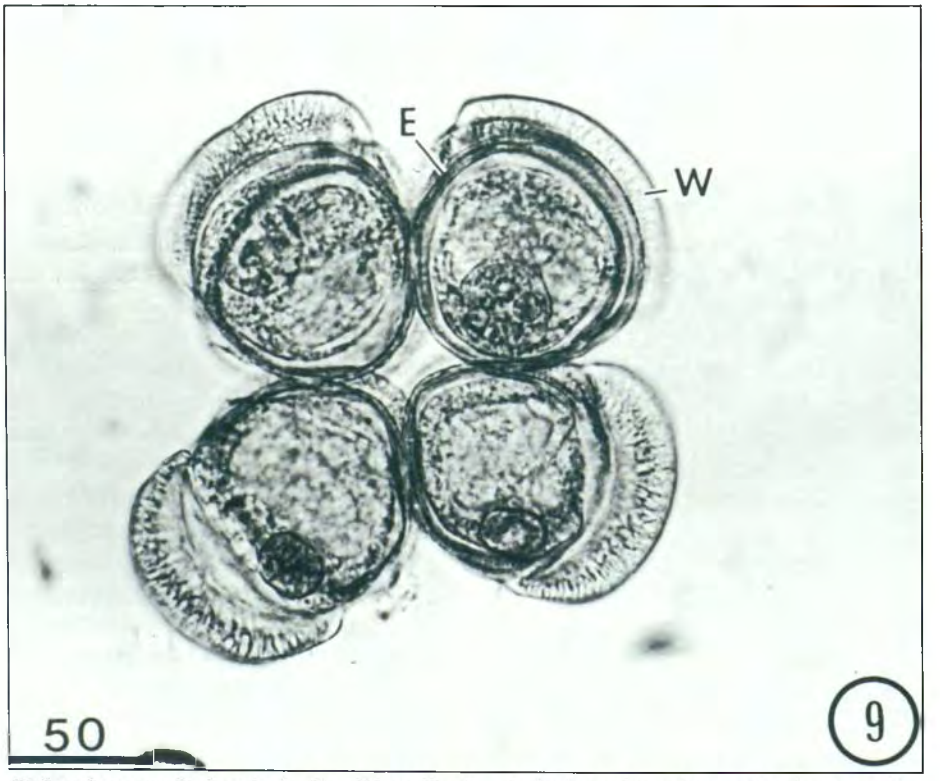
Analysis of data obtained in collaboration with Pathology Branch on *Heterobasidion annosum* infections in Sitka spruce is in progress, and early results indicate highly significant associations between the composition of xylem resin and both the extent of colonisation by the fungus and the severity of decay. In particular, a group of sesquiterpenes is implicated, some of which also undergo changes in concentration in stem xylem tissue when fungal invasion occurs. If substantiated, it is hoped that such correlations may lead to simple screening procedures to exclude those clones which are most susceptible to infection from the breeding populations.

In collaboration with Entomology Branch, work on the relationship between insect attack and host plant biochemistry is continuing. The effects of *Panolis flammea* attack on lodgepole pine terpene chemistry is being studied within trees and over the time following defoliation; and possible resistance mechanisms in Sitka spruce to the green spruce aphid (*Elatobium abietinum*) are being investigated using material collected from the area of forest decline in the South Wales coalfield (*Report* 1986, p. 34; 1987, p. 41).

Biochemical features associated with age in Norway spruce have been examined in a series of very young and mature plants. Some components, e.g. bornyl acetate (which decreases with age from 24% to 4% in leaf terpenes and from 0.4% to zero in stem cortical resin) are good individual indicators of age, from the first year onwards. Others are important discriminators in association with other components, e.g. the levels of α-pinene in association with those of myrcene and two diterpenes discriminate well between young and mature plants. A few, e.g. the two diterpenes, discriminate between certain ages both alone and also in association with other terpenes.



Mature five-celled pollen of high viability from grafts treated with gibberellin $A_{4/7}$ to induce flowering; with two prothallial cells (PC), stalk cell (SC), body cell (BC) and large tube cell (TC). Exine (E), intine (I) and wings (W) are well developed. Bar = 50μm.



Pollen from grafts treated with gibberellin $A_{4/7}$ to induce flowering and subsequently placed in a heated greenhouse to advance pollen development. The tetrad of living microspores failed to separate and pollen viability was low. Bar = 50μm. (Photographs by J. N. Owens.)

These same two diterpenes have been found to be of high diagnostic value in Sitka spruce in distinguishing Queen Charlotte Island from southern origins, in the first stage of a project on biochemical methods of identifying origins.

G. I. FORREST

MICROPROPAGATION OF SITKA SPRUCE AND HYBRID LARCH

A number of lines of research are being investigated. The micropropagation technique for Sitka spruce continues to be refined. Reduction of the atmospheric water vapour content within the incubation tubes has proved unsuccessful for the reversion of vitrified cultures to normal growth *in vitro*. Rooting of *in vitro*-produced shoots has been attempted in small, sealed Perspex boxes using non-sterile moist compost and no water spray. The first roots emerged after 21 days and rooting was as high as 80% after 50 days in some treatments. Green actively growing callus has been initiated on solid media from seedling roots grown in solution culture.

Preliminary experiments have commenced with hybrid larch. Cultures have been established on solid media *in vitro* from seedling apices, excised just after the opening of the cotyledons and from actively growing shoots on 2-year-old seedlings growing in pots.

A. JOHN

REJUVENATION

Cuttings were taken from Sitka spruce material, which represented a series of annual sequential grafts of scions on to juvenile rootstocks (*Report* 1983, p. 29). No increase in level of rooting was observed with frequency of previous repeat grafting and it was concluded that this approach was unlikely to lead to any rejuvenation of mature Sitka spruce. Two other approaches being taken are the establishment of cultures *in vitro* of vegetative resting buds from mature trees and of discs cut from female strobili. The former if successful is seen as providing an intermediate step towards rejuvenation or at least would facilitate application of manipulative treatments.

A. JOHN

IMPROVEMENT AND VEGETATIVE PROPAGATION OF OAK

Propagation of selected trees has continued, 150 clones are now in culture and stock plant hedges have been established in the nurseries at Alice Holt and Shobdon. A demonstration plot of clonal oak has been planted in Alice Holt Forest. Although methods for propagation of mature oaks exist, further studies using plant growth regulators have been initiated to develop less damaging procedures which would be more desirable for use on valuable trees.

To explain more clearly the behaviour of shoot and stem growth and to develop a selection test capable of identifying good genotypes when the trees are juvenile and readily propagated, detailed observations have been recorded both in the nursery and in the field. Most measurements have concentrated on shoot phenology and crown morphology and include: measurements of new crown shoots in spring; the influence of defoliation on lammas shoot growth; the relationship between root and shoot growth; development of epicormic shoots and the growth of suppressed buds; bud death and loss of the leading shoot; branch angles; and the relationships between bud activity, branch growth, crown form, production and seed origin. To date these measurements have only been made on seedling plants, but future studies will use clonal material from the vegetative propagation programme.

R. HARMER, C. BAKER

IMPROVEMENT OF BROADLEAVES FOR FARM FORESTRY

Work has begun on two projects funded jointly by the Ministry of Agriculture, Fisheries and Food and the Forestry Commission to improve broadleaved species of farm forestry potential. It has been decided to concentrate the effort on ash, sycamore and sweet chestnut and visits have been made to more than 100 stands of these species in various parts of England and Wales. Evaluation of stands and individuals is based on general vigour, form (straightness and branching) and health; using these criteria about 20 stands have been identified as potential seed sources and about 50 stands that contain trees suitable for vegetative propagation have been located.

Selected stands and individuals will be revisited at a later date to collect seed and material for vegetative propagation.

Crown branch material has been collected from ash and sweet chestnut trees of good size and form which were blown down in the storms of early 1990. Branches have been cut into 30 – 40 cm lengths and stood in trays of water in a heated polythene tunnel to induce epicormic buds to grow out into shoots. These shoots can later be detached and rooted under mist conditions.

Demonstration plots of ash and sycamore have been established to show the type and quality of planting stock of these species that are currently available from commercial forest nurseries.

C. M. CAHALAN, M. R. PLOWMAN

PRODUCTION

A new 6 ha Corsican pine seed orchard based on tested clones was planted at Spye Park, Wiltshire. The existing Sitka spruce seed orchards at Mereoak, Hereford and Rogate were extended.

Existing seed orchards of all species are being reviewed and their future assessed regarding the potential genetic gain expected. The number and extent of all new seed orchards will be based on future seed demand and the potential gain expected of plants from the orchards. The first of the 'approved' Scots pine seed orchards (No. 70 Ferndown) again produced good quantities of seed and the data from the annual monitoring are being used in this review of future seed orchard requirements.

A. M. FLETCHER, W. BROWN

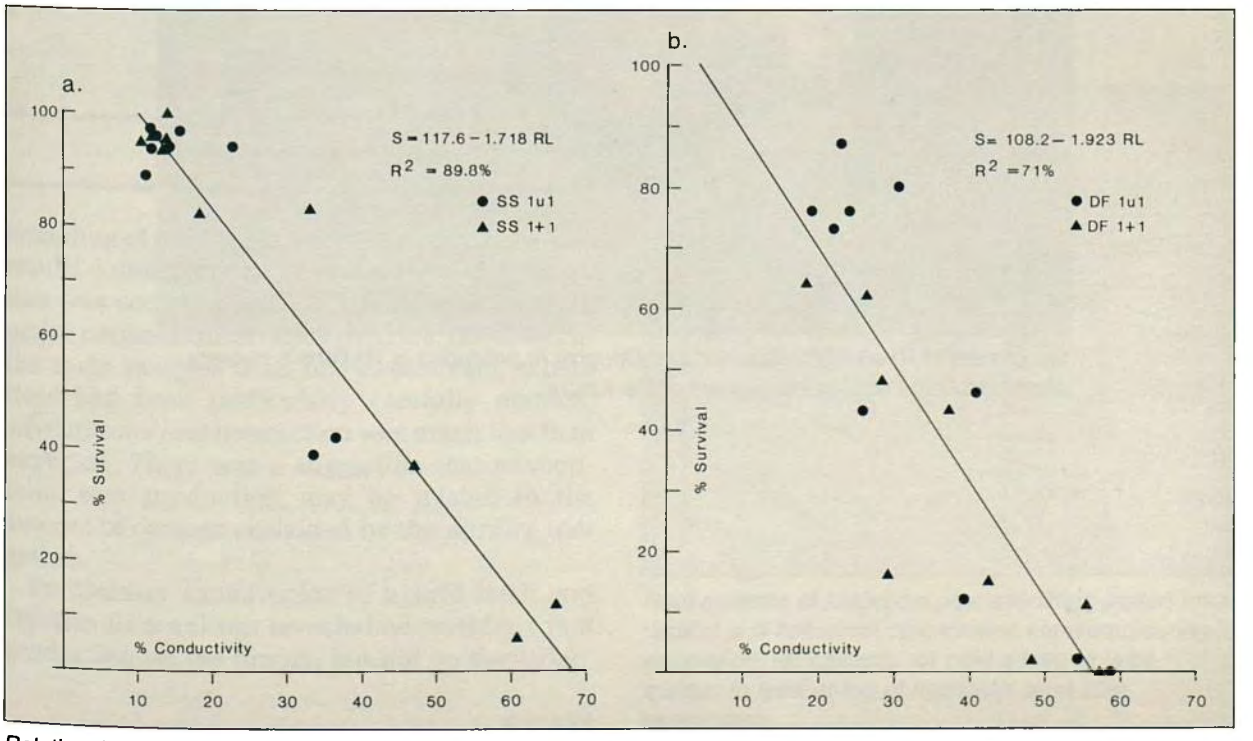
PHYSIOLOGY

PHYSIOLOGICAL QUALITY OF NURSERY STOCK

Patterns of Sitka spruce and Douglas fir activity through autumn, winter and spring were measured and related to climatic variables to establish periods when plants were most tolerant of stresses such as cold storage and handling. Sitka spruce shoots developed greater frost hardiness than Douglas fir; by mid-December 1988 temperatures of −28°C killed 50% of Sitka spruce shoots whereas −18°C killed 50% of Douglas fir shoots. Cell division in the terminal buds of both species fell to zero by mid-December and resumed in March. During autumn, fine roots of Sitka spruce become more tolerant of long-term (5 months) cold storage and storage beginning in mid-December caused no significant root deterioration. Douglas fir fine roots did not increase their tolerance to long-term cold storage. In both species, cell division of fine roots declined between October and mid-December. In Sitka spruce there was no cell division of fine roots between mid-December and February. In marked contrast, fine roots of Douglas fir were never completely inactive, and there was rapid cell division in January and February. These findings help to explain the greater sensitivity of Douglas fir to cold storage.

Measures of various aspects of the physiological status of nursery seedlings were evaluated as possible indicators of their tolerance to cold storage. Of the assessments made at the time of lifting, root growth potential indicated differences in survival between species and plant types but none of the indices clearly identified the earliest safe lifting date. The extent of root deterioration which occurred during cold storage was closely correlated with field survival (see Figures). Root deterioration is measured by the leakage rate of cell contents through cell membranes of fine roots.

H. M. McKAY



Relationship between survival of (a) Sitka spruce, and (b) Douglas fir, and root deterioration during cold storage.

Mycorrhiza of Rhizipogon vinicolor *and Douglas fir produced in Wykeham nursery after inoculation with basidiospores of the fungus.*

MYCORRHIZAS

Work on establishment of field experiments under a Commission of the European Communities' contract continued, in co-operation with Surrey University, INRA at Nancy, France and IRTA at Cabrils, Spain. Four new field plots, each 1 ha in size, were established (Douglas fir at Flimwell, Bedgebury Forest District and Broxa, North York Moors Forest District: Sitka spruce at Clintburn, Kielder Forest District and Loch Borralan, Dornoch Forest District). Surveys of fruiting body production in autumn indicated that at least one of the fungi used had become established successfully on the Sitka spruce plots. Unfortunately, one of the Douglas fir plots was damaged beyond redemption by erroneous application of herbicide.

An experiment, set up with the help of the Silviculture (North) Branch in 1988, to test the application of spores of *Rhizopogon vinicolor* to seedlings in Wykeham nursery showed that all trees in plots treated with that fungus became mycorrhizal (see photographs), whereas the controls remained free of all but naturally available contaminant fungi. Some plants from this experiment will be lifted and planted out in the North York Moors Forest District; others will be sent to colleagues in France and Spain for field testing. Establishment of mycorrhizas in container-grown Douglas fir seedlings in a greenhouse was successfully achieved by application of a suspension of *R. vinicolor* spores in water.

C. WALKER

ADVENTITIOUS ROOTS

Sampling of existing experiments continued and results confirmed that adventitious root production was common in Sitka spruce trees planted under normal Conservancy practice. However, in the early samples from one experiment, where trees had been particularly carefully planted, adventitious root production was much less than expected. There was a suggestion that adventitious root production may be related to the amount of damage sustained by the nursery root system.

Preliminary examination of hybrid larch and Douglas fir seedlings revealed adventitious root production on the former, but not on the latter.

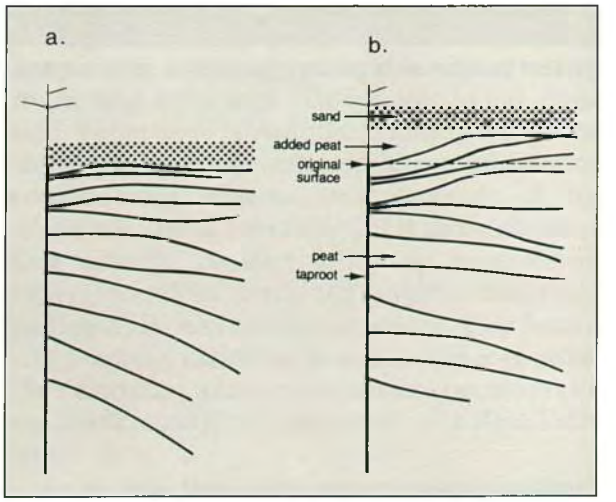
C. WALKER

ROOT GROWTH AND FORM

Upward growth of tree roots

In seedlings of most plant species many of the lateral roots are plagiogeotropic, growing obliquely downwards from the positively geotropic radicle, to fulfil the functions of anchorage and the acquisition of water and nutrients. However, in forests, nutrients and roots tend to be concentrated near the soil surface, and the main woody roots required for anchorage tend to grow near the surface on upland sites, raising questions as to how surface roots originate and what controls their development. These problems have been addressed by experiments on lodgepole pine and Sitka spruce.

Lodgepole pine. Seeds were sown at a depth of 2–3 mm in pots of peat. After germination an extra c. 20 mm depth of peat was added to half of the pots raising the level to the top of the hypocotyl, and leaving only the cotyledons exposed. In the remainder (controls) the original peat level remained, and in both a thin layer of sand was added to prevent growth of algae and bryophytes. After a further 170 days the angles to the vertical of the first-order lateral roots in the controls were found to vary with their depth of origin. Laterals from the lower part of the radicle grew obliquely downwards, whereas those from the upper 10 mm tended to grow upwards (Figure a). In the controls such upward growth was not always evident where roots originated close to the peat surface, but in the treated plants, where



Root systems of lodgepole pine seedlings plotted from vertical and horizontal co-ordinates measured during excavation; (a) controls, (b) peat added to raise surface to level of top of hypocotyl soon after germination.

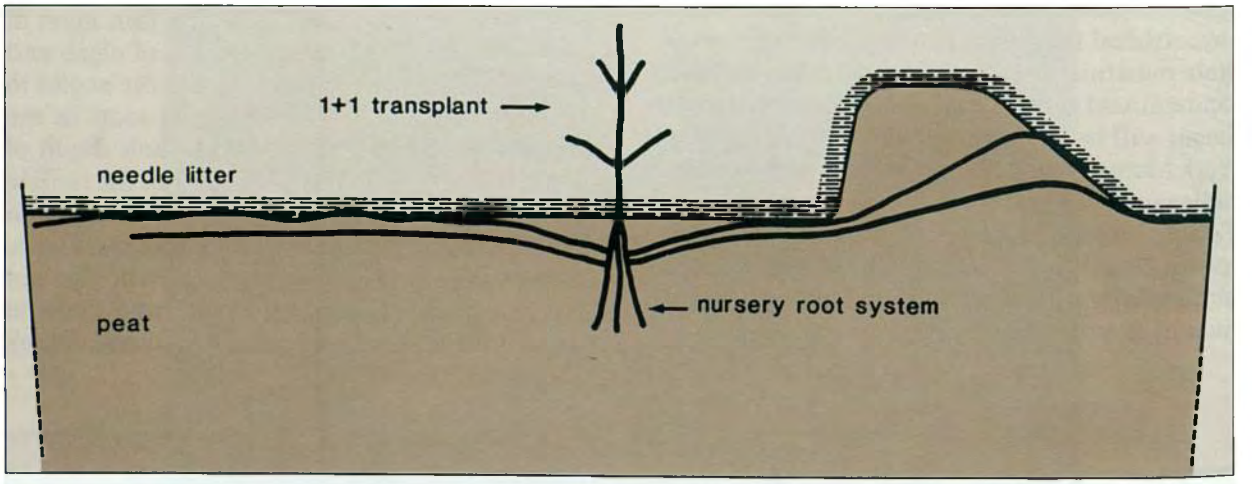
there was scope for growth in the layer of peat added after germination, the uppermost first-order laterals showed a clear tendency to upward growth (Figure b).

Sitka spruce. Transplants were planted in the centre of eight 900 mm diameter circular containers nearly filled with peat. A mound of peat, semi-circular in plan view and 100 mm high was then made in one half of each pot as shown (in profile). The peat surface was covered by a 20 mm layer of spruce litter. Excavations made 250 days after planting showed that many of the main roots which originated in the upper part of the nursery root system grew obliquely upwards. Those which grew in the flat area in a direction away from the mound showed two main patterns of behaviour. The roots either remained within the peat by deflecting downwards between 0 and 30 mm of the surface, or they penetrated the surface and deflected to a horizontal position at the peat–litter interface.

Roots from the upper part of the root system which grew towards the mound grew up inside it at a mean angle of 113° from the vertical. Most of them emerged into the litter on the far side of the mound, then deflected and followed the mound surface downwards. Others deflected downwards before arriving at the peat surface but this deflection was rarely sufficient to prevent the roots from growing out of the peat into the litter.

It is concluded that the development of the major lateral roots of these species near the soil surface results from an inherent tendency to upward growth in certain roots, counteracted by influences acting near or at the soil surface that induce downward deflection. The results described have basic implications for the way in which roots explore soil to optimise nutrient acquisition, and also help to explain the rooting patterns which result from different methods of site preparation (e.g. mounding) before planting.

M. P. COUTTS



Typical surface roots grown from a Sitka spruce transplant in a large container of peat with a mound on one side.

PATHOLOGY

DISEASE DIAGNOSTIC AND ADVISORY SERVICE

Scotland and northern England

Climate was the most frequently recorded damaging agency during the year owing largely to injuries associated with frosts and drought. In addition to the familiar kind of spring frost injury to newly flushed shoots of young trees, some instances of more severe and unusual dieback of older branches in Sitka spruce were also attributed to spring frost. The symptoms, some of which did not become evident until late summer, closely resembled those that occurred in 1981 (Report 1982, p.27) when frosts in late April followed 4 weeks of unseasonably warm weather. In 1989 air minima below −5°C were recorded at many places in Scotland and northern England between 24 and 26 April, while at Eskdalemuir (Borders Region) grass minima below −10°C occurred on three successive nights in the same period. Following the exceptionally mild winter of 1988/89, these were remarkably low temperatures. Damage believed to have been caused by these frosts was reported in individuals or small groups of trees at several sites in southern Scotland and northern England though it was on a far smaller scale than the damage recorded in 1981. Spring frost damage in larches leading to death of 1988 shoot tips as well as browning of 1989 foliage was a noticeable feature of several plantations in western Scotland early in the growing season. Frosts at the end of the growing season, in late September, caused some browning of current foliage in Sitka spruce in parts of north Scotland.

The 1989 summer drought was responsible for dieback and mortality of young conifers and for stem cracking in older conifers at several sites. Drought was also thought to be the cause of discoloration and death of scattered interior branches seen in the crowns of older spruces at a number of Scottish forests in late summer and autumn. This damage, which we had not previously seen, was particularly noticeable in its early stages when the affected foliage was bright yellow. Another product of the unusually hot, dry summer was a case of suspected 'hot soil' injury leading to bark lesions at the base of recently planted beech in northeastern Scotland.

'Top-dying' of Norway spruce, a progressive and often fatal disorder believed to be physiological in origin, was recorded in many plantations during the year. Although the causes of the problem are not well understood, it is known to be precipitated by mild, windy winters. The recent prevalence of affected Norway spruce stands may therefore be partly a consequence of the unusual weather conditions of the last three winters.

Among other abiotic causes of damage that were investigated, misuse of chemicals and cultural malpractices were, as in most years, common. Planting failure arising from poor handling or storage of transplant stock, or from inadequate site preparation, or from a combination of these factors, accounted for many losses of young trees.

Records of damage by living agents were more notable for their diversity than for either the predominance of particular pathogens or the occurrence of unusual ones. The most frequently identified disease was that caused by species of *Armillaria*. Members of this genus of root pathogens were generally found killing young conifers but some cases of *Armillaria* root or butt rot in large trees were also brought to our attention. Three cases of *Armillaria* killing were noteworthy in that they occurred in second rotation conifer crops whereas most accounts of this disease in British forests record it as a problem of first rotation conifers following broadleaves. Several enquiries concerned our other major root pathogen, *Heterobasidion annosum*. This fungus was generally identified as a cause of decay rather than mortality, a factor that probably accounts for the fewer records of it compared with *Armillaria* spp.

As in 1988, there were several cases of dieback in larches caused by one or other of the fungi *Lachnellula willkommii*, *Potebniamyces coniferarum* and an unknown *Cytospora* species. Also as in 1988, shoot dieback of lodgepole pine caused by the fungus *Ramichloridium pini* stimulated many enquiries, as did the common needle

pathogens *Lophodermium seditiosum* and *Coleosporium tussilaginis* on Scots pine. A less familiar pathogen, *Gemmamyces* (*Cucurbitaria*) *piceae*, the agent of 'bud blight' disease of spruces, was found to have caused some striking deformation in the upper crowns of 55-year-old Norway spruce at a forest in south Scotland.

Venturia tremulae on aspen, *Sclerotinia laxa* on *Prunus*, *Xanthomonas populi* on poplar, *Apiognomonia errabunda* on oak and *Ophiostoma* (*Ceratocystis*) *ulmi* on elm were among the many common pathogens of broadleaves that were recorded during the year. More unusual was *Diaporthe leiphemia*, a fungus not previously identified at the Northern Research Station and one which was found associated with severe dieback of newly planted oaks in treeshelters at a site in central Scotland. It seemed probable that the fungus, which is generally regarded as a weak pathogen of oaks, was secondary to some kind of stress, possibly drought.

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Southern England and Wales

The enquiries received often reflected the extremes of weather which were a feature of the whole period under review.

The remarkably mild winter of 1988/89 (in central England it was the second warmest since records began in 1659 (Anon., 1989a)) led to a repetition of the severe aphid damage to spruces and cypresses which was so prevalent in the previous year (*Report* 1989, pp. 52 and 54) and many of these cases of foliage browning and defoliation were referred to advisory pathologists in the first instance.

April was wet, which presumably accounted for the many cases of anthracnose of weeping willow (*Marssonina salicicola*) reported in April and May and of blossom wilt of flowering cherry (*Sclerotinia laxa*) reported in May and June.

May was one of the warmest, driest and sunniest on record (Anon., 1989b) and over most of southern Britain this fine weather continued with little respite into November. Consequently, drought symptoms appeared widely. The most common were a general, reversible wilting of many deciduous broadleaves, and the yellowing, browning and premature shedding of the older leaves on many deciduous and evergreen broadleaves and conifers, e.g. birch, beech, poplar, hornbeam, yew (see Plate) and some clones of Leyland and Lawson cypress. Less obviously a drought effect was the marginal browning and drying of sycamore leaves. Most unusual and conspicuous were the small, scattered patches of orange, then yellow and finally brown leaves on lime trees. This was the result of the death of often girdling patches of bark on the twigs. In the one tree examined in detail, these nearly always yielded a probable *Cytospora* species. Even though the summer appeared to be hot and dry enough for sooty bark disease of sycamore to develop (Young, 1978), no cases were reported. An outbreak was also expected following the hot, dry summer months in both 1983 and 1984 but unaccountably did not materialise.

Yew: Yellowing and loss of pre-1989 needles and death of shoots due to drought.

The 12 months reported on here ended with the third very mild winter in succession. The winter was further remarkable for the very high winds in January and February 1990. On 25 January, an estimated 1.3 million m^3 of timber was blown down in England and Wales (Quine, 1990).

For the second year running, an unusually large number of cases of lightning damage were investigated. In most cases damage had originated prior to the 1989 growing season, often in 1988 or earlier.

As usual, the commonest pathogen involved in damage which was not or not clearly associated with the weather was honey fungus (*Armillaria* spp.), mostly in parks and gardens, while the commonest abiotic causes of damage were herbicides.

The following unusual or interesting diseases were also recorded during the year:

For the first time since 1983, several cases of *Phaeocryptopus gäumannii* needle blight of Douglas fir were reported, all from the west of the country.

In June, large numbers of dead, 1-year-old (1988) shoots of Japanese larch were seen in a forest in South Wales. Of six girdling cankers examined, five yielded a *Cytospora* species (thought to be *C. kunzei* – *Report* 1975, p.34) and one, *Potebniamyces coniferarum* (cf. *Report* 1988, p. 41).

A strain of *Botrytis cinerea* resistant to benomyl (an MBC fungicide) was isolated from dying Douglas fir plants in a Forestry Commission greenhouse. The disease had been controlled there previously with alternating sprays of benomyl and iprodione.

A specimen dragon spruce (*Picea asperata*) in east Hampshire was found to be severely damaged by the bud-blighting fungus *Gemmamyces* (*Cucurbitaria*) *piceae*. Although this has been recorded once on Sitka spruce (Anon., 1932) and a few times on ornamental *Picea* species, it is principally a minor disease of Norway spruce and is largely confined to the north and west of the country. This seems to be far the most easterly recorded British case.

The canker-rot disease of *Thuja* species, *Amylostereum laevigatum*, (*Report* 1986, p. 36) was found killing two large Lawson cypress hedging plants in a Surrey garden.

Several large fruit bodies of the butt-rotting fungus *Fomes fomentarius* were seen on a dead silver birch in Surrey. It is quite common in Scotland especially on birch; the very few records

Lightning damage to a group of broadleaved trees, October 1989.

Lightning damage to Norway spruce: stem with outer bark removed to show discontinuous strip of dead inner bark running up the stem from the roots.

from southern England have been from beech.

Fruit bodies of the common root- and butt-roting *Heterobasidion annosum* were found on exposed roots of a windthrown yew in Kent. Peace (1938) found one (unspecified) site in Great Britain where yew butts were decayed by this fungus; the only other published record is from Norway (Jorgensen, 1954).

Ganoderma either *G. adspersum* or *G. applanatum*) was found to be responsible for a severe root and basal stem rot in a dying × *Crataemespilus grandiflora* street tree in Norwich. This is probably only the second disease to be recorded on this intergeneric hybrid (*Report* 1989, p. 43).

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NEEDLE BROWNING AND DIEBACK OF SCOTS PINE IN NORTHERN BRITAIN

This problem typically affects entire stands and varies in severity from minor needle browning to dieback and death. It was first observed on a significant scale in the mid 1970s in north-east England where pole-stage crops in the age range 20–30 years declined so severely that they were prematurely clear felled. Damage has occurred in crops of similar age elsewhere throughout upland, northern Britain and is associated with the fungi *Lophodermium seditiosum* and *Brunchorstia pinea* (*Ascocalyx abietina*) and with the bark beetle *Tomicus piniperda*.

L. seditiosum causes needle browning which usually appears in late winter and spring following infection the previous summer. Browning is most commonly confined to the lower crown but in severe cases the entire tree may be affected. Climatic conditions during winter may affect the outcome of infection since browning is frequently most severe on the windward sides of trees and individual shoots. The effects of defoliation generally seem to be unimportant in plantations but on at least one occasion (1985), exceptionally early and severe symptom development caused growth reduction and shoot dieback in the next growing season in many crops from Cumbria northwards. In several cases the effects persisted into 1987. Repeated attacks can also be damaging.

B. pinea causes shoot dieback. Infection occurs during the growing season but symptoms do not develop until the following winter (Aitkin, 1988). The disease typically appears first in the lower crowns of trees in thicket and early pole-stage crops and may then develop to affect the entire tree.

T. piniperda has also been present in most of the affected crops that we have examined but, since it is well known as a rapid colonist of moribund trees, its role may be entirely secondary. Nevertheless a number of cases have been brought to our attention in which this insect appeared to have made fatal breeding attacks on the main stems of weakened trees that would otherwise have recovered.

Field observations suggest that *B. pinea* is primarily responsible for the most serious outbreaks of dieback. *L. seditiosum* may contribute to crop deterioration when attacks are repeated or severe. The debilitating effects of defoliation by this fungus may be enough in some cases to render trees liable to breeding attacks by *T. piniperda*. The latter can itself cause crown reduction by shoot-pruning, particularly in the later stages of stand decline when dead and dying trees provide breeding material and permit the development of high local populations of the beetle.

Little information is available about factors affecting the incidence and severity of disease. *L. seditiosum* infects trees of all ages, but dieback in which *B. pinea* is the primary agent is mainly a problem which develops after canopy closure.

The significance of provenance is unknown. Many of the earliest outbreaks occurred in crops grown from seed of Thetford origin, but this may only reflect the common use of pines grown from such seed in the large plantings of the 1950s. The most significant factor in their decline may have been that these crops reached a particularly susceptible phase in their development at the same time. Inoculations with *B. pinea* on small plants have shown some differences in susceptibility between provenances but there were no consistent differences between native and non-native origins (Aitkin, 1988).

Observations on the distribution of damage are complicated by the history of planting, which has been mainly concentrated in the east. In spite of this and the informal nature of many of our observations, two factors seem to be important: damage occurs most frequently at higher elevations (>200–300 m) and is largely absent from the traditional Scots pine areas of the coastal lowlands, Speyside and Deeside. This suggests soils and/or rainfall might be important in disease development.

Scots pine is not prone to any other significant needle or shoot diseases but during the 1983/84 winter, damage of probable climatic origin, which bore a strong superficial resemblance to the effects of *L. seditiosum* and *B. pinea*, occurred in older crops at high elevation (Redfern, Gregory, Pratt and MacAskill, 1987).

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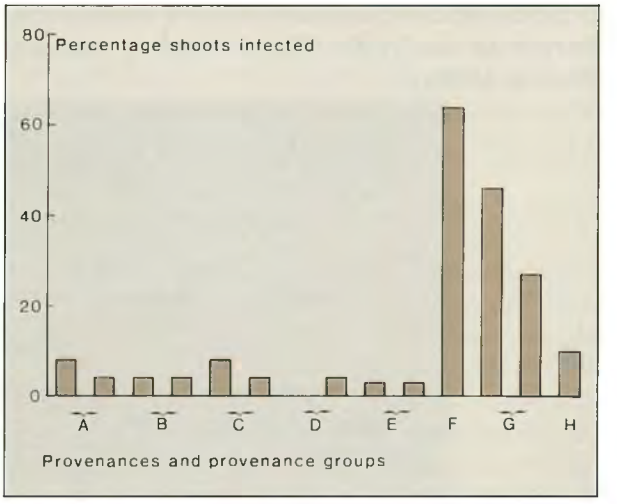
Yellowing in May of previous years' needles on lodgepole pine as a result of shoot-killing by Ramichloridium pini.

RAMICHLORIDIUM DIEBACK OF LODGEPOLE PINE

This disease, is present on lodgepole pine in western Britain from Cornwall to Wester Ross and in Ireland and the Isle of Man. In severe outbreaks, trees die and stands may have to be felled prematurely. The causal fungus, *Ramichloridium pini*, was described by de Hoog, Rahman and Boekhout (1983) following investigation of the disease by Rahman (1982). The etiology of the disease is similar to that of Brunchorstia shoot dieback of pine (caused by the fungus *Ascocalyx abietina*) in that the pathogen infects the elongating shoot in the spring but does not produce any symptoms until the autumn.

Experimental work in 1989 examined provenance susceptibility. Fifteen trees of each of 14 provenances of lodgepole pine (from north to south of its range) had been planted in a randomised block design at Brechfa Forest, Dyfed, South Wales in 1984. In early May 1989 two elongating shoots on each tree were inoculated with a spore suspension of *R. pini*. Disease symptoms were assessed in October 1989 and April 1990 and the results for April are shown in the Figure. The results indicate that the Lulu



Incidence of Ramichloridium dieback in April 1990 on lodgepole pine provenances inoculated in May 1989. Provenance groups:
A – Alaskan
B – North Coastal
C – Skeena
D – Central Interior
E – Southern Interior
F – Lulu Island
G – South Coastal
H – Washington Cascades

Island and South Coastal provenances are significantly more susceptible to the disease than many of the others. This finding confirms field observations made in South Wales during recent years.

D. R. ROSE

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DUTCH ELM DISEASE

The aggressive subgroup of Ophiostoma ulmi *is near clonal in North America*

Previous studies have shown that the 'old' non-aggressive subgroup of *Ophiostoma ulmi* responsible for the first pandemic of Dutch elm disease is 'near clonal' in North America in terms of vegetative compatibility (vc) groups, but is genetically highly heterogeneous in Europe. This remarkable contrast may reflect different epidemic pressures on the two continents, together with the role of fungal viruses or d-factors in bringing about a collapse of the first pandemic in Europe in the 1940s (*Report* 1986, p. 38, and Brasier, 1990a).

A similar contrast has now been found in the highly pathogenic NAN aggressive subgroup responsible (with the EAN aggressive) for the current pandemic of the disease across the northern hemisphere. In Europe local NAN populations usually begin as a vc clone but rapidly become genetically heterogeneous, possibly in response to the spread of d-factors (Brasier, 1988, 1990a). In North America, however (Table 12), the NAN still comprises mainly a dominant vc clone, termed the North American vc supergroup (~60%); a closely related secondary clone (~20%); and a genetically distinct tertiary clone, the 'European NAN' vc supergroup (~9%). Each vc clone is also largely morphologically recognisable in culture despite its widespread distribution across North America (Table 12). Only a small remnant of the population (~13%) has become genetically highly heterogeneous. As in Europe, this component probably results from an unknown process generating rapid variation (see also below). In North America, therefore, selection appears to have favoured the dominant vc clones over the newly emerging genotypes.

The survival of the clones may also reflect 'founder' effects, higher elm infection frequencies and greater 'pathogenic feedback' (see Webber and Brasier, 1984) on the more susceptible American elm population, and a resulting greater ability to tolerate d-factor mycoviruses. Moreover, the more weakly pathogenic A mating-type is often absent in European frontal vc clones (Brasier, 1988), and its presence at fairly high frequency in the three vc clones in North America (Table 12) may well reflect a lower intensity of host selection. A further possibility is that the

Table 12. Structure of NAN aggressive population in North America

	Population components			
	Dominant vc clone (North American supergroup)[1]	*Secondary vc clone ('n ×' North American supergroup)* [2]	*Tertiary vc clone (European NAN vc supergroup)*	*Heterogeneous component: 10 other vc groups*
Component as percentage of sample (101 isolates total)	58.4% (59)	19.8% (20)	8.9% (9)	12.9% (13)
% A mating-types in each component	20.3%	45.0%	22.2%	53.8%

Numbers of isolates shown in parentheses.

[1] The North American vc supergroup was present at almost all sample sites including Kansas, Minnesota, Iowa, Wisconsin, Illinois, Ohio, Maryland + Virginia, Vermont, Maine; Toronto, Montreal and Quebec; California and Oregon.

[2] 'n ×' : gives an 'n-reaction' against the North American vc supergroup, and is probably derived from the latter.

North American vc supergroup represents a residual vc clone surviving from the evolution of the NAN aggressive from the EAN following the latter's postulated introduction into America from eastern Europe in the 1940s (see Brasier, 1990b).

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Decline of the non-aggressive subgroup at current epidemic fronts

Epidemic sites in central Spain sampled in 1984 (*Report* 1987 and Brasier, 1988) were resampled in October 1989. The results showed a steady decline of the non-aggressive subgroup compared with the NAN aggressive (Table 13). The most dramatic decline was at Miraflores, where only the non-aggressive was found in 1984, despite high disease levels, but where it is now undetectable on the site. This supports the suggestion (*Report* 1987) that the heavy disease level at Miraflores in 1984 was actually due to an explosive build-up of the non-aggressive initiated by the arrival of the aggressive. The smallest decline recorded at Guadalajara may reflect the subsequent destruction of much of this site by development. The Sancti Spiritus site was pre-epidemic in 1984 (Mitchell, 1988) but now has ~30% dead and dying elms, and the non-aggressive is in strong decline. The steady replacement of the non-aggressive by the aggressive is believed due to several competitive ecological effects (Mitchell, 1988) and resembles a species–species interaction.

Considerable changes in the genetic composition of NAN aggressive population has occurred at the Spanish sites (cf. Brasier, 1988) and will be reported later.

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Molecular relationships of the O. ulmi *subgroups*

The aggressive and non-aggressive subgroups of *O. ulmi* show considerable differences in their mitochondrial and nuclear DNA polymorphism patterns consistent with their extensive evolutionary divergence. The EAN and NAN aggressive patterns also differ, but to a lesser degree (Bates, Buck and Brasier, 1990). Mitochondrial molecular weights for ten non-aggressive isolates were *c.*74–88 kb; for nine EAN aggressive isolates were 65–71 kb, and for eleven NAN aggressive isolates were 48–60 kb. These values were based on two restriction enzymes *Pvu*II and *BC1*I.

Other new evidence is consistent with the theory that the NAN may have evolved from the EAN following importation of the latter into North America from Romania/southern USSR during the 1940s (Brasier, 1988, 1990b). First, the two major North American vc clones show a very close vc relationship to the EAN vc supergroup.

Table 13. Recovery of non-aggressive isolates in samples from current epidemic outbreak areas in Spain, 1984 and 1989

Site	Total samples[1]		%Non-aggressive	
	1984	*1989*	*1984*	*1989*
Epidemic in 1984				
Guadalajara	51	63	43	32
Casa de Campo (Madrid)	82	98	87	4
Avila area (Penaranda to La Granja	108	196	32	6
Miraflores	38	51	100	0
Pre-epidemic in 1984				
Sancti Spiritus (near Ciudad Rodrigo)	26[2]	169	100[2]	32

[1] All twig samples are from separate diseased trees except for Sancti Spiritus which are bark samples.
[2] Data of Mitchell (1988)

The Guadalajara and Casa de Campo sites were combined as Guadalajara in Brasier (1988).

Second, some EAN isolates from the Moscow–Romania–Caucasus 'triangle' carry nuclear DNA polymorphisms otherwise found only in the NAN. Third, other vc groups in the NAN population in North America and Europe (e.g. the Tewkesbury second vc group or Guadalajara vc group in Europe (Brasier, 1988) carry nuclear polymorphisms characteristic of the EAN. These results suggest that a fairly variable population of the EAN may have been imported initially into North America. This may then have been followed by the evolution and emergence under selection and drift of the American vc supergroup, second vc supergroup and the tertiary or European NAN supergroup (see Table 12). The former might, therefore, be better fitted to the American elm population.

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Source of rapid variation in the aggressive subgroup at epidemic fronts

The source of the sudden genetic variation that occurs in the aggressive subgroup at current epidemic fronts is uncertain. 'Pseudoselfing', and introgression from the resident but reproductively isolated non-aggressive subgroup are possible mechanisms (Brasier, 1988).

A molecular study of 15 highly unusual genetical and morphological variants of the NAN which appeared at epidemic front sites in Portugal (Tomar and Mafra, see Brasier, 1988) revealed rare fragments of non-aggressive nuclear DNA in two of them (maf g4 and tom II d10). An exceptionally weakly pathogenic EAN isolate, AST–27 from Iran, possessing a single gene for 'low' pathogenicity to elm (Brasier, 1987), also carries a non-aggressive nuclear DNA fragment. In addition two out of 20 NAN epidemic front isolates from epidemic front sites in northeastern North America have a mitochondrial DNA profile which includes non-aggressive DNA segments, and are possible mitochondrial recombinants, though their nuclear DNA appears to be of solely NAN type. The sudden explosion of variation in the aggressive subgroup at epidemic fronts may therefore result in part from rare introgression from the non-aggressive gene pool. A possible mechanism is discussed by Kile and Brasier (1990), and involves fertilisation of aggressive protoperithecia (♀) by conidia (♂) of transient non-aggressive × aggressive F_1 progenies.

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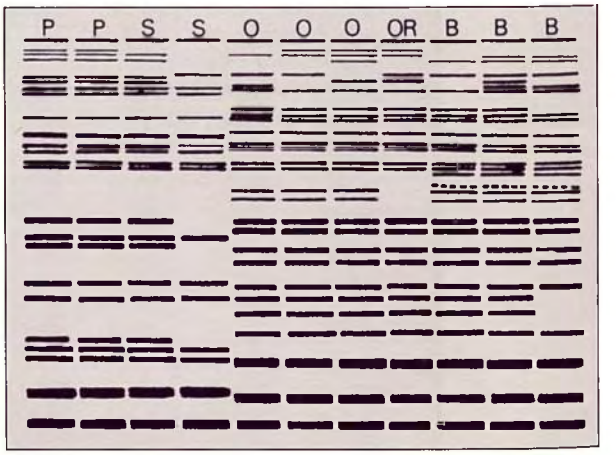
STATUS OF *OPHIOSTOMA PICEAE* ON HARDWOODS AND CONIFERS

Hardwood and conifer isolates of the common bluestain fungus *Ophiostoma piceae* were recently shown to be intersterile, and suggested to be sibling species (*Report* 1989, p. 47). In a further study the buffer soluble protein patterns of ten hardwood isolates (from oak and beech)



Total soluble protein patterns of hardwood and conifer isolates of Ophiostoma piceae *from pine (P), spruce (S), oak (O), beech (B).*
OR indicates the single isolate known as Ophiostoma roboris.

and six conifer isolates (from spruce and pine) have been shown to have important differences. The mean hardwood × conifer similarity coefficient was only 69% compared with 88% for the within hardwood and 92% for the within conifer coefficient. Although Hunt's (1956) synonomisation of *O. querci* Geogevitch with *O. piceae* (Münch) H. & P. Sydow. on grounds of morphological similarity has been quite widely accepted, the name *O. querci* may need to be re-established for the hardwood taxon.

In addition, the soluble protein pattern of a single isolate of *O. roboris* isolated from oak in Azerbaijan, USSR, and brought into Britain under licence, was found to be identical with the patterns of several *O. piceae* isolates originating from oak in Britain. This further supports the earlier suggestion (*Report* 1989, p. 47) that *O. roboris* is the same taxon as the western European *O. piceae*, and corresponds to the hardwood type.

J. F. WEBBER, C. M. BRASIER

REFERENCE

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ARBORICULTURE: DEPARTMENT OF THE ENVIRONMENT CONTRACT

Decay in amenity trees

Work has continued on pruning wounds created at different times of year, to measure the following effects; cambial dieback around the wounds, the initial rate of wound occlusion by cicatrix ('callus') formation and the extent of staining in the wood beneath the wound surface (*Report* 1989, p. 45). Nine tree species were included in the experiment: cherry (gean), pedunculate oak, red oak, sycamore, Norway maple, hornbeam, ash and yew. Eight – or, for some species, nine – times of pruning were spread through the four seasons. For each combination of species and pruning time, 20 wounds were created and either left untreated or covered with a proprietary sealant, 'Lac Balsam'. Cicatrix formation and dieback were assessed at 12 circumferential positions 1 year after wounding. Wood staining was measured (a) to its maximum linear extent on cores extracted from the pith region of the wound, and (b) from the sapwood/heartwood boundary where present.

The amounts of cambial dieback and cicatrix formation differed very significantly between times of year for all nine species. Positional differences around the wound circumference were very marked, and significant for all the species. Dieback was greatest underneath wounds, and least at the top, while cicatrix formation was least below, greatest at the sides and intermediate in extent above the wounds. Significant interactions occurred between season and wound position. Seasonal variations in the depth of xylem staining beneath wounds were also statistically significant and in most species there was a distinct cyclic pattern, showing a minimum after summer pruning, and a maximum after pruning in January or February.

In some combinations of species and time of pruning, treatment of the wounds with the sealant had a significant effect on cicatrix formation, dieback, or wood staining, but this effect was not consistently beneficial, since it operated either positively or negatively in different treatment combinations.

These data provide a preliminary basis for deciding when pruning may be inadvisable, and their reproducibility is being tested by more detailed work on beech and pedunculate oak, in which wounds are created at weekly intervals over two periods, in autumn and spring, when the change in response to wounding seems to be most rapid.

D. LONSDALE, I. T. HICKMAN, S. E. BROWN, C. PALMER

ENTOMOLOGY

The problems of controlling restocking pests have led to changes in the Branch's research programme to increase research effort investigating alternatives to the existing chemical control measures. Some reduction in effort, as a result of progress in research and of the decrease in populations, has occurred on the *Dendroctonus micans* project.

Pine wood nematode surveys were carried out throughout Great Britain during 1989. Although neither *Bursaphelenchus xylophilus* nor the closely related *B. mucronatus* were found, an unidentified *Bursaphelenchus* sp. was present at a number of locations. This will be investigated further in 1990. As part of a continuing commitment to assessing the risks from pine wood nematode, Mr N. J. Fielding has been seconded for a year to the Pacific Forestry Centre, Victoria, British Columbia studying pine wood nematode/vector relationships.

Visiting researchers from Bhutan, Ghana and Turkey spent 6 months each working on a range of topics with members of the Branch.

H. F. EVANS

GREAT SPRUCE BARK BEETLE, *DENDROCTONUS MICANS*

Biological control of Dendroctonus micans

In excess of 100 000 adults of the predatory beetle *Rhizophagus grandis* were produced during the year. About 5000 *R. grandis* adults were released at new infestations found during surveys; the remaining beetles were used for research.

Research surveys to assess the levels of *D. micans* populations continued. The rate of population change remained the same as the previous 2 years; populations increased at around 20% per annum. Assessment of stocking density and overall levels of attack at some sites revealed that an average of 5% (0.3% – 12.7%) of trees showed symptoms of attack. However, detailed surveys at other sites have revealed that the majority of *D. micans* attacks are normally abortive resulting in tree mortality levels of less than 0.5%.

Adults of the predatory beetle, Rhizophagus grandis, *taking flight in a laboratory wind tunnel* (Photograph: Dr T. Wyatt)

Populations of *D. micans* continued to fall at the three permanent study plots and no destructive samples were carried out in 1989. *R. grandis* has been found at a number of locations where no releases were carried out thus confirming previous findings that the adult predators disperse readily and locate low densities on their prey, *D. micans*.

C. J. KING, N. J. FIELDING, H. F. EVANS

Dispersal of Rhizophagus grandis *adults*

A blend of five monoterpenes isolated from *D. micans* frass was tested in a laboratory wind tunnel for its attractiveness to *R. grandis* (see photograph). Flying and walking beetles responded strongly to this artificial lure and it appeared to be as attractive as frass, although this was not confirmed in the field.

The lure was tested in field trials in August/September 1989 in 'Theyson' bark beetle slot traps. Traps were deployed on four sides of a 60 m square in a randomised block design. Captures in unbaited control traps were compared with those baited with 5–10 g of frass or 2.5–5 g of lure. Within the areas enclosed by the traps, 2600 – 4700 *R. grandis* adults were released and trapped over 2 – 3 days. Captures in traps containing the lure were about 10–20% of those in frass-baited traps. No beetles were caught in unbaited traps. About 1.5–8% of the beetles released were captured.

D. WAINHOUSE, P. BEECH-GARWOOD*, T. WYATT*†, D. R. KELLY*†, M. BARGHIAN*†

* Part-supported by Scottish Forestry Trust.

† Cardiff University, M. Barghian supported by Forestry Commission grant.

THE PINE BEAUTY MOTH, *PANOLIS FLAMMEA*

Monitoring and control

Routine pupal surveys carried out in the known susceptible areas of north Scotland in autumn 1989 showed no need for a control programme in 1990.

J. T. STOAKLEY

Population ecology

Panolis flammea populations in lodgepole pine in the Elchies block of Moray Forest District showed a slight increase, with 0.14 pupae m^{-2} being found overall, almost three times the number found in 1988. The average fecundity of the females was also much higher than described in recent years (*Report* 1988, p. 36; *Report* 1989, p. 52), being 132.5 eggs per female in deep peat sites and 125.0 eggs per female in ironpan sites.

As part of a new investigation of the influence of lodgepole pine seed origin on *P. flammea* population dynamics, replicated study plots have been set up using Alberta, Central Interior and South Coastal provenances at Elchies. The following assessments were made: in autumn 1988, numbers of pupae and extent of pupal parasitisation; in 1989, numbers of eggs, larvae and pupae and extent of pupal parasitisation. There were no significant differences between provenances but all counts were very low and the data provided a base from which to follow future trends.

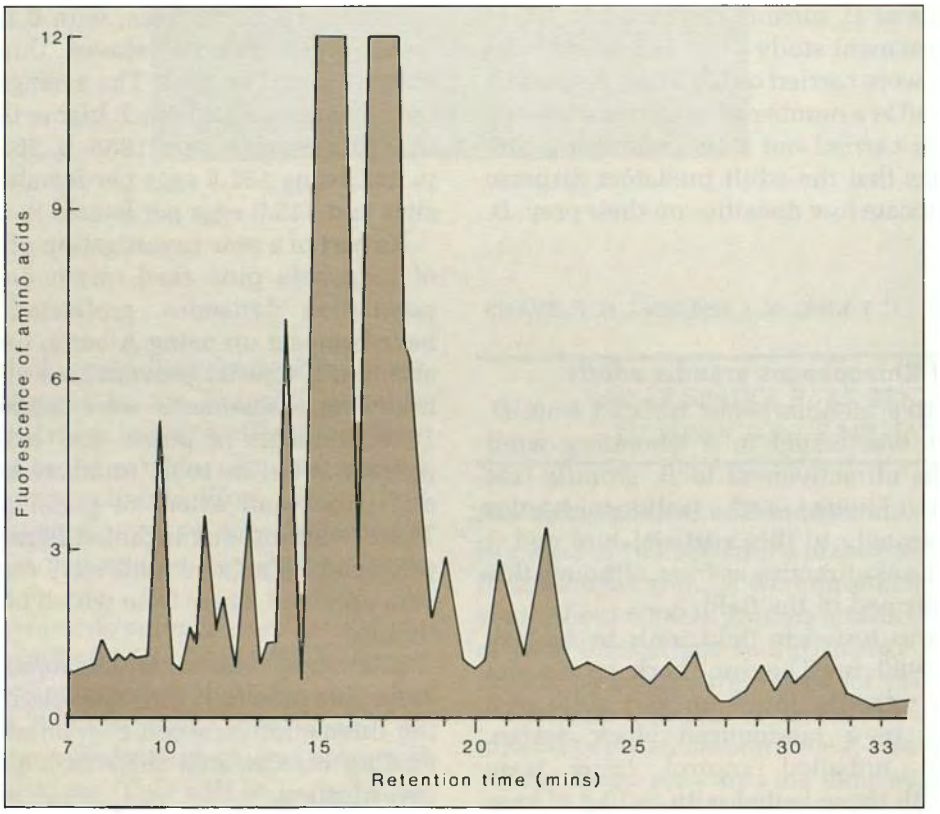
Laboratory work on resistance studies of lodgepole pine to *P. flammea* has continued and the interaction between *P. flammea*, other pine feeding insects, and their host plant is under investigation.

S. R. LEATHER

GREEN SPRUCE APHID, *ELATOBIUM ABIETINUM:* INTERACTIONS WITH SPRUCE

Studies on the resistance of different spruce species to *Elatobium abietinum* have continued. Fifteen species of spruce have been sampled in early and late spring in a study plot at Alice Holt to compare aphid size and reproductive capacity. Three asiatic spruces, *Picea koyamai, P. glehnii* and *P. maximowiczii*, all showing resistance features, have been compared with *P. sitchensis*. Aphid performance was tested in a controlled environment bioassay and compared with variation in plant secondary chemical composition. Aphid growth rates on *P. koyamai* and *P. glehnii* were as little as 50%, and *P. maximowiczii* about 25%, of that on *P. sitchensis*.

In the study on host plant resistance to aphids, the analytical parameters have been refined to determine amino-acids in spruce foliage extracts on the high performance liquid chromatography equipment. A trace from a Sitka spruce tree being studied as part of the bent top syndrome in South Wales is illustrated. Earlier studies on the comparison of phenolic compounds correlated with resistance have been resumed to include additional clones, some of which show partial resistance to *E. abietinum*.



Amino acid analysis of Sitka spruce foliage from the south Wales study on bent top syndrome. The trace is from a quantitative technique being used to analyse small (80µl) extracts of foliage for nutrients (amino acids) that are essential for aphid growth and performance. Retention time in minutes is shown on the x-axis while fluorescence of amino acids complexed with an indicator (FMOC) is shown on the y-axis. The large peaks at 15.161 and 16.92 minutes are excess indicator.

During 1989, sporadic attacks of *E. abietinum* occurred over a wide area of Britain (Carter, 1989). Particularly heavy attacks on P. *sitchensis* occurred in parts of Wales. This has enabled selected trees that are currently being monitored for aphid infestation to be chemically analysed for susceptibility in the context of the spruce decline syndrome (bent top) on the South Wales Coalfield plateau.

A hitherto unrecognised species of root aphid has been found to be more widespread, and persistent throughout the year, on the roots of *P. sitchensis* on the peaty soils of South Wales than previously realised. This has now been identified as *Pachypappa vesicalis* Koch. Its population trends, migration and impact on growth are being investigated.

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

REFERENCE

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THE PINE WEEVIL, *HYLOBIUS ABIETIS,* AND BLACK PINE BEETLES, *HYLASTES* SPP.

Chemical protection

The principle of protecting plants by the application of a narrow band of insecticide, as an alternative to complete dipping, was tested. Treated bands between 50 mm and 150 mm wide round the plant stem at the root collar level provided a good level of protection.

The treatment of transplants with permethrin using the Electrodyn Sprayer Conveyor (ESC) was tested for efficacy in both field experiments and Forestry Commission conservancy trials. The experiments showed that, despite damaging beetle populations, indicated by their impacts on control plants, the ESC gave a good level of protection which was not significantly different from dipping with insecticide. It was found that bridging the treatment zone with brash did not reduce the level of protection. However, protection from the ESC system was not adequate at all sites and further improvements will be made during 1990.

In experiments on cold storage of plants treated with wettable powder or emulsifiable concentrate formulations of permethrin, it was shown that plants could be cold stored for at least 9 weeks after treatment with no reduction in root growth potential. There was no significant difference between the two formulations of permethrin.

Biological protection

Laboratory experiments showed that species of either *Steinernema* or *Heterorhabditis* nematodes could kill both adults and larvae of *H. abietis*. Sub-lethal concentrations of nematodes applied to adult *H. abietis* resulted in a change of behaviour which may have implications for prevention of damage to plants in the field.

First generation adult male (small) and female (large) Steinernema bibionis *nematodes. Infective juveniles of this species of nematode are being tested for use against* Hylobius abietis.

Infective juveniles of the entomogenous nematode *Steinernema feltiae* survived the winter at three forest sites, but the percentage survival varied considerably between sites. Bioassays with different soil types showed lower extraction of infectives from soil compared with sterile sand.

A small demonstration trial was set out applying two species of nematodes to nursery plants damaged by larvae of the weevil *Otiorhynchus sulcatus*. Weevil larvae, containing developing nematodes of both species, were found. Treatment with a mixture of *Steinernema* sp. and a *Heterorhabditis* sp. appeared to provide the best level of control.

S. G. HERITAGE, S. A. COLLINS, T. JENNINGS, I. WATT

PINE LOOPER MOTH, *BUPALUS PINIARIA*

Pupal surveys were carried out in 38 blocks from 15 forest districts (FD). Counts were low except in east Scotland where the highest compartment means were 8.8 m^{-2} at Lossie and 9.2 m^{-2} at Roseisle (both in Moray FD) and 20.8 m^{-2} at Tentsmuir (Abertay FD). In England and Wales only Delamere (Cheshire FD) showed a marked increase to 4.0 m^{-2} while Cannock (Midlands FD) decreased to 3.2 m^{-2}.

T. G. WINTER

STUDIES ON THE IMPACTS OF INSECTS ON TREE GROWTH

Two main models are being studied to assess impacts on tree growth.

Impact of pine looper moth, *Bupalus piniaria*, is being assessed by stem analysis studies allied to biological experimentation. During October 1989, stem cross-sectioned discs were cut from 40 mature, 65-year-old, Scots pine felled in Tentsmuir Forest, Abertay Forest District. Tree ring measurements from these discs are being analysed to determine whether a relationship exists between radial and volume increments and past *B. piniaria* populations as recorded in Forestry Commission pupal surveys.

To study the impact of pine shoot moth, *Rhyacionia buoliana*, artificial manipulation of larval densities has been established at a range of infestation rates in 2–3 m tall, 6-year-old Bishop pine (*Pinus muricata*) in replicated experimental plots in Wareham Forest, Dorset. The proportion of upper shoots attacked in the five larval density treatments was 0, 5, 16, 25 and 30% in February, 1990. Tree growth was similar between plots prior to treatments. Assessments in 1990 will quantify the impact on tree growth in relation to *R. buoliana* larval numbers.

N. A. STRAW, D. WAINHOUSE

ADVISORY AND TAXONOMIC SERVICES

Numbers of enquiries concerning the control of *Hylobius abietis* and *Hylastes* spp. remain high as a result of changes in the Statutory Approvals for use of insecticides and the increasing replanting programme.

The green spruce aphid, *Elatobium abietinum*, caused extensive defoliation of Sitka spruce plantations for the second year, although most enquiries related to Norway spruce Christmas tree plantations or to amenity trees in private gardens. Damage to Leyland and Lawson cypresses by *Cinara cupressi* remained high until the summer of 1989. Large numbers of *Cinara pilicornis* were noted on Norway spruce at several nurseries in East Anglia during January and February. *Cinara cedri*, only previously reported from Kew Gardens and in Middlesex, was found on a deodar cedar in a Cheshire garden. From July onwards, localised browning of oak foliage by *Phylloxera glabra* was noted, particularly affecting roadside trees in southern England.

No reports of oak defoliation by caterpillars were received but spangle galls on the leaves caused by *Neuroterus quercusbaccarum* and knopper galls on the acorn cupules due to *Andricus quercuscalicis* were more abundant than for several years. At Oundle, Northamptonshire, defoliation of cricket bat willows by *Yponomeuta rorrella*, together with the dense silk webs spun by the larvae, was very striking and caused local concern until the trees flushed again in midsummer. Defoliation of Corsican and Scots pine by *Neodiprion sertifer* was noted as far south as Nottinghamshire and Wiltshire.

Forestry Commission plant health inspectors intercepted several exotic species of scolytids on imported timber. The most significant find was *Dendroctonus pseudotsugae* from Canada found on Douglas fir boards at Bristol. *Polygraphus rufipennis*, also from North America, was found at Cardiff and at Liverpool. Two occurrences of *Ips typographus* in dunnage from Europe were reported from east coast ports. Larvae of a cerambycid beetle, *Monochamus* sp., together with adults of a *Tetropium* sp., probably *T. cinnamopterum*, were intercepted at Leith, together with live nematodes of an unidentified species.

T. G. WINTER, J. T. STOAKLEY

WILDLIFE AND CONSERVATION

DEER

Work has concentrated on reviewing long-term research, particularly on roe deer, reviewing and rationalising data collection, and analysing and concluding some experiments.

We are encouraging forest managers to make collections of jaw bones from culled deer of all species for age determination and subsequent cohort analysis to reconstruct population size retrospectively, in anticipation of the publication of further advice on age determination techniques for all deer species.

P. R. RATCLIFFE

Roe deer

Preliminary analysis of the roe deer population data shows differences between populations in the mean number of corpora lutea per doe (see Figure). This suggests that most adult does in the Pickering, Alice Holt and Thetford populations will produce twin kids each year, while those in Queens will only have single births.

In all populations yearlings (12–24 months of age) achieve at least 80% of adult fertility and in high performance populations (i.e. Pickering, Alice Holt) >90% adult fertility is achieved. The proportion of yearling does carrying two or more corpora lutea is also greater in these populations (Table 14).

Kids are the most sensitive age class. In low performance populations no kids had corpora lutea (Table 15) while 48% of kids at Pickering had corpora lutea, of which 9.3% had 2 or more.

There are significant differences in the mean bodyweight of does in a given population carrying 0, 1, 2, 3 or 4 corpora lutea.

Inter-uterine losses, indicated by comparing numbers of corpora lutea with numbers of embryos present after mid-January (impossible earlier due to delayed implantation) are above 20% in most cases and over 60% in the low performance population at Queens. Successful implantation and embryonic development occurred in only 32% of mature females at Queens Forest, and over 75% at Pickering, Spadeadam and Craigellachie (see Figure). This level of loss is much higher than normally cited for European roe populations, but compares with that reported by Chapman and Chapman (1971), Chaplin (1977) and Loudon (1980) in other British roe deer populations.

Only at Pickering have kids carrying embryos been found, although kids carrying corpora lutea are found in five of the seven populations. These kids must have become sexually mature, ovulated and mated at 3–5 months of age.

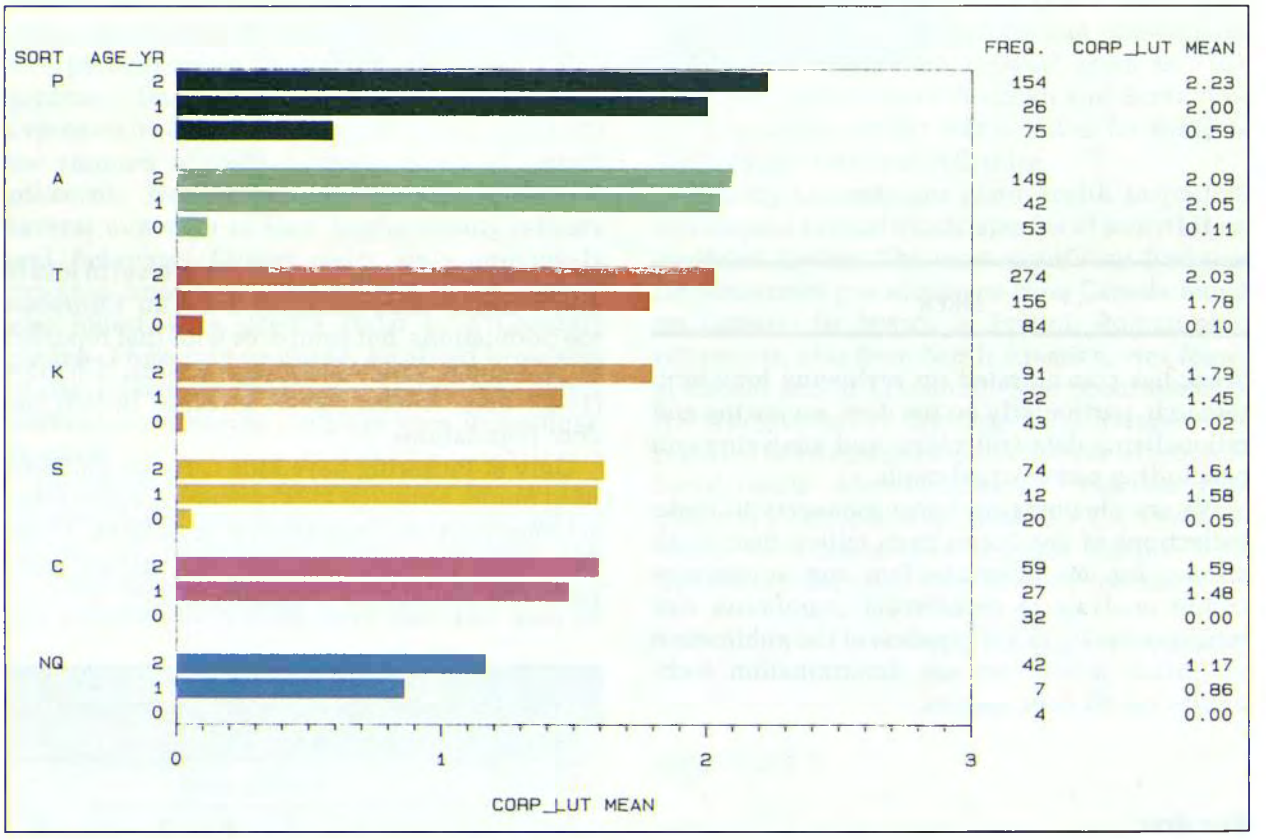
Table 14. Percentage of yearling roe deer does carrying 0, 1, 2, 3, 4 corpora lutea

Forest	*Corpora lutea*					
	0	1	2	3	4	N
Pickering	0.0	4.0	92.0	4.0	0.0	25
Alice Holt	0.0	4.8	85.7	9.5	0.0	42
Thetford	1.9	21.8	72.4	3.3	0.6	156
Spadeadam	0.0	41.7	58.3	0.0	0.0	12
Craigellachie	3.7	44.4	51.9	0.0	0.0	27
Kershope	4.5	45.5	50.0	0.0	0.0	22
Queens	14.3	85.7	0.0	0.0	0.0	7

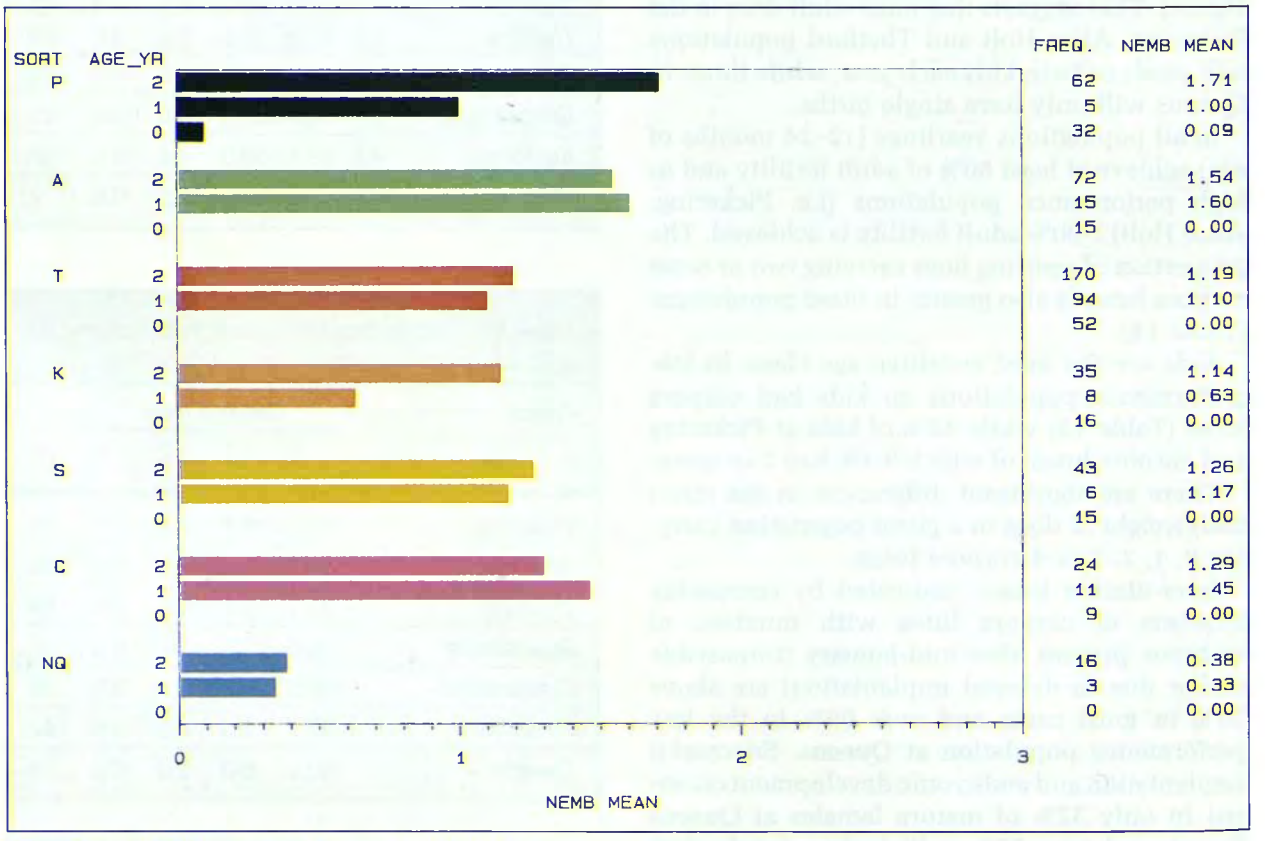
Table 15. Percentage of roe deer kids carrying 0, 1, 2, 3 corpora lutea

Forest	*Corpora lutea*				
	0	1	2	3	N
Pickering	52.0	38.7	8.0	1.3	75
Alice Holt	90.8	7.5	1.9	0.0	53
Thetford	95.2	0.0	4.8	0.0	84
Spadeadam	95.0	5.0	0.0	0.0	20
Craigellachie	100.0	0.0	0.0	0.0	32
Kershope	97.7	2.3	0.0	0.0	43
Queens	100.0	0.0	0.0	0.0	4

P. R. RATCLIFFE, B. A. MAYLE



Mean number of corpora lutea by age class.



Mean number of embryos by age class; day 80+.

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CHAPLIN, R. E. (1977). *Deer*. Blandford Press Ltd., Dorset.

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Fallow deer

A 3-year study of fallow deer ecology and demography, supported by Forestry Commission's West England Conservancy and Staffordshire County Council has commenced. Dr P. R. Ratcliffe and Dr S. Harris of University of Bristol are supervising the study.

P. R. RATCLIFFE

Sika deer

Data on skull morphometrics have been collected from all the main British populations, and from the two Japanese sub-species on Hokkaido and Honshu. Preliminary analysis is suggesting large differences between populations indicative of hybridisation between sika and red deer in some British populations.

P. R. RATCLIFFE, A. H. CHADWICK

SQUIRRELS

Work is progressing on improving the success of grey squirrel control in conifer forests, and in winter index trapping aimed at predicting damage risk in the following spring/summer. If successful this will substantially reduce the need for control every year.

Following the introduction of the new grey squirrel bait hopper which prevents access by non-target species (Pepper, 1989) further work is in hand to prevent access by red squirrels. If access by red squirrels can be prevented it may be possible to recommend changes in legislation aimed at controlling grey squirrels within red squirrel areas. This will have important benefits for red squirrel conservation and for damage prevention.

It has proved possible to detect the presence of red squirrels at very low population densities using modified feeding hoppers with sticky entrance tunnels. These 'collect' hairs from the coat of feeding animals.

REFERENCE

PEPPER, H. W. (1989). *Hopper modifications for grey squirrel control*. Forestry Commission Research Information Note 153.

H. W. PEPPER, P. R. RATCLIFFE

AUTECOLOGICAL STUDIES OF SENSITIVE SPECIES

Bats

During summer 1989 the habitat requirements of woodland bats were studied by investigating bat activity, insect prey availability and vegetational structure in six discrete habitat types; oak woodland, coniferous plantation, felled/restock areas, woodland rides/glades, riparian/pond habitats and pasture.

Results suggest that there are significant differences in vegetational structural complexity and insect availability between habitats. Greater numbers of large (>10 mm) insects were found over ponds. Bats use pond and woodland ride habitats significantly more than other habitats and bat activity increased with increasing ambient night temperature. Bat activity was significantly related to insect size, insect abundance at ground level, and vegetation in the lower shrub layer (2–4 m).

It may be possible to predict bat activity and habitat selection from a knowledge of vegetation structure. Guidelines on habitat management for woodland bats were published (Mayle, 1990), and presented to woodland managers (Forest Officers) at conservation management courses.

REFERENCE

MAYLE, B. A. (1990). *Habitat management for woodland bats*. Forestry Commission Research Information Note 165.

B. A. MAYLE

Birds

Work continues on the adaptations of birds of prey to second-generation forests in the uplands and how these habitats can be improved. Goshawks are slowly expanding their range in Britain, and because they breed in older stands of timber, they increasingly need to be considered when planning harvesting operations. Guidelines have been published on the management of goshawk nesting areas (Petty, 1989a). In the largest of two study populations, range expansion has almost stopped. This is considered to be due largely to the persecution of adults and juveniles once they disperse from the forest after the breeding season.

Tawny owls and their main prey, the field vole, continue to be monitored in Kielder (Northumberland) and Cowal (Argyll) Forest Districts. Vole populations were low in both study areas in 1989 resulting in many pairs of owls failing to produce eggs. Those which did lay, reared very small broods. Mean brood size at Kielder was 1.27 chicks per pair laying and at Glenbranter 0.67

chicks, the lowest recorded during the study. Analysis of habitat in Kielder indicates that the density of tawny owls is regulated largely by the spatial diversity of crop types within the forest (Petty 1989b). The highest densities are found where a patchwork of different-aged stands provides pole-stage crops where the birds breed and roost together with heavily-vegetated restocked sites where they feed.

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S. J. PETTY

DAMAGE

Research on wildlife damage has continued with a major assessment of a long-term study into the effect of bark stripping on the growth of Sitka spruce and lodgepole pine. Studies on the long-term effect of browsing continue. A review of wildlife damage in forests has been completed which identifies areas for damage research.

A visiting scientist from Japan has begun a 1 year study of the interactions between browsing damage, deer density and habitat factors.

R. M. A. GILL

REPELLENTS

Electric fencing

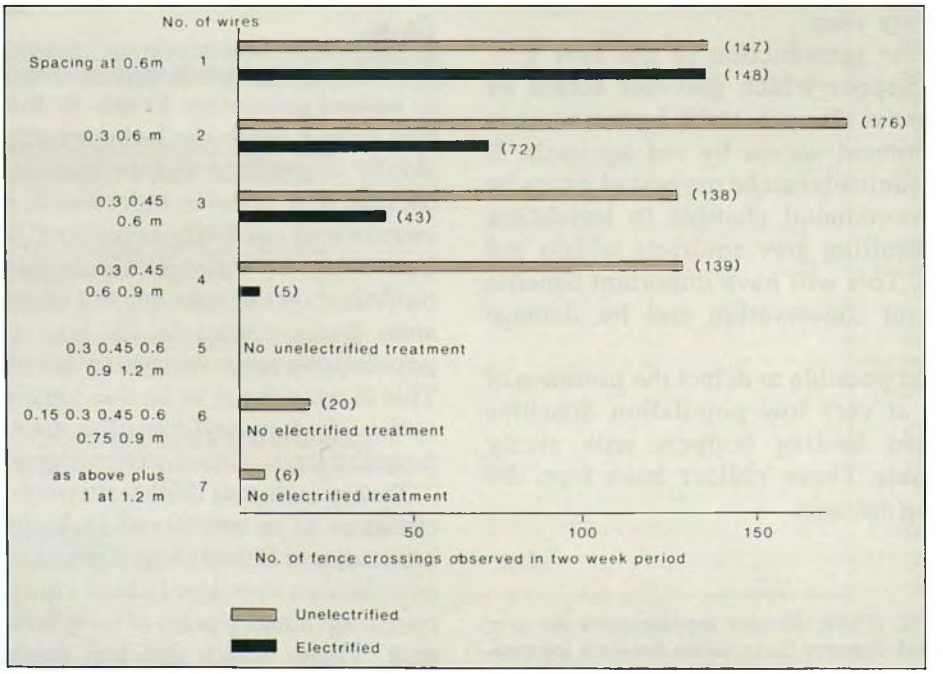
Trials to compare the barrier effect of fences of five and seven line wires at 0.3 m spacing both unelectrified and electrified, around two restock areas are in progress. One of the restock areas in Kielder, has pressure from roe deer and the other, in Cowal, has roe and red deer. Data from Kielder show that none of the fences is an effective barrier to roe deer. At least 50% of the trees within all the fenced areas are damaged.

A further trial in the Alice Holt roe deer enclosure is investigating the effectiveness of different specifications, (numbers of wires and wire spacing) both electrified and unelectrified. The reactions of the deer to these fences is being observed using video surveillance.

Fences of one and two powered line wires at 0.3 m spacing did not deter the deer effectively even though the animals were observed touching the wires. Using four electrified wires a significant difference was observed (see Figure). The deterrent effects of an electric deer fence appears to depend on the number and positioning of wires and the pressure of deer against them. It seems likely that relatively small areas may be adequately protected over short periods.

The application of electric fencing and the cost and practicalities of maintaining it for the protection of farm woodlands from domestic stock is also being investigated.

H. W. PEPPER, A. H. CHADWICK



Results from a trial to investigate the effectiveness of different fencing specifications as a barrier against roe deer incursions.

VEGETATION MANAGEMENT

Vegetation of old conifer stands (over 60 years old)

Further sampling of selected stands was carried out to add to the survey conducted in 1988, to relate plant assemblages to parameters such as distance from stand edges, canopy cover and amount of direct sunlight.

The number of species, especially vascular plants, is greater than has been recorded in studies of younger plantations. Cover of vegetation is also greater than recorded in younger plantations of the same species of tree. Comparisons can be made with data for broadleaved woodlands, both semi-natural and plantations, which have been sampled as part of the NCC's National Vegetation Classification (NVC) project.

Old spruce and Douglas fir stands, most of which were on sites which have previously carried broadleaved or mixed woodland, had slightly fewer species on average than the average number of species in the equivalent NVC broadleaved woodland type for similar soils. The range was considerable however and some, including the oldest stand sampled, which was 100 years old, had more species than would be expected in an equivalent broadleaved wood.

The species composition of the conifer stands varied considerably. Species adapted to rapid colonisation, surviving shading or surviving as buried seed, were dominant as would be expected, but in old woodland sites where woodland herbs were probably present in the previous rotation or in adjacent areas, a considerable variety was present in the old conifer stands, for example species classified by Nature Conservancy Council, in eastern England at least, as 'ancient woodland indicators' *Dryopteris affinis, Circaea lutetiana, Lysimachia nemorum, Melampyrum pratense, Mercurialis perennis,* were found in a wide range of Douglas fir, spruce and larch stands (up to 8–10 species in some stands).

The total numbers of species present in a stand were quite variable and tended to be higher on fertile soils and on old woodland sites with a heavily thinned canopy. The maximum recorded was 102 species in a stand of Douglas fir on brown earth in the Lake District (based upon 20 plots of 200 m^2). Douglas fir stands tended to have more species than spruce but this could be due to differences in soil and history rather than tree species.

G. S. PATTERSON

SURVEY OF RIDE MANAGEMENT PRACTICES IN ENGLAND AND WALES

In response to concern that current management practices might not be meeting objectives, particularly where plant conservation has been given priority, a questionnaire survey of all Forest Districts in England and Wales was conducted in 1989/90. The survey was aimed at evaluating the extent of ride management undertaken for conservation purposes, and to establish the way in which management might be refined.

The survey revealed large regional differences in the extent to which forest ride systems are managed for conservation. Other objectives of management include firebreak maintenance and access. Of Forest Districts undertaking management for conservation, a substantial number considered that their objectives were not being met. Declining conservation value, expressed as decreased floristic diversity, was reported by many respondents. It is proposed that the timing of ride cutting operations, coupled with the failure to remove cut material, has led to changes in the vegetation communities. Nutrient enrichment caused by the breakdown of this mulched material may lead to the loss of some broadleaved herbs and increased dominance by a few aggressive species.

Future work will examine the use of forage harvesters on selected conservation rides, as part of a wider study to examine the timing and intensity of cutting regimes.

R. FERRIS-KAAN

STUDIES OF THE USE OF HERBICIDES AND GROWTH REGULATORS TO MANIPULATE GROUND VEGETATION FOR CONSERVATION

The management of ground vegetation on rides and other open areas within forests usually involves repeated mowing. This may be expensive and does not always meet conservation objectives. Herbicides and growth regulators provide an alternative and flexible means of vegetation management. The use of herbicides can, by controlling the specific target species, introduce a greater diversity of plant species. The development of broadleaved herbs, in response to the reduction in grass competition, may be followed by an increase in the number of invertebrates associated with the particular foodplants present.

In a study currently underway in Micheldever Forest, West Downs Forest District, the ground

vegetation on a 4-year-old ride is being managed using a range of herbicides and one growth regulator. It is hoped that these treatments will enable the supression of some of the aggressive species present, encouraging a shift in species composition to favour desirable broadleaved herbs. In addition to this work, a detailed study is being carried out to evaluate the environmental changes occurring within the sward in response to herbicide treatments.

R. FERRIS-KAAN

MENSURATION

SAMPLE PLOTS

A total of 179 permanent sample plots were due for measurement in the programme for 1989/90. There was serious disruption as a result of gales in southern England and Wales on and after 25 January 1990. Approximately 83 sample plots were damaged, 25 severely. The worst damage to plots was in Somerset and South Devon Forest District where a total of ten plots were damaged eight of which will have to be abandoned. In the New Forest District eight plots suffered wind damage, five of which will have to be abandoned with full final measure. The photographs depict a windthrown underplanting experiment at Haldon, near Exeter. Although standing volume is assessed throughout the life of a sample plot, the final felled measure is the most accurate. Unless trees are shattered and unmeasurable a final plot measure will always be attempted.

Five new sample plots were established in 1989. Three plots of Corsican pine in Suffolk Forest District form an unreplicated thinning experiment. They replace similar plots established in Suffolk in the 1940s, which were destroyed in the gale of October 1987. The new plots are on a restocked site, and will give information on the yield of second rotation crops. Two plots were established in unthinned lodgepole pine, one each in Buchan and Fort Augustus Forest Districts. These will provide much needed additional data on the rate of growth and yield of such plantations.

J. M. METHLEY, R. W. MATTHEWS, S. R. ABBOTT

YIELD STUDIES

Sitka spruce

A yield model for unthinned Sitka spruce planted at 1.5 m spacing was produced in response to a request from Forest Surveys Branch for use in the production forecast for Kielder Forest District. The existing yield model computer program was employed in conjunction with specially developed programs to interpolate between models already available for other planting spacings.

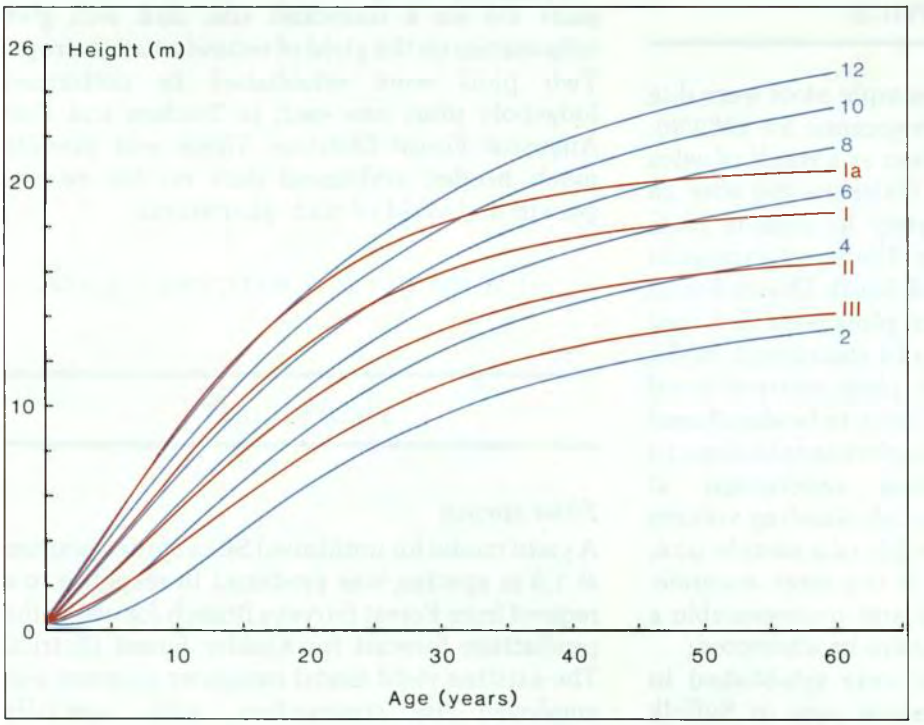
Measurement of windthrown trees in a permanent sample plot. (39338, 39339)

Ash

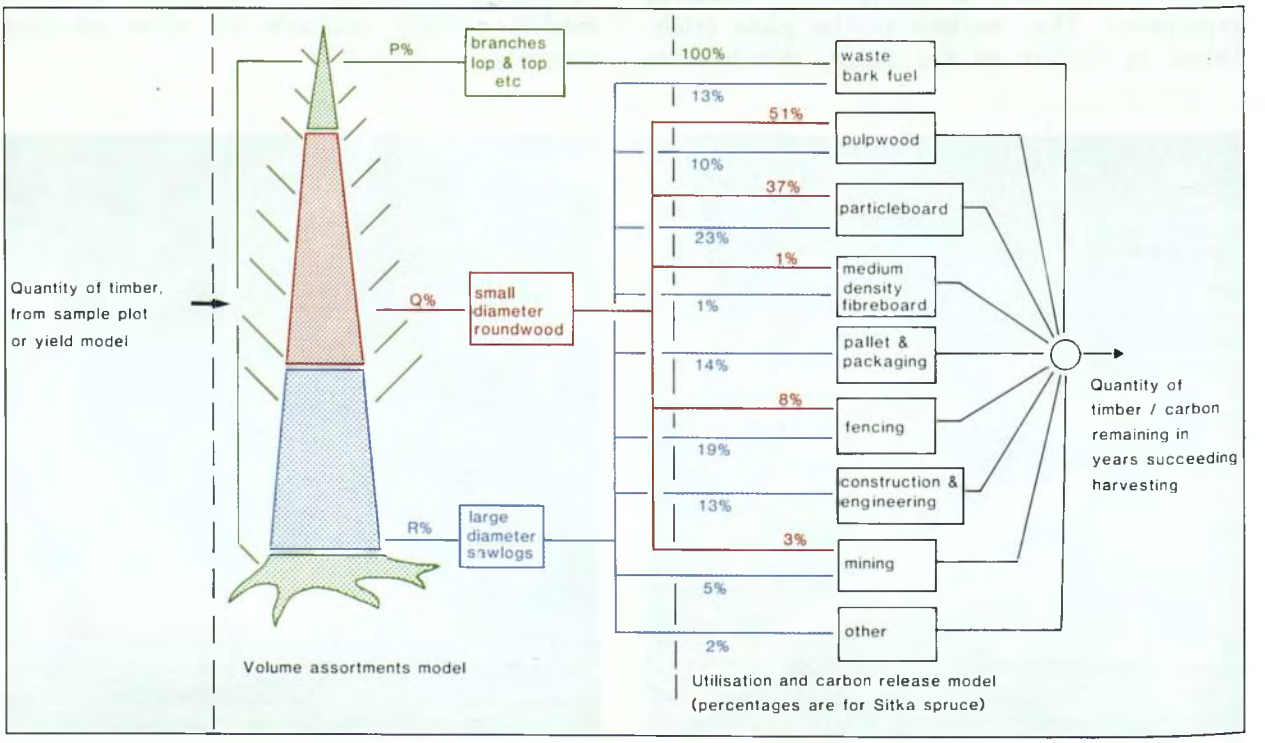
Assistance was given to Silviculture (South) Branch in the construction of a yield model for free-grown ash. Computer programs for fitting anamorphic and polymorphic families of growth curves were employed. The graph immediately below shows the height growth predicted by this yield model for four site classes, compared with the curves for top height from the published yield model for sycamore, ash and birch (SAB). The curves suggest that free-grown ash trees do not maintain the height growth of ash grown at close planting spacings.

Carbon storage

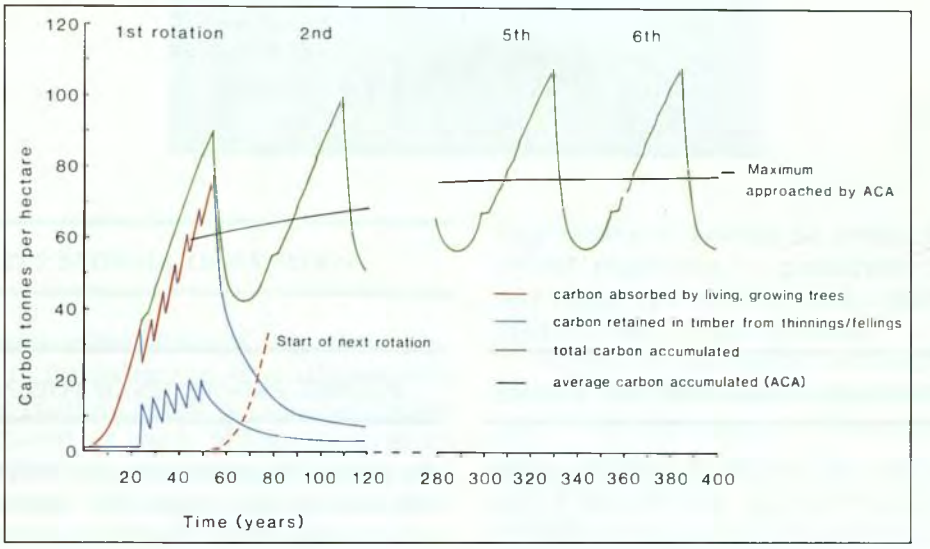
Models for simulating the absorption and release of carbon by plantation forests and forest products were developed. These models can be used to assess the effectiveness of a range of forest management options for removing carbon diox-



Comparison of models for height growth free- and plantation-grown ash. Blue curves = SAB General Yield Class Curves. Red Curves = free-grown ash Quality Class curves.



Model used for simulating utilisation of timber, and release of carbon from timber products.



Sitka spruce YC 12, 2 m planting spacing, Management Table thin. Carbon absorbed and retained by repeated rotations, with timber going to typical products.

ide from the atmosphere. The rate of absorption of carbon is predicted using functions for whole tree volume derived from the yield models which is then converted to a tonnage of carbon using appropriate values for wood density and carbon content. A model for predicting the release of carbon from timber products was also developed and is illustrated in the schematic diagram in the Figure opposite. The predicted quantity of carbon stored by growing and utilising yield class 12 Sitka spruce over repeated rotations of 55 years duration is shown in the Figure above. Examples of output from the models have been published in Research Information Note 160, *The storage of carbon in trees and timber.*

R. W. MATTHEWS, J. M. METHLEY

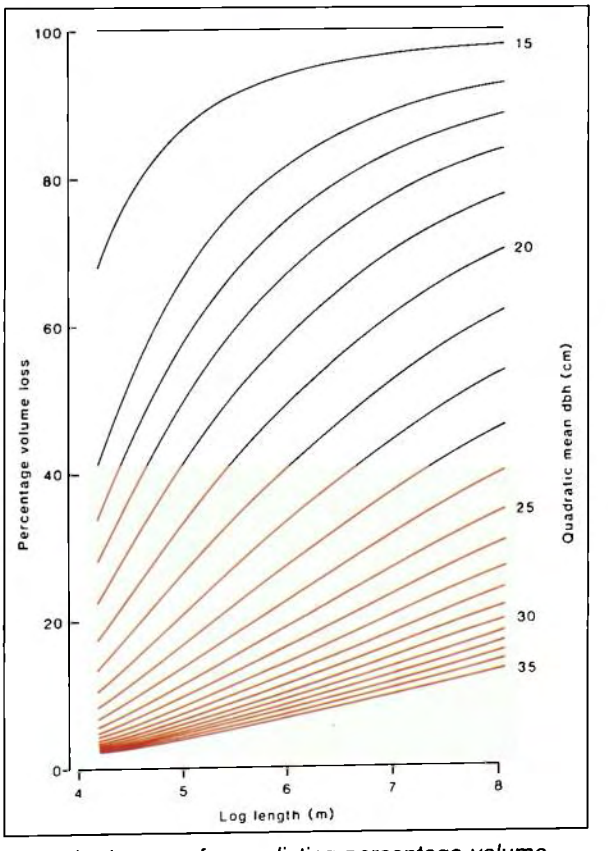
MANAGEMENT SERVICES

A set of tables was produced for Harvesting and Marketing Division, showing the loss of potential sawlog volume associated with cutting specified log lengths greater than 4 m. Tables showing volume loss for a range of log lengths cut to 12, 14, 16 and 18 cm top diameter underbark were compiled. The relationship between percentage volume loss and log length for logs to 18 cm top diameter are shown in the adjacent Figure. The functions are based on predictions of sawlog volumes for different length and diameter specifications obtained using the assortment forecasting program. Results from this study have been published in Field Book 9, *Classification and presentation of softwood sawlogs.*

Advice and assistance was given to three research branches on the methodology of measurement and analysis of experiments for which information on yield was required.

Numerous requests for advice on measurement and yield were dealt with. The Branch continued to advise Forest Districts on the use of the tariff checking and calculation package.

J. M. METHLEY, R. W. MATTHEWS, S. R. ABBOTT



Smoothed curves for predicting percentage volume loss when cutting logs greater than 4 m in length.

WOOD UTILISATION

ANTI-SAPSTAIN TREATMENT OF SOFTWOODS

Timber sawn from freshly felled and water stored logs of Corsican pine (see Inter-Branch Report opposite) was treated with a range of commercial anti-sapstain chemicals. The effectiveness of these treatments was compared with a NaPCP control and an untreated control over a 12-week period. Each chemical was tested at three recommended concentrations. Of the three concentrations of NaPCP used, only the strongest gave adequate control and on this basis it is believed that site conditions for the experiment gave a severe test for all chemicals used. Most of the commercial chemicals gave good control of bluestain and mould growth, albeit with slightly poorer protection at lower chemical concentrations in the water stored material. The untreated control of fresh material had significant levels of bluestain colonisation, whereas the equivalent water stored material was affected mainly by superficial mould growth. This trial was supported by United Kingdom Softwood Sawmillers' Association, Hoptons Timber Company, the companies supplying chemicals and conducted under the direction of Dr D. Dickinson of Imperial College.

PULPING PROPERTIES OF POPLAR CLONES

As part of a programme for testing timber of different poplar clones, two clones have been selected for study: T×T32 and Robusta. Three trees of each clone, corresponding to two age groups (10–15 years and 30–35 years), have been felled at three different sites. These trees have been despatched to the Wiggins Teape laboratories at Beaconsfield, for pulping trials. In addition, similar numbers of birch and sycamore are being included in this co-operative study to allow comparison of poplar material with other potential 'farm forestry' species.

J. F. WEBBER

INTER-BRANCH REPORT
WOOD UTILISATION AND PATHOLOGY

WATER STORAGE OF SAWLOGS

Work continues on the effects of water storage on timber quality following the establishment of a waterstore at Thetford Forest in 1988, (see *Report* 1989, pp. 59–60). A batch of logs removed in September 1989 for examination after 12 months storage, consisted of Corsican pine, Sitka spruce and beech. An 18 month batch removed in February 1990, contained the same species and also Scots pine, Norway spruce, Douglas fir, Japanese larch, ash and sycamore. Moreover, the Corsican pine, Sitka spruce and beech sampled after 18 months included treatments in which logs had been 'aged' for various periods before being introduced into the waterstore. Thus logs pre-stored for 5–6 weeks and 9–10 weeks after cutting from windthrown trees, were compared with logs put into the store within 0–2 weeks of cutting or after fresh felling. Assessment of the logs involved sawing to produce 25 mm or 50 mm edged boards, quantifying the extent of any visible stain or decay and culturing from the stained areas on agar medium.

All species continue to saw easily after water storage. Very little stain or decay was evident in any of the logs except for those of the Corsican pine subject to the 9–10 weeks pre-store treatment. Boards from these logs had, on average, about 12% of the surface showing blue-stain, the stain generally being present at the ends and along the edges of the boards. Close examination also revealed that much of the stain emanated from scolytid breeding galleries excavated in the bark and underlying sapwood of the logs. However, even when stain was clearly evident in the logs, isolation was rarely successful, suggesting that fungal growth had been arrested and the fungus itself rendered inviable by the water storage procedure.

J. F. WEBBER, J. N. GIBBS

STATISTICS AND COMPUTING

STATISTICS: ALICE HOLT

'The oak and the ash. . .'

Differences between oak progeny in branching, budding, crown shape and the number of flushes in a season, were examined for the Tree Improvement Branch. A stepwise discriminant approach gave some pointers to the characteristics most useful for classifying progeny groups.

Programs were written for Pathology Branch, to tabulate and analyse data collected in a survey of ash and oak trees in the countryside. The survey was designed to investigate relationships between ash dieback and land use. A second survey of ash bud flushing over two seasons, provided data to test links between bud development and any fungal or insect damage.

Tawny owls

Several home range models were programmed during the analysis of a radio tracking investigation into the territory size of tawny owls (*Strix aluco*). Contour plots and utilisation distributions were obtained (see diagrams) and used to investigate habitat selection and movement of owls and also post-fledging behaviour of juveniles.

Sequential significance testing

A sequential significance test was adopted to test the effectiveness of various types of wire strainer used in fencing. By measuring the proportion of times the steel wire slips, the sequential binomial test allows a direct comparison with the strainer currently used for tensioning Forestry Commission fences. The number of tests required and the time-consuming nature of each test were important factors in the choice of this sequential scheme.

Work study

A new data processing and analysis system has been developed on the Prime computer, to enable Work Study officers to use and modify Genstat programs and analyse their own data from remote locations. Studies can be selected from a large file, grouped and batched for processing in one of the standard batch queues, or run immediately. Genstat programs were added to the system so that 'standard times' appropriate to harvesters and processors could be produced. Particular attention was paid to the problems of working in wind-damaged crops where entry to tables is required by end-product and whole-tree measurements. Some synthesis was necessary to overcome problems related to broken or split trees.

Genstat

The task of updating all the Silviculture analysis programs to Genstat 5 is continuing. Where possible a common Genstat procedure is used for all experiments; the options control the output of tables, graphs and analyses and the parameters are used to name the input files and variates and they help to annotate the output. Project leaders are being encouraged to use this new system to produce their own tables, graphs and analyses from standard data files.

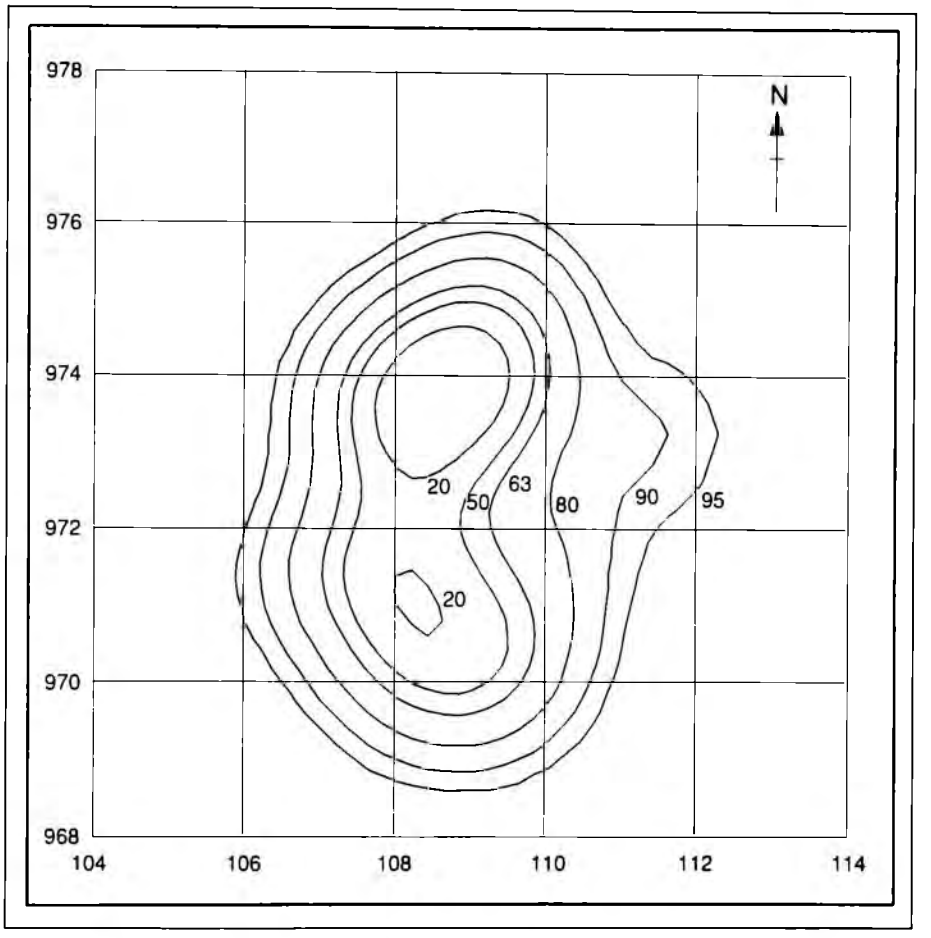
SAS

The purchase of the SAS system has complemented our existing statistical and graphical software. SAS/STAT has been used in complex multivariate analyses and SAS/GRAPH has been used to produce high quality colour graphics on a variety of devices including laser printers and flat-bed plotters.

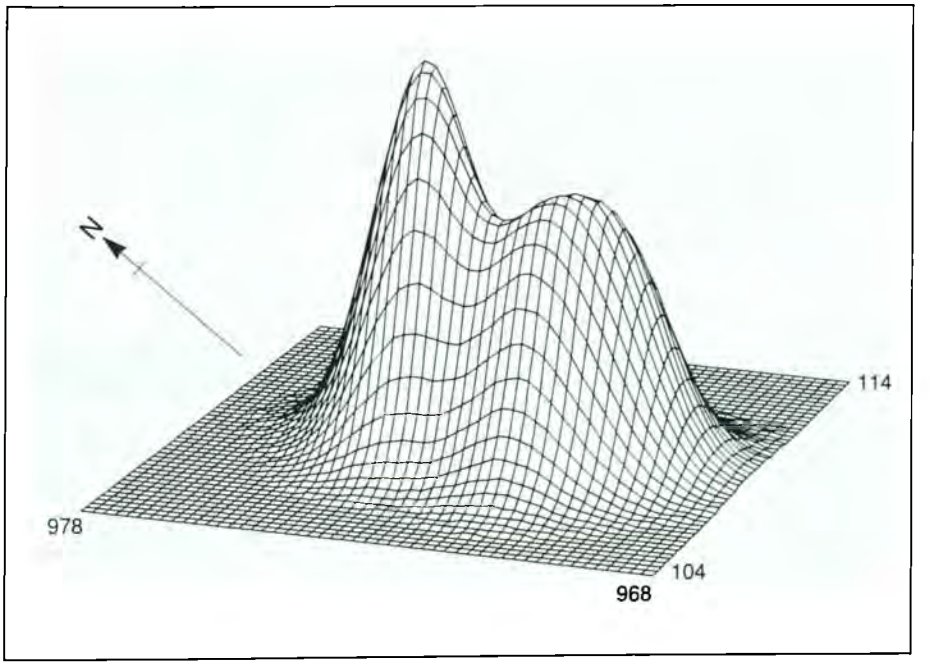
R. C. BOSWELL, T. J. HOUSTON, I. D. MOBBS, A J. PEACE

Modelling the effect of spacing on timber strength

The influence of tree spacing on timber strength in Sitka spruce is being investigated using data on trees from unthinned spacing experiments and temporary sample plots. Logs from sample trees from 20 stands were converted, and battens were sawn and tested, at the Building Research Establishment, Princes Risborough. In the first stage of the analysis the three-parameter Weibull distribution was found capable of fitting breast-height diameter distributions over the complete range of spacing from 0.9 m to 3.9 m.



The estimated utilisation distribution of tawny owl 779 using a Fixed Kernel method. Above: *Domain contours show the 20%, 50%, 63%, 80%, 90% and 95% probability levels of the utilisation distribution.* Below: *A surface plot of the same utilisation distribution; x and y axes represent eastings and northings (200 m intervals) and the vertical axis the probability density.*



The maximum-likelihood estimators for this distribution are not generally regular when all parameters are to be estimated, neither is the distribution among those which are natural to the GLIM system. The GLIM library routine WEIBULL, which is designed for estimating the two-parameter Weibull distribution was therefore adapted and combined in an iteration with a quadratic minimiser (Nelder, 1985) to find the best values of the location parameter for each sample-site separately. To obtain acceptable fits, the constraint that no trees should have a d.b.h. of less than 7 cm was imposed where this was required (i.e. in eight plots). This constraint conforms to the Sample Plot convention that only trees with a d.b.h. of 7 cm or above are measured.

Once the three parameters had been estimated for each plot, attempts have been made to find relationships between the parameter estimates and 'crop condition' variables. One use of such relationships would be to predict the general character of crops given only the planting spacings or given only the spacing and a range of, say, yield classes; both of these measures normally being available before the felling age is reached.

The shape parameter is a measure of the skewness of the distribution. The shape estimates were found to be closely related to percentage mortality at the time of felling. Fitting the best equation left only 8% of the variance unexplained.

The scale parameter is a measure of the spread of the distribution to the right of the minimum d.b.h. The scale estimates were found to be closely related to the planting distance, the function having a sigmoid form. The best equation found was a generalisation of a logistic function of spacing; fitting this equation left only 3.5% of the variance unexplained.

The location parameter is the minimum of the distribution and its estimated value was found to have a low correlation with all other variables investigated. The variation of this parameter is presumably determined to some degree by how sensitive the smallest trees are to competition from their larger neighbours but, wherever this natural sensitivity is low, the convention of ignoring trees with a d.b.h. less than 7 cm will have imposed a constraint which would be difficult to distinguish from the effects of severe suppression in the present data. The only way found so far to obtain a satisfactory prediction of the location parameter has been to use the mean d.b.h. of the measured trees and to relate this to the other Weibull parameters themselves. One such predictor was found to have a correlation coefficient of 0.88 with the original parameter estimate and the regression of the original estimate on this left only 22% of the original variance unexplained.

The diagram shows six Weibull distributions drawn from the equations calculated and tested, as described above. The values of mortality, yield class, mean d.b.h. and spacing used were averaged over the groups of plots with spacing nearest the values given.

Study of the taper of the trees in stands of different spacing and of the yield of logs and battens continues.

R. S. HOWELL

REFERENCE

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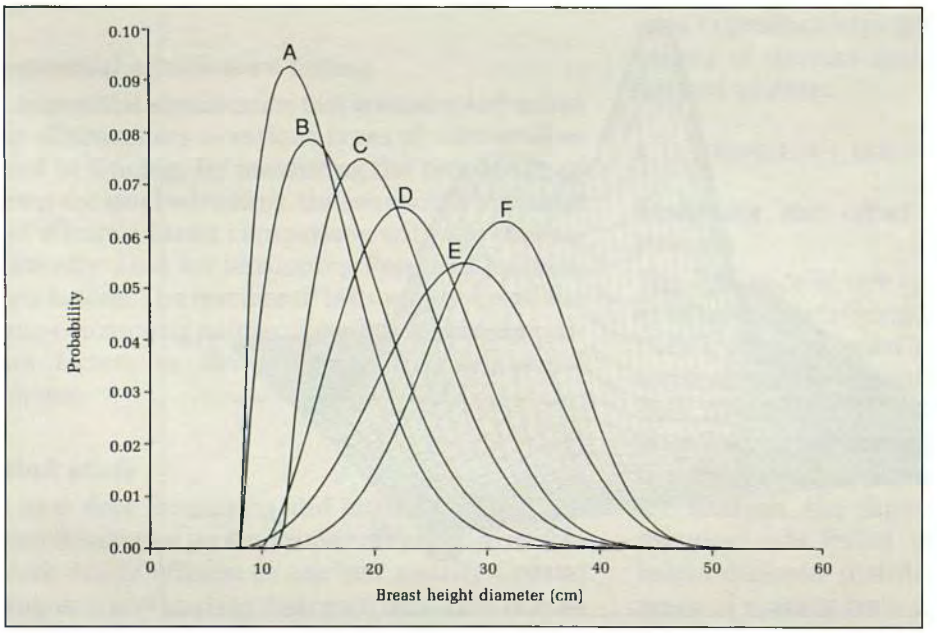

Six Weibull curves of typical shapes for the given spacing.

STATISTICS: NORTHERN RESEARCH STATION

Relating flag tatter to aspect, elevation and topex in exposure studies

An equation relating flag tatter rate to elevation, aspect, "topex", and geographical position was improved by a non-linear transformation of the topex measurement from the standard open-ended scale to one with fixed end points.

Modification of a model for borehole water level

It was found that a model for borehole water levels (Rennolls *et al.*, 1980), designed for open ground, could be used with canopy cover simply by subtracting a measure of interception loss from the rainfall input. The only change required was a slight re-interpretation of one of the parameters. A good fit was obtained with experimental data.

Interpreting mensurational effects of growth

During a period of declining growth, treatment may push a crop along the growth curve until it is growing more slowly than an untreated control. During a period of increasing growth rate, the opposite effect will cause the treated crop to continue to grow faster than the control after the direct effect of treatment has ceased (Miller, 1981). 'Compound interest' calculations have been tried to eliminate these anomalous effects from experimental comparisons.

Allowing for over-dispersion of counts

Root growth potential measurements, being counts, are routinely subjected to analysis of variance after a transformation. Over-dispersion is allowed for by a variance inflation factor. The possibility of using a negative binomial distribution as the basis for analysis was investigated, using a fitting algorithm due to Breslow (1984). This invariably gave similar results to the simpler analysis and it was not felt that the gain in flexibility justified the extra complexity.

The centre of diameter of the root plate

Studies of the effects of planting treatments on root growth continued with the use of the 'centre of diameter' method described last year. A comparison of the effects of different root measurement techniques and tree sizes on the 'centre of diameter' used as a summary statistic has begun. Published root growth models were reviewed to find out what kind of data would be needed to construct one.

Statistical training for foresters

Dr Trudy Watt (formerly of the Oxford Forestry Institute) repeated her successful course on practical statistics at both the Northern Research Station and Alice Holt. The practical problems of experimental design and layout were emphasised, and simple analyses were tried and discussed.

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

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RENNOLLS, K., CARNELL, R., and TEE, V. (1980). A descriptive model of the relationship between rainfall and soil water table. *Journal of Hydrology* **47**, 103–114.

COMPUTING: ALICE HOLT

The computing system

At the beginning of the year we asked Prime to conduct a Computer Audit to monitor the use of the Prime 9655. The results obtained were then analysed and used by them to advise on ways of improving the performance of the machine. They concluded that, in spite of the recent increase in memory, the load on the machine made it impossible to improve performance significantly.

Parameters for the Weibull curves (see Figure opposite)

	A	*B*	*C*	*D*	*E*		*F*
Spacings of	0.90m,	1.50m,	1.85m,	2.40m,	2.80m,	&	3.20m
Shape parameter	1.62,	1.75,	1.84,	2.54,	3.44,	&	4.08
Scale	8.24,	10.1,	10.9,	15.6,	24.1,	&	24.6
Location	8.02,	8.23,	11.8.	9.68,	6.41,	&	8.66

During the year some of the load on the Prime has been transferred to micros although these have been used, too, to handle new work which was not and could not be done on the Prime. At the end of the year a 496Mb disk drive was purchased to replace two existing 80Mb drives (which had come to the end of their life) and to provide much needed extra on-line disk space. A Prime EXL Matchbox – a multiuser UNIX box, based on 386 technology, was also purchased, so that we can experiment with the UNIX operating system; it will form part of a planned local area network, linking the Prime 9655 and the various micros.

After initial teething problems the link to JANET (Joint Academic NETwork) is now working well and traffic is gradually increasing as researchers realise the value of its file transfer, mailing and remote log-in facilities. The link between the HQ Network and the Prime now works well and Work Study HQ now use this to log-in to the Prime remotely, they seem to have fewer problems using this method of access than using dial up modems.

B.J. SMYTH

Data entry and data capture

New systems to replace the Kode were reviewed and the Rode/PC data entry system was chosen. One PC has been purchased and a start has been made on programming it ready for the change-over.

The analysis of floristic data using TWINSPAN and DECORANA has been simplified by creating a new data entry program for quadrat and sample data that greatly reduces the amount of duplicated information which had previously been required.

Updated software and the purchase of a macro-zoom lens have increased the usefulness of the image analysis system. It has been used extensively to measure the areas of leaves from photocopies made soon after sampling.

R. C. BOSWELL, T. J. HOUSTON, A. J. PEACE

Programming

The software package for the JANET link has been upgraded. Investigations have taken place to provide facilities for running jobs on a remote machine. TURBO-CPL was purchased which has considerably speeded up the user-interface to many of our systems.

Work study

Enhancements to the Microfin Data Checking System have been undertaken. The most important of these being to allow entry on to the Microfin data loggers of time-study data in an abbreviated format and to calculate the mean weighted ratings of each of the cyclic and other work elements in a study. Provision has been made to check and analyse data concerning both bed and grapple Harvesters working in thinnings, fellings or windthrow.

Forest surveys

An audit of the sub-compartment database system carried out by Audit Branch showed satisfactory data validation and robustness of the forecasting programs. Software for the entire system was updated and major parts rewritten following revision of the basic data format. Programs were written to convert existing data to the new format. All the data were successfully converted and the revised Oracle database loaded. The forecasting programs were revised for the valuation to incorporate new basic assumptions and some improvements which time prevented in the last valuation.

G. J. HALL, L. M. HALSALL

Expert systems development

A Prolog system for identifying fungi in culture was completed and is being used by members of Pathology Branch. We are now writing a 'model builder' to simplify the development of simulations models. As soon as the first equation is typed in, the system prompts the user to define each of the variables on the right-hand side and reminds him of further undefined variables as the model is entered. It has facilities for storing, editing and recombining submodels and, most valuable of all, for checking the consistency of units on each side of any equation. Output of the system is in the DARE P simulation language.

A. COLLINS, A. R. LUDLOW

COMPUTING: NORTHERN RESEARCH STATION

Data capture

Each Silviculture (N) outstation was given an FW60 data encoder and 2 days training. Staff learnt how to do field assessments with it and how to transfer the data from it to a microcomputer's floppy disc, for posting to the Northern Research Station. Amstrad 640D micros were issued. The Silviculture staff who have had most experience with the encoder now prefer to use it for almost all their assessment work.

Micro software

The graphics software, Lotus Freelance Plus, was installed and has proved very popular. It is used to design overheads and slides of professional quality for seminars, reports, etc.

The move to IBM-compatible microcomputers is almost complete. All but the last few programs, which are still running under the UCSD-p system on various older micros, have now been rewritten. Standardisation has made it easier to provide user support and allowed access to a wider range of commercial software.

Databases

A report was produced on the costs of database work.

Use of the Experiment Register Database for management purposes has increased, partly due to Forest District reorganisations and land disposals. To help to provide accurate and up-to-date information about the valid interests of Research Division, Forest District and Outstation ownership fields were added to each experiment record and all the relevant grid references were checked with the outstation staff. A replacement experiment register book was then laser printed for office use, with new columns for Forest District and Outstation.

A package of drawing routines has been developed for the laser printer, to assist with form design. Various forms have been produced, including the one on which data are compiled prior to entry in the Experiment Register Database.

For his MSc project, a Dundee University student transferred a copy of the Experiment Register Database into Oracle, to run under Edinburgh University's VAX/VMS service. He also wrote a C/SQL program to retrieve information, with numeric codes translated to helpful text.

A database was set up in Ingres, for the windthrow hazard survey, on Edinburgh University's new central UNIX service.

New software written for the mainframes

A program, PNJOINSITES, was written for Tree Improvement Branch. It is used to select progeny-test datasets from the TIB database and combine them, ready for the across-sites analysis developed in Genstat by I.M.S. White.

Routines (such as start-up files which limit the CPU time for a session and programs which log costs) are being developed to help users manage their computing effectively as they move into the UNIX operating system.

R. W. BLACKBURN, K. P. DONNELLY

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

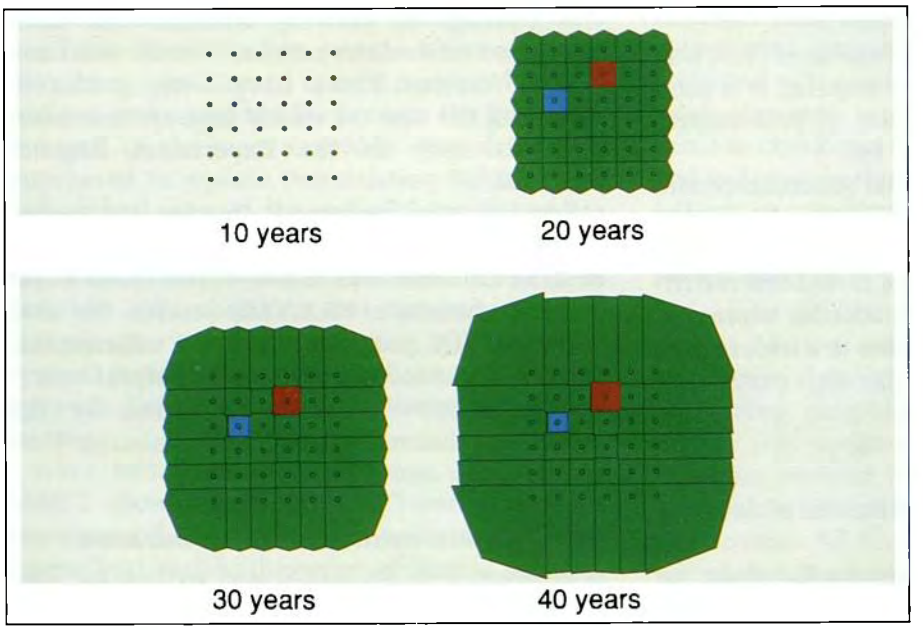
The Sitka spruce growth model described in last year's *Report* (p. 65) has been refined and extended and is now being fitted to sample plot data. When fitting models to data from sample plots, it has become almost standard practice to use the data from the first plot measurement to start the model off. Unfortunately, this is a weak test for a model because regression analysis shows that the state of the plot at the first measurement is a very strong predictor of its state at later measurements. There is little variation left for any model to predict, so it is hard to discriminate between models.

To overcome this, the model is now given typical measurements for 1+1 seedlings, 24 – 30 cm tall, and is required to simulate the growth of the trees in the sample plot at *all* measurement dates *including* the first.

This new test requires the model to simulate the growth of trees before and after their crowns have started to compete. The effects of increasing competition are taken into account by assuming that the crowns are conical and then calculating the points at which the crown touches the ground or the crown of a neighbouring tree. Photosynthesis is then related to crown size and foliage density so that adding foliage brings diminishing returns, as new foliage shades the old, while a large crown structure allows foliage to be distributed so that there is less self-shading.

The illustration shows how crown size changes over 40 years. Note how the growth of the small blue tree and the large red tree diverge in just the way that foresters have observed.

The model's parameters are now being optimised to obtain the best forecast for particular



The polygons represent the projected area of crowns in a simulated stand, grown over 40 years. Individual large and small trees are identified by colour. In this simulation there were 16 simulated trees plus a border of 20 trees whose height was linearly related to the mean-height of the simulated trees. Modifications to the program should allow much larger numbers of trees to be simulated.

sample plots and it is proposed to calibrate the model over a range of yield classes, spacings and thinning regimes. Because the model is based strongly on the structure and processes in trees, all of its parameters can be measured in real trees and sensible ranges for each parameter are usually well known. For the model to be correct it must not only fit the data, but also do so using sensible parameter values. For example, if the ratio of sapwood area to foliage dry-weight were wildly different from known values we would know that the model was structurally wrong. This is a more rigorous test than is possible with previous empirical models whose parameters normally have no physical significance. The best-fitting curves have been obtained with all parameters well within sensible ranges.

The fitting program optimises mean height, d.b.h. and volume to 7 cm simultaneously by calculating the *deviances* for each of these measures (McCullagh and Nelder, 1983, p. 17),

$$D = \sum_{i=1}^{N} (y_i - \mu)^2/\sigma^2$$

where D is the deviance, y_i is the d.b.h., height or volume of the actual tree, i, at a given measurement time, μ is the mean for the simulated trees at that time, and σ^2 is the variance and N the number of actual trees at that measurement time. The deviances are calculated separately at each measurement time for d.b.h., height and volume and each is then summed separately over all measurement times, giving separate overall deviances for each measure. This allows us to tell whether the model fits height better than volume or d.b.h. better than height, etc. However the fitting program adjusts the model's parameters to minimise the sum of all three deviances, giving them equal weight.

A special feature of the method is that the minimum possible deviance for d.b.h., height or volume is known in advance. It would be reached if the mean of the simulated trees equalled the mean of the actual trees at all measurement times. Then

$$\sigma^2 = \sum_{i=1}^{N} (y_i - \mu)^2/(N - 1)$$

so, for each measurement time, $D_{\min} = N - 1$. The overall minimum is $\Sigma(N_j - 1)$ for all measurement times j or, more simply, the number of data points minus the number of measurement-times. This is a great help in deciding how close to a perfect fit the model has come and how the fitting process is converging. While the method is useful for locating a minimum deviance, however, it could not be used to estimate confidence limits because successive observations are not independent. The method will later be extended to match the variance of the simulated trees against the variance of the actual trees.

A. R. LUDLOW, R. W. MATTHEWS, J. M. METHLEY, T. J. RANDLE

REFERENCE

McCULLAGH, P. and NELDER, J.A. (1983). *Generalized linear models*. London: Chapman Hall.

COMMUNICATIONS

Demand for information services continues to rise and new systems and methods for storage, retrieval and dissemination of information are being introduced as the means for keeping pace with the increase. Technical visits and seminars at Alice Holt and at the Northern Research Station increased by 31% over the previous year. At Alice Holt the number of visitors was 1043 and at NRS 539. The rate of technical visits in the Division, involving organised programmes of lectures and demonstrations has now arisen to approximately one per week.

LIBRARY

During the year book loans were 1089, journal loans 6731, photocopies 4480 and inter-library loans 1659, totalling 13 959 responses to demand. Online searching in the international databases continues to be a growing acitivity in the library, and in the year 107 searching sessions were carried out. At the end of the year a CAIRS Serials Management package was purchased. It is planned to bring this into operation during the forthcoming year with the aim of more efficient control of the circulation of journals and other periodicals.

PHOTOGRAPHY

The MICRO-CAIRS computerised photographic catalogue contained details of over 3000 slides by the end of the year. Computer generated graphics were in very heavy demand with the Principal Photographer and the Graphics Officer producing approximately 1000 images for lectures and publications. Fieldwork was a priority with special attention being given to northern research needs.

B. G. HIBBERD

PUBLICATIONS

This year there has been an increase in published titles (24 priced, 33 unpriced) compared with the previous 12 months (12 priced, 18 unpriced). This was particularly noticeable for Research Information Notes, which are produced to disseminate technical forestry information quickly and inexpensively to field practitioners. Of the 29 Notes issued during the year, two were illustrated in colour in a new (trimmed A4) format and are intended for distribution to a wide audience.

In 1988, at the first UK conference on urban forestry, the Forestry Commission undertook to prepare a Handbook detailing technical information for those engaged in providing forests for the community; one year later *Urban forestry practice* was published. It incorporates practical advice and information on the establishment and health of urban trees gained from research funded by the Department of the Environment, and being attractively designed, the Handbook has been well received and is a major contribution to the Countryside Commission/Forestry Commission initiative for promoting and developing community forests.

Two Bulletins, *Forests and surface water acidification* and *Monitoring of forest condition in the United Kingdom 1988*, provided objective information in response to increasing public concern on environmental matters.

The following titles were published during the year ending 31 March 1990.

Report on forest research 1989

Bulletins

81 Goshawks: their status, requirements and management, by S.J. Petty (£3)

82 A systems approach to forest operations planning and control, edited by M.A. Pritchard (£12)

84 Taxation of woodlands (£2.50)

85 *Dendroctonus micans* in Britain: its biology and control, by C.J. King and N.J. Fielding (£3)

86 Forests and surface water acidification, by T.R. Nisbet (£2.00)

87 The 1987 storm: impacts and responses, edited by A.J. Grayson (£4)

88 Monitoring of forest condition in the United Kingdom 1988, by J.L. Innes and R.C. Boswell (£8.80)

Field Books

3 Land capability for forestry: northern Scotland (map £6, explanatory booklet £2.50)

4 Land capability for forestry: western Scotland (map £6, explanatory booklet £2.50)

5 Land capability for forestry: eastern Scotland (map £6, explanatory booklet £2.50)

6 Land capability for forestry: south-west Scotland (map £6, explanatory booklet £2.50)

7 Land capability for forestry: south-east Scotland (map £6, explanatory booklet £2.50)

8 The use of herbicides in the forest (3rd edition), by D.R. Williamson and P.B. Lane (£4)

9 Classification and presentation of softwood sawlogs (£2)

Guidelines

Forest landscape design guidelines (£3)

Handbooks

4 Lichens in southern woodlands, by K. Broad (£4)

5 Urban forestry practice, edited by B.G. Hibberd (£11.50)

Occasional Papers

20 Nursery stock root systems and tree establishment: a literature review, by J.J. White (£4.50)

21 Provisional code of practice for the use of pesticides in forestry (£2)

22 Forest nursery herbicides, by D.R. Williamson and W.L. Mason (£1.50)

23 Trends in forestry research 1982–1988, by D.A. Burdekin (£1.50)

24 Mechanical characteristics of Sitka spruce, by B.A. Gardiner (£1.50)

Miscellaneous

Marketing for small woodlands: county lists of mills, merchants and contractors (£2)

The recognition of hazardous trees (3rd edition) (free)

Farm woodlands poster (free)

Seed Branch leaflet (free)

Silviculture (North) Branch leaflet (free)

Research Information Notes
(issued April 1989 – March 1990)

150 Wind–tree interaction studies in Sitka spruce plantations.

151 Application leaflet on the use of 'Permit' and 'Permasect 25 EC' for post-planting treatment against *Hylobius abietis* and *Hylastes* species attacking young trees.

152 Gardoprim-A liquid: experimental results on grass weed control and crop tolerances.

153 Hopper modification for grey squirrel control.

154 Tolerance of Sitka spruce roots to waterlogging.

155 Farm forestry research.

156 Demonstration plots for farm woodland and amenity tree establishment.

157 The effects of broadleaved trees on birds of conifer plantations in north Wales – report of joint RSPB/FC study 1984.

158 The use of nitrogen fixing plants in forest reclamation.

159 A brief guide to some aspects of the Control of Pesticides Regulations 1986.

160 The storage of carbon in trees and timber.

161 The 1989 outbreak of the green spruce aphid *Elatobium abietinum*.

162 Weather conditions during the summer of 1989 and their effect on trees.

163 Forest condition in 1989 – preliminary results of the monitoring programme.

164 The nutrition of Sitka spruce on upland restock sites. (colour)

165 Habitat management for woodland bats. (colour)

166 Site preparation for restocking.

167 Establishment of Sitka spruce in relation to mound size, plant handling and soil temperature.

168 Soil temperature regimes of mounds on gley soils.

169 Planting at stump – preliminary evidence of its effect on root architecture and tree stability.

170 A brief guide to some aspects of the Control of Pesticides Regulations 1986 (supersedes RIN 159).

171 Butisan S: weed control in forest nursery transplant lines.

172 The clearance of trees after the gale of 25 January 1990.

173 Insects and storm damaged conifers (supersedes RIN 134).

174 Wet storage of timber.

175 Restocking after windthrow in southern Britain (supersedes RIN 131).

176 Distinguishing Sitka spruce seed origins.

177 Application leaflet on the use of 'Permit' and 'Permasect 25 EC' for pre-planting treatment of young trees against *Hylobius abietis* and *Hylastes* spp.

178 Water-stored timber after 12 months.

E. J. PARKER

DEVELOPMENT DIVISION

WORK STUDY

Silviculture

A wide range of subjects has been examined. Particular attention was paid to the packaging and transport of bare-root transplants and detailed designs drawn up for a plastic box suitable for the standard range of plant sizes. A batch of boxes has been made and is undergoing field trials in Wales. The 'Electrodyn' (ICI registered trademark) spray conveyor developed to apply small targeted doses of synthetic pyrethroids has undergone field scale trials; results were mixed. Under carefully monitored experimental conditions they were entirely satisfactory. However, there was unacceptable late season damage in some field trial planting; reasons for this are being actively investigated. A spray booth, to apply aqueous formulations of permethrin to Japanese paperpot-grown Corsican pine was installed at Thetford and is being fully evaluated. Deposition levels are as good as, or better than those from a knapsack sprayer used on trays of seedlings. Efficacy and operator contamination are being monitored.

With evaluation and extended hire of the Donaren 870 mounder in 1988/89 we have now looked at the main machines thought capable of mounding for spruce restocking sites. The only machine capable of consistently fully mounding is the back hoe type digger mounted on an excavator base. All other machines just rearrange the slash in the slash zone resulting from organised harvesting systems and can make mounds only in former timber zones or where slash cover is extremely light and well decayed.

Work has continued on the recovery and chipping of spruce harvesting residues. Yields of up to 200 green tonnes of slash per hectare have been recovered. Extraction can be done very economically with a modified 7-tonne Bruunett 578 forwarder but, so far, it has proved impos-

Donaren 2-row continuous mounder mounted on an OSA 280 Master forwarder.

sible to chip material economically. With energy values of £2.40 per giga joule the cost of producing energy chips is still about £4.00 per tonne at 50% moisture content, more than their value. The work is being done in conjunction with Aberdeen University with sponsorship from the Department of Energy and is continuing.

A weeding survey again showed that herbicides are less widely used than their potential. Part of the problem is fitting work into the sometimes small 'windows' of suitable weather during the optimum season for herbicide application. A tractor-mounted Ulvaforest has been successful in lowland conditions and to allow similar progress in the uplands a forwarder mounted version has been built and tried out in Wales. Experience gained with the first attempt has been incorporated into the design for the rebuilt machine which is now undergoing field trials.

Harvesting

Mechanisation of harvesting continues to be the main target for investigation with the emphasis on early thinning. To find an economical system would release more small roundwood to satisfy the expected future shortfall as well as increasing the sawlog content of later thinning and clear felling. An early silvicultural thinning of crops on sites of borderline stability should also enable the terminal height to be increased and rotation length.

The Norcar 490 TH grapple harvester from Finland equipped with Danish Silvatec 330 harvesting head was tested. Width is only 2.27 m on 500 tyres. It has eight wheels, all hydrostatically driven and, like the 490 forwarder on which it is based, has the ability to cross steep and difficult ground and will manoeuvre well in the forest.

Outputs from the harvesting head are good with the produce being accurately measured and well sned. This head features three feed 'rollers' which are really chains providing a very positive and powerful feed.

The Swedish/Norwegian Tohr 970 grapple harvester with SMT 45 head proved similarly able, if not more so – the SMT head using traditional roller drive. This harvester is completely new and possesses various innovative features, being able to independently raise and lower its height both in length and width and also possesses a solid base to lower itself on to for stability when required. Being designed specifically as a harvester rather than based on a forwarder chassis it is compact.

North England Conservancy and Wales Conservancy both acquired grapple harvesters – Lokomo 990/762 and Osa 250 E/746 respectively – and we are involved in providing guidance on both method study and work measurement.

In East England Conservancy the Osa 250/706 bed harvester has been undergoing trials on working methods at Thetford following its release from windthrow working and the Valmet 862/948 grapple harvester is to follow it. The intention is to provide guidance on working methods and outputs in standing crops. Some high outputs have been achieved but particularly significant increases in the extraction output have resulted from the concentration of produce resulting from harvester working compared to the normal Thetford manual system.

However, all these purpose-built harvesters are very expensive and one means of reducing capital cost is to put the harvesting head on a cheap base machine. Excavator based harvesters are an effective means of doing this, especially for clear felling operations, and the tracks do not suffer the damage which might be expected. Mid Scotland Conservancy have a JCB 814/Osa 746 machine at Loch Awe with which we have learnt much information on techniques, abilities and also basic requirements during our trials. One key area is matching the hydraulic requirements of the head to the base machine. A second supporting hydraulic pump is sometimes required to provide the necessary hydraulic flow for roller feed harvesting heads. A reciprocating head, such as the Tapio range, have lower requirements and can be fitted without additional pump capacity. 1990 will see a JCB/Tapio outfit in West England Conservancy and an Akermann H3b/Lako in North England Conservancy. Both these are aimed primarily at clear felling operations but we are also investigating small machines such as the Atlas 1104 for thinning operations. This company has produced a forestry version with higher ground clearance and extended tracks.

On the extraction scene the main interest must be with the British built 6-wheeled Twose 12 tonne capacity forwarder which, following our recommendations is now with Mid Scotland Conservancy in full operational duties. A very stable machine with total control on the steepest slopes it is good to see that there is sound British competition to the Scandinavians. The company have taken on board all our recommendations for improvement and an eight-wheeled version is nearing completion.

Work measurement

National Output Guides for the thinning and felling of the main species are either available or in hand. Updating the tables is an ongoing task as the aim is to produce updated tables every 2–3 years. Local output guidance is provided for minor species. Extraction has been receiving attention, to produce Output Guides related to

Silvatec 335 grapple harvester head.

Norway spruce P56 clear fell worked with a Silvatec 335 mounted on a Gremo forwarder adapted base machine.

our modern forwarder fleet. Forwarding 6 for the Bruunett 678 has been completed and incorporates some graphical presentation of the times to aid interpolation. Work continues with the intention of publishing output guidance for medium forwarders in 1990. A Lokomo 990/762 harvester has been introduced into North England Conservancy and an Osa 250 E/746 into Wales Conservancy. Output guidance is to be provided for both with a further two, possibly three harvesters planned for 1990. Work measurement for harvesters must be substantial in 1990.

Attention is increasingly directed at silviculture. Revision of the bare-root stock replanting guide is under way and should be completed by autumn 1990. The complexity of chemical spot weeding and the need to encourage the optimum dosage, has prevented issue of a conventional national output guide. A modified approach is being used with the parameter for table entry being the distance covered in one minute's piecework rate weeding.

Work study tables are issued in the expectation that: work is done in the manner prescribed, to the specification laid down and using tools and equipment detailed in the Output Guide, the time predicted by the Output Guides to complete a job of standard performance (i.e. standard time) will be within plus or minus 10% of standard time derived from any local studies. Generally in local studies we use the other work and rest factors built into the published tables. Where standard time derived from local studies is outside the plus or minus 10% range we have almost invariably been able to account for the variance by identification of non standard conditions or work specifications. An index of all current Output Guides is available from Work Study Branch at Forestry Commission Headquarters.

With the increasing emphasis on mechanisation in forest operations, a Working Group is looking into performance rating of machine limited or dominated operations and is due to report by the year's end.

A paper on performance rating and the use of standard time in forestry has been accepted by IUFRO for Division 3.04 proceedings at the Montreal Congress in August 1990.

K. G. BUSWELL

PART II

WORK DONE FOR THE FORESTRY COMMISSION BY OTHER AGENCIES

SILVICULTURE

HERBICIDE EVALUATION FOR FORESTRY USES

by D. V. CLAY and J. LAWRIE
Department of Agricultural Sciences, University of Bristol, Institute of Arable Crops Research, Long Ashton Research Station

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

Improving glyphosate performance on grass weeds and heather

Glyphosate (Roundup) activity on the more intractable species is severely reduced if rain falls within 6 h of spraying. The ability of certain additives to reduce the adverse effects was tested using the Long Ashton Research Station rain simulator. Results were variable dependent on species and the glyphosate formulation used but the additive Mixture B (a mixture of hydrophilic and lipophilic surfactants) gave the most consistent enhancement of activity. Results with Silwet L77 an organosilicone surfactant were variable.

Control of naturally-regenerating Sitka spruce

The activity of imazapyr ('Arsenal') and glyphosate ± additives was compared on trees sprayed in June or November. Application to dormant trees in November was more effective; the non-ionic surfactant Galion was a more effective additive than Silwet L77 or Agral.

***Control of* Rhododendron ponticum**

Metsulfuron (Ally) and imazapyr were effective on *Rhododendron* at low doses but there was no appreciable increase in activity with mixtures of the two herbicides either together or with glyphosate or triclopyr (Timbrel). Addition of Silwet L77 increased the activity of metsulfuron and glyphosate on *Rhododendron*.

Broadleaved trees – tolerance to foliar-applied herbicides

Overall spraying in May with clopyralid (Dow Shield) was well tolerated by six species (ash, beech, birch, cherry, oak, sycamore) but bentazone (Basagran) and phenmedipham (Betanal E) generally caused appreciable necrosis of sprayed foliage. Metsulfuron was damaging to ash and cherry.

FACTORS AFFECTING NUTRIENT SOURCE/SINK RELATIONS ON RESTOCK SITES

by M. F. PROE
Macaulay Land Use Research Institute, Aberdeen

Collaborative work with the Forestry Commission into factors affecting nutrition on restock sites has continued. Long-term effects of nitrogen fertiliser on Corsican pine have been investigated at Culbin Forest, Moray. Results from whole-tree sampling prior to clear felling showed there to be a continued significant ($p<0.01$) response to fertiliser in dry weights of stems and stumps but there was little difference in the standing biomass of crown components 20 years after the last application of fertiliser. Three years after clear felling and replanting with Corsican pine there was significantly ($p< 0.05$) greater ground vegetation biomass on fertilised plots and this appeared to be associated with a reduction in tree growth, although this effect was not statistically significant.

Investigations have continued into the physical and nutritional roles of harvest residues on an age-series of Sitka spruce restock sites in Kielder Forest, Northumberland. The aim has been to quantify tree growth in the presence or absence of residues and determine the importance of interactions with planting position (against the stump versus on the flat).

The Nutritional Advisory Service to Forest Nurseries continues to operate and a collaborative project has been initiated to quantify nutrient uptake profiles for a range of species with a longer-term objective to improve nitrogen top dressing regimes.

SITE STUDIES

SOIL EROSION ON LAND CULTIVATED AND DRAINED FOR AFFORESTATION

by P. A. CARLING
Institute of Freshwater Ecology, Windermere Laboratory, Ambleside, Cumbria

Erosion is being measured on three types of cultivation on a peaty gley soil at Glen Skible, Kintyre Forest District. The treatments are a standard D45/T60 tine plough, a non-tine D45 plough and moling. Rainfall is recorded continuously and the resulting incremental runoff down one furrow is being measured. Relationships between rainfall intensity, distance down slope and runoff are being formulated with a view to providing guidelines on the spacing of cross drains designed to intercept furrow discharges and minimise soil losses.

THE NATURE AND PATTERN OF SOILS UNDER ANCIENT WOODLAND

by B. R. WILSON
Department of Soil Science, University of Reading

Field studies were extended to encompass a range of twelve sites including ancient woodland, recent woodland and non-wooded sites. These sites were chosen on three distinct parent materials (sand, loam, and clay). Soil samples were analysed for pH, carbon, nitrogen and organic phosphate. Absolute values and rates of change of these properties are found to differ significantly between the three parent materials. The type and direction of changes in soil properties resulting from establishment and increased maturity of woodland is, however, similar for all parent materials sampled.

The influence of woodland cover on soil properties is found to be most significant at or near the soil surface. Increase in soil carbon and nitrogen rapidly follow the establishment of trees on a previously non-wooded site. The accumulation of organic phosphate however takes considerably greater time periods. Organic phosphate is also found to be closely correlated to total phosphate and parent material would appear to determine the limit of organic phosphate accumulation.

The magnitude of variability of soil properties is consistently greater under woodland and a pattern of soil variability associated with the tree cover would appear to be imposed within the lifetime of individual trees. This again is most significant at the soil surface.

THE ROLE OF THE SOIL MICROBIAL COMMUNITY IN AREAS RECLAIMED TO FORESTRY AFTER OPENCAST MINING

by H. F. BIRCH, P. BIRCH and J. A. HARRIS
Environment and Industry Research Unit, Polytechnic of East London

Sites were investigated in the Neath Valley of South Wales, they included the study areas of Bryn Pica, Abercrave, Ffyndaff and Dunraven former opencast coal workings.

Studies on the mycorrhizal associations of Japanese larch (*Larix kaempferi*) have shown that, on many sites, the association is very poor with much of the fungal material being dead. Where tree growth has been improved, the fungal associations have also improved; but where concentrations of phosphorus are very low the amount of infection is also low and in some cases the fungi have become saprophytic on the plants.

Even where the phosphorus concentration is slightly enhanced, the association of roots and fungi is much improved. Phosphorus, mineralisation and nitrification levels have proved to be low on all of the sites.

Tree growth has been improved by the inadvertent mixture of topsoil and subsoil into the shales, coupled with an increased soil microbial activity.

Work has started on investigations of the growth of Japanese larch seedlings and the addition of varying amounts of NPK and P liquid fertilisers to these shales. Also work has been undertaken to look at the effects on growth of adding root inocula from a well developed forest stand, leaf mould and peat to the spoil.

Preliminary visual results of the experimental trees indicate that the addition of leaf mould and compost improves tree appearance and that the spoil is able to retain moisture. However, the addition of liquid fertilisers produces little visual improvement in growth and health.

Further work will investigate the application of sewage sludge to some of these areas and the effects on growth of Japanese larch. Work will also be undertaken to look at the effects of zeolite additions to the shale system.

EFFECTS OF AFFORESTATION ON WATER RESOURCES

by J. R. BLACKIE and R. J. HARDING
Institute of Hydrology, Wallingford, Oxon

During this final year of the Balquhidder catchments study (Central Region, Scotland) the emphasis is on data analysis, interpretation and development of water use and catchment response models. Field work will continue throughout 1990, however, and will include final checks on streamflow structure calibrations and the precipitation networks as well as routine data collection. The 1989 water use figures for the catchments were similar to those in previous years with no apparent change in the Kirkton value despite the progressive felling of half the forested area. Record winter precipitation (520 mm in February alone at the Tulloch Farm site) has caused significant erosion on the Kirkton road network and a major land slip above the tree line on 4 February 1990 damaged trees and roads and added to the already high stream sediment concentrations.

EFFECT OF CLEAR FELLING ON STREAM SEDIMENT

by I. C. GRIEVE
Department of Environmental Science, Stirling University
and
R. I. FERGUSON
Department of Geography, Sheffield University

Suspended sediment concentrations (SSC) and bedload movement have been monitored in a forested control and a felled experimental catchment in the Loch Ard area since mid-1987. Clear felling of the experimental catchment with cablecrane extraction of timber began in early 1988 and is continuing. Some very large peaks in SSC occurred during the first three months of 1988, but median SSC for the remainder of 1988 was approximately twice that of 1987. A further reduction to 1.4 times the 1987 median occurred in 1989. There has been little effect on bedload quantity or grain size.

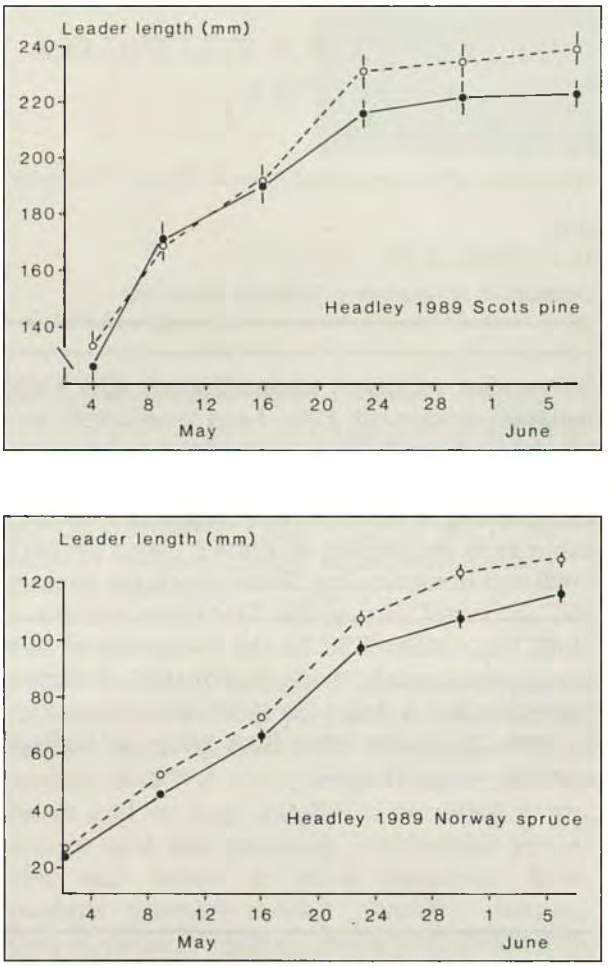
AMBIENT POLLUTION AND TREE GROWTH AT THREE SITES IN BRITAIN

by GAIL TAYLOR
Institute of Environmental and Biological Sciences, University of Lancaster

Measurements of current year needle and leader lengths have shown that ambient pollutant concentrations presently found in rural areas of Britain may be sufficient to alter the growth of Norway spruce, Sitka spruce and Scots pine.

Work conducted in the open-top chambers showed that at Headley, Hampshire, leader growth was significantly reduced for Scots pine and Norway spruce for trees grown in unfiltered air (containing the gaseous pollutants present at the site), compared with those grown in filtered air (see graphs).

Needle and leader growth were also altered at Chatsworth, where both growth stimulations and reductions were observed which varied between species and growing seasons. Scots pine appeared to be most sensitive with a 5.58% reduction of needle extension measured in July 1989. In contrast, growth of needles increased by 8.82% for Sitka spruce exposed to unfiltered air at



Comparison of leader length of Scots pine and Norway spruce grown at Headley and exposed to either filtered (open symbols) or unfiltered (closed symbols) air.

Chatsworth. It is possible that such stimulations were due to enhanced foliar nitrogen resulting from flux of NO_x to young shoots of Sitka. The same result was documented for Norway spruce during 1988. At Glendevon large reductions of needle extension were observed for Sitka spruce and Scots pine (14.42% and 14.78% respectively). Data for leader growth at Chatsworth and Glendevon were more complicated with both stimulations and reductions observed depending on species and site.

DETECTION OF ANY WIDESPREAD AND UNPRECEDENTED CHANGES IN GROWTH IN EUROPEAN CONIFERS

by K. R. BRIFFA
Climatic Research Unit, University of East Anglia

The project is concerned to establish the details of annual tree growth in recent decades across western Europe and to examine this variability against the background of changes during the last two centuries. The basic data set, including ring-width and densitometric measurements from trees at over 70 European sites, was selected from the extensive databank produced at the Swiss Federal Institute of Forest, Snow and Landscape Research, Birmensdorf, Switzerland. The network now includes data from three additional sites in central Europe produced as part of this project.

Work has concentrated on producing site chronologies of mean ring width, maximum latewood density and annual total basal area using various techniques to distinguish the effect of tree age and to highlight growth fluctuations on different timescales. Temporal changes in within-site growth variability have been documented at all sites and the spatial and temporal patterns of mean growth have been examined using principal components analysis.

TREE IMPROVEMENT

SEASONAL CAMBIAL ACTIVITY AND ROOT DEVELOPMENT IN CUTTINGS IN OAK

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

Institute of Horticultural Research, East Malling, Maidstone, Kent

The relationship between cambial activity and rooting of softwood cuttings of *Quercus robur* continued to be investigated. Two distinct flushes of cambial activity were observed; these did not correspond to the periods of early and late wood production. The first flush extended from mid-April to early June, the second from mid-July to mid-August.

In rooting studies, no consistent anatomical differences were found between cuttings which rooted well or badly. The ability of any cutting to form roots was dependent on its age. The site of root information is consistently in the outer phloem, on the flank of a large vascular bundle, and at the end of one or more primary rays of a stem beginning secondary growth.

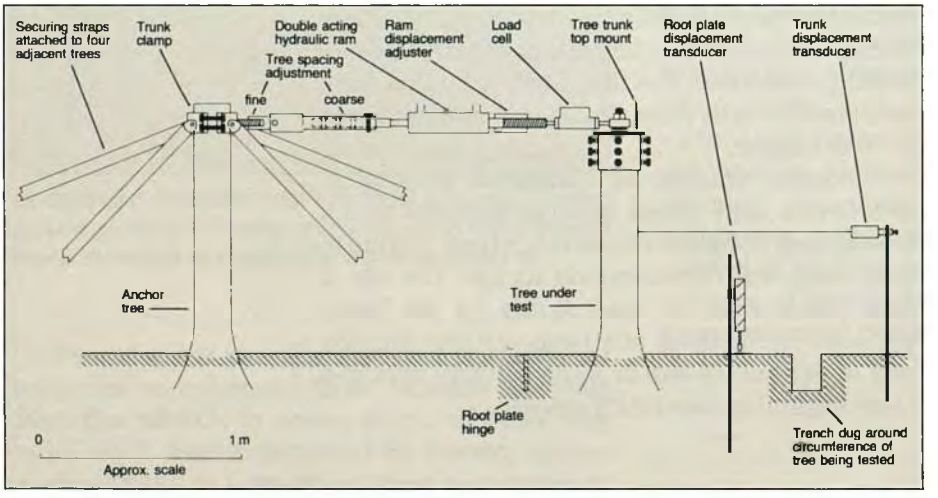
PHYSIOLOGY

AN APPARATUS TO APPLY DYNAMIC LOADS TO TREES

by M. F. O'SULLIVAN and R. M. RITCHIE
Scottish Centre of Agricultural Engineering, Bush Estate, Penicuik

Static pulling tests may over-estimate tree stability. We built an apparatus which would simulate the effect of wind by applying dynamic loads to trees. This consisted of a double-acting hydraulic ram mounted between a test tree and an anchor tree, both felled at breast height. Power was supplied by a battery, which drove a manually-operated hydraulic power pack. A ram displacement adjuster controlled displacement of the test tree. The force required for a given trunk displacement and the accompanying root plate displacement were measured.

Preliminary results showed that force decreased with repeated load cycles, whereas root plate displacement increased, indicating that the strength of the soil decreased under repeated loading.



Schematic diagram of the apparatus.

The apparatus in use.

PATHOLOGY

VIRUSES IN BEECH

by J. I. COOPER
Department of Plant Sciences, University of Oxford

Bioassays revealed infectious agents transmissible mechanically to *Chenopodium quinoa* from bud extracts of four beech trees. In total, bud samples from 95 trees judged to be healthy and 70 trees considered unhealthy (mainly supplied by Ms S. Power, Imperial College, Silwood Park, Ascot, Berks) were tested. Three of the, as yet, uncharacterised agents were obtained from 'healthy' trees. Serological tests done in parallel on each sample of buds failed to detect three viruses (cherry leaf roll, tomato blackring, brome mosaic virus) that have been recorded as infecting beech naturally or two other viruses (arabis mosaic, strawberry latent ringspot) which have broad natural host ranges among woody plants.

A hitherto undescribed virus (with polyhedral particles c.25 nm in diameter) containing infectious polyadenylated RNA (a major species of molecular weight 2.4×10^6 and a minor one of 2.6×10^6 Da) was detected in an ash tree severely affected by dieback.

BEECH HEALTH IN SOUTHERN BRITAIN

by *S. A. POWER and M. R. ASHMORE*
Centre for Environmental Technology, Imperial College of Science, Technology and Medicine

This tree health study has two main objectives: to monitor the health of beech at sites of conservation interest in southern Britain and to investigate the factors influencing tree health both above and below ground.

Approximately 25% of all trees surveyed are in a moderate or severe state of poor health. This figure has not changed significantly over the last 3 years, but individual sites have, in some cases, experienced an improvement or deterioration in health over this period.

An earlier study (Power *et al.*, 1989) indicated that tree health is worse on sites with acidic soils receiving a high input of atmospheric pollution. This current study is therefore investigating the possibility that tree health is determined by soil conditions and root vitality. Comparisons are being made between healthy and unhealthy trees growing at the same site. So far, a pilot study has revealed that there are indeed significant differences in the numbers of fine root tips between healthy and unhealthy trees, as judged by crown condition. Soil chemistry is also different under trees in these two contrasting health classes, with healthy trees generally having a greater availability of soil nutrients. This indication of nutritional differences between healthy and unhealthy trees has also been supported by leaf nutrient analyses. A full study of root and soil conditions will be carried out this summer.

In addition to below-ground investigations, patterns of branch growth over the past 20–25 years are also being measured for both healthy and unhealthy trees. Although a detailed analysis has not been undertaken yet, the first results do indicate that those trees that are now unhealthy responded to the severe drought of 1976 in a different way to healthy trees at the same site.

The work carried out so far clearly indicates that there are difference in both above and below ground growth of unhealthy compared with healthy trees, and suggests that nutrient status may be an important factor influencing tree health.

This work is jointly funded by the Forestry Commission and the Nature Conservancy Council.

REFERENCE

POWER, S.A., LING, K.A. and ASHMORE, M.R. (1989). Beech health and air pollution in southern Britain. In, Poster abstracts for the international congress on forest decline research: State of knowledge and perspectives, 43–44. 2–6 October 1989, Friedrichshafen, FRG.

ENTOMOLOGY

PREDATORS AND THE PINE BEAUTY MOTH

by P. J. WALSH
Department of Biological and Biomedical Sciences, University of Ulster

In an investigation in the north of Scotland extending over 3 years, predatory arthropods were sampled by pitfall trapping and canopy fogging in Scots pine, lodgepole pine and Scots/lodgepole mixtures in forest blocks with differing histories of pine beauty moth, *Panolis flammea*, infestation. Population levels of small mammals were also studied in the same range of crops. Experimentally, pine beauty larvae and pupae were exposed to, and protected from, predators in order to determine the levels of predation due to the various guilds present.

Differences in the species diversity and community structure of arthropods and small mammals were significant between forests, but not between crop types. Predators had most effect on mortality of pupae. The differences between forest blocks may be due to the existence within them of greater or lesser diversity in soil types, stand structure and surrounding land use. The ability of extant predator communities to expand their range, within particular forest areas, appears to be limited. In forest blocks where lodgepole pine has not yet dried the peat to a sufficient extent for habitat improvement to occur, predators, such as arthropods and small mammals, are likely to be comparatively less effective in influencing levels of the pest population.

Sampling following aerial spraying operations showed that, where, due to previous heavy defoliation, fenitrothion was able to penetrate to the ground, there was an immediate detrimental effect on the ground-dwelling predatory arthropods.

WILDLIFE AND CONSERVATION

NIGHTJAR RESEARCH IN THETFORD FOREST IN 1989

by C. G. R. BOWDEN
Royal Society for the Protection of Birds, Sandy, Bedfordshire

The aims of this project are to define nightjar habitat requirements and to relate these to forest management practices.

Over 50 volunteers were used to collect census data. Restocked areas have now received a minimum of two visits on fine evenings in June or July in 1988 or 1989, and 60% have been surveyed twice in both years. An estimate of 229 churring males in the forest probably represents a 20% underestimate according to results from areas where both intense work and an independent census method was carried out. Regional differences in density were evident within the forest and the numbers of nightjars on heathland were found to have dropped dramatically from 27 in 1981 to only 10 in 1989.

Twenty-one adult nightjars were caught and radios attached to their central tail feathers. Despite a higher than normal failure rate with the radios, data were collected on a minimum of three nights for 17 birds in a range of plantation ages and parts of the forest. In addition, 19 nests at the egg stage were continuously weighed in a range of plantation ages, yielding data for 169 bird nights.

WOODLARK ECOLOGY IN THETFORD FOREST

by C. G. R. BOWDEN
Royal Society for the Protection of Birds, Sandy, Bedfordshire

This project has been continued alongside the work on nightjars. The suitability of clear felled areas for woodlarks is influenced by the proportion of the ground cover that is either bare or covered by short vegetation. Current forestry practices maintain the required conditions for the first 3–5 years after planting. Ways of extending this period are under investigation and include the use of herbicides and mechanical disturbance.

Vegetation structure was again recorded for all plantations up to 15 years since planting, and this will be analysed in conjunction with both woodlark and nightjar data.

CAPERCAILLIE IN COMMERCIAL FORESTS

by R. MOSS, N. PICOZZI and D. C. CATT
Institute of Terrestrial Ecology, Banchory, Kincardineshire

Capercaillie are now scarce. The aim of this 3-year project is to provide guidelines for forest management which will result in increasing numbers. For this we need to know the habitat requirements of the birds both in typical semi-natural Scots pine forests, and in commercial plantations dominated by exotic conifers, notably Sitka spruce.

We are counting displaying cocks at about 30 leks and describing the structure and species composition of the surrounding vegetation. The assumption is that the number of cocks reflects the suitability of the habitat. The cocks' main requirement for display seems to be enough space, provided by open woodland, roads, racks and rides, or by clear felled areas within the forest.

A preliminary finding is that, in a forest with a predominance of Sitka spruce, birds in winter seem to subsist on a diet largely of Sitka needles. This is encouraging, because it suggests that capercaillie are adapting to exotic forest tree species. A factor limiting populations may be a shortage of ground vegetation for the chicks.

WOODLAND MANAGEMENT PRACTICES BY NON-GOVERNMENTAL ORGANISATIONS

by M. KING and F. B. GOLDSMITH
University College, University of London

This 2-year contract examined various aspects of woodland management. A number of topics were identified as requiring further research. An issue of common concern was how best to manage the deadwood resource.

A final phase of the contract therefore, examined the extent of the deadwood component in selected ancient semi-natural woodlands in Essex, Suffolk and Hertfordshire. Deadwood is recognised as being an important component of deciduous European woodlands, especially for taxa such as beetles and fungi. It was considered important, as a first step, to obtain more information about the distribution of the deadwood resource. The information recorded from the woods surveyed was stored in a computerised database, sufficiently versatile to allow data manipulation. Information was collected in relation to the size and locality of the wood, its management status and ownership, the stand type, the principal tree species, various topographic characteristics, and assessments of the quantity and quality of the standing and lying deadwood.

It is hoped that such a system can be expanded to include information about the flora and fauna associated with the deadwood resource, and that this approach can be used on a wider scale.

FOREST EDGE MANAGEMENT TO CONSERVE WILD PLANTS

by G. P. BUCKLEY
Wye College, University of London

Plant species distributions resulting from 'edge-management' practices such as ride-widening have been investigated in ten plantation and coppice woods since 1987, using permanent quadrats set up across the forest edge. In the cut areas formerly under canopy, rapid vegetation cover has occurred as germination from buried seed (e.g. *Hypericum*, *Euphorbia*) or from adventives (e.g. *Epilobium*, *Cirsium*). True woodland plants such as *Lamiastrum*, *Mercurialis* and *Hyacinthoides* have tended to decline in abundance in the cut zone but have remained prominent at the new canopy edge, while perennial grasses and herbs have begun to dominate the central areas of the ride.

Up to 1989, no differences in vegetation cover or frequency were significant in relation to aspect (i.e. in rides orientated east–west or north–south) or grazing, although an increase in woody shrubs within grazing exclosures protected from roe deer is now visually obvious. Seedbanks, assessed by germination of soil samples from the sites, were markedly edge-zoned, the grasses in particular being confined to the original ride area, while an overall decline in germinable seed density was apparent in the hinterland of old beech plantations.

Recording will continue during 1990, the seedbank from that year being estimated in soil samples collected in winter and germinated in 1991, when a final appraisal of vegetation trends over four complete seasons will be made.

WOOD UTILISATION

RESEARCH ON BRITISH-GROWN TIMBER

by A. F. BRAVERY
Building Research Establishment, Garston, Watford

Effect of forest management on machine grade yields of Sitka spruce

The investigation into the relationship between growing space and structural wood properties is in the final stages of analysis and reporting. Stem size does not appear to be a significant factor since it has shown no relationship with structural performance of wood in machine stress grading. Moreover, it does not correlate with growing space until later in the growth of the tree, although this may be an artefact of thinning policy (favouring larger trees). This suggests growth features other than stem size need to be identified which correlate both with timber stiffness and growing space.

Relationship between wood characteristics and machine grading performance of Sitka spruce

Data on density, slope of grain, knot size and position, microfibril angle and other growth features have now been recorded for 460 battens and a comprehensive database established. Work to refine the statistical analysis of data, identify and weight the significant growth characteristics, develop the predictive model and test the initial sensitivity of the important variables is now complete.

Knot surface area is the most significant within batten variable but span position and bow are also important. Density and microfibril angle are the most significant between batten variables. The predictive model now developed gives a robust basis for further work, in particular on the limits for density, to relate controllable growth characteristics with structural quality.

Structural properties of windthrown softwood

Examination of 200 waney-edged boards of windthrown Corsican pine revealed a preponderance of compression creases on the impact side of the tree. Initial analysis of machine stress grading results for battens cut from this side of the tree, revealed no differences between these and those from the diametrically opposite side. Machine grading could not detect the presence of compression creases.

Evaluation of timber held in wet storage

Material held under long-term water storage in Thetford Forest is being sampled at 6-monthly intervals to assess any changes in structural properties and porosity. Sawing and kiln-drying of softwood and hardwood material removed up to the end of 1989 is complete. An 'air leakage' porosity measuring system has been developed and applied to material stored for 6 months and (hardwood only) 12 months. Machine grading has been completed on material stored for 6 and 12 months.

RESEARCH ON BRITISH-GROWN SOFTWOOD

by C. J. GILL
The Timber Research and Development Association, Hughenden Valley, High Wycombe, Bucks

Drying and presentation of British-sawn softwood

Earlier work has shown it is possible to dry Sitka spruce at temperatures above the boiling point of water. Such high temperature (HT) treatment speeds up the drying process and helps to minimise distortion by making the wood more plastic during drying. The technique is used commercially in Australia, New Zealand, North America and more recently, France. One disadvantage is that significant strength loss occurs with some species.

To test the effect of high temperature drying on Sitka spruce, four matched packs of battens, each 52 × 103 mm, sawn from butt logs were characterised for strength properties. A fifth pack of timber sawn from similar material was prepared

to represent fresh felled material. Following this, one batch was air dried slowly, one was dried to a conventional medium temperature schedule, two were HT dried to above boiling point following a gradual temperature schedule increase, and the final batch was dried to the severe 'Australian' type HT schedule.

After drying, the timber was tested for strength and stiffness. This was undertaken jointly by BRE and TRADA. Extensive honeycombing and some collapse in the battens was caused by the more severe schedules. However, no change was detected in the strength/stiffness relationship. This suggests the Sitka spruce timber dried under high temperatures could, on the basis of these results, be acceptable for grading and engineering design use.

Strength assessment of windthrown pine logs

Corsican pine is known as a brittle timber, with wind action or impact damage occasionally causing compression creases which can potentially lead to brash failure. The strong winds of October 1987 raised concerns about this problem and led to their subsequent investigation. The main objectives were to identify the effect, if any, of compression creases on pole strength using the pole testing facilities at TRADA, and if possible, to detect such damage by non-destructive methods. Fifty green poles were tested to destruction. However, no meaningful correlation was detected between strength and stiffness, although reduced bending strength appeared to be associated with positions on the poles likely to have suffered impact damage.

TIMBER PRESERVATION

by R. J. MURPHY
Timber Technology Research Group,
Department of Biology,
Imperial College, London

Co-operative research on the preservative treatment and durability of home-grown timber has continued through the sponsored lectureship at Imperial College. The main emphasis has been on the further development of the gas phase treatment of wood-based board materials and on the treatment of home-grown building timber. Research on the durability of preservative treated spruce within the EEC research programme 'Wood, including cork, as a renewable raw material' has also been extended with colleagues in Europe.

Much basic research on the gas treatment of wood-based boards has been completed. In the last year the preservative retentions needed to protect several types of boards from fungal decay have been determined in a co-operative study with the Timber Division of the Building Research Establishment. The results of these trials provide a basis for the levels of gas phase treatment to be used in practice. The types of boards that can be treated range from plywood to MDF. A particular advantage of the method that was highlighted in the decay trials is that any cutting of the boards 'on site' would not require the re-treatment of cut edges due to the excellent penetration achieved in the initial treatment. Research on UK manufactured oriented strandboard (OSB) has also shown that strength properties of the boards are not adversely affected by the treatment. Recent work has been concerned with the development of the method for industrial application. Scale-up trials are currently in progress with colleagues at the Forest Research Institute in New Zealand using full size 8 ft × 4 ft sheets of OSB.

Research on the treatment of home-grown building timbers has been concentrated on the use of accelerated diffusion techniques with borate preservatives. Sitka spruce, typical of the material now available from UK forests, has been treated by these methods with very promising results. Consistent, deep penetration of spruce has been obtained in treatment times that are similar to those needed overall for conventional methods. In addition to this, the performance of treated UK grown Sitka spruce in ground contact is under investigation in an attempt to define the relationship between depth of penetration and long-term durability for this species. The results to date confirm the need for thorough drying of spruce before treatment in order to avoid subsequent checks breaching the preservative envelope and the great difficulty in obtaining deep penetration. The longer-term investigations necessary to assess the implication of these characteristics for durability in service are in progress.

PREVENTION AND TREATMENT OF DECAY IN UTILITY POLES

by D. J. DICKINSON
Timber Technology Research Group, Department of Biology, Imperial College, London

The first part of this project showed that air-seasoned British-grown Scots and Corsican pine poles are subject to colonisation by wood rotting basidiomycetes during air seasoning. In order to promote effective use of British-grown pine such decay has to be prevented. An 18-month trial was set up at Thetford Chase to test the effectiveness of simple borate treatments and preinfection with *Trichoderma* sp. which are known to inhibit decay fungi. The effect on the fungal microflora has been assessed at 6 and 12 months, with a further sampling to take place at 18 months. The results so far are very promising with the data clearly showing that the treated poles have an extremely low incidence of basidiomycete infection, while a high level of mould and stain growth is maintained. This is necessary to increase permeability, leading to the successful creosoting of the poles without any subsequent 'bleeding' problems. In comparison, isolations from the untreated controls have given a high level of wood decaying basidiomycetes.

On the basis of these results, further work has been initiated to ascertain the minimum levels of borate required and to investigate the potential use of *Trichoderma* sp. alone as a 'biological' control agent. Consideration is also being given to environmental impact studies and to optimising the pretreatment of these poles. We are confident that by the end of this work, it will be possible to make practical recommendations for the safe, cost-effective air seasoning of UK grown poles.

FERTILISATION AND WOOD QUALITY

by J. A. PETTY
Forestry Department, University of Aberdeen

This work aims to determine how application of N, P and K fertilisers to stands of Sitka spruce and lodgepole pine separately affects the anatomy and hence quality of the wood subsequently formed, in ways independent to those associated with vigour. Density, growth ring width, knot diameter, tracheid length and diameter are the parameters being measured. Wood samples have been obtained from Forestry Commission fertiliser experiments showing significant growth response following application of fertiliser. Both fertilised and control trees have been sampled. Results obtained so far indicate little effect on the wood quality of Sitka spruce following application of N or K.

DEVELOPMENT

THE AGGREGATE VALUE OF THE NON-PRICED RECREATION BENEFITS OF THE FORESTRY COMMISSION ESTATE

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

This study has taken the results of two surveys (outlined in the last two *Reports*), and has drawn conclusions from them about the total value of recreation on the Forestry Commission estate.

Estimates of visitor numbers were obtained from local Forestry Commission staff, and were compared with previous estimates, and traffic counter records to see if any trends could be identified. These sources suggested that about 27 million people visited the estate in 1987/88. However, a household survey carried out on behalf of the Forestry Commission over the same period (see *Report*, 1989) estimated the number of visits to Forestry Commission land to be 38 million. These two figures were also compared to other recreation surveys, and further discrepancies were discovered. One conclusion of this work therefore, was that reliable estimates of forest visitor numbers are difficult to obtain.

The most conservative estimate of visitor numbers (27 million) was used to generate a figure of £53 million for the value of non-priced recreation on the estate as a whole. This is probably an underestimate. However, the researchers pointed out that the large number of visits that may not have been captured, are likely to be of only short duration. These would have low values of benefit per visit and would not therefore, add much to the final figure.

THE IMPACT OF FORESTRY ON OUTPUT AND EMPLOYMENT IN THE UK AND ITS MEMBER COUNTRIES

by P. G. McGREGOR and I. H. McNICOLL
Fraser of Allander Institute and Department of Economics, The University of Strathclyde

The objective of this project was to determine the aggregate impact of forestry activity on UK and regional output and employment. The basic approach was to examine its impact by considering the likely effects of a total absence of forestry.

The vehicle for exploring this idea was an input–output model of the UK and regional economies.

Data collected by Mutch covering 1984 (see *Report*, 1989) were used in the construction of the model. It allowed the existing UK input–output model to be expanded to cover a wide range of forestry and timber related industries as separate sectors of the economy. The analysis highlighted several critical dependencies, where other industries relied on the domestic forest sector for their timber supplies. Just over 20% of timber processing, and 2% of pulp, paper and board processing were identified as critically supply-dependent on domestic forestry. In the absence of forestry, these industries would no longer be profitable, and would be likely to disappear.

The results of the analysis were presented under two different scenarios. The first was that all industries could replace domestic supplies with imports. This gave the result that the contribution of forestry to national output was £839 million. Direct forestry output only contributed £383 million, so this implied that the supply and processing linkages resulted in total output being a multiple of 2.19 times direct output. The second scenario took into account the critical supply linkages mentioned above. This resulted in a total contribution of forestry to the economy of £1954 million, with an output multiplier of 5.10. The first scenario was also used to generate

employment and income multipliers. It was estimated that 24.6 thousand full-time jobs depended on forestry and generated a household income of £263 million. The multipliers for these figures were 2.09 and 1.63 respectively. Several interesting regional differences were also highlighted in the report.

APPENDIX I

PUBLICATIONS BY RESEARCH DIVISION STAFF

ANDERSON, A.R., PYATT, D.G. [and STANNARD, J.P.] (1990). The effects of clear felling a Sitka spruce stand on the water balance of a peaty gley soil at Kershope Forest, Cumbria. *Forestry* **63** (1), 51–71.

Over 5 years the stand intercepted 38% and transpired 12% of the annual precipitation of 1260–1690 mm, leaving 50% to run-off in the ditches. After clear felling, annual run-off increased to 68% of precipitation due to a decrease of 290 mm in total evaporation loss.

[ANDERSON, C.J.,] COUTTS, M.P., [RITCHIE, R.M. and CAMPBELL, D.J.] (1989). Root extraction force measurements for Sitka spruce. *Forestry* **62** (2), 127–137.

Extraction force and displacement were measured on roots pulled horizontally from the sides of a pit made in the soil after removal of the tree and the bulk of its root system. Measurements were made on a brown earth and a deep peat, in 24- and 27-year-old crops respectively. The brown earth soil was drier and more deeply rooted than the peat, but the root diameter at the pulled end, the length of root extracted and the root displacement at maximum extraction force were similar on both soils. Extraction force was related to the root cross-sectional area at the pulled end and regressions showed that roots required significantly more force for extraction on the peat than on the brown earth. However, the difference was small, and any differences in tree stability between the two sites would have to be explained by other features of the anchorage. Data are also presented on effects of root morphology and depth on extraction force.

[ANDERSON, D.I.K.,] PETTY, S.J., [LITTLE, B. and DAVIDSON, M.] (1989). Possible incestuous breeding by yearling barn owls *Tyto alba*. *The Naturalist* **114**, 137–138.

Matings between close relatives (parent/offspring or sibling/sibling) are uncommon in wild birds. A pair of barn owls reared from successive broods at the same nest site in 1987 bred successfully in 1988.

[APUD, E., BOSTRAND, L.,] MOBBS, I.D. [and STREHLKE, B.] (1989). *Guidelines on ergonomic study in forestry: prepared for research workers in developing countries*. International Labour Office, Geneva. (242pp.)

A short introduction on work study was included in the guidelines, drawn up by I.D. Mobbs.

[BATES, M.R., BUCK, K.W., and] BRASIER, C.M. (1990). Molecular variation on the Dutch elm disease fungus. In, *Molecular evolution,* eds Clegg, M.T. and O'Brian, S.J., 171–178.

Major differences were found on the mitochondrial and nuclear DNA patterns of the aggressive and non-aggressive subgroups of *Ophiostoma ulmi,* providing further evidence of their considerable evolutionary divergence. The EAN and NAN races of the aggressive subgroup also showed a number of unique polymorphisms. A small number of aggresive isolates exhibited mitochondrial patterns intermediate between the aggressive and non-aggressive types while having an aggressive nuclear DNA pattern. This suggests some introgression of non-aggressive mitochondrial DNA may occur at current epidemic fronts.

[BAYES, C.D.,] TAYLOR, C.M.A. and MOFFAT, A.J. (1989). Sewage sludge utilisation in forestry: the UK research programme. In, *Alternative uses of sewage sludge,* University of York, 5–7 September 1989, ed. Hall, J.E.

The UK research programme for utilising sewage sludge in forestry commenced in 1981 and has defined the potential in terms of tree species, crop stage and soil type. Tree growth responses are presented from the forest experiments, and from these appropriate sludge application regimes are proposed. The results of the environmental monitoring for heavy metal additions, vegetation effects, health implications and water resource protection are described and used to determine the constraints. Methods of application are also reviewed.

BLACKWELL, P.G., RENNOLLS, K. and COUTTS, M.P. (1990). A root anchorage model for shallowly rooted Sitka spruce. *Forestry* **63** (1), 73–91.

This mathematical model regards the tree and soil as a simple mechanical system. Various components of root anchorage are modelled as

springs with different strengths and positions. Results are given showing the sensitivity of root anchorage to changes in measurable parameters.

BRASIER, C.M. (1990). China and the origins of Dutch elm disease: an appraisal. *Plant Pathology* **39** (5), 5–16.

Circumstantial evidence has led to the widespread assumption that Dutch elm disease (*Ophiostoma ulmi*) spread to Europe and North America from China. The author's recent surveys indicate that the disease is probably absent from China, and only a relatively recent arrival in the Soviet Tien Shan mountain region on the western Chinese border. Alternative origins for the disease include introduction from the Himalayas, and recent rapid evolution within Europe from another fungus, such as *Ophistoma piceae.* Elucidation of the various possibilities is complicated by the need to account for the spread of at least three genetically divergent subgroups of *O.ulmi.*

BURDEKIN, D.A. (1989). *Trends in forestry research 1982 to 1988.* Forestry Commission Occasional Paper 23. Forestry Commission, Edinburgh.

Increasing interest in forestry in Britain has followed the search for alternative land uses to agriculture and the growing importance of conservation. Research requirements have adapted to this new situation. This paper looks at recent trends and seeks to ask whether resources are reasonably matched to requirements.

Reprinted as a special edition in 1990 for the Forestry Research Co-ordination Committee.

[CANNELL, M.G.R.,] TABBUSH, P.M., [DEANS, J.D.,] HOLLINGSWORTH, M.K., (SHEPPARD, L.J.,] PHILIPSON, J.J. [and MURRAY, M.B.] (1990). Sitka spruce and Douglas fir seedlings in the nursery and in cold storage: root growth potential, carbohydrate content, dormancy, frost hardiness and mitotic index. *Forestry* **63** (1), 9–27.

Seedlings (transplants) were grown in a nursery at Bush Estate, Scotland. Batches were lifted and cold stored at 0.5°C in November, December and January. Changes in growth, shoot apical mitotic index, root growth potential, carbohydrate content, bud dormancy and shoot frost hardiness were monitored throughout the winter by taking samples at intervals from the nursery and from cold storage.

CARTER, C.I. (1989). *The 1989 outbreak of the green spruce aphid,* Elatobium abietinum. Forestry Commission Research Information Note 161.

Severe attacks of the green spruce aphid, *Elatobium abietinum,* have been reported from some parts of Britain in 1989. The weather during the preceding autumn and winter was ideal for successful overwintering of the aphid and the summer drought during 1989 appears to have exacerbated the situation. Factors affecting the development of severe infestations are discussed.

CARTER, C.I. and NICHOLS, J.F.A. (1989). Winter survival of the lupin aphid *Macrosiphum albifrons* Essig. *Journal of Applied Entomology* **108,** 213–216.

The lupin aphid *Macrosiphum albifrons* has recurred on lupin plants in Britain every year since its first appearance in 1981 in spite of harsh winter weather. Experimental tests of exposure to freezing conditions are reported and indicate that this aphid probably survives and reproduces on *Lupinus arboreus* Sims. through most winters in the parthenogenetic viviparous stage on account of its low temperature tolerance.

[COOK, E.R. and] INNES, J.L. (1989). Tree-ring analysis as an aid to evaluating the effects of air pollution on tree growth. In, *Biologic markers of air-pollution stress and damage in forests.* Ed. Committee on Biological Markers of Air-Pollution Damage in Trees, 157–168.

Tree-ring analysis provides an extremely useful tool for the evaluation of cause-effect in declining forests. The onset of the decline can be dated and its spatial extent delimited. An accurate assessment of the volume of wood involved can be obtained, enabling the economic impact to be determined. Analyses have indicated the overriding importance of climate in tree growth and climatic changes may well have a considerable impact on tree growth.

COUTTS, M.P. (1989). Factors affecting the direction of growth of tree roots. *Annales des Sciences Forestières* **46** (Suppl.), 227s–287s.

A review of external and environmental controls that influence the direction of growth of the radicle, lateral root and sinker roots of trees.

COUTTS, M.P. and NICOLL, B. (1989). Tolerance of Sitka spruce roots and associated mycorrhizal strands to waterlogging. *Aspects of Applied Biology* **22,** 441–444.

In clonal plants grown out of doors in perspex tubes of peat, waterlogging was more damaging to the roots in October than in November. Hyphal strands of a mycorrhizal fungus tolerated waterlogging over winter.

COUTTS, M.P. and NICOLL, B.C. (1989). *Tolerance of Sitka spruce roots to waterlogging.* Forestry Commission Research Information Note 154.

Three clones of Sitka spruce were grown out of doors, and the lower part of the root system was flooded in either October or November. Roots flooded in October, when they were still growing, showed extensive dieback whereas roots flooded

in November, when growth had stopped, survived to a much greater depth. Practical implications of these results for rooting depth and tree stability are discussed.

COUTTS, M.P., WALKER, C. and BURNAND, A.C. (1990). Effects of establishment method on root form of lodgepole pine and Sitka spruce and on the production of adventitious roots. *Forestry* **63** (2), 143–159.

Root systems of trees established 15 years earlier from transplants and by direct sowing were influenced more by the ploughing used in site preparation than by whether they were planted or sown. In Sitka spruce grown from transplants, major roots often originated adventitiously from the stem. This was not so for direct sowing, and adventitious roots were absent from the pine. Establishment method influenced the size class distribution of major roots in Sitka spruce.

[DEANS, J.D., LUNDBERG, C.,] TABBUSH, P.M., [CANNELL, M.G.R., SHEPPARD, L.J. and MURRAY, M.B.] (1990). The influence of desiccation, rough handling and cold storage on the quality and establishment of Sitka spruce planting stock. *Forestry* **63** (2), 129–141.

In January 3-year-old Sitka spruce were lifted and treated either carefully or roughly. Carefully handled plants maintained large Root Growth Potential (RGP) which was positively correlated with plant water potential, root water content, shoot relative growth rate and field survival. Overall RGP was reduced: 59% by desiccation; 85% by rough handling; and 98% by desiccation and rough handling in combination. On site storage for 4 weeks in April/May reduced RGP. Where plants produced more than 30 new roots > 1 cm long in RGP tests, field survival exceeded 90%. Cold storage at −1°C maintained RGP (of carefully handled plants), bud dormancy and shoot frost hardiness at approximately pre-storage values.

[DEANS, J.D.,] MASON, W.L., [CANNELL, M.G.R.,] SHARPE, A.L. [and SHEPPARD, L.J.] (1989). Growing regimes for bare-root stock of Sitka spruce, Douglas fir and Scots pine. 1: Morphology at the end of the nursery phase. *Forestry* **62** (Suppl.), 53–60.

Two-year-old plants of Sitka spruce, Douglas fir and Scots pine were produced either as transplants or as precision sown undercut plants. In Douglas fir and Scots pine, the undercut stock were found to be superior plants, but there were no differences in Sitka spruce.

EVANS, H.F. (1989). Biological balancing acts. *Forest Life* No. 6, July, 12–13. Forestry Commission, Edinburgh.

A general article on the balance between natural enemies and forest pests. Examples are drawn from the work of Entomology Branch.

EVANS, H.F. and KING, C.J. (1989). Biological control of *Dendroctonus micans* (Coleoptera:Scolytidae): British experience of rearing and release of *Rhizophagus grandis* (Coleoptera: Rhizophagidae). In, *Potential for biological control of* Dendroctonus *and* Ips *bark beetles,* ed. Kulhevy, D.L. and Miller, M.C., 109–128.

Describes the development of a biological control programme using the imported predatory beetle *Rhizophagus grandis,* against *Dendroctonus micans* attacking spruce in the west of Britain. From 1984 to 1986 annual releases of *R. grandis* were 31 168, 39 392 and 17 604 respectively. The predator has established well and has spread from the sites of release.

EVANS, H.F., GIBBS, J.N. and THOMPSON, D.A. (1989). Timber degrade. In, *The 1987 storm: impacts and responses,* ed. Grayson, A.J., Forestry Commission Bulletin 87, 32–35. HMSO, London.

Pathological and entomological aspects.

EVANS, J. (1989). Community forestry in Ethiopia: the Bilate Project. *Rural Development in Practice* **1** (4), 7–8.

Report of development from 1983–1989 of 460 ha community tree planting project to control soil erosion and provide poles, firewood and fodder for villagers.

EVANS, J. (1989). Forestry and the environment: global perspectives. In, *Proceedings of the Institute of Chartered Foresters discussion meeting 'UK forest policy into the 1990s',* eds Aldhous, J.R. and Field, A.B., 21–33.

Changes in tropical forest cover and the climate are likely to be the principal influences on how forestry develops in the next century, and point to a continuing need to expand Britain's forest estate.

EVANS, J. (1989). Managing existing woodlands. In, *Urban forestry practice,* ed. Hibberd, B.G., Forestry Commission Handbook 5, 115–120. HMSO, London.

EVANS, J. (1988). The Usutu forest: twenty years later. *Unasylva* **40** No. 159, 1988/1, 19–29.

The Usutu forest is a 52 000 ha pine plantation in Swaziland which has supported a Kraft pulpmill for more than 20 years. Productivity of second and third rotations of pine remain at least as good as the first except in one part of the forest showing significant phosphate deficiency.

EVANS, J. (1989). The planting stock. In, *Urban forestry practice,* ed. Hibberd, B.G., Forestry Commission Handbook 5, 72–77. HMSO, London.

EVANS, J. and PATERSON, D.B. (1990). *Restocking after windthrow in southern Britain.* Forestry Commission Research Information Note 175.

The storms of January and February 1990 caused extensive windthrow across southern Britain. This Note discusses the particular problems of restocking the wind damaged areas and advises on techniques.

FLETCHER, A.M. [and BASTIEN, J.C.] (1989). *Douglas fir seed sources: field inspection, southern Oregon and northern California.* 2 vols. v.p. FC Research Division, Edinburgh. Commission of the European Communities, DG VI. (CEC-DG-6-90-EN-REV)

Funding by DGVI of the European Community allowed a field survey to be carried out in southern Oregon and northern California in October 1988. A total of 40 IUFRO stands were visited and 72 General Collection Areas were defined during the 31 days of the survey. These stands were spread over 37 seed zones.

FORREST, G.I. (1990). *Distinguishing Sitka spruce origins.* Forestry Commission Research Information Note 176.

Diagnostic biochemical features have been identified which can be used to distinguish Queen Charlotte Islands origins from southern origins of Sitka spruce. The method is applicable to populations rather than to individual trees. It involves the analysis of stem cortical resin and can be carried out on very young material.

FREER-SMITH, P.H. and DOBSON, M.C. (1989). Ozone flux to *Picea sitchensis* (Bong.) Carr. and *Picea abies* (L.) Karst during short episodes and the effects of these on transpiration and photosynthesis. *Environmental Pollution* **59** (2), 161–176.

Sitka and Norway spruce were exposed to mid-afternoon episodes of O^3 similar to those experienced in the forest. There were linear relationships between exposure concentration and O^3 uptake rates. Physiological condition (dormancy or active growth), species and photon flux density were found to influence O^3 uptake rates via effects on stomatal conductance. 80 nl litre $^{-1}$ of O^3 increased stomatal conductance and decreased water-use efficiency.

FREER-SMITH, P.H., DOBSON, M.C. and TAYLOR, G. (1989). Factors controlling the rates of O^3 uptake by spruce and beech. In, *Air pollution and forest decline* volume 2. Proceedings of the 14th international meeting for specialists in air pollution effects on forest ecosystems, IUFRO Project Group P2.05, Interlaken, Switzerland, 2–8 October 1988. Eds Bucher, J.B. and Bucher-Wallin, I., 407–409.

Analysis of the whole shoot gas exchange of individual trees shows that physiological condition (dormancy or active growth), application of an antitranspirant and water availability influence the stomatal conductance and alter the uptake rates of O^3 by spruce (*Picea abies* (L.) Karst., *Picea sitchensis* (Bong.) Carr.) and beech (*Fagus sylvatica* L.). Additionally the importance of the interacting effects of drought and pollutant exposure is indicated by the establishment of the influence of water availability on O^3 uptake, stomatal conductance and pollutant responses in open-top chambers.

GARDINER, B.A. (1989). *Mechanical characteristics of Sitka spruce.* Forestry Commission Occasional Paper 24. Forestry Commission, Edinburgh.

A series of tests has been carried out on 10 Sitka spruce trees about 15 metres tall in order to determine their mechanical characteristics. Such information is necessary for the design of model trees for use in wind-tunnel studies of airflow over forests.

GIBBS, J.N. (1990). *The clearance of trees after the gale of 25 January 1990.* Forestry Commission Research Information Note 172.

The windspeeds of up to 90 knots (100 m.p.h.) during the gale of 25 January resulted in widespread damage to trees in an area south of the line between Aberystwyth and Ipswich. This Note gives guidance for the ordering of priorities in clearance, taking account of the possible deterioration of timber.

GOSLING, P.G. (1989). Report on the 1989 ISTA post-Congress forestry tour. *ISTA Bulletin* **95,** 10–14.

The places visited and topics studied during a week long tour of England by tree seed testers are reported.

GOSLING, P.G. (1989). The effect of density separation on the germination of Corsican pine seed. *Forestry* **62** (Suppl.), 117–123.

Two seed lots of Corsican pine with germination capacities of 94% and 85% (neither contained empty seed) were fractionated using a specific gravity (s.g.) separator into three grades comprising 46, 44 and 10% of the original weights respectively. Density separation did not significantly increase either the maximum percentage germination or rate of germination for even the densest fraction of either lot. If the germination capacity of Corsican pine seed is to be improved by s.g. separation then studies will have to concentrate on the quality of the top 40% by weight or less.

GREIG, B.J.W. (1990). *Ceratotect: a fungicide treatment for Dutch elm disease.* Arboriculture Research Note 61/90/PATH.

Results of Forestry Commission trials with the fungicide thiabendazole (TBZ) hypophosphite as a treatment for Dutch elm disease are summarised. Over the 5 years of trials 81% of treated trees have recovered while all but 11% of the control trees have died.

HARMER, R. (1989). Some aspects of bud activity and branch formation in young oak. *Annales des Sciences Forestières* **46** (Suppl.), 217s–219s.

The effect of mineral nutrition and decapitation on the growth of buds on different parts of the shoot is described.

HARMER, R. (1989). The effect of mineral nutrients on growth, flushing, apical dominance and branching in *Quercus petraea* (Matt.) Liebel. *Forestry* **62** (4), 383–395.

Seedling plants receiving large amounts of fertiliser were more vigorous, producing longer shoots with more buds and branches than those given smaller quantities. High nitrogen plants flushed more frequently and produced more branches per bud. There were significant relationships between shoot length and number of buds. Buds near the tip of each flush showed the greatest tendency to form branches. Fertilisation of trees in the field increased branching during the lammas flush.

HIBBERD, B.G. (1989). Choice of species. In, *Urban forestry practice,* ed. Hibberd, B.G., Forestry Commission Handbook 5, 48–71. HMSO, London

An approach to choice of species is outlined which can be adopted in most situations, with increasing attention to the smaller or slower growing species and cultivars as one progresses from rural to city centre conditions. Examples are given which can help to avoid the frequent problem of trees that look incongruous in their surroundings.

HIBBERD, B.G. (1989). The need for advice. In, *Urban forestry practice,* ed. Hibberd, B.G., Forestry Commission Handbook 5, 10–17. HMSO, London.

Because of the wide variety of interests and aims involved, there is more danger of projects failing in urban forestry than in less specialised forms of forestry. It is essential to the success of urban forestry schemes that the basic needs of trees are understood and that the appropriate choice of species, site treatment and subsequent treatment on each location are carefully related to the trees' needs and the nature of the site.

HIBBERD, B.G. (ed.) (1989). *Urban forestry practice.* Forestry Commission Handbook 5. HMSO, London. (150 pp.)

Practical advice is provided on the establishment and subsequent management of trees and woodlands in urban and urban fringe areas of the United Kingdom.

HODGE, S.J. and WHITE. J.E.J. (1990). *The ultimate size and spread of trees commonly grown in towns.* Arboriculture Research Note 84/90/ARB.

Published information on the ultimate sizes of the commonly planted amenity trees reflects performance in open grown positions. This Note reports sizes of trees growing in urban conditions. If the data are used when selecting trees for urban situations the need for future expensive pruning and early felling can be reduced.

INNES, J.L. (1989). Acid rain and trees. In, *Acid deposition: sources, effects and controls,* ed. Longhurst, J.W.S., 229–242.

The evidence linking air pollution to forest health is frequently taken for granted. While it is clear that forest health and air pollution are closely related in some areas, this does not mean that air pollution is the primary factor determining forest health in all areas. There is a general consensus that forest decline is the result of air pollution and, in some cases, there is good evidence to support this. In other instances, factors other than air pollution have been demonstrated to be more important. Forest decline may not be as widespread as once feared, although in many areas there is obvious cause for concern.

INNES, J.L. (1989). Rapid mass movements in upland Britain: a review with particular reference to debris flows. *Studia Geomorphologica Carpatho-Balcanica* **23,** 53–67.

Mass movements are particularly common in some parts of upland Britain. In some areas at least there has been an increase in activity over the last 200 years. This is especially true of debris flows, which are responsible for the mass transport of considerable volumes of material downslope. There is a need to determine the regolith conditions that favour the development of debris flows, and the environmental conditions that predispose regoliths to failure.

INNES, J.L. (1989). Rapid yellowing of needles of *Picea abies. European Journal of Forest Pathology* **19,** 21–28.

Severe chlorosis developed in a 45-year-old stand of Norway spruce over a period of 3 weeks in July and August 1986. The chlorosis was followed by necrosis and, eventually, shedding. The trees showing the most severe effects had all been damaged by timber extraction operations in 1985.

The symptoms superficially resembled those on many trees in central Europe but air pollution is unlikely to be a primary factor in the chlorosis and defoliation in this stand.

INNES, J.L. (1990). General aspects in the use of tree rings for environmental impact studies. In, *Methods of dendrochronology,* eds Cook, E.R. and Kairukstis, L.A., 224–229.

INNES, J.L. (1990). Plants and air pollution. In, *Landscape design with plants.* 2nd edn, ed. Clouston, B., 199–211.

Describes the adverse effects of pollution upon plants and the ways in which planning and appropriate planting can reduce the impacts of air pollution.

INNES, J.L. (1990). Pollution and forest decline. *Country Landowner,* February, 15, 17.

Although air pollution is frequently blamed for forest decline, an analysis of the literature reveals that the evidence is shaky. Some clear-cut cases of pollution-induced decline exist, but many other examples are brought about by natural factors. There is little, if any, evidence that the condition of forests in Britain is declining.

INNES, J.L. (1990). *Surveys of tree condition 1990.* Arboriculture Research Note 83/90/SSS.

Surveys of tree 'health' became increasingly common in the late 1980s. The majority aim to determine the effects of air pollution on trees. In most cases, surveys assess tree condition rather than tree health *per se.* Assessments of tree condition are based on the appearance of the tree and may bear little relation to its state of health. Despite numerous surveys, both in Britain and Europe, no clear association has been identified between air pollution and tree condition. An extremely complex picture has emerged and it is becoming increasingly clear that in most situations, air pollution plays a secondary role to factors such as management practices, climate and site conditions.

INNES, J.L. and BOSWELL, R.C. (1989). *Forest condition in 1989: preliminary results of the monitoring programme.* Forestry Commission Research Information Note 163.

The preliminary results of the 1989 forest condition monitoring programme are presented. Altogether, 7436 trees were assessed in the main project, with a further 1800 trees being examined as part of the standardised European survey. All the species have shown an overall improvement, although some Sitka spruce have shown a deterioration which can be attributed to defoliation by the green spruce aphid *Elatobium abietinum.* The improvement in the condition of the trees within forests contrasts with many open-grown trees which have suffered from drought stress during the summer. The improvement in condition can be attributed to the recovery of many trees following damage by the October 1987 storm, an absence of winter damage and the benefits brought about by the mild, wet conditions of the summer of 1988.

INNES, J.L. and BOSWELL, R.C. (1989). *Monitoring of forest condition in the United Kingdom.* Forestry Commission Bulletin 88. HMSO, London.

There was little change in tree condition between 1987 and 1988. Crowns of Sitka spruce and Scots pine were a little thinner whereas Norway spruce and oak showed no change. Beech showed some improvement. There were indications of both negative and positive interactions between tree condition and levels of air pollution. Distinct spatial patterns in tree condition were observed, but these cannot be readily related to patterns of pollution. The analysis emphasised the presence of a complex set of interacting factors affecting the condition of trees in Britain.

INNES, J.L. and BOSWELL, R.C. (1989). Sulphur contents of conifer needles in Great Britain. *GeoJournal* **19** (1), 63–66.

Analysis of the total sulphur contents of needles of Sitka spruce, Norway spruce and Scots pine in Britain revealed marked patterns that are correlated with modelled atmospheric concentrations of sulphur dioxide. Correlations with other indices of sulphur pollution, including wet and dry deposition and sulphate aerosol concentrations, were less consistent. No association was found between the sulphur contents and the crown densities of trees.

INNES, J.L. and COOK, E.R. (1989). Tree-ring analysis as an aid to evaluating the effects of pollution on tree growth. *Canadian Journal of Forest Research* **19** (9), 1174–1189.

To assess the impact of regional pollutants, non-stationary response functions, as developed using the Kalman filter technique, offer considerable potential. In the current spruce-fir debate in North America, tree ring analysis has indicated that the current decline are unprecedented within the last 200 years in terms of the duration of depressed growth and the extent to which growth has been depressed. Since the onset of the decline the growth of *Picea rubens* has been less than predicted from climatic factors, suggesting that the importance of some other effect on growth has increased or that there has been a change in the climatic factors influencing growth.

INNES, J.L. and FREER-SMITH, P.H. (1989). Forest health and acidification. In, *Acidification in Scotland.* Symposium held in Edinburgh, 8 November 1988, 42–50.

Standardised methods based on crown density and discoloration now exist for assessing the health of trees in relation to pollutant deposition. However, changes in both of these parameters can be brought about by a range of environmental factors. The surveys are combined with a second research programme which is examining the growth of Scots pine, Norway spruce, Sitka spruce and beech in open-top chambers ventilated with filtered or ambient air.

INNES, J.L., MOFFAT, A.J. and LONSDALE, D. (1989). *Weather conditions during the summer of 1989 and their effect on trees.* Forestry Commission Research Information Note 162.

Hot, dry conditions over some parts of Britain during the summer of 1989 have created problems for a wide range of tree species. Wilting, discoloration and premature leaf loss have been reported.

KING, C.J. and FIELDING, N.J. (1989). Dendroctonus micans *in Britain: its biology and control.* Forestry Commission Bulletin 85. HMSO, London.

The great European spruce bark beetle (*Dendroctonus micans*) was first identified as a breeding species in Britain in 1982. This insect's distribution, pest status, biology, life cycle and control methods are described.

LEATHER, S.R. (1989). Do alate aphids produce fitter offspring? The influence of maternal rearing history and morph on life-history parameters of *Rhopalosiphum padi* (L.). *Functional Ecology* **3** (2), 237–244.

A series of experimental 'migrations' using good and bad hosts was carried out under controlled conditions. It was concluded that the apterous offspring of alate mothers are adapted to exploit better conditions than those which their mothers experienced, whereas the apterous offspring of apterous mothers are adapted to exploit worse or similar conditions to those experienced by their mothers. The best predictor of total fecundity was adult life span. Adult life span was not correlated with adult weight.

LEATHER, S.R. (1989). *Phytodecta pallida* (L.) (Col., Chrysomelidae): a new insect record for bird cherry (*Prunus padus*). *Entomologist's Monthly Magazine* **125,** 17–18.

Found whilst sampling in Roslin Glen, A Scottish Wildlife Trust's nature reserve.

LEATHER, S.R. (1990). Sex ratio and reproductive success in the pine beauty moth, *Panolis flammea* (Den. & Schiff.) (Lep., Noctuidae). *Journal of Applied Entomology* **109,** 200–204.

When sex ratio was manipulated in the pine beauty moth, *Panolis flammea,* it was found that in terms of fecundity the optimal sex ratio was 1 female:3 males. Sex ratio had no significant effects on the pre-oviposition period or the life span of adult fed female *P. flammea.* Egg fertility, however, was greatest in those eggs produced by mated females from the 1:1 sex ratio. When males were outnumbered by females by 3:1, egg fertility was greater (55%) than in the reverse situation (42%). At ratios of 5:1 in eight bias, fertility was much reduced. These results are discussed in light of the natural population structure of this insect and the implications for pest management are considered.

LEATHER, S.R. (1990). The anlaysis of species-area relationships, with particular reference to macrolepidoptera on Rosaceae: how important is insect data-set quality? *Entomologist* **109** (1), 8–16.

The species lists of insects associated with the British Rosaceae have been greatly extended by incorporating unpublished data and 'poor quality' macrolepidopteran data from standard source books. The use of these additional data give essentially the same results as the use of previous data. Within the Rosaceae, trees support more insect species than shrubs which in turn support more insect species than herbs. The number of species feeding on British Rosaceae generally increases with the size of the geographic range of the host species, and with the complexity of the host's morphology.

LONSDALE, D. (1989). Diseased and damaged trees. In, *Urban forestry practice,* ed. Hibberd, B.G. Forestry Commission Handbook 5, 101–107. HMSO, London.

Correct management of damage depends on recognition of the cause and the ability to decide whether action is necessary. Prevention, which is better than cure, may involve exclusion or chemical control of damaging agents, choice of resistant species for planting or site amelioration. Also, arboricultural work should prevent damage rather than cause it. Management of existing damage may involve pruning, bark excision, fungicide injection or the periodic inspection of potentially hazardous trees.

LONSDALE, D. (1989). Pruning practice. In, *Urban forestry practice,* ed. Hibberd, B.G., Forestry Commission Handbook 5, 94–100. HMSO, London.

Advice is provided on pruning and other aspects of tree surgery which involve a risk of attack by decay organisms. Items discussed include the advisability of surgery, the value of formative pruning and the risks associated with 'topping'.

Relationships between pruning practice and decay are outlined with regard to tree species, the size, position and number of wounds and the time of year.

LONSDALE, D. (1990). *Treatment of storm-damaged trees.* Arboriculture Research Note 73/90/PAT.

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., HICKMAN, I.T., MOBBS, I.D. and MATTHEWS, R.W. (1989). A quantitative analysis of beech health and pollution across southern Britain. *Naturwissenschaften* **76,** 571–573.

At eight beech stands among 15 studied, declines in shoot growth over the last 32 years exceeded predictions based on the effect of ageing. At only two stands was performance better than predicted. Losses increased after the 1975–76 drought, but pre-dated this event at four stands. The stands lay on a 450 km transect which traversed strong pollution gradients across southern Britain. Growth decline was not significantly related to position on the transect.

LUDLOW, A.R., RANDLE, T.J. [and GRACE, J.C.] (1990). Developing a process-based growth model for Sitka spruce. In, *Process modelling of forest growth responses to environmental stress.* Eds Dixon, R.K., Meldahl, R.S., Ruark, G.A. and Warren, W.G., 249–262.

MASON, W.L. (1989). From one small seed, many trees can grow. *Forestry and British Timber* **18** (4), 20.

Reviews recent developments in vegetative propagation of Sitka spruce and highlights the potential for improving timber yields.

MASON, W.L. (1989). Vegetative propagation of hybrid larch (*Larix* × *eurolepis* Henry) using winter cuttings. *Forestry* **62** (Suppl.), 189–198.

The effects of various factors (e.g. rooting hormone, nutrition, rooting medium, date of collection) upon the rooting of hybrid larch winter cuttings were investigated. Good rooting was obtained with most treatments, suggesting that commercial propagation of hybrid larch could be a possibility.

MASON, W.L., [DEANS, J.D. and THOMPSON, S.] (Eds.) (1989). Producing uniform conifer planting stock. *Forestry* **62** (Suppl.). 314 pp.

The proceedings of an international nursery conference in 1988 covering many aspects of nursery production and outplanting performance.

MASON, W.L., SHARPE, A.L. [and DEANS, J.D.] (1989). Growing regimes for bare-root stock of Sitka spruce, Douglas fir and Scots pine. 2: forest performance. *Forestry* **62** (Suppl.), 275–284.

Undercut plants of Scots pine and Douglas fir had higher survival and height increment than transplants two years after planting on a forest site. However, few differences were found between Sitka spruce plant types.

MATTHEWS, R.W. (1989). The greenhouse effect and UK agriculture. *CAS Paper* 19, 101–103. Centre for Agricultural Strategy, University of Reading.

Current research on the storage of carbon in plantation forests and forest products is summarised.

MAYLE, B.A. (1990). *Habitat management for woodland bats.* Forestry Commission Research Information Note 165.

Most British bats are dependent to some extent upon woodland habitats from foraging and roosting. All are highly sensitive to disturbance and habitat change and are legally protected. Methods of identifying and protecting natural roost sites and providing artificial sites are described, these should ensure that roost sites are always available. Bat habitats can be improved by increasing the structural and species diversity of woodlands, by planting native broadleaves, by retention of a few old trees beyond rotation age, and by the sensitive management of waterside habitats, scrub, and open grassland.

McKAY, H.M. and COUTTS, M.P. (1989). Limitations placed on forestry production by the root system. *Aspects of Applied Biology* **22,** 245–254.

For different rates of fine root turnover, the cost in carbohydrate for fine root production and maintenance is evaluated in terms of nutrient acquired. The allocation of carbon to the coarse roots required for anchorage is also considered.

[McMURTRIE, R.E.,] ROOK, D.A. [and KELLIHER, F.M.) (1989). Modelling the yield of *Pinus radiata* on a site limited by water and nitrogen. *Forest Ecology and Management* **30.**

A process-based model is described and applied to a range of *Pinus radiata* stands aged 9–12 years growing on stabilised sand dunes in a stocking and fertiliser experiment in New Zealand. The model required inputs of daily weather data, physical characteristics of the site and crop, and crop physiological parameters and was used to simulate components of the forest water balance and annual net photosynthesis for a defined crop canopy architecture. Operational applications of the model to forest management in quantifying environmental requirements for stand growth and examining silviculture alternatives are discussed.

MOFFAT, A.J. (1989). Forestry and soil erosion in Britain: a reply. *Soil Use and Management* **5** (4), 199–200.

Letter to the editor: criticism of a recent review by R.G. Soutar who claimed that accelerated soil erosion was common in established forests.

MOFFAT, A.J. (1989). The new site. In, *Urban forestry practice*, ed. Hibberd, B.G., Forestry Commission Handbook 5, 40–47. HMSO, London.

Many urban sites will require substantial site preparation, including the importation of soil materials, or the modification of existing ones. Soil compaction and drainage usually require attention, but soil chemical properties are likely to be adequate except on contaminated sites or those without topsoil.

MOFFAT, A.J. and BOSWELL, R.C. (1990). Effect of tree species and species mixtures on soil properties at Gisburn Forest, Yorkshire. *Soil Use and Management* **6** (1), 46–51.

The soil has been investigated at a long-term experiment examining the silvicultural and site-related effects of four tree species (Scots pine, Norway spruce, oak, common alder), planted pure or in mixtures at Gisburn Forest, Yorkshire, in 1955. After 32 years, small significant differences were found for soil properties relating to soil organic matter accumulation and incorporation; the soil under the conifers and alder was slightly more acid than that under oak and grass control plots, and the conifers had thicker F and H but thinner A horizons. There was also some evidence that the conifers and alder has retarded the formation of a grey iron-deficient B horizon. Soil pH has declined under all plots since 1954; the effect of mixing species on this property is discussed.

MOFFAT, A.J. and ROBERTS, C.J. (1989). Experimental tree planting on China clay spoils in Cornwall. *Quarterly Journal of Forestry* **83** (3), 149–156.

Experiments to establish trees on china clay spoil in Cornwall are described. Sitka spruce, Corsican pine and several alder species have been established successfully; *Alnus viridis* shows most promise where climatic conditions are harsh. Site factors limiting establishment are discussed and silvicultural practices to overcome them are described.

MOFFAT, A.J. and ROBERTS, C.J. (1989). The use of large-scale ridge and furrow landforms in forestry reclamation of mineral workings. *Forestry* **62** (3), 233–248.

MOFFAT, A.J., [JOHNSON, M. and WRIGHT, J.S.] (1990). An improved probe for sampling soil atmosphere. *Plant and Soil* **121**, 145–147.

A probe for the extraction of soil gases is described. Novel features are the way the probe aperture within the soil can be manipulated from above, and the designs of the tip to minimise gas extractions.

MOFFAT, A.J., ROBERTS, C.J. and McNEILL, J.D. (1989). *The use of nitrogen-fixing plants in forest reclamation.* Forestry Commission Research Information Note 158.

The ability of nitrogen-fixing trees, shrubs and herbaceous plants to enhance the growth of conifers interplanted with them on reclamation sites has been examined. There is evidence that these plants can improve tree and site nutrition, but less evidence that useful increases in tree growth will be obtained, at least in early years. Pure stands of alders are successful on a range of substrate types and may be the most sensible choice for very infertile sites unless these can be ameliorated by artificial or organic fertilisers.

[MORITZ, T.,] PHILIPSON, J.J. [and ODEN, P.C.] (1989). Detection and identification of gibberellins in Sitka spruce (*Picea sitchensis*) of different ages and coning ability by bioassay, radioimmunassay and gas chromatography-mass spectrometry. *Physiologia Plantarum* **75**, 325–332.

Gibberellins A_1 (GA_1), GA_3, GA_4, GA_9 and conjugate-like fractions of GA_9 and GA_{15} were identified in shoots of Sitka spruce. The qualitative differences between the three ages of material examined (48, 16 and 6-year-old) were the presence of GA_3 and GA_1 in the better flowering 48-year-old material and the absence of GA_4 in this material. This indicates a difference in GA metabolism which may reflect the difference in ability to form reproductive buds.

[MORITZ, T.,] PHILIPSON, J.J. [and ODEN, P.C.] (1989). Metabolism of tutiated and deuterated gibberellins A_1, A_4 and A_9 in Sitka spruce (*Picea sitchensis*) shoots during the period of cone-based differentiation. *Physiologia Plantarum* **77**, 39–45.

A mixture of radioactively labelled gibberellins was injected into elongating shoots of Sitka spruce grafts grown under conditions which were either inductive (heat and drought, HD) or non-inductive (cool and wet, CW) for flowering metabolic pathways were studied. The amount of detectable metabolites was highest in the HD material and it was found that GA_4 was deactivated to GA_{34} only in plants grown in non-inductive conditions. The results are discussed with reference to possible control mechanisms for flowering.

NELSON, D.G. (1990). Herbicide experiment update. *Forestry and British Timber* **19** (2), 30–31.

The results of experiments on the sensitivity of Douglas fir transplants to Gardoprim-A herbicide and of *Rhododendron ponticum* to Imazapyr herbicide when both are applied to foliage are given and discussed. A table is provided highlighting the seasonal sensitivity of common conifers to overall applications of commonly used herbicides.

NELSON, D.G. and QUINE, C.P. (1990). *Site preparation for restocking.* Forestry Commission Research Information Note 166.

The silvicultural advantages of cultivation on restocking sites are discussed. The suitability of a range of cultivation machinery for different site types is reviewed and potential outputs are given. Characteristics of the required microsites for planting are discussed and the recommended planting positions on these are shown.

NELSON, D.G. and RAY, D. (1990). *Establishment of Sitka spruce in relation to mound size, plant handling and soil temperature.* Forestry Commission Research Information Note 167.

Experiments have shown that the survival of outplanted Sitka spruce cuttings on mounds is significantly better than on screefed or uncultivated planting sites (Tabbush and Ray, 1989), and that growth is improved in both the first and second seasons for plants handled carefully compared with plants handled roughly before planting. Mounds 20–30 cm high provide a good site for the establishment of Sitka spruce under normal weather conditions.

NELSON, D.G. and WILLIAMSON, D.R. (1989). *Gardoprim-A liquid: experimental results on grass weed control and crop tolerances.* Forestry Commission Research Information Note 152.

Discusses the effects of the herbicide Gardoprim-A on grass control and on the health of a range of crop trees from a number of experiments which investigated different rates and dates of application. Recommendations for the use of this product are given.

NISBET, T.R. (1989). Forestry and surface water acidification. *Timber Grower* No. 111, Spring, 18–19.

Considers the evidence concerning the role of conifer forests in the acidification of surface waters.

NISBET, T.R. (1990). *Forests and surface water acidification.* Forestry Commission Bulletin 86. HMSO, London.

Reviews the evidence for a suggested forest effect in the acidification of surface waters in Great Britain. Acid deposition from the atmosphere within susceptible areas of Britain has affected fresh water flora and fauna, causing the decline and in some instances the complete loss of fish populations. Currently there is a debate about whether the presence of forests has increased the acidity of surface waters and contributed to the observed decline. The evidence for the significance and scale of such a forest effect is by no means clear and only limited conclusions can be drawn from studies undertaken so far.

NISBET, T.R., [MULLINS, C.E. and MACLEOD, D.A.] (1989). The variation of soil water regime, oxygen status and rooting pattern with soil type under Sitka spruce. *Journal of Soil Science* **40** (1), 183–197.

The above were characterised in five soil types: a waterlogged peaty gley, a peaty gley, a flushed peaty gley, a surface water gley and a brown forest soil during 1982. The incidence of a high, anoxic water-table restricted rooting to the near-surface soil horizons at the first two sites. Conditions remained oxygenated below the water-table at the third site enabling root survival at depth.

PATCH, D. (1989). Managing the growing trees. In, *Urban forestry practice,* ed. Hibberd, B.G., Forestry Commission Handbook 5, 92–93. HMSO, London.

PATCH, D. (1989). *Stakes and ties,* Arboriculture Research Note 77/89/ARB.

Stakes and ties used to anchor a newly planted tree will damage the tree if they are not adjusted, repaired or, in time, removed. The materials used should be capable of accommodating tree growth without applying a damaging compression, or allowing abrasion of the stem to occur between maintenance visits to the tree.

PEPPER, H.W. (1989). Anatomy of a hopper: welcomes a grey squirrel but not tree-friendly mammals. *Forestry and British Timber* **18** (9), 30, 32.

Design of the grey squirrel control hopper has remained unchanged since 1973. Now available are a modification for existing hoppers and a newly-designed model. They prevent access to all non-target primary feeders (small mammals and birds) but provide unrestricted access to grey squirrels. This represents a major conservation improvement.

PEPPER, H.W. (1989). *Hopper modification for grey squirrel control.* Forestry Commission Research Information Note 153.

Control of bark-stripping to trees by grey squirrels is most effectively and economically achieved by poisoning squirrels with 0.02% warfarin dispensed from hoppers of approved design. Risks to non-target wildlife can be eliminated by a modification to the hopper without reducing the impact on squirrels.

PEPPER, H.W. (1989). The urban squirrel: friend or foe? *The Living World* **3** (4), Autumn.

The grey squirrel dwelling in the urban environment can be very destructive to property and garden crops. It can also give great pleasure to many urban people. The conflict resulting from the need to control the damaging squirrel and the desire to retain the enjoyable squirrel can only be resolved by good communication and understanding.

PETTY, S.J. (1989). Nestbox project: second year results. In, *Fifth Argyll Bird Report,* 40–45.

This study aims to establish pied flycatchers in Argyll by providing nestboxes and to monitor the productivity of these and other hole-nesting passerines. Data are given on nestbox occupancy, time of breeding and clutch and brood sizes for blue tit, great tit and pied flycatcher.

PETTY, S.J. (1989). Productivity and density of tawny owls *Strix aluco* in relation to the structure of a spruce forest in Britain. *Annales Zoologici Fennici* **26,** 227–233.

A population of tawny owls was monitored from 1981 until 1987 in a spruce forest in northern England, where the owls fed largely on field voles. Vole populations showed a cyclic trend, with a peak every third year. This led to annual variations in the number of young owls reared. The productivity of individual owl territories varied greatly over the 7-year period, but was not density-dependent. A multiple regression model incorporating three habitat categories explained 70% of this variability and emphasised the importance of habitat heterogeneity. The density of owl territories increased with the spatial diversity of the habitat.

PETTY, S.J. (1989). Return of the goshawk. *Forest Life* No.6, July, 6–7. Forestry Commission, Edinburgh.

Describes hunting behaviour of goshawks and their recent increase in Britain.

PETTY, S.J. (1990). A nestbox study of blue tit, great tit and pied flycatcher: third year results. In, *Sixth Argyll Bird Report,* 72–77.

Twelve study areas contained 534 nestboxes of which 40% were occupied in 1989, a similar figure in 1988. In total 1409 chicks were reared from the boxes including 156 pied flycatchers.

PETTY, S.J. [and ANDERSON, D.I.K.] (1989). A decrease in carrion crow *Corvus corone* numbers following sheep removal and afforestation. *The Naturalist* **114,** 81–84.

The breeding density of crows is often assumed to increase following the afforestation of previously grazed areas. A study of carrion crows in upland Northumberland from 1967 to 1986 compared two valleys, one of which was afforested and the sheep removed and the other under a continuing sheep grazing regime. Prior to the removal of the sheep the area constantly supported seven breeding pairs of crows. Between 1971 and 1984 the population dropped to two pairs and remained at this level until 1986. Sheep remained in the adjacent valley, and here the breeding density of crows remained at seven pairs.

PETTY, S.J. [and ANDERSON, D.I.K.] (1989). Egg measurements from a northern goshawk (*Accipiter gentilis gentilis*) including one abnormally large egg with twin embryos. *The Journal of Raptor Research* **23** (3), 113–115.

Describes one very large egg with twin embryos from a clutch of four eggs laid by a 10-year old goshawk. The size of this large egg is compared with other eggs laid during the lifetime of this female.

PETTY, S.J. [and THIRGOOD, S.J.] (1989). A radio tracking study of post-fledging mortality and movements of tawny owls in Argyll. *Ringing and Migration* **10** (2), 75–82.

The post-fledging mortality and behaviour of tawny owls was investigated in an upland conifer forest in Argyll. Twelve unsexed juvenile and six adult female owls were fitted with back-mounted radios. Eleven (91.7%) of the juveniles died between fledging and independence. Deaths occurred in two peaks, initially in the period immediately following fledging when they were vulnerable to mammalian predators, and later when they died mostly of starvation. These results are discussed in relation to the method of radio-tracking used and the food supply available.

POTTER, C.J. (1989). Establishment and early maintenance. In, *Urban forestry practice,* ed. Hibberd, B.G., Forestry Commission Handbook 5, 78-90. HMSO, London.

POTTER, C.J. and TAYLOR, C.M.A. (1989). *Demonstration plots for farm woodland and amenity tree establishment.* Forestry Commission Resarch Information Note 156.

A series of 22 demonstration plots is being set up throughout Britain at agricultural colleges and showgrounds, and Agricultural Development and Advisory Service (ADAS) establishments. Their purpose is to demonstrate the effects of good and bad establishment techniques on the survival and growth of broadleaved and coniferous trees. It is intended that the plots will be widely used as venues for events organised by the Forestry Commission, ADAS and other organisations in order to encourage better silvicultural and arboricultural practices.

POTTER, C.J. and TAYLOR, C.M.A. (1989). *Farm forestry research.* Forestry Commission Research Information Note 155.

The Forestry Commission is involved in several research initiatives on farm forestry. Much of this work is in collaboration with ADAS, agricultural colleges and university departments. As well as experimentation using new production systems on fertile agricultural sites, many continuing projects on large-scale broadleaved and coniferous forestry are being re-evaluated for their application to farm forestry.

POTTER, C.J., TAYLOR, C.M.A. and HODGE, S. (1989). *Demonstration plots for amenity tree establishment and farm woodlands.* Arboriculture Research Note 82/89/SILS.

A series of 22 demonstration plots is being set up throughout Britain at agricultural colleges, showgrounds, and Agricultural Development and Advisory Service (ADAS) establishments. Their purpose is to demonstrate the effects of good and bad techniques on the survival and growth of trees. It is intended that the plots should be widely used both by unaccompanied individuals, and groups and as venues for meetings organised by the Forestry Commission, ADAS and other organisations in order to encourage better tree establishment practices.

PRATT, J.E. and REDFERN, D.B. (1989). Stump treatment against *Fomes* is vital in UK. *Forestry and British Timber* **18** (5), 33–34.

A review of the continued need for stump treatment in British conifer stands.

PRATT, J.E., REDFERN, D.B. and BURNAND, A.C. (1989). Modelling the spread of *Heterobasidion annosum* in Sitka spruce plantations in Britain. In, *Proceedings of the Seventh International Conference on root and butt rots,* ed. Morrison, D., Forestry Canada, Pacific Forestry Centre, 308–319.

A mathematical model of the development of *Heterobasidion annosum* in Sitka spruce plantations was used in a study of the costs and benefits of disease control by stump treatment. The model is driven by estimates of the probability of occurrence of each of seven clearly defined stages in the epidemology of the disease.

PYATT, D.G. (1990). Long term prospects for forests on peatland. *Scottish Forestry* **44** (1), January, 19–25.

Chairman's report of the annual meetings of the Royal Scottish Forestry Society's Silvicultural Group on this theme. Discusses species choice, nutrition, yield, mixtures of species, cultivation, drainage, rooting and wind stability of crops in the first rotation and early research results in the second rotation.

PYATT, D.G. [and JOHN, A.L.] (1989). Modelling volume changes in peat under conifer plantations. *Journal of Soil Science* **40,** 695–706.

It is proposed that the shrinkage of well-decomposed peat beneath conifer plantations owing to the irreversible loss of water takes place in two stages. The first stage of pure subsidence is followed by a second stage of the formation of natural aggregates with a network of large cracks and a slower rate of subsidence. The assumption of equi-dimensional shrinkage in stage two allows a prediction of the relative amounts of subsidence and crack formation. The shrinkage of non-cracking fibrous peat is also dealt with.

QUINE, C.P. (1989). Description of the storm and comparison with other storms. In, *The 1987 storm: impacts and responses,* ed. Grayson, A.J. Forestry Commission Bulletin 87, 3–8. HMSO, London.

The meteorology of the 16 October 1987 storm is reviewed and examples of the exceptional windspeeds are given. The role of windspeed and other possible contributory factors is discussed in the light of experience from other catastrophic forest damage events.

QUINE, C.P. (1990). *Planting at stump: preliminary evidence of its effect on root architecture and tree stability.* Forestry Commission Research Information Note 169.

A study of root architecture of 14-year-old Sitka spruce trees planted at stump, away from stump, and on mounds has been carried out. Marked root system asymmetry was found on trees planted close to stumps. The implications for tree stability are considered and advice is given on how to avoid the detrimental effects.

RATCLIFFE, P.R. (1989). A scientific background to woodland red deer management. In, *Deer and forestry,* Proceedings of a conference, Glasgow June–July 1987, ed. McIntosh, R., 48–60. Institute of Chartered Foresters, Edinburgh.

Practical management prescriptions are presented which enable managers to estimate fertility, survivorship and density of woodland red deer populations. These data are used to model deer dynamics as a basis for setting culls. Differences in performance between forest and open-range populations are discussed. Retrospective construction of minimum population size is described. Finally, practical achievement of the cull and the value of deer management groups are discussed.

RATCLIFFE, P.R. (1989). Realising the potential of red deer: lessons from wild populations. *Deer Farming* No. 25, Summer, 7–9.

This paper is an abstract of that appearing in 'Management, conservation and interpretation of park deer'.

RATCLIFFE, P.R. (1989). Realising the potential of red deer in parks: lessons from wild populations. In, *Management, conservation and interpretation of park deer,* Proceedings of a symposium at Manchester Polytechnic, 6–7 April 1988, eds Brown, M.B. and Goldspink, C.R., 118–125. British Deer Society.

Red deer have survived in Scotland by compromising individual survival and reproductive performance as their preferred woodland habitats were destroyed. High performance populations are found in some woodlands and this paper compares performance in different habitats and questions whether deer in parks are achieving their full potential.

RATCLIFFE, P.R. (1989). The control of red and sika deer populations in commercial forests. In, *Mammals as pests,* ed. Putman, R.J., 98–115.

Red and sika deer populations are increasing in density and expanding their range in many Scottish forests. These populations are causing damage to tree crops and modifying vegetation structure and species diversity. Hybridisation between red and sika deer is occurring in some areas. These problems require improved population control. The costs of damage are unknown, but are almost certainly of economic significance. Red deer in Scotland are being underexploited by at least 3500 animals each year and this can be interpreted as an economic loss. Costs of control amount to about £2.8 million.

RAY, D. and ANDERSON, A.R. (1990). *Soil temperature regimes of mounds on gley soils.* Forestry Commission Research Information Note 168.

Three experiments have shown that soil temperatures are higher early in the growing season in mounds 20–50 cm high than in screefed or uncultivated sites. This should be an important benefit to the establishment of a crop on cold upland gley soils.

ROOK, D.A. (1989). Use of genetically improved forest trees and weed control. In, *Proceedings of the British Crop Protection Council Conference,* Brighton, **1,** 333–338.

The Forestry Commission tree breeding programme includes the identification of most suitable seed origins, establishment of clone banks and seed orchards, breeding new cultivars and field testing of progeny. Increasing attention is being paid to the use of vegetative propagation, including in vitro methods, which can offer substantial savings in making the genetically improved stock available earlier to the tree grower. The investment in genetically improved trees is likely to be wasted unless it is combined with sound silviculture including efficient weed control.

ROSE, D.R. (1989). *Marssonina canker and leaf spot (anthracnose) of weeping willow.* Arboriculture Research Note 78/89/PATH.

Marssonina canker and leaf spot damages the leaves and shoots of weeping willows and, less frequently, other willows during spring and early summer. Though it can seriously disfigure trees, the disease is not fatal. Chemical control is possible to prevent or limit damage.

ROSE, D.R. (1989). *Scab and black canker of willow.* Arboriculture Research Note 79/89/PATH.

In some years willow scab and black canker cause serious damage to the leaves, shoots and young branches of several willow species. The diseases often occur together on the same tree and can easily be confused with each other. Repeated severe attacks can cause considerable dieback and in some cases may lead to the death of the tree. Chemical control may be necessary in commercial plantings but is rarely needed for ornamental trees. However, the currently approved chemical is for scab only.

ROSE, D.R. (1990). *Lightning damage to trees in Britain.* Arboriculture Research Note 68/90/PATH.

Lightning damage to trees is far more common than the incidence of obvious external signs suggests. It is often necessary to examine trees carefully for evidence of internal symptoms to distinguish between lightning damage and progressive root-killing diseases. Lightning strikes affect groups of trees, in plantations or hedges, as well as isolated trees. Oak, poplar and Scots pine appear to be the species most frequently affected. Lightning conductors can be fitted to valuable amenity trees where the risk of a strike is high.

SPEIGHT, M.R. and WAINHOUSE, D. (1989). *Ecology and management of forest insects.* Clarendon Press, Oxford. (374pp.)

A textbook aimed at students, postgraduates and research workers. An ecological approach to forest pest management with many examples from Europe.

[STEELE, M.J.,] COUTTS, M.P. [and YEOMAN, M.M.] (1989). Developmental changes in Sitka spruce as indices of physiological age 1: changes in needle morphology. *New Phytologist* **113,** 367–375.

Measurements made on trees ranging in age from 3 to 38 years showed that all leaf characteristics changed with age, but different characteristics changed at different rates and reached asymptotes at different ages. All measured parameters had reached their theoretical asymptotes by age 20.

[STEELE, M.J., YEOMAN, M.M. and] COUTTS, M.P. (1990). Developmental changes in Sitka spruce as indices of physiological age 2: rootings of cuttings and callusing of needle explants. *New Phytologist* **114,** 111–120.

Callusing ability of needles in vitro and rooting ability of cuttings decreased with increasing tree age, and were related to changes in leaf morphology. Basal shoots and their needles were more juvenile in character than those from the upper part of the tree.

STEVENS, F.R.W. (1989). Buildings and trees. In, *Urban forestry practice,* ed. Hibberd, B.G., Forestry Commission Handbook 5, 108–114. HMSO, London.

STOAKLEY, J.T. and HERITAGE, S.G. (1989). *Application leaflet on the use of 'Permit' and 'Permasect 25 EC' for post-planting treatment against* Hylobius abietis *and* Hylastes *species attacking young trees.* Forestry Commission Research Information Note 151.

This Note describes the use of two formulations of permethrin, 'Permit' (PBI) and 'Permasect 25 EC' (Mitchell Cotts) as post-planting treatments to protect young trees in the forest against *Hylobius abietis* and *Hylastes* species which are frequently destructive on felled conifer sites. It takes the form of an 'Application Leaflet' and incorporates the conditions of formal 'off-label'. Approvals for the described uses given by the Pesticides Safety Division of MAFF under the Control of Pesticides Regulations 1986. The Approvals to which this Note refers expire on 10 August 1991. Alternative insecticidal treatments against *Hylobius abietis* and *Hylastes* are discussed.

STOAKLEY, J.T. and HERITAGE, S.G. (1990). *Application leaflet on the use of 'Permit' and 'Permasect 25 EC' for pre-planting treatment of young trees against Hylobius abietis and Hylastes spp.* Forestry Commission Research Information Note 177.

Describes the use of two formulations of permethrin, 'Permit' (PBI) and 'Permasect 25 EC' (Mitchell Cotts) as pre-planting treatments to provide protection of young planting stock – either bare-rooted or raised in containers – against *Hylobius abietis* and *Hylastes* spp. which are frequently destructive on felled conifer sites. It takes the form an 'Application Leaflet', which is a mandatory adjunct to the formal Approval given by the Pesticides Safety Division of MAFF for the described uses under the Control of Pesticides Regulations 1986. The need for specified protective clothing and detailed attention to safety procedures is emphasised throughout. The use of these treatments in the context of the COSHH Regulations, which now apply, is explained. The Approvals to which this publication refers expire on 6 February 1991.

STROUTS, R.G., GIBBS, J.N. and WINTER, T.G. (1989). The main diseases and pests of urban trees. In, *Urban forestry practice,* ed. Hibberd, B.G., Forestry Commission Handbook 5, 136–140. HMSO, London.

The main effects of the pests and diseases, listed by tree name are described and their relative importance stated. References to more detailed accounts are given.

TABBUSH, P.M. and RAY, D. (1989). Effects of rough handling and microsite on the establishment of Sitka spruce on clearfelled sites in upland Britain. *Forestry* **62** (Suppl.), 289–296.

Mounds gave higher soil temperatures than screefs or uncultivated soil, but rough handling had more effect on plant growth in the first year.

TAYLOR, C.M.A. (1990). Survey of forest fertiliser prescriptions in Scotland. *Scottish Forestry* **44** (1), 3–9.

The results of a forest survey of fertiliser prescriptions conducted on 49 randomly chosen afforestation sites in Scotland are discussed. The main problem identified was incorrect prescription of requirements for topdressing, associated with inability to recognise nutrient deficiencies. In some cases fertiliser application was not planned when nutrient deficiency was present or was delayed because of financial restriction. Elsewhere fertiliser was being applied when it was not required. References are listed which give general advice on fertiliser requirements.

TAYLOR, C.M.A. (1990). *The nutrition of Sitka spruce on upland restock sites.* Forestry Commission Research Information Note 164.

A recent series of Sitka spruce nutrition experiments established on a range of restock sites indicates that there is no need for application of fertiliser at the time of replanting, irrespective of site type. It is unlikely that subsequent fertiliser will be required on sites where there was a satisfactory crop yield in the first rotation without application of fertiliser. However, there are indications that topdressing may be required on the more infertile sites. This will be quantified in due course by monitoring growth responses to topdressing treatments planned for the experiment series.

TAYLOR, C.M.A. and MOFFAT, A.J. (1989). The potential for utilising sewage sludge in forestry in Great Britain. In, *Alternative uses of sewage sludge,* University of York, 5–7 September 1989, ed. Hall, J.E.

Recent experimental results have indicated that sludge can be successfully utilised as a forest fertiliser. This paper describes two surveys carried out in 1987 to assess the potential programme and summarises the results. It is estimated that up to 11% of the total sludge production of 1.2 million tonnes dry solids could be applied to forest land. When the transport distance is reduced from 32 km to 16 km the proportion decreases to 6%.

TAYLOR, C.M.A. and TABBUSH, P.M. (1990). *Nitrogen deficiency in Sitka spruce plantations.* Forestry Commission Bulletin 89. HMSO, London.

On moorland and heathland soils in Great Britain nitrogen deficiency can severely restrict the growth of certain conifer species, including Sitka spruce, the main commercial species. Until the 1970s this was thought to be due solely to competition from heather and was commonly known as 'heather check'. However, increased planting of Sitka spruce on very nutrient-poor soils revealed that, even after removal of heather by herbicide treatment, growth was still limited by low availability of nitrogen. This can be overcome by applications of nitrogen fertiliser prior to full canopy closure.

TAYLOR, G. and DOBSON, M.C. (1989). Photosynthetic characteristics, stomatal responses and water relations of *Fagus sylvatica:* impact of air quality at a site in southern Britain. *New Phytologist* **113,** 265–273.

Beech transplants were grown in open-top chambers ventilated with charcoal filtered and unfilterd air. Unfiltered (polluted) air decreased the stomatal conductance of the first flush of leaves but increased the values for the second, lammas flush. Values of solute and water potential were higher for trees grown in unfiltered air. Laboratory analysis indicated that pollution enhanced regeneration rates of RuBP while drought decreased both RuBP regeneration and carboxylation efficiency.

TAYLOR, G., DOBSON, M.C. and FREER-SMITH, P.H. (1989). The effects of O_3 and water deficit on the stomatal conductance and physiology of spruce. *Annales des Sciences Forestières* **46,** 124–126.

For both beech and spruce stomatal conductance was decreased by unfiltered (polluted) air compared to values in filtered (clean) air. Photosynthesis and transpiration were decreased by the ambient pollutant concentrations at Headley. The reduced carbon uptake and water loss resulted in reduced root biomass in beech and also altered root morphology. The results suggest that trees grown in polluted air may be more susceptible to drought.

THOMPSON, D.A. (1989). Home-grown drying. *Timber Trades Journal and Wood Processing* **350** (5867), 8 July, 26–27.

A review of an experiment on the use of high temperature drying for British-grown Sitka spruce which suggests that this form of drying has no effect on strength properties.

THOMPSON, D.A. and MATTHEWS, R.W. (1989). CO_2 in trees and timber lowers greenhouse effect. *Forestry and British Timber* **18** (10), October, 19, 21, 24.

Describes the Forestry Commission's model for estimating carbon in trees and timber and gives results for some alternative tree crops and products.

THOMPSON, D.A. and MATTHEWS, R.W. (1989). *The storage of carbon in trees and timber.* Forestry Commission Research Information Note 160.

Trees have a positive role to play in countering the greenhouse effect. They absorb carbon dioxide by photosynthesis, some of which is stored as carbon compounds in wood, both during the growth of trees and, after felling, in various forms of wood products. This Note describes some preliminary calculations on the amounts of carbon likely to be involved for different tree species and end users.

THOMPSON, D.A., GIBBS, J.N., NISBET, T.R. and WEBBER, J.F. (1990). *Water-stored timber after 12 months.* Forestry Commission Research Information Note 178.

Samples of Corsican pine, Sitka spruce and beech logs maintained under a water sprinkling system were removed after 6 months and 12 months storage. All logs were found to saw easily and accurately. A small amount of blue-stain and other fungal associated stain was revealed in Corsican pine and beech respectively, but laboratory assessment suggested that fungi were quiescent and their development had been checked by the method of storage.

[WATT, A.D.,] LEATHER, S.R. and STOAKLEY, J.T. (1989). Site susceptibility, population development and dispersal of the pine beauty moth in a lodgepole pine forest in northern Scotland. *Journal of Applied Ecology* **26** (1), April, 147–157.

The population behaviour of the pine beauty moth was analysed from 1977 to 1984 to see whether part of the lodgepole pine forest was intrinsically more susceptible that the rest to attack. Population growth was not significantly greater in the small part of the forest defoliated by larvae in 1984. The 1984 outbreak centred on the area where pine beauty moth numbers had been

greatest one year after an insecticide operation in 1979. Large and significant differences were observed in population development in different years. Significant differences in adult emergence and egg laying were observed. The number of eggs laid per female per site ranged from 18 to 163.

WEBBER, J.F. (1990). *Guidelines for the water storage of timber.* Forestry Commission Research Information Note 174.

Drawing on the experience of setting up and maintaining a 700 000 M^3 wet store for sawn timber logs, this Note discusses some of the requirements for the water storage of timber.

WHITE, J.E.J. and PATCH, D. (1989). *Ivy: boon or bane?* Arboriculture Research Note 81/89/ARB.

Ivy, which is the only native British evergreen climbing shrub, may be unsightly and it can create problems for tree managers. These adverse effects of ivy should be compared with its conservation benefits before destroying the climber. This Note reviews both the benefits and problems of ivy growth.

[WILDING, N., COLLINS, N.M., HAMMOND, P.M. and] WEBBER, J.F. (1989). *Insect-fungus interactions.* 14th Symposium of the Royal Entomological Society of London in collaboration with the British Mycological Society. Academic Press, London. (344 pp.)

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

WILLIAMSON, D.R. (1989). *A brief guide to some aspects of the Control of Pesticides Regulations 1986.* Forestry Commission Research Information Note 159.

Superseded by Research Information Note 170 – see below.

WILLIAMSON, D.R. (1989). Forest weed control. *Timber Grower* No. 111, Spring, 30.

A brief summary of the theory and practice of forest weed control by mulching and herbicide application.

WILLIAMSON, D.R. (1990). *A brief guide to some aspects of the Control of Pesticides Regulations 1986.* Forestry Commission Research Information Note 170.

The Control of Pesticides Regulations 1986 have been introduced in stages from October 1986. This Note answers some of the most frequently asked questions regarding the use of pesticides (i.e. herbicides, fungicides, insecticides, etc.).

WILLIAMSON, D.R. and FERRIS-KAAN, R. (1990). Herbicides in forestry: herbicides for tree establishment can also provide conservation benefits. *Timber Grower,* Spring, 30, 32.

An outline of the principles underlying effective weed control in forestry is given, followed by a brief description of some of the ways in which selective herbicides/growth regulators may be used to manipulate vegetation in order to benefit plants of conservation value.

WILLIAMSON, D.R. and MASON, W.L. (1989). *Forest nursery herbicides.* Forestry Commission Occasional Paper 22. Forestry Commission, Edinburgh.

A technical manual on forest nursery weed control.

WILLIAMSON, D.R. and MASON, W.L. (1990). *Butisan S: weed control in forest nursery transplant lines.* Forestry Commission Research Information Note 171.

Gives recommendations for the use of metazachlor, sold as Butisan S, on forest nursery transplant lines. Because the current legislation is geared towards product approval it has been necessary to use product names.

WILLIAMSON, D.R. and MASON, W.L. (1990). Weed control in forest nurseries and forests. In, *Weed control handbook: principles.* 8th ed. Chapter 17, eds Hance, R.J. and Holly, K., 457–471.

Chapter on the general principles of weed control in the forest nursery and the forest.

WILLIAMSON, D.R. and MOFFAT, A.J. (1990). Tree crop production systems: a change in land use with the potential to reduce inputs. *Journal of the Science of Food and Agriculture* **53** (1), 113–115.

Summary of paper given at the Society of Chemistry on low input uses for ex-arable land.

WINTER, T.G. (1989). *Cypress and juniper aphids.* Arboriculture Research Note 80/89/ENT.

Two aphid species which have caused recent serious damage to cypresses and junipers are described and their control is discussed.

WINTER, T.G. and EVANS, H.F. (1990). *Insects and storm-damaged conifers.* Forestry Commission Research Information Note 173.

Pine will be the principal conifer at risk from insect attack in the aftermath of the storm of 25 January 1990. Attacks by bark beetles will be followed by blue stain. *Tomicus piniperda* will preferentially attack and breed in severed trees and these should be removed first. In all cases Scots pine will be attacked in preference to Corsican pine. There will be no danger of a new generation of *T. piniperda* emerging from logs before June 1990. The longhorn beetle *Arhopalus rusticus* may cause serious degrade of any pine butts not harvested before the summer of 1991. Some degrade due to the larch longhorn *Tetropium gabrieli* is possible in any larch left through the summer of 1990.

APPENDIX II

RESEARCH DIVISION ORGANISATION

Chief Research Officer (North)

- Silviculture (North Branch)
- Site Studies (North) Branch
- Tree Improvement Branch‡
- Physiology Branch
- Statistics and Computing (North) Branch
- Administration – *Instrumentation (North) Section*

Director

- Mensuration Branch
- Communications Branch
  - *Library and Information Section*
  - *Photography Section*
  - *Publications Section*
- Administration

Chief Research Officer (South)

- Silviculture (South) Branch – *Wood Utilisation Section*
- Seed Branch
- Site Studies (South) Branch – *Instrumentation (South) Section*
- Pathology Branch*
- Entomology Branch*
- Wildlife and Conservation Research Branch*
- Statistics and Computing (South) Branch – *Biometric Modelling Section*

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

APPENDIX III

RESEARCH DIVISION BRANCHES AND THEIR PROJECT GROUPS‡

Seed	*Project leader(s) at 31/3/90*
Research	P.G. Gosling, S.K. Jones
Service	P.G. Gosling
Silviculture (South)	
Nursery	R.L. Jinks, D.R. Williamson
Arboreta	J.E.J. White
Establishment	G. Kerr, D.R. Williamson, S.J. Hodge
Siliviculture operations	G. Kerr, C.J. Potter
Arboriculture	
Advice	D. Patch
Establishment	S.J. Hodge
Farm forestry	D.R. Williamson, C.J.Potter, S.J. Hodge
Wood quality	J.F. Webber
Preservation	J.F. Webber
Utilisation of broadleaves	J.F. Webber
Silviculture (North)	
Plant production	W.L. Mason
Species	C.J. Nixon
Planting (including weed control)	D.G. Nelson
Nutrition	J.C. Dutch
Cultivation	D.G. Nelson, C.P. Quine
Stability	B.A. Gardiner, C.P. Quine
Farm forestry	C.J. Nixon
Reclamation (N)	J.D. McNeill
Site Studies (South)	
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, H.S.J. Lee
Chemical analysis	E. Ward
Instrumentation	T.R. Nisbet
Site Studies (North)	
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
Tree Improvement	
Forest reproductive material regulations	A.M. Fletcher
Testing progeny and clones	S.J. Lee
Origin	A.M. Fletcher, C.J.A. Samuel
Production: clone banks and orchards	A.M. Fletcher, W. Brown
Biochemical variation	G.I. Forrest
Biometrical studies	C.J.A. Samuel
Flowering	J.J. Philipson
Micropropagation	A. John
Rejuvenation	A. John
Improvement and propagation of broadleaves	R. Harmer
Improvement and propagation of farm forestry broadleaves	C.M. Cahalan
Physiology	
Root growth and form	M.P. Coutts
Bent top	M.P. Coutts
Lowland restocking	M.P. Coutts, H.M. McKay
Planting stock quality	H.M. McKay
Mycorrhizas	C. Walker
Development of rooting patterns	C. Walker
Pathology	
Disease diagnosis, damage monitoring and risk assessment	D.B. Redfern, S.C. Gregory, R.G. Strouts, J.N. Gibbs
Cankers and shoot diseases	B.J.W. Greig, D.R. Rose
Wilt disease	C.M. Brasier, B.J.W. Greig
Root diseases	D.B. Redfern, B.J.W. Greig

Stem decays and stain	D. Lonsdale, J.N. Gibbs
Complex diebacks and chronic declines	D. Lonsdale, B.J.W. Greig

Entomology

Dendroctonus micans	H.F. Evans, D. Wainhouse
Panolis flammea	J.T. Stoakley, S.R. Leather
Beech bark disease	D. Wainhouse
Elatobium abietinum	C.I. Carter
Hylastes and *Hylobius*	J.T. Stoakley, S.G. Heritage
Advisory and taxonomic	T.G. Winter
Genetic variations	M.R. Jukes

Wildlife and Conservation

Red deer	P.R. Ratcliffe
Other deer (fallow, roe and sika)	P.R. Ratcliffe
Squirrels (red and grey)	H.W. Pepper
Birds	S.J. Petty
Damage	R.M.A. Gill
Repellents (fencing and tree guards)	H.W. Pepper
Autecological studies of sensitive species	B.A. Mayle
Vegetation management	R. Ferris-Kaan, G.S. Patterson
Community ecology	P.R. Ratcliffe

Mensuration

Sample plots	J.M. Methley
Measurement studies	J.M. Methley
Yield modelling	R.W. Matthews
Management services	J.M. Methley

Statistics and Computing (South)

Forest growth modelling	A.R. Ludlow

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

APPENDIX IV

NET EXPENDITURE OF RESEARCH DIVISION 1989/90

£000

Branch[a]	*Expenditure by Branch direct*[b]	*Net value of in-house services received less than those provided*[c]	*Commissioned*[d] *research*	*Expenditure attributable to Branch*[e]
Seed	129	45		174
Silviculture (South)	843	76	47	966
Arboreta	436			436
Silviculture (North)[f]	1815	−194	25	1646
Site Studies (South)[g]	737	24	97	858
Site Studies (North)	141	68	1	210
Tree Improvement	941	237		1178
Physiology	214	83	28	325
Pathology	522	113	45	680
Entomology	611	90	24	725
Wildlife and Conservation	410	88	79	577
Mensuration	275	33		308
Wood Utilisation	78	21	211	310
Statistics and Computing (South)	406	−299		107
Statistics and Computing (North)	247	−247		
Communications	396	−138		258
Total[e]	**8201** [h]	**0**	**557**	**8758**

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 £1490(000) plus Forestry Commission headquarters overheads for common services of £555(000) net of income of £381(000) for contract services provided to outside parties.

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

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

e. Totals do not always add owing to rounding.

f. Including Experimental Workshop (North) £66(000).

g. Including Experimental Workshop (South) £81(000).

h. Branches' work on behalf of Forest Authority Plant Health amounted to £69(000).

APPENDIX V

CONTRACTS FOR WORK UNDERTAKEN BY RESEARCH DIVISION

Department of the Environment	Arboriculture Pathology Arboriculture Advisory and Information Service De-icing salt and tree damage
Energy Technology Support Unit	Biomass energy
British Coal	Opencast coal spoil
Department of Engineering, Oxford University	Aerolastic modelling
Central Electricity Generating Board	Trees on gypsum soil
Lothian Regional Council	Root trainers
Research Institute for Forestry and Landscape Planning, 'De-Dorschkamp', The Netherlands	Dutch elm disease
Ministry of Agriculture, Fisheries and Food	Vegetative propagation Progeny testing Yield assessments
BP Chemicals	De-icing salt and tree damage
Pilkington Trust	Dutch elm disease
Incitec International	*Hylobius*
EEC/EOLAS (Irish Science and Technology Agency)	Pinewood nematodes

APPENDIX VI

STAFF ENGAGED IN RESEARCH AS AT 31 MARCH 1990

RESEARCH DIVISION

Director — D.A. Burdekin, B.A., Dip.Ag.Sci., M.I.C.For. (*Alice Holt*)

Administration and Finance Officer — J. Lumley (*Alice Holt*)

Chief Research Officer (South) — J. Evans, B.Sc., Ph.D., D.Sc., F.I.C.For. (*Alice Holt*)

(With general responsibilities for research south of the Mersey/Humber line, and with specific responsibilities for silviculture and site studies in the lowlands, and throughout Britain for research in pathology, entomology, wildlife and conservation, seed, arboriculture, instrumentation and technical aspects of legislation relating to plant health.)

Chief Research Officer (North) — T.C. Booth, B.Sc., M.I.C.For. (*Northern Research Station*)

(Head of the Northern Research Station with general responsibilities for research north of the Mersey/Humber line and in Wales, with specific responsibilities throughout Britain for research in tree physiology and tree improvement, and for silviculture and site studies in the uplands.)

STAFF AT ALICE HOLT LODGE

Seed Branch

P.G. Gosling, B.Sc., Ph.D., Head of Branch
S.K. Jones, C.Biol., M.I.Biol., M.I.Hort.
Miss A.D. Kitching
Miss F.S. Patch
Mrs P.J. Rigg
Mrs Y.K. Samuel, B.A.

Silviculture Branch (South)

D.A. Thompson, B.Sc., M.I.C.For., Head of Branch
D. Elgy
S. Hodge, B.Sc., M.Sc., M.I.C.For.
R.L. Jinks, B.Sc., Ph.D.
G. Kerr, B.Sc., M.I.C.For.,
Mrs C.J. Potter, B.Sc., M.I.C.For.
J.F. Webber, B.Sc., Ph.D.
J.E.J. White (*Westonbirt*)
D.R. Williamson, B.Sc., M.I.C.For.

Outstation staff	*Centre*
East England Region	
S.M. Colderick, M.I.C.For.	
A.R. Hall	Alice Holt
C. Morgan	Bedgebury
R.B. Collins	
T.D. Cooper	
D.A. Hendrie	Thetford
West England Region	
H.C. Angus	
A. Russell	Westonbirt
D.G. Rogers	
N.A. Smith	Exeter
M.W. Allen	
I. Collier	Midlands

Arboricultural Advisory and Information Service (Department of the Environment)

D. Patch, B.Sc., M.Sc., M.I.C.For., N.D.Arb.(RFS), F.Arbor.A.
F.R.W. Stevens

Site Studies Branch (South)

P.H. Freer-Smith, B.Sc., Ph.D., Head of Branch
N.A.D. Bending, B.Sc., M.Sc.
Mrs S.E. Benham,
P.G. Crow
D.W.H. Durrant, B.A.
J.L. Innes, M.A., Ph.D.
P.C. Jokiel, B.Sc.
H.S.J. Lee, B.Sc., Ph.D., C.Biol., M.I.Biol.
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., C.Chem., M.R.S.C.,
A. Willson, B.Sc., Ph.D.

Instrumentation Section (South)

T.R. Nisbet, B.Sc., Ph.D., Head of Section

Tree Improvement Section (of Branch at Northern Research Station)
R. Harmer, B.Sc., Ph.D., Head of Section
Mrs C.A. Baker
C.M. Cahalan, B.Sc., M.Sc., Ph.D.
M.R. Plowman, B.Sc., M.Sc.

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.
M.C. Dobson, B.Sc.
B.J.W. Greig, M.I.C.For.
Mrs S.A. Kirk
D. Lonsdale, B.Sc., Ph.D.,
C.A. Palmer
D.R. Rose, B.A.
R.G. Strouts

Entomology Branch (with Section at Northern Research Station)
H.F. Evans, B.Sc., D.Phil, F.R.E.S., Head of Branch
C.I. Carter, M.Sc., C.Biol., M.I.Biol., F.R.E.S.
N.J. Fielding
M.R. Jukes, C.Biol., M.I.Biol.
Miss J.F.A. Nichols, B.Sc., M.Phil., C.Biol., M.I.Biol., F.R.E.S.
N.A. Straw, B.Sc., Ph.D., F.R.E.S.
D. Wainhouse, M.Sc., Ph.D., F.R.E.S.
T.G. Winter, F.R.E.S.

Wildlife and Conservation Research Branch
P.R. Ratcliffe, B.Sc., Ph.D., C.Biol., M.I.Biol., M.I.C.For., Head of Branch
A. Chadwick (*Cowal, Strathclyde*)
R. Ferris-Kaan, B.Sc., Ph.D.
R.M.A. Gill, B.Sc.
Mrs B.A. Mayle
H.W. Pepper
S.J. Petty (*Cowal, Strathclyde*)
G.S. Patterson, B.Sc., M.I.C.For. (*Northern Research Station*).

Mensuration Branch
Mrs J.M. Methley, B.Sc., Head of Branch
S.R. Abbott
R.W. Matthews, B.Sc., M.Sc.

Statistics and Computing Branch (South)
I.D. Mobbs, M.I.S., 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.
R.S. Howell
A.R. Ludlow, B.Sc., Ph.D.
M.A. Mellergaard
A.J. Peace, B.Sc.
T. Porter, 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

Library and Information Section
Miss C.A. Oldham, B.A., M.A., Dip.Lib. A.L.A, Head of Section and Librarian
Mrs E.M. Harland, M.A. (Assistant Librarian)

Photography Section
G.L. Gate, Head of Section
Miss M. Trusler

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

Administration
HEOs: Mrs B.K. Bartlett (*Personnel*)
R. Murray (*Accounts*)
EOs: Mrs J.C. Gates (*Office Services*)
Miss J.R. Lacey (*Personnel*)
Mrs K. Potter (*Accounts*)

STAFF AT NORTHERN RESEARCH STATION

Silviclture Branch (North)
D.B. Paterson, B.Sc., M.I.C.For., Head of Branch
J.C. Dutch, B.Sc., Ph.D.
B.A. Gardiner, B.Sc., Ph.D., F.R.Met.S.
W.L. Mason, B.A., B.Sc., M.I.C.For.
D.G. Nelson, B.Sc., M.I.C.For.
C.J. Nixon, B.Sc., M.I.C.For.
C.P. Quine, M.A., M.Sc., M.I.C.For.

Outstation staff:	*Centre*
Stability Project	
A.L. Mackie	Northern Research Station
North and Mid Scotland Region	
A.L. Sharpe	Newton, Grampian
North Scotland Area	
W.G. Paterson	
J. Boluski	Lairg, Highland
North-east Scotland Area (including Central Highlands and Islands)	
A.A. Green	
J. Davidson, B.A., M.I.C.For.	
A.W. Macleod	Newton, Grampian
West Scotland Area (including Mull)	
D.R. Tracy	
S. Stables, B.Sc.	Cairnbaan, by Lochgilphead, Strathclyde
East Scotland Area	
F.S. Smith	
D. Anderson	Perth, Tayside
South Scotland and North England Region	
J.D. McNeill	Northern Research Station

South-east Scotland Area
M.K. Hollingsworth
A.J. Harrison — Northern Research Station
South-west Scotland Area (including Arran)
M. Riley
D.M. Watterson — Mabie
Borders Area
P.H. Priestley
P.W. Gough
D. Kerr — Kielder, by Hexham, Northumberland
North-east England Area
R.E.J. Howes
A.D. Edwards — Wykeham, Scarborough, North Yorkshire

Wales Region
N.P. Danby — Talybont-on-Usk
Wales Area
S.J. Corcoran, B.A., N.D.F., M.I.C.For.
S.A. Mead, B.Sc. — Talybont-on-Usk

Site Studies Branch (North)
D.G. Pyatt, B.A., B.Sc., Ph.D., Head of Branch
A.R. Anderson
D. Ray, B.Sc.

Tree Improvement Branch (with Section at Alice Holt)
D.A. Rook, B.Sc., M.Sc., Ph.D., Head of Branch
Miss C.M.M. Baldwin
A.M. Fletcher, B.Sc., Ph.D., A.I.W.Sc., M.I.C.For.
G.I. Forrest, B.Sc., M.Sc., Ph.D., S.J. Lee, B.Sc., M.I.C.For.
A. John. B.Sc., Ph.D.
Mrs M.O'Donnell
J.J. Philipson, B.A., Ph.D.
C.J.A. Samuel, B.Sc., Ph.D.

Outstation staff: — *Centre*
Northern Scotland
C.E.S. Fleming
R.J. Sykes — Newton, Grampian
Mid Scotland to northern England
W. Brown
J.S. McIntyre
N.A.D. Muir — Northern Research Station
Wales and southern England
G.C. Webb
A.S. Medhurst, M.I.C.For. — Shobdon, Hereford

Physiology Branch
M.P. Coutts, B.Sc., PhD., 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 J. Harrower,
C. McEvoy
H.M. McKay, B.Sc., Ph.D.
B.C. Nicoll, B.Sc.

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

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

Administration
HEO: C.K. Smith
EO: Mrs M. Farm

Instrumentation Section (North)
D.J. Brooks, Head of Section

INDUSTRIAL STAFF

The total number of industrial employees in Research Division at 31 March 1990 was 137.5.

STAFF CHANGES

Transfers in:

D.R. Anderson (Forest Officer IV) from Wales Conservancy to Silviculture North, Perth.

I. Collier (Forest Officer IV) from West England Conservancy to Silviculture South, Midlands.

A.D. Edwards (Forest Officer IV) from North England Conservancy to Silviculture North, Wykeham.

A.R. Hall (Forest Officer IV) from South Scotland Conservancy to Silviculture South, Alice Holt.

A.J. Harrison (Forest Officer IV) from Mid Scotland Conservancy to Silviculture North, Northern Research Station.

A.L. Mackie (Forest Officer IV) from North Scotland Conservancy to Silviculture North, Northern Research Station.

A.W. Macleod (Forest Officer IV) from West England Conservancy to Silviculture North, Newton.

C. Morgan (Forest Officer III) from South Scotland Conservancy to Silviculture South, Bedgebury.

Miss C.A. Oldham (Librarian) from Ministry of Defence to Communications, Alice Holt.

M.R. Plowman (Forest Officer IV) from Wales Conservancy to Tree Improvement, Alice Holt.

New appointments:

Dr C.M. Cahalan (Higher Scientific Officer) Tree Improvement, Alice Holt.

Dr J.C. Dutch (Forest Officer II) Silviculture North, Northern Research Station.

Miss A.D. Kitching (Assistant Scientific Officer) Seed, Alice Holt.

Dr H.S.J. Lee (Higher Scientific Officer) Site Studies South, Alice Holt.

Dr J.F. Webber (Higher Scientific Officer) Silviculture South (Wood Utilisation), Alice Holt.

Transfers out:

M. Crosby (Forest Officer IV) from Tree Improvement, Northern Research Station to Health and Safety, HQ.

A.F. Martin (Forest Officer III) from Mensuration, Alice Holt to North Scotland Conservancy.

W.F. Rayner (Forest Officer IV) from Silviculture North, Perth to Forest Surveys, Perth.

B.R. Reynard (Forest Officer III) from Silviculture North, Northern Research Station to North Scotland Conservancy.

C.M.A. Taylor (Forest Officer I) from Silviculture North, Northern Research Station to Mid Scotland Conservancy.

Promotions:

Mrs S.E. Benham (Site Studies South, Alice Holt) to Scientific Officer.

D.A. Burdekin (Director Research) to Grade 5.

D. Elgy (Silviculture South, Alice Holt) to Forest Officer I.

J. Evans (Chief Research Officer, South) to Grade 6.

N.J. Fielding (Entomology, Ludlow) to Higher Scientific Officer.

Mrs J.M. Methley (Mensuration, Alice Holt) to Senior Scientific Officer.

A.J. Moffat (Site Studies South, Alice Holt) to Grade 7.

H.W. Pepper (Wildlife and Conservation, Alice Holt) to Forest Officer I.

D.R. Rose (Pathology, Alice Holt) to Forest Officer II.

C.J.A. Samuel (Tree Improvement, Northern Research Station) to Grade 7.

D.A. Thompson (Silviculture South, Alice Holt) to Grade 7.

C. Walker (Physiology, Northern Research Station) to Grade 7.

+ 13 promotions from Forest Officer IV to Forest Officer III.

Resignations:

A.T. Armstrong (Forest Officer IV) Silviculture South, Alice Holt.

Miss A.M. Bolster (Assistant Scientific Officer) Seed, Alice Holt.

M.J. Potter (Forest Officer I) Silviculture South, Alice Holt.

Mrs T.C. Reffold (Scientific Officer) Pathology, Alice Holt.

Retirements:

A.J. Grayson (Director Research) Alice Holt.

P.A. Gregory (Forest Officer III) Silviculture South, Westonbirt Arboretum.

C.J. King (Forest Officer II) Entomology, Alice Holt.

P. Marsh (Forest Officer IV) Silviculture South, Alice Holt.

APPENDIX VII

ADDRESSES OF RESEARCH LOCATIONS

Main Centres

Forestry Commission
Forest Research Station
Alice Holt Lodge
Wrecclesham
Farnham, Surrey
GU10 4LH
Tel: 0420 22255

Forestry Commission
Northern Research Station
Roslin
Midlothian
EH25 9SY
Tel. 031 445 2176

Some staff engaged in research are also stationed at:
Forestry Commission
Headquarters
231 Corstorphine Road
Edinburgh EH12 7AT
Tel. 031 334 0303

Research Outstations

Ardentinny Wildlife
Forestry Commission
Wildlife & Conservation
Research Branch
Ardentinny
Dunoon
Argyll
PA23 8TS
Tel: 036 981 253

Bedgebury Silv(S)
Forestry Commission
Bedgebury Pinetum
Bedgebury
Goudhurst
Cranbrook
Kent
TN17 2SL
Tel: 0580 211044

Bush Silv(N)
Forestry Commission
Northern Research Station
Roslin
Midlothian
EH25 9SY
Tel: 031 445 2176

Cairnbaan Silv(N)
Forestry Commission
Research Office
Cairnbaan
Lochgilphead
Argyll
PA31 8SQ
Tel: 0546 2304

Exeter Silv(S)
Forestry Commission
Research Office
Bullers Hill
Kennford
Exeter
Devon EX6 7XR
Tel: 0392 832262

Headley Silv(S)
Forestry Commission
Headley Research Nursery
Headley Park
Bordon
Hampshire
All mail via Alice Holt Lodge
Tel: 0420 473466

Kielder Silv(N)
Forestry Commission
Research Office
Kielder
by Hexham
Northumberland
NE48 1ER
Tel: 0434 250235

Lairg Silv(N)
Forestry Commission
Research Office
Ord Croft
Lairg
Sutherland
IV27 4AZ
Tel: 0549 2150

Ludlow Entomology
Forestry Commission
Entomology Office
Whitcliffe
Ludlow
Shropshire
SY8 2HD
Tel: 0584 878322

Mabie Silv(N)
Forestry Commission
Research Office
Mabie
Troqueer
Dumfries
DG2 8HB
Tel: 0387 52267

Midlands Silv(S)
Forestry Commission
Research Office
Woodside
Arley
Coventry
Warwickshire
CV7 8GH
Tel: 0676 41668

Newton Silv(N) &
Tree Improvement
Forestry Commission
Research Office
Newton Nursery
Elgin
Morayshire
IV30 3XR
Tel: 0343 543165

Perth Silv(N)
Forestry Commission
Research Office
10 York Place
Perth PH2 8EJ
Tel: 0738 25344

Shobdon Tree Improvement
Forestry Commission
Research Division
Uphampton
Shobdon, Leominster
Hereford HR6 9PB
Tel: 056 881 8881

Talybont-on-Usk Silv(N)
Forestry Commission
Research Office
Cefn Gethiniog
Talybont-on-Usk
Brecon
Powys LD3 7YN
Tel: 0874 87444

Thetford Silv(S)
Forestry Commission
Research Office
Santon Downham
Brandon
Suffolk IP27 0TJ
Tel: 0842 810271

Westonbirt Silv(S)
Forestry Commission
Westonbirt Arboretum
Tetbury
Gloucestershire GL8 8QS
Tel: 0666 88220

Wykeham Silv(N)
Forestry Commission
Research Office
Wykeham, Scarborough
Yorks YO13 9HQ
Tel: 0723 862031

INDEX

GLOSSARY

Latin names of trees cited by common name in this Report

BROADLEAVES	
alder, common	*Alnus glutinosa*
ash	*Fraxinus excelsior*
aspen	*Populus tremula*
beech (European)	*Fagus sylvatica*
southern	*Nothofagus procera*
birch, silver	*Betula pendula*
cherry, wild (gean)	*Prunus avium*
chestnut, sweet	*Castanea sativa*
elm	*Ulmus procera*
hornbeam	*Carpinus betulus*
lime, common	*Tilia* x *europaea*
small-leaved	*T. cordata*
maple, field	*Acer campestre*
Norway	*A. platanoides*
oak, pedunculate	*Quercus robur*
red	*Q. rubra*
sessile	*Q. petraea*
poplar	*Populus* spp.
rowan	*Sorbus aucuparia*
sycamore	*Acer pseudoplatanus*
willow, cricket bat	*Salix, alba* var. *coerulea*
weeping	*S.* x *chrysocoma*

CONIFERS	
cedar, deodar	*Cedrus deodara*
western red	*Thuja plicata*
cypress, Lawson	*Chamaecyparis lawsoniana*
Leyland	x *Cupressocyparis leylandii*
fir, Douglas	*Pseudotsuga menziesii*
grand	*Abies grandis*
noble	*A. procera*
larch, hybrid	*Larix* x *eurolepis*
Japanese	*L. kaempferi*
pine, Bishop	*Pinus muricata*
Corsican	*P. nigra* var. *maritima*
lodgepole	*P. contorta*
Scots	*P. sylvestris*
spruce, dragon	*Picea asperata*
Norway	*P. abies*
Sitka	*P. sitchensis*
yew	*Taxus baccata*

Printed in the UK for HMSO Dd.291300 9/91 C15 488/2 12521

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