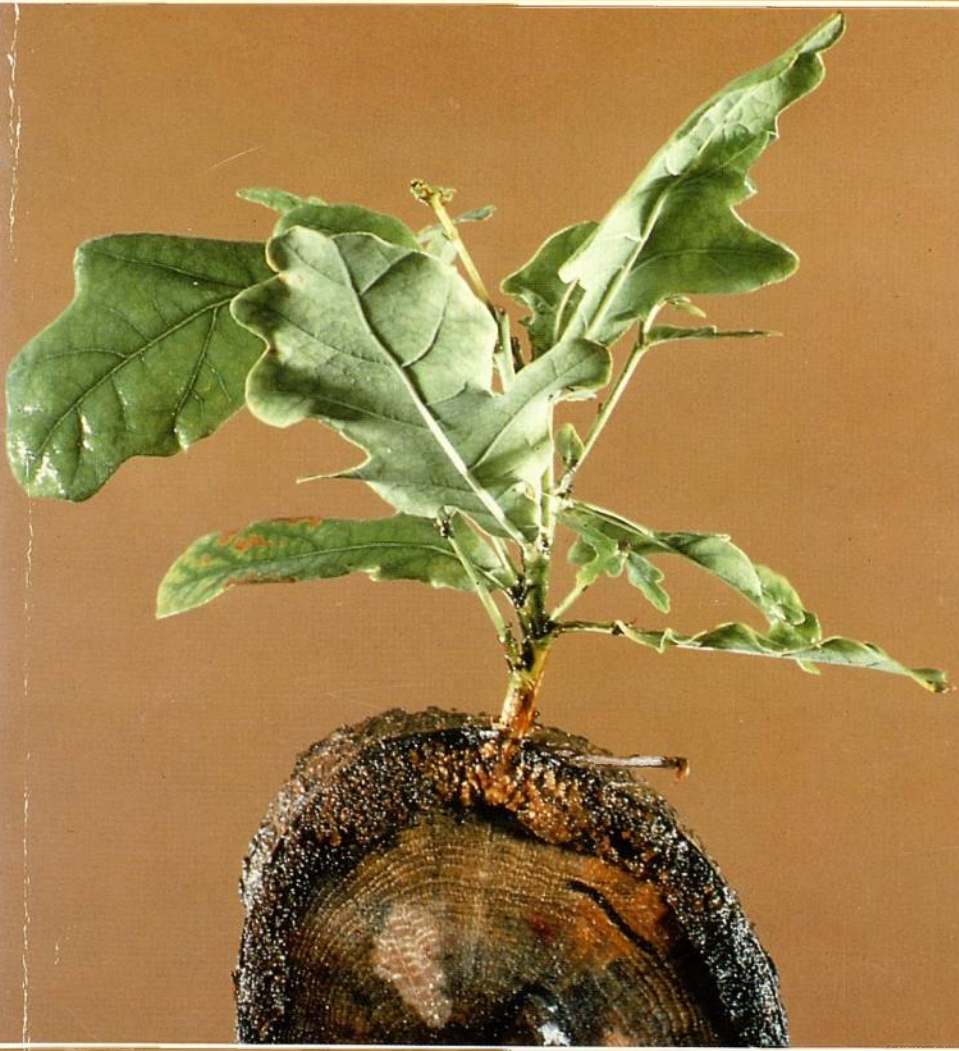
Forestry Commission



REPORT ON FOREST RESEARCH 1987

REPORT ON FOREST RESEARCH

for the year ended
March 1987

LONDON
HER MAJESTY'S STATIONERY OFFICE

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Front Cover: Oak shoots growing from suppressed epicormic buds following partial burial of a section of branch wood in a mixture of moist peat and sand. (*CS37345*)

Back Cover: Agroforestry experiment in Radnor (Powys) where a grass sward has been established under a re-spaced 9-year-old Japanese larch stand to test the effects of agricultural rates of fertiliser on tree growth and form. (*C.M.A. Taylor*)

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PART II

WORK DONE FOR THE FORESTRY COMMISSION BY OTHER AGENCIES

APPENDICES

INTRODUCTION

By A. J. GRAYSON
Director of Research

Advisory Committee on Forest Research

Two areas of the Division's work were reviewed by visiting groups in the course of the year. The first, under the leadership of Mr J. W. Dodds, Managing Director of Fountain Forestry Ltd., assisted by Mr B. O. Hall of the Building Research Establishment, considered communications between researchers and our customers. The principal recommendations were to strengthen links and in some cases to form new links between the organisations concerned; steps have been taken to implement these changes. Traditionally, our customers have been those managing Forestry Commission forests and those managing private woodlands on estates. The visiting group also recognised that a new clientele is likely to develop, made up of farmers. It is clear that research communications with this audience can never be as close as with the forestry profession and, with the agricultural advisory agencies, steps are being taken to ensure that communications of the appropriate kind and level are directed towards this new audience.

Whatever the target chosen for an organisation's communications, the measurement of success is intensely difficult. There is a dearth of expert advice based on proven experience to guide managers in this field. At one extreme there are the studies of diffusion of, for example, agricultural innovations by agricultural historians and economists, at the other the use of market research methods by those concerned with selling consumer goods or parliamentary candidates. Despite the inherent difficulties of assessing the penetration of research findings and advice based upon them, we have begun a study analysing the ways in which and extent to which research advice is carried into practice. The purpose is to investigate lags and penetration of particular lines of advice issued in recent years with a view to understanding reasons for variation in these features and enhancing performance. It may well be that the medium is the vital area for improvement rather than refinement of the content of the message.

The second visiting group was led by Professor H. G. Miller, Professor of Forestry at Aberdeen University, assisted by Dr M. Cary, Irish Forest and Wildlife Service, and reviewed work on tree nutrition. Their principal scientific recommendations related to the study of differences between the results of fertilisation as applied in practice and those obtained in experiments and to the need to analyse more fully the long series of fertiliser experiments undertaken by the Division. The first of these recommendations is being investigated in collaboration with Work Study Branch. The subjects of the two visiting groups are intensely practical areas in which the contributions to greater efficiency in satisfying forestry goals can more clearly be identified than in many fields of research. I am grateful to members of the groups for their most helpful and practical advice.

Forestry Research Co-ordination Committee

The Committee continued with the review of the main fields of forestry research. Responses to the reports of three review groups were issued: these

related to research on forestry and the environment, biotic damage to forests, and farming and forestry in the uplands. Two further groups were formed to review research on arboriculture and research on forest economics. The Committee monitors the actions of the agencies responsible for financing research in relation to the agreed action set out in each response to review groups' recommendations. Work has continued on the subject of research evaluation and a paper was in an advanced stage of preparation at year end.

Alternative Land Use and Rural Employment (ALURE)

As noted in my 1985 *Report* (Introduction, p. 3), policies leading to continued over-production of farm crops have become increasingly difficult to defend. It is interesting to note that the latest in the series of timber trends studies prepared by the Economic Commission for Europe (ECE) and FAO which was published in 1986 concluded that there would be continued growth in European wood consumption and supply. Unlike earlier ECE/FAO studies, this latest review concluded that the increase in demand would broadly balance that of supply. This view is in contrast to earlier ECE/FAO studies, though not, it must be said, recent analyses by the US Forest Service, which had foreseen increasingly tight supply leading to higher prices. However it is clear that in other European countries, as in Britain, the desire to reduce import dependence is strong.

On the agricultural front different considerations currently apply, notably among which is the prominent impact of support on the EEC's budget, and restriction of growth in supply is now favoured. In February 1987 the government issued papers under the above title of ALURE, a major theme of which was the desirability of diversification of farm output away from edible crops. Trees are important in this connection and a farm woodland package was proposed. This would offer, in addition to Forestry Commission planting grants, an arrangement for bona fide farmers to be given annual payments before the trees in plantations attain merchantable size.

An alternative system of tree growing to that of conventional woodland is the establishment of trees at wide spacing combined with the maintenance of some form of food cropping between the trees. After a period determined by the competitive ability of the trees and their spacing, agricultural output falls close to zero. Experimentation in this field has proved highly attractive to agricultural research institutes, as well as to forest researchers, and progress in establishing experiments is reported in following sections dealing with the two Silviculture Branches. This work is novel in such diverse aspects as methods of protection from inter-crop damage by domesticated stock and competition for light, water and nutrients. Our understanding of tree physiology and of trees' reactions to a wide variety of grassland, and even ex-arable, conditions is bound to grow as a result of these research initiatives whatever the uptake of the concept in the British agricultural scene.

Whichever system of tree growing, including dense, short rotation coppice, is adopted, it is clear that more knowledge and understanding is required in two fields, apart from the clearly technical one. The first concerns design in all its aspects, from at one extreme the detail of mixtures of trees, shrubs, herbs and grass desirable to supply wood, game and other wildlife and visual amenity, to, at the other extreme, the lay-out of boundaries, drains and species which have their influences on the wider countryside scene. Increasingly we

shall encompass these aspects in our work on the enhancement of conservation values in lowland woods. The other area is more the province of the rural sociologist, economist and social historian. It is clear that, if trees could be made to grow in a way that meant there was no long gap between installation and first harvest and the annual net income was comparable to that of existing food crops, the problem of the shift to one non-edible crop at least would disappear. Short rotation coppice offers one route to this end but the value at farm gate is hardly likely to be higher than that of small roundwood produced by conventional means.

In contrast to that of farmers the longer term horizon of foresters is associated with quite different attitudes both to the design of the system of production of raw material, notably its flexibility, and to the choice of method of conversion with, historically, a dependence on a less clearly defined standard of commodity than may be common in other branches of manufacturing industry. Forest owners have moved on from the attitude well expressed by Lord Caernarvon who, according to Pepys, asserted that wood was "an excrescence of the earth provided by God for the payment of debts" and yet for any product requiring a long period of gestation this remains a very useful function. Although increasingly with time, wood producing systems have been geared to particular markets, the study of the lives of forest enterprises and forest stands themselves is one of adaptation to change. Exceptionally, one system which has enjoyed great stability occurs in that archetypically traditional country, West Germany: Spessart oak continues as it has for some centuries to be grown on a 300 year rotation for veneers.

Elsewhere the changes in utilisation of wood products, in conversion methods and harvesting technology have continued to upset the carefully laid plans of forest managers. There is here a major theory explaining this history of the long-lived tree facing short-lived fashions bursting to get out. The immediate need in relation to farm forestry and the shorter cycles that it will engender is that the future orientation of research in the technical field calls for fuller understanding of the development of both wood producing and wood using industry since any new source of supply has to be integrated with existing ones. The other area of research interest relates to the attitudes of a new category of tree grower and his responsiveness to the special requirements of the favoured technology. So far, very few enquiries have been undertaken into this intriguing area of social behaviour.

Forest health

The effort devoted to survey, investigation and experimentation in the field of tree and forest health has increased. We have continued with the Forest Health Days in Forestry Commission Districts including participation by some private estates. The heightening of awareness, both of damage and the factors responsible for it, that has been engendered is a widely welcomed benefit of this activity. The weather of the winter of 1985/86 and the preceding autumn were associated with fungal diseases of Scots pine needles, and winter desiccation damage to a number of coniferous species. The wide scale nature of the damage and lack of correspondence with the geographical distribution of known pollution events or average pollutant loadings argue against the presence of any air pollution predisposing factor. It is the need to be able to clarify whether there are such interrelations between air pollution and either

other abiotic or biotic factors that is the reason for our current concentration on more detailed surveys and analyses. Accordingly, surveys designed to detect associations between air pollution and tree condition as assessed by crown thinness, needle age and needle colour continued.

The Council of the EEC approved a Regulation on acid rain in November 1986 and as a result of this plans were laid at the end of the year to establish a grid network on the original German model, though at considerably lower density. Ironically, in the same year, the need for the current intensity of the West German grid survey was questioned in the *Report* of Forschungsbeirat Waldschäden/Luftverunreinigungen, May 1986; questions also raised in my Introduction last year, *Report* 1986, p. 3. We repeated the more detailed and specific survey we have undertaken annually since 1984 and plan to intensify the cover this provides. Plans have also been drawn up for a collaborative project with the Nature Conservancy Council assessing the health of older Scots pine and beech relative to pollution gradients in southern England.

Investigation of long period evidence of shoot elongation in beech continued although attempts to associate changes in extension growth rate with causal agents, including climate, have not been wholly successful. Experimental work in open-top chambers has concentrated on methods of assessment, using Scots pine seedlings and various poplar cultivars as test material. Growth of the fine roots of the former have been shown to be reduced by high ozone concentrations and by ozone concentrations occurring in east Hampshire.

Studies have continued of the origins of the different races of the Dutch elm disease fungus, including surveys of parts of Soviet Central Asia for assistance with which I gratefully acknowledge the help of the USSR authorities. Work has also continued on the unravelling of the competition between aggressive and non-aggresive forms of *Ophiostoma (Ceratocystis) ulmi* at the epidemic front of the former. Efforts have been concentrated on the relative rates of population growth of different clones of the aggressive strains and the evolution of new clones. This work is important to our understanding of the wilt disease organisms generally, a matter of concern to foresters at all times, but especially in the context of oak wilt disease in the eastern states of the US and reported increases in incidence of oak decline in SW USSR and SE Europe.

We have continued to receive valuable help from colleagues in Belgium with the supply of new stocks of *Rhizophagus grandis*, the predator of the Great spruce bark beetle (*Dendroctonus micans*), and further useful collaboration with the USSR has been achieved through a visit to the Caucasus.

Wind

The most dramatic evidence of wind damage is windthrow and windbreak: severe local damage in southern England was caused by a gale on 27 March 1987. So far as upland forests and the study of damage by 'endemic' gales are concerned, our principal current aim is to establish more precisely the wind climate of stands as influenced by thinning and in particular to understand sway phenomena. In addition refinement of the present windthrow classification is in hand.

Upland restocking

An aspect of crop establishment which has concerned many research disci-

plines in recent years is that of the poor success in restocking certain upland sites. In contrast to afforestation of the same land, the establishment of a successor crop has proved time consuming and the many operations needed have made establishment expensive. A multi-disciplinary team was formed early in 1986 to determine cost-effective systems to improve restocking. Its leader is a member of the Branch most concerned with the applied end of work to this goal, Silviculture (North), and membership includes other researchers and representatives from other Divisions in Headquarters.

Wildlife and conservation research

The Division's Wildlife Branch has long included work aimed at assisting managers to achieve conservation goals, whether in relation to animals, plants or habitats, as part of its remit. In keeping with the responsibilities placed on the Commission by the Wildlife and Countryside (Amendment) Act 1985 and following the Forestry Commission's announcement in 1986 of its initiatives in the field of nature conservation, we have strengthened this Branch in order to encompass work on conservation explicitly and to give added attention to in-house work and to the design of studies to be conducted through commissioned research.

A meeting under the title 'Ecology and conservation in UK forests' was held with the British Ecological Society in April 1986. This led to the suggestion, which was widely welcomed, that a specialist forest ecology group be formed. Steps to bring this into being were in hand at the year's end.

Timber research

The bulk of Forestry Commission research on wood science and utilisation is done by commissioning studies. In the course of the year, a Timber Research Group was formed to take over the functions of two committees progressing research into wood utilisation. The principal function of the Group, which includes main contractors and which I chair, will be to advise on the selection, design and appraisal of all timber research projects funded by the Commission. The Group will exchange views with the Technical sub-committee of the Home Grown Timber Advisory Committee and with an informal liaison meeting of sawmillers and the Forestry Commission's Harvesting and Marketing Division: final decisions on the commissioning of studies in this field will remain the Forestry Commission's.

Conferences, courses and visits

The number of conferences attended by staff at home and abroad continues to increase, those of a primarily scientific nature being highly valued. Overseas visits, excluding EEC business meetings, numbered 40 compared with 36 in 1985/86. Training and the provision of advice absorbed a significant element of the time of Silviculture (South) Branch especially, this increase in activity arising mainly on account of the introduction of the new broadleaves policy in late 1985. It is pleasing to report a substantial increase in interchanges with farmers, farm advisers and agricultural researchers through visits to both Research Stations.

Staff and visiting scientists

Mr G. D. Holmes retired as Director General in November 1986. He joined the then Research Branch in 1949 and, after a field appointment in north Wales, served as Director of Research for 5 years to 1973, when he became a Commissioner. He was appointed Director General in 1976. Mr Holmes' contribution to the development of British forestry over the post-war era has been a powerful one. His period of direct involvement with research in the field of seed and silviculture was one of great activity and much innovation, and subsequently, in higher management posts, his influence in ensuring that forest research was supported and its relevance to forest practice maintained has been of the greatest importance. It was therefore a pleasure to wish him farewell officially at occasions at both Alice Holt and the Northern Research Station. At a commemorative tree planting at Alice Holt Mr Holmes planted a *Quercus robur* and Mrs Holmes a *Liriodendron tulipifera*.

Mr Roger Lines, a pillar of northern silvicultural research, retired in March 1986 and was honoured with the award of an O.B.E. For his services to forestry, Dr W. O. Binns also received a richly deserved O.B.E. Drs C. M. Brasier (Pathology Branch) and M. P. Coutts (Physiology Branch) were awarded Individual Merit Promotions to Grade 6 (SPSO).

I regret to report the death shortly after his return from the XVIII IUFRO Congress at Ljubljana of Mr Robin Carnell who had in recent years done much to bring foresters and water engineers together in the study of effects of trees and forest operations on water quantity and quality.

A valuable role in the work of the Research Division is played by students. Their contribution is important and we are pleased to provide the training and experience, the number concerned in 1986/87 employed for 3 or more months being 30.

It is pleasing to report that three visiting scientists worked in the Division during the year. Dr Jay Jacobson of the Boyce Thomson Institute, Maryland, USA worked on open-top chambers at Alice Holt. Dr G. Kile, of CSIRO's Tasmanian Regional Laboratory has also been working at Alice Holt with the Pathology Branch. Dr R. Jalkanen of the Finnish Forest Research Institute has been studying frost hardiness of Sitka spruce with the section of the Pathology Branch at the Northern Research Station.

The Division's complement of non-industrial staff remained unchanged over the year. Gross expenditure and income from contracts were broadly unchanged in real terms (as measured relative to the most general index of prices, the implicit GDP deflator).

PART I

The Work of the Forestry Commission

RESEARCH DIVISION

SEED

Research

Laboratory experiments

Astragalus glycyphyllos is a woody shrub thought to have potential for establishment on mine spoils and other waste sites prior to afforestation. Following a request to test a seed sample of this species, an extensive literature search failed to discover any information on pretreatment or germination methods for this species and it was therefore necessary to select techniques which experience led us to believe might be successful. Most legumes possess a coat imposed dormancy, which prevents or retards both imbibition and embryo emergence, and chipping was therefore selected as one potentially suitable pretreatment. Since the germination of many species benefits from a moist chilling period of 3–4 weeks, this was selected as another. The pretreatments were also applied in combination, and the results are shown in Table 1. Clearly, separate chipping and chilling are each beneficial, but when applied in combination, chipping followed by chilling is the best sequence to adopt.

Table 1 The maximum percentage germination of *Astragalus glycyphyllos* (at 35 days) at different temperatures and after different pretreatments

Pretreatment	Germination temperature °C		
	15°	20°	20/30°
Untreated	nd	10	nd
Chipped only	nd	24	nd
28 day prechill only	50	60	66
Chilled, then chipped	61	61	88
Chipped, then chilled	96	96	98

nd = not determined

Service

Official Seed Testing Station (OSTS)

Over the last 4 years a number of databases and applications programmes have been developed by the Statistics and Computing Branch in conjunction with the OSTS. These have facilitated easier input, analysis and retrieval of routine seed test results. This year, only one additional file, assisting seed analysts with the 'Allocation of seed tests', has been added. The computerisation programme is virtually complete.

In 1985 the FC OSTS organised a Referee Test on behalf of the International Seed Testing Association (ISTA) (*Report* 1985, p. 6). The purpose of the test was to monitor the ability of OSTS's throughout the world to employ the methods prescribed by the ISTA for the germination of Douglas fir (DF). All the results have now been returned and analysed and Table 2 shows the maximum percentages of normal germinants obtained with and without prechilling by the different stations. Numbers have been used to refer to the stations as a means of preserving anonymity.

Table 2 Maximum percentages of normal germinants obtained with (PC) or without (NPC) prechilling, by different stations

Station number	Lot 1 % germination NPC	PC	Lot 2 % germination NPC	PC
1	64	84*	71	89*
2	71	91*	81	91*
3	62	67*	65	69* O/T
4	86*	86*	89*	85
5	73	88*	79	91*
6	31	72*	40	75* O/T
7	86	90*	81	94*
8	62	77*	60	82*
9	68	82*	71	86*
10	41	84*	58	88*
11	83	95*	88	92*
12	O/T 60*	6	O/T 43*	5
13	73	89*	73	90*
14	73	83*	78	89*
15	66	83*	74	87*
16	83	88*	89	94*
17	80	84*	89*	89*

* indicates station's highest percentage of normal germinants.
O/T indicates station is out of tolerance.

Table 2 shows that most stations observed as high, or higher, germination from prechilled seed as from unchilled. However, two stations surprisingly reported the opposite. Since ISTA prescribe 'double' germination tests (± PC) but do not specify which results should be reported in preference, comparisons of like with like could not be routinely adopted without automatically discriminating against the two stations in the minority. The solution agreed by the referee test committee chairman was to give overriding priority to comparing the *highest percentage of normal germinants* obtained by each station, regardless of which test result (NPC or PC) was used. Statistical analysis then showed that one station (Number 12) was out of tolerance for both seedlots, and two stations were out of tolerance for DF lot 2. These stations were asked to make every attempt to find the cause of the problem by carefully reviewing their testing equipment, techniques and classification of seedlings, and then to remedy any faults.

P. G. GOSLING

SILVICULTURE (SOUTH)

Lowland silviculture

Tree shelters

Until recently most tree shelters were produced from white polypropylene which, while being effective in promoting plant growth, did not fit well in the rural scene. Latterly manufacturers have offered shelters in a variety of shades of brown, green and yellow. The addition of coloured dyes to the shelter material affects both the nature and amount of light received by the young plant. Forest-based experiments undertaken in a range of locations through southern England have examined how colour (*Report* 1986, pp. 8–9) and opacity of shelters affect plant growth.

In a series of experiments designed to determine the influence of light levels on the growth and survival of transplants in tree shelters the white polypropylene base material was overprinted with screens of black and three shades of grey. The performance of transplants in these shelters, in the standard white shelter, in a shelter made from clear PVC and in a plastic mesh guard was assessed regularly.

Figures 1–4 illustrate the effects on a variety of plant growth parameters. In initial tests it was clear that apparent relative illumination within shelters (i.e. light levels expressed as a percentage of full ambient light) could vary substantially depending on techniques employed in measurement. The scale used in these figures relates to an average of several measurements taken at the base of a tree shelter held upright in oblique, clear sunlight. These percentages should not therefore be extended or applied to conditions outside the scope of this experiment, though it is useful to realise that a typical brown shelter is likely to lie within the range 60–70 per cent interception on this scale.

The height increment curves (Figure 1) suggest that this parameter will not be affected by normal interception levels, though a coloured shelter used in an already shady position might simulate the conditions encountered in the darker grey shelters, where a decline in height growth was observed. The diameter development (Figure 2) declines at higher light levels than height increment suggesting that a degree of etiolation is responsible for maintaining height growth at interception levels between 86 and 92 per cent.

In the middle of the second growing season a proportion of the plants were excavated. It can be seen from the root:shoot ratios in Figure 3 that these are generally not affected by light levels, the decline in shoot development being roughly paralleled by the same effect underground.

In field practice possibly the most important parameter is that of survival (Figure 4). With oak and ash, both light demanding species, survival was not affected other than by the most extreme treatments. With the shade tolerant beech, however, survival began to decline as soon as light levels fell below ambient.

M. J. POTTER

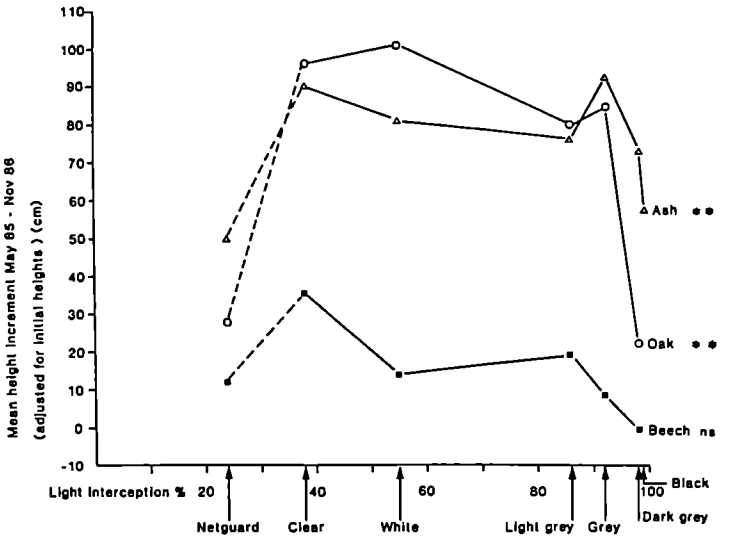

Figure 1. **Effect of tree shelters on height increment.**
ns = not significant, ** = significant at $p<0.01$; all comparisons refer to differences between treatments within each species.

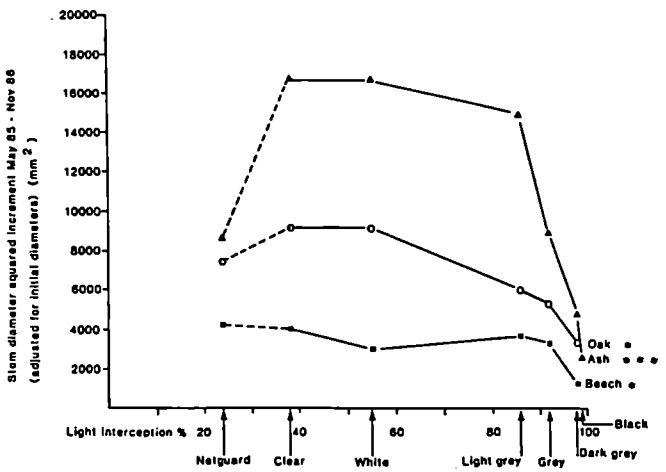

Figure 2. **Effect of tree shelters on stem diameter.**
*** = significant at $p<0.05$, *** = significant at $p<0.001$; all comparisons refer to differences between treatments within each species.**

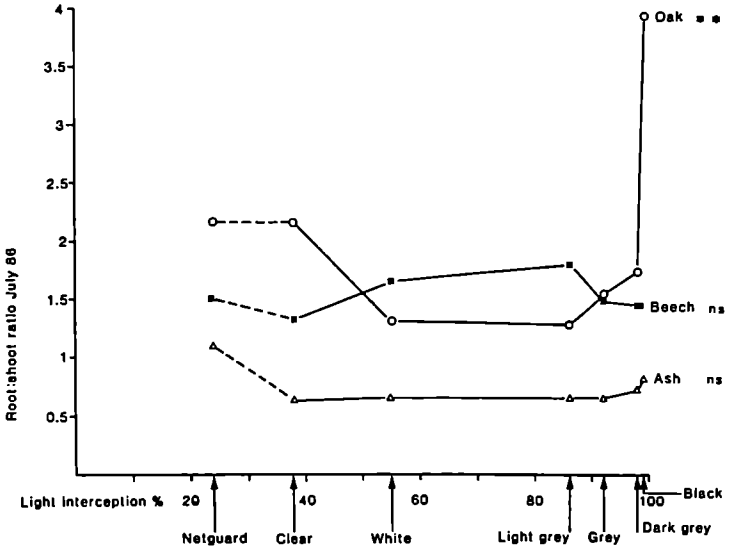

Figure 3. **Effect of tree shelters on root:shoot ratio.**
ns = not significant, ** = significant at $p<0.01$; all comparisons refer to differences between treatments within each species.

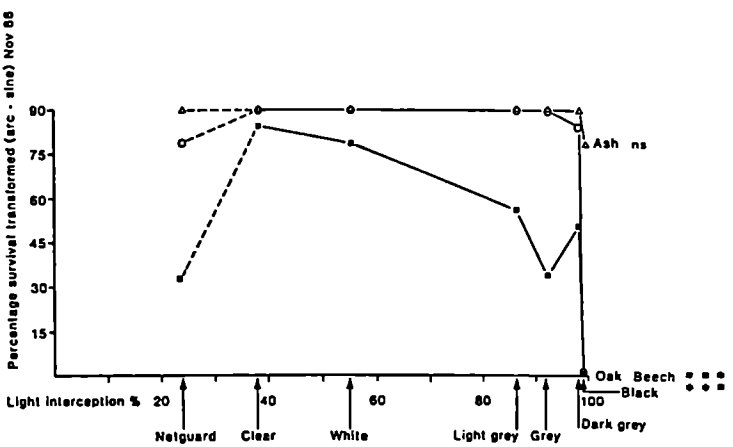

Figure 4. **Effect of tree shelters on survival of transplants.**
ns = not significant, * = significant at $p<0.001$; all comparisons refer to differences between treatments within each species.**

Plant production

Vegetative propagation

Experiments were carried out under automatic mist in glasshouses to compare the effects of different treatments on the rates of rooting of softwood cuttings of sycamore, ash, Wild cherry and Small-leaved lime. Sycamore and ash cuttings were taken from old trees in annually trimmed hedges, cherry cuttings were collected from imported 2-year-old transplants and lime cuttings were taken from nursery stools cut back each winter. The cuttings, prepared and inserted in July and early August, were examined in early autumn to assess numbers of live cuttings, callus formation and root initiation and development.

The work showed that with sycamore, apical cuttings have higher rooting rates ($p<0.05$) than sub-apical cuttings, cuttings dipped in 2-naphthyl acetic acid (NAA) dust in talc at 2000 ppm (Murphy rooting powder) root better ($p<0.05$) than untreated cuttings or cuttings dipped in an NAA solution at 2000 ppm (Rhizopon), while cuttings inserted in a vermiculite:peat (75:25) substrate root better than those in a bark:peat (50:50) substrate. The best combination of treatments led to 80 per cent of the cuttings developing a good root system. In the case of ash, apical cuttings had a higher rooting rate than sub-apical cuttings, Rhizopon was found to depress the rate of rooting and insertion in vermiculite:peat significantly improved rooting ($p<0.05$). The rate of rooting varied considerably (38 per cent to 85 per cent) from one tray of cuttings to another; the best treatment combination led to 50 per cent of the cuttings rooting. The experiment on cherry was designed primarily to test root initiation in polyurethane foam blocks and to observe the behaviour of the rooted cuttings in different potting composts. Results so far show that cuttings in vermiculite:peat root better than those in polyurethane blocks which, in turn, root better than cuttings in a bark:peat substrate.

The experiments on lime revealed that cuttings inserted in pure bark or bark:peat substrates have significantly higher rooting rates ($p<0.01$) than cuttings in a vermiculite:peat rooting medium, while rooted cuttings from each of the three substrates potted-on into a soil based compost have a lower survival rate, poorer health and slower growth rate in the first season than rooted cuttings potted-up in a standard peat based compost or in two bark based composts. In a third experiment on lime, apical cuttings rooted better ($p<0.01$) than sub-apical cuttings, and storage of cuttings up to 16 days in plastic bags at a temperture of 2°C had no effect on their rooting ability. The best treatment led to 92 per cent of the cuttings developing a good root system.

A large programme of propagation was also undertaken for other research Branches. 3000 cuttings of Sitka spruce, 500 cuttings of Scots pine and 4000 cuttings of poplar were rooted for the Site Studies (South) air pollution project. 500 Sitka spruce were grafted for this investigation. More than 1000 elm cuttings were rooted for Pathology Branch and 60 cuttings of Bird cherry and 200 cuttings of sallow were rooted for Entomology Branch. Additionally 150 cuttings of one oak clone were rooted for a Silviculture Branch experiment and 400 cuttings of Small-leaved lime were rooted for the East Hampshire Hangers Project.

J. JOBLING

Arboriculture: Department of the Environment contract

Arboriculture Advisory and Information Service

During the review period the current arboriculture research contract was completed and a new contract between the Department of the Environment and the Forestry Commission was signed. The new contract under which the Arboriculture Advisory and Information Service operates is for the 3 years 1987 to 1989. This contract also covers research into plant production, establishment and management (pp. 13–15) and decay in amenity trees (pp. 47–48).

In order to streamline the administration of 'Assistance with Arboriculture Reading', annual subscriptions now provide for the supply of photocopied articles. Arboriculture Research Notes continue to be in demand. Four new titles were published during the year (see p. 70). When necessary, texts of existing Arboriculture Research Notes are being revised. In order to ensure that practitioners have the most up to date research results copies of the revised texts are being sent to all subscribers.

Requests for advice continued at the level of recent years, 2101 enquirers received replies to their questions. The proportion of enquiries from private tree owners fell compared with previous years. Agents damaging trees – pests, diseases, environmental factors and cultural practices – continued to give rise to the most common enquiries. Advice on the management of mature trees, that is how to maintain them in a safe condition by pruning and tree surgery, was frequently sought by both owners of trees and consultants. In spite of the generally wet weather there was continuing concern about the effect of tree root activity on man-made structures. Requests for information about careers and training were also an important element of the Advisory Service's work.

D. PATCH, F. R. W. STEVENS

Plant production, establishment and management

An experiment has been established in a disused sand pit in Norfolk to test the effects of various ground-cover species (including grasses, wild flowers, legumes and small shrubs) on tree establishment. The taller ground-cover species protected the newly planted Scots pine seedlings from the severe cold dry winds of early 1986; some of the unprotected trees were killed. But after one growing season survival of pine which are surrounded by vegetation has fallen slightly below that of pine in bare soil; and the diameters of the pine in bare soil are significantly greater than those of pine surrounded by vegetation ($p<0.001$). Survival, height and diameter growth of the birch seedlings were greater in bare soil than where the ground-cover species had been allowed to grow nearer the trees ($p<0.001$, $p<0.01$ and $p<0.01$ respectively). These early results suggest that all the ground-cover species will be detrimental to tree establishment.

An experiment was established in Thetford Forest to test the effects of different standards of weed control on tree establishment. The site is dominated by grasses, but there is some bracken and the herbicides have encouraged some broadleaved weeds to colonise the area. Contact herbicides are being applied at various frequencies ranging from a single pre-planting application to fortnightly applications. Because contact herbicides are used

there is some weed regrowth between herbicide applications. The nine treatments are:

1. control, no weeding;
2. regular mowing;
3. pre-planting autumn glyphosate application (G);
4. G + paraquat application in April;
5. G + 3 paraquat applications between April and September;
6. G + 4 paraquat applications between April and September;
7. G + 5 paraquat applications between April and September;
8. G + 7 paraquat applications between April and September;
9. G + 13 paraquat applications between April and September.

Figure 5 shows first-year growth in this experiment. The sycamore transplants grew better the higher the standard of weed control. The same trend is apparent with the birch transplants, but many of them suffered die-back. This

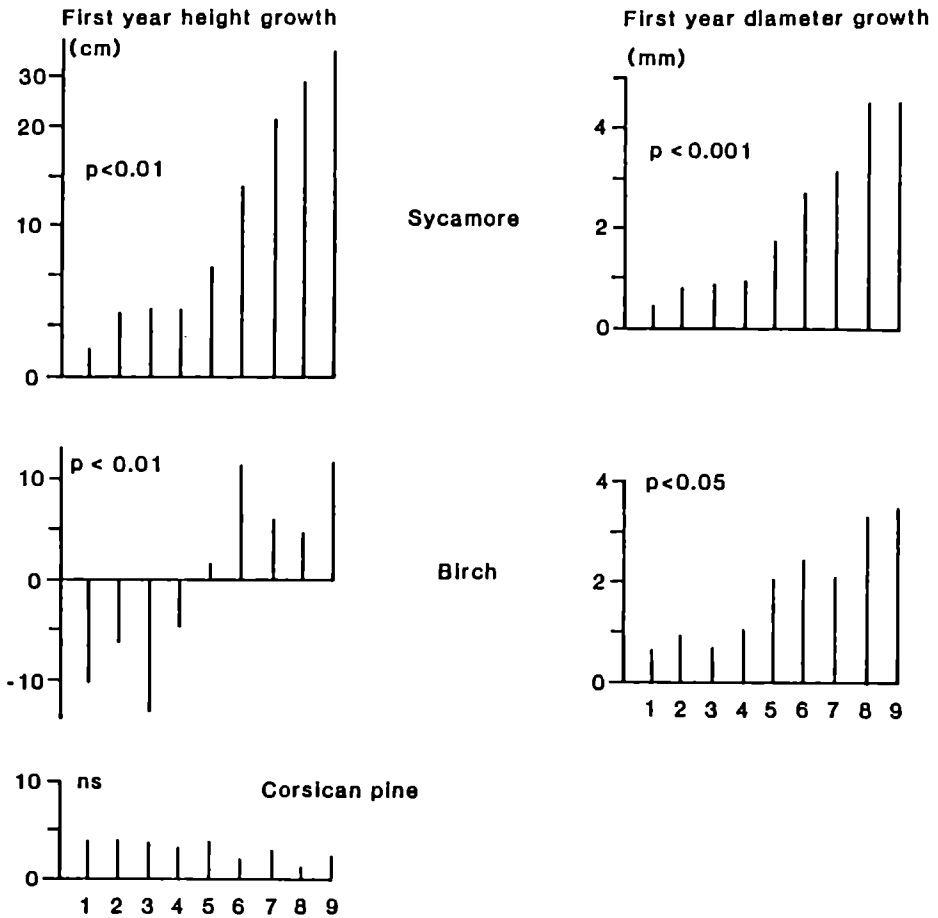

***Figure* 5. The effect of nine different weeding regimes on first-year growth of sycamore and birch transplants and Corsican pine seedlings raised in Japanese paperpots. The Corsican pine were too small for assessment of diameter growth. The nine treatment means differ at the probability levels indicated.**
ns = non-significant differences ($p<0.05$).

shows as oscillations in the bar charts. The Corsican pine seedlings did not respond, possibly because their shoot growth was pre-determined by the buds they formed in the polyhouse in which they had been raised. These results suggest that even weed cover which is sparse by current forestry standards can check tree growth.

In the staking experiment established in 1985 (*Report* 1985, p. 10) all the unstaked cherry and rowan standards (which were between 2 and 2.5 m tall) stayed upright: staking was unnecessary. Staking increased height growth, but diameter growth on the lower stem was depressed by all but the shortest of the stakes tested (these short stakes extended 0.5 m above ground). The same experiment also compared three pruning regimes. Pruning increased the height growth of both species. Pruning depressed the diameter of the lower stems of the cherry, but increased it higher up the tree. With the rowan, pruning increased the diameter growth of the upper stem, and one pruning regime also slightly increased lower stem diameter growth, but the other regime reduced it. Pruning increased the size of, and concentration of macronutrients in, the leaves produced in the first year; so that pruned trees looked healthier than unpruned trees. It is clear that pruning affects tree growth, but these results neither support nor detract from the theory that pruning at planting helps tree establishment by redressing the root:shoot ratio which is inevitably depressed by transplanting.

In a series of experiments using avenues of broadleaved trees up to 100 years old (*Report* 1985, p. 10), foliar nutrient concentrations, particularly nitrogen, have in most cases been boosted by applying compound fertilisers. Growth responses have been less evident, but these may take longer to show. However, 100-year-old Common lime at Tatton Park in Cheshire appear to have responded ($p<0.05$): mean 2-year diameter growth of unfertilised and fertilised trees were 4.2 and 5.4 mm respectively. Removal of the ground vegetation with herbicides increased the foliar nutrient concentrations and growth in most of the younger avenues, but not the older ones. Soil augering, which may be used to relieve compaction or as a means of applying fertilisers, has had little effect in any experiment.

R. J. DAVIES

Forest weed control – bracken

Work continued on a new technique of bracken control. Soil acting herbicides are applied as a ribbon of relatively concentrated herbicide along the centre line of each inter-row. Following success with dicamba and hexazinone (*Report* 1986, p. 10) these chemicals plus imazapyr were used on a restocking site at Ringwood (Hants). The site, which had previously grown a crop of Japanese larch, was shallow ploughed and planted with Corsican pine transplants in March 1986. Herbicides were applied at the beginning of April and end of May of the same year.

The April application proved most effective and good control of bracken was achieved with dicamba and imazapyr. Bracken control with hexazinone has proved disappointing. None of the herbicide treatments damaged the planted pine. Work is now taking place to study the effects of herbicide application from November to April. The technique offers great flexibility of timing and simplicity of application at a time when access is easy before frond development.

D. R. WILLIAMSON, D. ELGY, C. W. SHANKS

Establishment of Corsican pine

An experiment was laid down at Thetford in April 1986 to compare the survival and early growth of Corsican pine planted as JPPs (Japanese paperpots), transplants and new Lännen Ecopots. The Lännen Ecopots are similar to conventional JPPs but are designed to be separated a row at a time in the trays by stripping off the intercellular walls, leaving a naked 'plug' of peat and root to be planted. The trees were planted into a restock site which had been shallow ploughed and received routine maintenance and protection. At the end of the first growing season there was no difference in survival but the height increment of the transplants was superior ($p<0.01$) to that of the JPPs or Ecopots.

An experiment was established to test the effect of the third and fourth annual doses of atrazine on Corsican pine at two sites at Thetford. The experiment was laid out in March 1986 on existing restocked sites which had already received two annual doses of 8–10 l atrazine treated ha^{-1}. On both sites the third dose of atrazine did substantially reduce the percentage vegetation cover but gave no increase in height or diameter increment and did not affect tree health.

D. R. WILLIAMSON, S. E. MALONE, T. D. COOPER

Arboreta

Westonbirt Arboretum, Gloucestershire

The revised 10-year Working Plan (1986–1995) was introduced. The objects of management remain (i) to maintain and extend the tree and shrub collection, (ii) to make the collection publicly available, (iii) to use the collection for silvicultural and arboricultural research, (iv) to provide educational facilities, and (v) to respond to enquiries on tree matters from the general public.

Whilst almost 186 000 people visited the arboretum, including some 15 000 children who used the Education Centre, maintenance of the collection was achieved to a high standard. Almost 500 taxa were planted in the spring of 1987, including 89 new taxa. The collection almost escaped winter (1986/87) damage until the severe gales of late March 1987, when over 100 mature specimens were uprooted or broken off.

M. L. PEARCE

Bedgebury National Pinetum, Kent

Work progressed with the development of the new glades area. Within the oriental glades, 50 new specimens were planted with the aim of enhancing the collection and adding attractive colours to the site in years to come. The dwarf conifer collection continues to be an extremely popular attraction with visitors. Work is now progressing on a new dwarf conifer layout adjacent to the exisiting Visitor Centre. A team of planning consultants has been commissioned to submit a feasibility study on a Forest Recreation and Interpretive Centre, which will include the Pinetum as a major contributor to the scheme.

J. A. McINTYRE

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

Agroforestry

Members of the two Silviculture Branches have been actively involved in a UK agroforestry research discussion forum which has been set up to co-ordinate the approaches to agroforestry research of the organisations involved. The main organisations involved are the Forestry Commission, the Macaulay Land Use Research Institute, the Institute for Grassland and Animal Production, Edinburgh University, UCNW Bangor and the Institute of Terrestrial Ecology, who are all actively involved in setting up agroforestry network experiments. The forum also has links with Queen's University Belfast, the Irish Forest and Wildlife Service and the Open University. The forum met four times in 1986/87 and has agreed a common set of treatments for a network of major long-term agroforestry experiments on a range of sites in the uplands and lowlands to be planted in 1987/88. At each site, sycamore will be planted at 5 m and 10 m spacings in grazed pasture and at 2 m spacings in a conventional forestry plantation. A grazed open pasture control will also be maintained. Detailed records of meteorological data, animal and tree production will be kept, and a range of other tree species will be grown on the same sites according to local conditions, particularly hybrid larch on the upland sites and ash on the lowland sites.

Lowland agroforestry

A lowland agroforestry study team with one member from Silviculture (South) Branch and two from the Animal and Grassland Research Institute (now the Institute for Grassland and Animal Production) published its economic model of a lowland agroforestry system using ash trees and grazing animals (Doyle *et al.*, 1986). The model assessed the implications for the combined income from the sale of wood and livestock of varying the annual rainfall, annual application of fertiliser, density and planting pattern of the trees and size at which the trees are felled. Results suggest that combining sheep production with ash trees grown for timber on land that receives <150 kg nitrogen ha^{-1} $year^{-1}$ could be financially more attractive than either pure grazing or plantation forestry, at a discount rate of 5 per cent. Much care is needed in interpreting the results of this model as many of the assumptions used have not been validated.

Upland agroforestry

Following the study team report on agroforestry in the uplands (*Report* 1986, p. 19) experimentation has begun. The first experiment was established at Glentress (Borders) in conjunction with the Hill Farming Research Organisation (now part of the Macaulay Land Use Research Institute) and Edinburgh University. Here, three areas of Sitka spruce of different height (3, 5 and 8 m) were reduced to 4, 6 and 8 m spacing. Within these stands growth of pasture is measured directly in sward boxes sown with perennial ryegrass and sunk to ground level in a stratified layout. Various microclimate parameters are also being monitored to gain an understanding of the effect of canopy structure on microclimate and the consequences for pasture growth.

Another experiment has been established in Radnor (Powys) to test the effects of agricultural rates of fertiliser on tree growth and form. An area of 9-year-old Japanese larch was respaced to 200–300 stems per hectare, under which a grass sward has been established. This was grazed by sheep throughout 1986 and three levels of nitrogen fertiliser will be applied in 1987 now that the site has settled (Back Cover).

In conjunction with the Welsh Plant Breeding Station, a species trial has been planted at Bronydd Mawr experimental farm (Powys). Ten species, six conifer and four broadleaved, will be monitored to determine their potential in an agroforestry system. This research is necessary since it is not certain which species will produce high quality timber when grown at wide spacing on upland sites.

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

Reference

Doyle, C. J., Evans, J. and Rossiter, J. (1986). Agroforestry: an economic appraisal of the benefits of intercropping trees with grassland in lowland Britain. *Agricultural Systems* **21**, 1–32.

Nursery herbicides

Joint experiments were carried out at Bush (Lothian), Newton (Grampian) and Headley (Hampshire) to test herbicides for use in nurseries. At Bush, metamitron and napropamide were tested on Sitka spruce and Japanese larch for pre-emergent use on seedbeds in comparison with a standard (diphenamid). Four rates of each product were used; results were promising, particularly since low rates of each gave good weed control without crop damage. Some promising alternative herbicides to simazine for use on freshly lined-out transplants (Sale and Mason, 1986) were tested on summer lined-out Sitka spruce. Oxadiazon caused crop damage, but both napropamide and oryzaline gave good weed control without crop damage. Development of alternatives to simazine is of particular importance because a number of nurseries are experiencing problems with simazine-resistant groundsel (Mason and Williamson, 1987).

At Headley three rates of napropamide, metramitron and oryzaline were compared with the standard diphenamid treatment for pre-emergence application to seedbeds of Sitka spruce, Japanese larch, Corsican pine, Douglas fir, Common alder and birch. Oryzaline gave excellent weed control but was too damaging on all tree species. Napropamide and metramitron gave promising results, napropamide gave similar weeding times to diphenamid while metramitron gave higher weeding times at all rates. Japanese larch was the only species which did not appear tolerant of the higher doses of metramitron or napropamide.

W. L. MASON, D. R. WILLIAMSON

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Mason, W. L. and Williamson, D. R. (1987). Control of simazine resistant weeds in forest nurseries. *Forestry and British Timber* **16** (2), 27–28.

The need to weed

Effective weeding has consistently improved the survival and growth of broadleaved trees on mineral soils in England (Davies, 1985); competition for moisture and nutrients appears to be the main cause. However, Sitka spruce in upland experiments has usually not responded to weeding and where it has responded, competition for light appeared to be the main reason since cutting the weeds was as beneficial as killing them (Tabbush, 1984). These contrasting results may be related to differences in climate, soil, weed species or tree species. To elucidate the relative importance of these factors a series of experiments using a range of broadleaved and coniferous species has been established on sites in England, Wales and Scotland. Tree growth responses to weeding were clearly visible in the first year with conifers in the southern experiments (Plates 1 to 4). Responses were not apparent with any species in the northern experiments except for a notably poor batch of Hybrid larch at Wykeham (Yorks) which did show benefit from all the weeding treatments compared with the control in terms of height and survival after one growing season.

R. J. DAVIES, P. M. TABBUSH

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Tabbush, P. M. (1984). Effects of different levels of grass weeding on the establishment of Sitka spruce. *Proceedings, Crop Protection in Northern Britain 1984*, 339–346. SCRI, Invergowrie, Dundee.

SILVICULTURE (NORTH)

Production of planting stock

Vegetative propagation of Sitka spruce

First cycle cuttings of Sitka spruce are normally collected from 2-year-old stock plants grown in polythene greenhouses (Mason, 1984). A trial at Newton Nursery (Grampian) examined whether stock plants could be reared successfully outdoors under less capital-intensive conditions. Yield of cuttings from out-door plants was substantially lower, being 45 cuttings per plant as opposed to 86 for the recommended regime. However, in a cold season when rooting in unheated mist houses was frequently depressed, rooting percentages of cuttings from outdoor plants were higher than for cuttings from plants grown indoors (98 and 69 per cent rooted respectively; $p<0.001$).

Collecting cuttings some weeks prior to insertion and placing them in cold storage allows nursery managers to spread their workload. Experiments at Bush Nursery (Lothian) re-examined the effects of cold storage (0° to +2°C) on rooting performance and included a comparison with freezer storage (−2°C to 0°C). Results again confirmed a detrimental effect of cold storage after 3–4 weeks. However, there was no significant effect of freezer storage upon rooting performance for cuttings stored for up to 6 weeks.

Earlier work (*Report* 1985, pp. 13–14) indicated poorer rooting performance of second cycle than of first cycle cuttings and suggested this could be caused by nutritional regimes. An experiment at Newton compared first cycle cuttings with second cycle cuttings from plants given four different top-dressing regimes. The best rooting percentage for a second cycle treatment was from plants given a balanced NPK feed, and was not significantly different from first cycle cuttings (98 and 99 per cent rooted). Both were better ($p<0.05$) than second cycle cuttings from plants given standard top dressing regimes (90 per cent rooted) with NPK in a 10:1:5 ratio.

In another experiment at Newton, there was no significant difference in rooting percentage in half-sibling cuttings from five different propagation cycles (i.e. 2–10 years old from seed). Differences in root volume were found, with second, third and fifth cycle material being poorer ($p<0.05$) than first cycle cuttings. However, the lack of a consistent decline with increasing age suggests nutritional regimes may be involved (see above). This indicates that repeated propagation is at least partially successful in maintaining juvenility (c.f. St Clair *et al.*, 1985).

The trial of plants produced by micropropagation (*Report* 1986, p. 15) continued. Again, no significant differences were found between these and seedling controls.

Vegetative propagation of Hybrid larch

An experiment at Bush nursery contrasted first and second cycle hardwood cuttings inserted in two different media (peat:grit and peat:bark mixtures) with four different rates of basal fertiliser. Overall rooting was 94 per cent with no differences between the two cycles after 24 weeks; greater rooting volume was obtained with higher rates of fertiliser. This result, combined with those of earlier years (*Report* 1986, p. 16; *Report* 1985, p. 14; *Report* 1984, p. 15) suggests that a reliable propagation system has been developed

for Hybrid larch. Limitations to commercial development of the system are due to a shortage of guaranteed F_1 seed.

Precision sowing and undercutting

The large-scale trial at Wykeham nursery (N. Yorkshire: *Report* 1986, p. 16) continued for a fourth season. An investigation into the interaction between undercutting and top-dressing regimes showed that additional nitrogen applications were required to maintain adequate nutrient status once undercutting had started.

The effect of cold storage on precision sown and undercut stock and on conventional transplants was examined in an experiment at Wykeham. Douglas fir and Sitka spruce were lifted and placed in the cold store (0 to +2°C) at regular intervals from mid October to April: all treatments were planted on the same date in April on a cultivated site. Overall, undercut plants showed higher survival than transplants ($p<0.001$). In Douglas fir, undercut stock showed consistently better survival than transplants from the mid December lift onwards. In Sitka spruce, both plant types showed equally good survival after the mid December lift, but prior to that only undercut stock had satisfactory survival. These results suggest both that undercut plants are better conditioned to withstand cold storage and that intensive undercutting could extend the recommended periods for lifting plants to store (Tabbush, 1987).

Forest experiments comparing undercut stock and transplants continue to demonstrate the better performance of the former. The most striking improvements in survival have been found with Douglas fir (Table 3), but lesser gains have also been found with Scots pine. In Sitka spruce, both plant types normally survive equally well, but undercut plants frequently show better height increment in the first year after planting. Wider use of a precision sowing and undercutting system should result in improved planting stock quality and survival, especially with Douglas fir.

Table 3 First year survival of Douglas fir (%) of different production type

	1u1	1+1	1+2	Significance
Hambleton 7 P85	94	43	–	$p<0.001$
Wykeham 157 P85	93	69	–	$p<0.01$
North York Moors 1 P86	93	73	75	$p<0.001$
North York Moors 2 P86	69	39	46	$p<0.01$
Glenurquhart 3 P86	94	37	53	$p<0.001$

1u1 = precision sown and undercut stock
1+1 and 1+2 = transplants

W. L. MASON

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St Clair, J. B., Kleinschmit, J. and Svolba, J. (1985). Juvenility and serial vegetative propagation of Norway spruce clones. *Silvae Genetica* 34(1), 42–48.

Tabbush, P. M. (1987). *Safe dates for handling and planting Sitka spruce and Douglas fir.* Research Information Note 118/87/SILN. Forestry Commission, Edinburgh.

Planting

Plant handling

Collaborative work with the Institute of Terrestrial Ecology on the seasonal variation in root growth potential (RGP; number of new roots per plant after 14 days under test conditions) and associated physiological parameters has continued (*Report* 1986, p. 7). Clear seasonal trends were established for Sitka spruce and Douglas fir (Figure 6). RGP for freshly lifted Douglas fir was generally lower than that for Sitka spruce, and this partly explains the sensitivity of the former species to poor plant handling, especially in relation to cold soils (Tabbush, 1986). Cold storage generally held the RGP of Sitka spruce at the levels found at lifting, although the RGP of plants lifted in November increased for 2 months during storage. RGP increases throughout the winter as bud dormancy is released in response to the satisfaction of a chilling requirement (Ritchie and Dunlap, 1980), and the increase for Sitka spruce lifted in November is interpreted as the result of partial dormancy

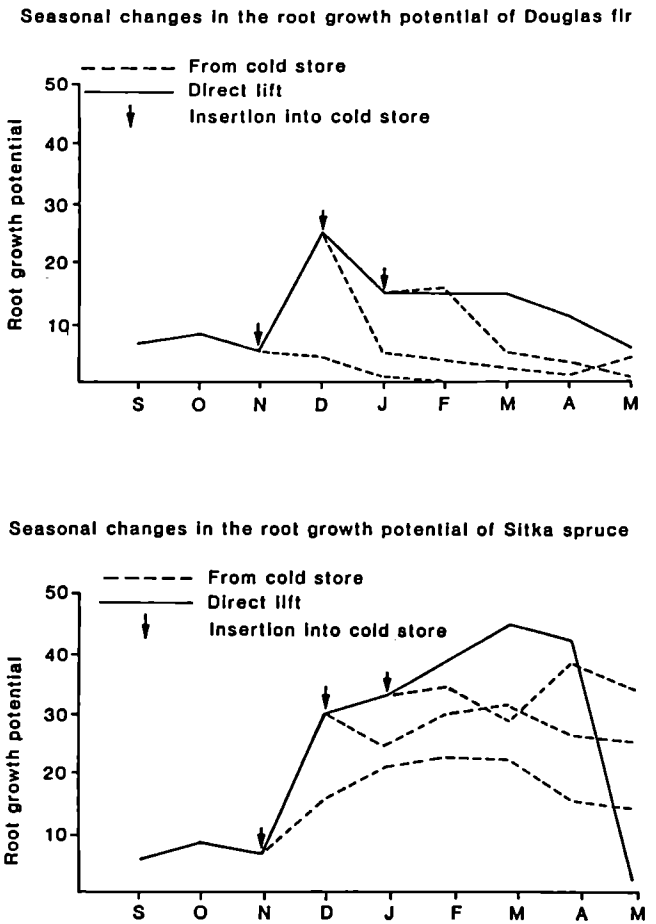

Figure 6. **Seasonal variation in root growth potential (number of new roots per plant after 14 days under test conditions) for Douglas fir and Sitka spruce.**

release under the store conditions. Examples from the May assessment of Sitka spruce root growth in observation boxes are shown in the photograph (Plate 6). By May, the freshly lifted plants (extreme right) had very low RGP and the RGP of cold stored stock was higher the shorter the storage period and the later they were placed in store (left to right). The freshly lifted plants broke bud and produced new foliage during the test despite their sparse root growth. Plants in this condition are less likely to survive and grow well, since the poor root system will be unable to meet the demands of the developing shoots. Douglas fir performed badly partly because of the wet conditions in the nursery during 1985. However, the decline in RGP during cold storage is consistent with previous results.

Another experiment at Bush investigated the effects of mechanical shock on RGP in Sitka spruce following a period of cold storage. Treatments involved dropping sealed bags of plants, which had an average package weight of 750 g, from a height of 3 m on to a hard floor, 0, 5, 15 or 25 times. RGP was assessed in a growth chamber before or after a subsequent period of 6 weeks in cold storage (1±1°C) (Table 4).

Table 4 Root growth potentials (numbers of new roots >1 cm in length per plant) for Sitka spruce after a range of rough handling treatments assessed before or after 6 weeks cold storage

	Number of drops			
	0	5	15	25
Before cold storage	15.3	9.6	4.7	3.7
After cold storage	20.4	13.6	5.3	6.5

Insertion into cold store was in early January and RGP rose during storage for all treatments ($p<0.05$). The effect of rough handling was significant ($p<0.001$) and there was no interaction between rough handling and storage, i.e. rough handling effects were not increased or reduced by cold storage.

Forest weed control

Three experiments at Kilmichael (Argyll), Ae (Dumfries and Galloway) and Mynydd Du (Gwent) included monthly applications of granular and liquid propyzamide on grass and herbaceous broadleaved weeds. At Kilmichael and Mynydd Du liquid propyzamide applied by 'spot-gun' gave a greater percentage vegetation control than granular application, whilst at Ae granules were more effective, particularly on *Agrostis* spp. However, during the period of maximum efficacy, December–January, differences between formulations were small.

Application of glyphosate of various concentrations by paint-brush to the freshly cut stumps of *Rhododendron ponticum* at Benmore (Argyll) every other month from May 1984–March 1985 resulted in almost total prevention of regrowth in all treatments. The most dilute solution tested contained one part product (36 per cent ae glyphosate) and three parts of water.

Chemical thinning

At Glentrool (Ayrshire) glyphosate product (36 per cent ae) was diluted in

water to give 10, 25, 50 and 100 per cent solutions for injection into the stems of Sitka spruce planted in 1952. Injection was by 'spot-gun' with solid stream nozzle delivering a 2 ml dose to a downward slasher cut at breast height. Treatments were applied every other month from April 1984–February 1985. Only the undiluted product gave acceptable results with more than 95 per cent of Sitka spruce up to 10 cm diameter at breast height being killed by a single 2 ml dose applied at any time of year. Trees of larger diameter would require two cuts on opposite sides of the tree and each cut should receive 2 ml of undiluted product.

P. M. TABBUSH

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Nutrition

Investigation of interaction between genotype and nutrient use efficiency

In nutrient deficiency demonstrations interesting differences in Sitka spruce growth have emerged between individual trees. This was particularly striking in those plots where phosphorus and potassium were the deficient nutrients. These differences appeared to be genetically based and were large enough to warrant investigation of the interaction between genotype and nutrient utilisation. A preliminary experiment has been established in large peat-filled boxes where the response of 16 Sitka spruce clones to four levels of phosphate application will be measured.

Nitrogen requirements of different spruces

Field and experimental observations on Alaskan Sitka spruce and White spruce/Sitka spruce crosses suggest that they have lower nitrogen requirements than QCI Sitka spruce. To test this, an experiment comparing these provenances with and without nitrogen fertiliser has been established on a nitrogen deficient deep peat in north Scotland. This may lead to a broadening of the range of lower input alternatives for such sites.

Sewage sludge

The continued vigour of sludge-treated trees on the heathland site (*Report* 1985, p. 17) and promising response to a sludge application in a small trial on a former opencast site have encouraged further investigation in co-operation with the Water Research Centre. Two potential site types have been identified, that is, restocking on poor heathland soils and reclamation of opencast coalmine sites, which both suffer from low availability of nitrogen. Sewage sludge will both supply readily available nitrogen (ammonium) and act as a longer term source of nitrogen (organic-N).

C. M. A. TAYLOR

Cultivation, site preparation and drainage

Results of a 15 year basal area assessment for a large restocking cultivation experiment at Wykeham (North Yorkshire) have been analysed. The experiment compares different intensities of cultivation on an ironpan soil with a

strongly compacted subsoil, and also contrasts the performance of Sitka spruce with alternative species in clear felled and strip felled areas. The previous crop was mainly low-yielding Scots pine, and the felling brash was cleared prior to cultivation. The five treatments in order of increasing intensity are:

0 no cultivation control;
DR deep ripping;
SF spaced deep furrow ploughing;
DC deep complete ploughing;
DCR deep ripping plus deep complete ploughing.

The results for Sitka spruce on the clear fell area show the progressive decline in growth advantage of intensive cultivation that has also been noted on another ironpan cultivation experiment at Teindland (Grampian) (Wilson and Pyatt, 1984). At year 6 at Wykeham mean heights for treatments DC and DCR were significantly greater than for treatments SF and DR ($p<0.05$), which were in turn significantly greater than for treatment 0 ($p<0.01$). At 15 years there were no significant differences in basal area between the five treatments. In contrast, both Lodgepole pine on the clear felled area, and Grand fir on the strip felled area continue to show significant height and basal area gains with increasing intensity of cultivation.

In conjunction with Site Studies (North) Branch, boreholes have been installed in a cultivation experiment established in 1984 on a peaty gley site at Glendaruel (Strathclyde). The two treatments to be compared in this study of borehole water levels are standard D45/T60 ploughing, and hand-cut planting turves placed over 60 cm deep mole drains. Boreholes have been sited adjacent to the line of cultivation, and also midway between these lines, in order to provide a further comparison.

C. P. QUINE

Reference

Wilson, K. and Pyatt, D. G. (1984). An experiment in intensive cultivation of an upland heath. *Forestry* **57**(2), 117–141.

Stability

New impetus has been given in both basic and applied research into plantation stability. The applied work will concentrate upon windthrow prediction and aims to validate, refine and extend the Windthrow Hazard Classification. A series of monitoring areas will be established throughout upland forests to allow data collection on the onset and progression of windthrow. These areas will be selected to represent a range of hazard classes, soils, topographies, and stand types. To date, suitable areas have been located in Leanachan Forest (Highland), and Tywi Forest (Powys), in addition to those at Glentrool Forest (Dumfries and Galloway) already noted (*Report* 1986, p. 22). A further four areas are envisaged and suitable forest sites are being sought.

The strategy for future basic research into the interaction of the tree canopy with the wind, and into the effect of topography on airflow is being reviewed. Potential study methods include wind tunnel work at Oxford University, further aerodynamic experiments in forests, topographic modelling, and computer simulation. The scope for collaboration with other research agencies is promising.

C. P. QUINE, B. A. GARDINER

INTER-BRANCH REPORT: SILVICULTURE (NORTH) AND ENTOMOLOGY

Insecticide phytotoxicity

As part of the work of the Restocking Special Project Team (see p. 5) the root growth potential method (see plant handling, pp. 22–23) was used to assess the effects of dipping and spraying with a range of candidate insecticides for the control of the Large pine weevil (*Hylobius abietis*) and Black pine beetles (*Hylastes* spp.). Results are given in Table 5.

Table 5 Root growth potentials (RGP) (numbers of new roots >1 cm long per plant after 14 days in a growth chamber) for plants top-dipped (T) or totally immersed (R) in insecticide and heeled in until the foliage was surface dry.

Insecticide	T	R
Water	32.9	31.8
1.6% HCH as 'Gamma-Col'	9.2	0.2
1.5% HCH as 'Lindane 20'	8.8	2.5
0.5% Permethrin as 'Permit'	17.6	17.1
0.5% Cypermethrin as 'Ambush C'	14.4	12.7

RGP was reduced by all treatments involving insecticides ($p<0.001$). HCH gave the most severe reduction, especially when whole plants (including roots) were dipped. The two pyrethroids (permethrin and cypermethrin) were both much less phytotoxic than HCH, and cypermethrin was slightly more phytotoxic than permethrin. The pyrethroids acted equally when applied to shoots or shoots and roots: these plants were from cold storage with quiescent roots. The effects on active roots on fresh lifted stock are not known.

P. M. TABBUSH, S. G. HERITAGE

SITE STUDIES (SOUTH)

Chemical analysis

A method for determination of non-structural carbohydrates in tree tissue has been developed to provide information for projects relating to vegetative propagation of trees and the 'bent top' phenomenon in Sitka spruce (see inter-Branch report page 41).

E. WARD

Effects of trees on sites

The work on clear felling impact previously described (*Report* 1984, pp. 21–22; 1985, p. 21) has continued at three upland sites in Devon, Snowdonia and at Kershope in the Scottish Borders. Nutrient budgets have been calculated at Kershope and at the main experiment in Beddgelert Forest, Snowdonia. Large pulses of nitrogen, phosphorus and potassium leaching have been observed in the 3 years since clear felling at Beddgelert. Marked nitrate and potassium pulses also occurred in stream-water samples. Joint work with the Institute of Terrestrial Ecology at this site revealed that the pulse of nitrate derived from the old forest floor, whereas the pulses of phosphorus and potassium came largely from recent felling debris. An initial study of nutrient budgets suggested that soil reserves of phosphorus might support two rotations of Sitka spruce if all above-ground parts were to be harvested. Reserves of nitrogen and potassium appear adequate for several more rotations.

First-year survival of Sitka spruce transplants in both harvesting treatments was very low (Figure 7). The plants were heavily attacked by the Large pine weevil, though other causes may have contributed to the failure. Survival was

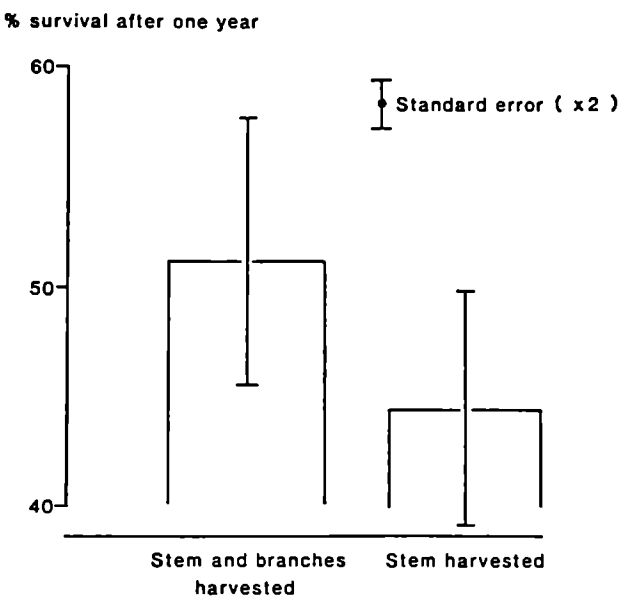

***Figure* 7. First-year survival of Sitka spruce transplants following clear felling treatments (conventional and whole-tree harvesting) at Beddgelert Forest, Snowdonia.**

higher in the conventionally-harvested than in the whole-tree harvested treatment, but the difference is not significant ($p<0.05$); better survival had been expected on the clean ground because planting is so much easier.

M. A. ANDERSON

Reclamation

Inoculation of alders

Alders have the potential to build up soil nitrogen reserves, which is important in reclamation, and to do this they must be well nodulated; nursery stock, however, is often poorly nodulated. An experiment tested the effect of inoculating open-grown seedlings of six alder species at the two-leaf stage with two strains of *Frankia* provided by the Department of Microbiology, University of Surrey; one strain of inoculum increased numbers of seedlings with nodules ($p<0.001$) and number of nodule sites per seedling ($p<0.05$) (Table 6). Apparent increases in shoot and root weight and height growth for *Alnus cordata, A.sinuata*, and *A.rubra* were not significant. Thus one *Frankia* strain produced useful increases in nodulation for some species but others, particularly Common alder, need different strains.

Table 6 Percentage nodulation of *Alnus* spp. with different inoculants. Headley, 1986

	Control	CPI3 inoculant	ARI7 inoculant
A. glutinosa	3	13	25
A. incana	43	42	63
A. cordata	21	18	43
A. rubra	22	32	48
A. sinuata	13	16	80
A. viridis	16	15	52

Inoculation of legumes

Nodulation of legumes is as important as it is with alders, but newly restored sites are likely to be poorly endowed with the nodulating *Rhizobium* species. Commercially available peat-based inoculants were tested in a pot experiment using four mine spoils (two from opencast coal spoils, one each from china clay and sand spoils) on 10 commonly used legumes. Most species showed increased nodulation and nodule sites per plant, but survival and growth of several was poor in opencast spoils. The most successful species were *Lupinus arboreus, L.polyphyllos, Lathyrus latifolius, L. sylvestris* and *Galega officinalis*.

Effects of nitrogen-fixing plants

In an experiment begun in 1980, Sitka spruce and Japanese larch planted among alders and legumes have shown a significant ($p<0.01$) increase in foliar nitrogen concentration. *Lupinus arboreus, L.polyphyllos, Alnus incana* and *A.sinuata* gave the greatest increase over unplanted controls, but so far there has been no increase in tree growth.

Amenity forestry and arboriculture

Some earlier work (*Reports* for 1982 and 1983) suggested that heat from decomposing landfill can cause undesirable soil drying and hence death of trees. A domestic refuse landfill site in Essex was reinvestigated (see Insley and Carnell, 1982) and measurements of temperature, methane, oxygen and moisture in the soil were made in August 1986. Soil moisture was, surprisingly, correlated with temperature, probably because where the cover over the landfill is thin water vapour moves upwards to condense in the overlying layers. Some measurements showed acute oxygen deficiency and high methane contents; these factors are considered more important than desiccation in causing tree deaths.

A. J. MOFFAT, C. J. ROBERTS

Reference

Insley, H. and Carnell, R. (1982). The influence of depth and type of cover material on tree establishment on a domestic refuse landfill site. *Reclamation and Revegetation Research* **1**, 225–232.

Lowland forestry

Sewage sludge

An assessment of diameter growth in a pole-stage stand of Corsican pine (planted in 1952) which was treated with liquid digested sludge from 1982 has shown small but significant ($p<0.05$) improvements in growth over untreated controls; there were suggestions that annual applications of sludge at 200 m^3 ha^{-1} gave better growth than single applications. On nutrient-poor sites, sewage sludge may offer a cheap and potentially valuable form of forest fertiliser.

At the request of the Water Research Centre, a desk exercise was undertaken to assess the suitability of forests in England and Wales for the disposal of sewage sludge. Starting from the Forestry Commission subcompartment database, forests were considered for their suitability for sludge disposal (in terms of soil type and nitrogen and phosphorus need), taking into account environmental factors such as water resource protection. Most forest districts had some potential, those with the largest being mainly in the North England conservancy and parts of Wales.

A. J. MOFFAT, C. J. ROBERTS, D. BIRD

Impact of forestry on water resources

The interaction between forestry and water resources, particularly the effects of afforestation on water quality, continue to attract attention. One aspect causing concern among those responsible for water supply and quality standards is the lack of clear and up-to-date guidelines for forest managers working in sensitive areas over acid geologies.

To help develop communication between the industries and to define and resolve technical and administrative problems, the Forestry Commission and Water Research Centre (Environment Laboratory) jointly organised a work-

shop in December 1986. A report (Solbé, 1987) has been produced and a working party from the two industries has been set up under the chairmanship of the Forestry Commission to finalise guidelines based on the report.

W. O. BINNS

Reference

Solbé, J. F. de L. G. (1987). *Forestry and the water industry*. A report of a Forestry Commission/ Water Research Centre collaborative workshop held at Burn Hall (Water Industry Training Association) near York, 8–10 December 1986. Report PRU 1413–M/1, WRC Environment, Medmenham, Marlow, Bucks.

Air pollution

Experimental studies

The sensitivity of 4-year-old Sitka spruce and Scots pine plants to an acute dose of ozone (500 ppb for 4 hours) depends upon the state and development of the foliage and the method of assessment. For Sitka spruce in the early part of the growing season only the new foliage shows visual symptoms caused by the ozone. Depending upon the individual tree, this ranges from small lesions to extensive necrotic areas. The variability of occurrence and intensity of this visual damage within a population is large. Later in the season, after shoot elongation has ceased, the foliage becomes much more resistant to damage, showing only small necrotic lesions on the edges and ribs of a small proportion of needles on some of the trees. Measuring the sensitivity as change in net transpiration caused by the ozone shows no correlation with the occurrence or the extent of physical damage to the needles of individual trees at any stage during the growing season. Large changes in net transpiration occurred throughout the growing season and variability within a population was large.

Scots pine showed similar variability in change in net transpiration within a population, but the sensitivity of the foliage increased during the season. In contrast to Sitka spruce, almost all Scots pine plants showed damage, as tip burn on the current year's foliage.

In another experiment one-year-old Sitka spruce and Scots pine seedlings were grown for 10 weeks in four different air qualities. Treatments were filtered and unfiltered air, 100 and 200 ppb ozone. The growth of the shoots and roots of Sitka spruce were not affected by the air quality. A significant reduction in the fine root (<2 mm diameter) and large root biomass of Scots pine was observed; the biomass of needles decreased with increasing ozone but the differences were not significant (Figure 8). No visual symptoms which could be attributed to the air quality were found on the foliage of either species. These experiments indicate large differences between species in the effects of and sensitivity to ozone.

Growing poplars in filtered and unfiltered air in open-top chambers showed that air quality affects the onset of leaf senescence. In unfiltered air the leaves became chlorotic and plants began losing leaves as early as mid-August. Comparing the responses of individual cultivars grown at Headley (Hants) and Glendevon (Tayside) suggests that climatic factors alter the sensitivity of the foliage to air quality. Cultivars of *Populus trichocarpa* which can tolerate the cooler, wetter conditions in Scotland showed a larger response there than varieties of *P.euramericana*. In the south-east of England the opposite effect

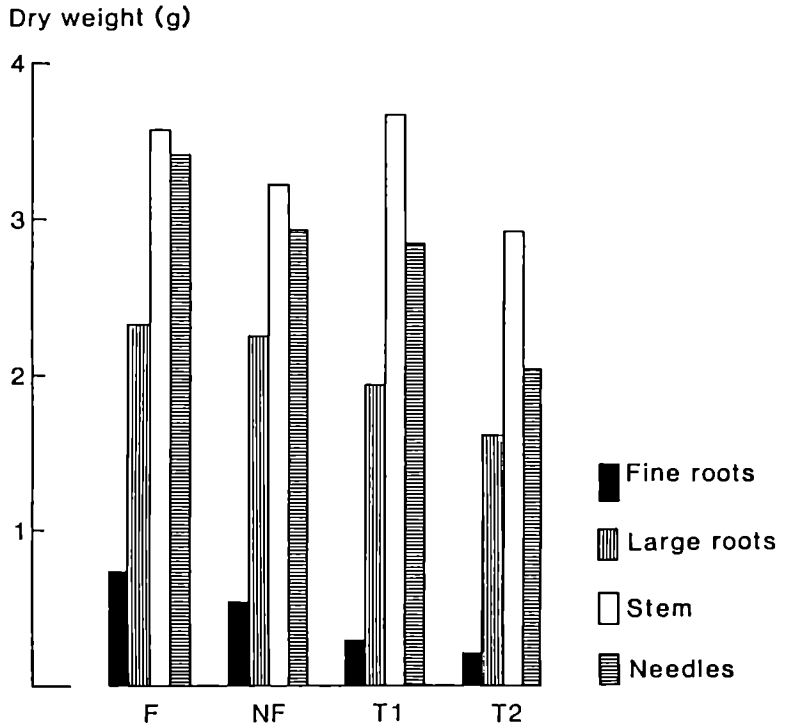

***Figure* 8. Root and shoot biomass of Scots pine seedlings grown for 10 weeks at Headley (Hampshire) in filtered air (F), ambient air (NF), 100 ppb ozone (T1), and 200 ppb ozone (T2).**

was observed, with varieties of *P. euramericana* showing most response to air quality. These results suggest that identification and assessment of air quality effects in trees under field conditions will be difficult.

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

Forest health (air pollution) survey

All the plots surveyed in 1985 were surveyed again in 1986. In addition, the survey was extended to include older stands (up to 106 years) of Norway spruce. The total number of plots is now 141 and the distribution is shown in Figure 9 (see also Innes *et al.*, 1986).

The main criteria used in the assessment of tree health are crown density, needle discoloration and needle retention. Crown density is measured in 10 per cent classes and the results from 1986, together with the results from 1985, are given in Table 7. It appears that there has been a marked decrease in that assessed crown density since 1985 and that the position is also substantially worse than in 1984.

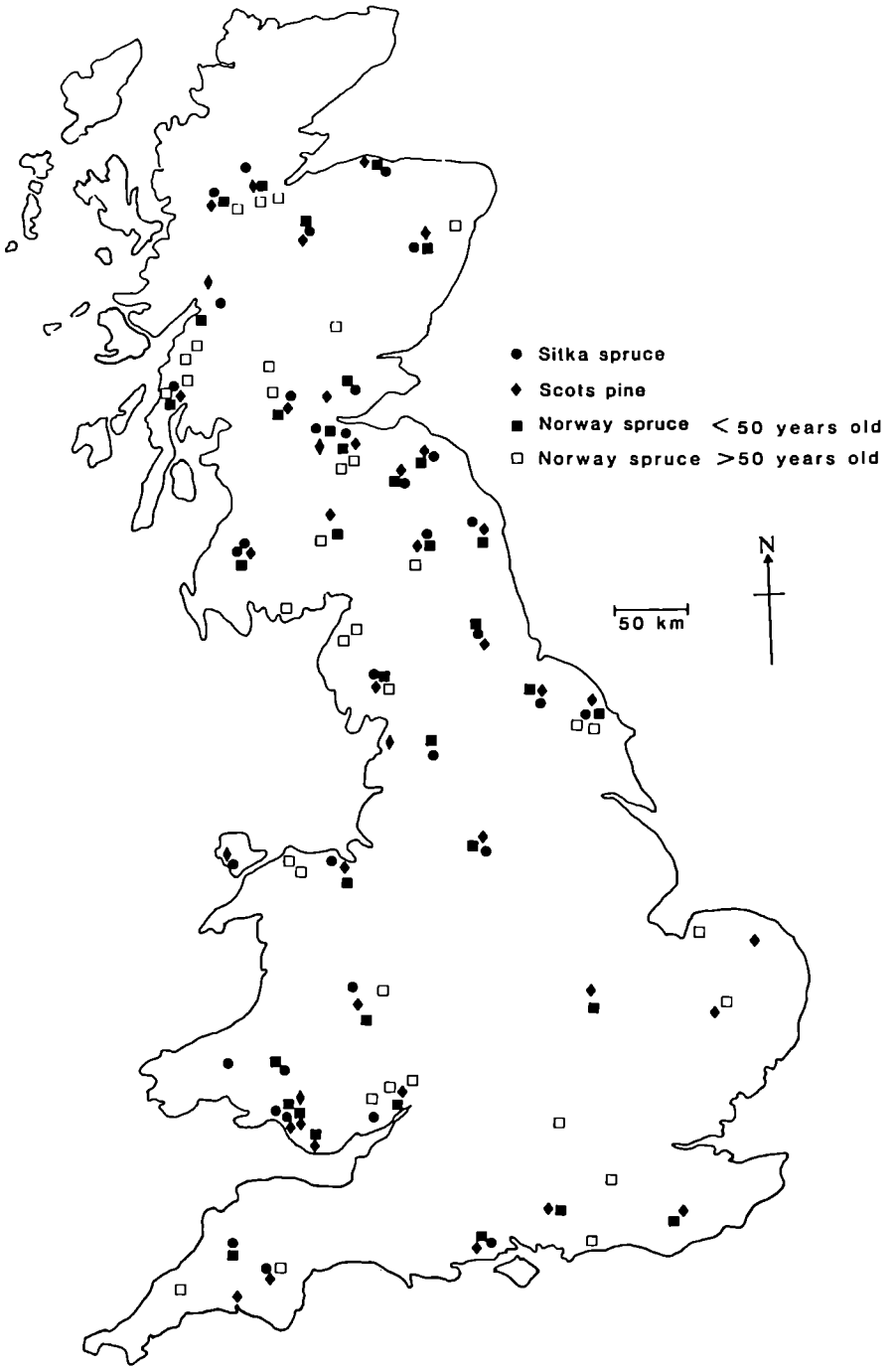

Figure 9. **Approximate location of plots assessed in the 1986 survey of forest health.**

Table 7 Forest health survey. Percentage distribution of trees by 10 per cent needle loss classes 1986; all plots. (1985 data are given in parentheses below.)

	Needle loss class									
	0	1	2	3	4	5	6	7	8	9
Sitka spruce	45	32	14	6	2	1	—	—	—	—
	(83)	(10)	(4)	(3)	(—)	(—)	(—)	(—)	(—)	(—)
Scots pine	25	31	21	14	5	2	2	—	—	—
	(71)	(17)	(7)	(4)	(1)	(—)	(—)	(—)	(—)	(—)
Norway spruce (less than 50 years old)	52	31	11	4	2	—	—	—	—	—
	(81)	(16)	(2)	(1)	(—)	(—)	(—)	(—)	(—)	(—)
Norway spruce (more than 50 years old)	11	21	27	26	9	4	2	—	—	—

Note: Class 0 = 0–10%, 1 = 11–20%, etc.

There are various possible reasons for this. Firstly, some of the increase may be attributable to a change in observer perception following more intensive training. Secondly, adverse climatic conditions in February 1986 were followed by the appearance of foliage browning in a number of conifer species including those examined in this survey. Thirdly, extensive damage by the needle-cast fungus *Lophodermium seditiosum* alone and in combination with the Pine shoot fungus *Brunchorstia pinea* and the Pine shoot beetle *Tomicus piniperda* was probably responsible for a large part of the increase in damage to Scots pine. The role of other factors, such as drought (1984), waterlogging (1985), exposure, nutrient deficiency and air pollution, remains uncertain.

In Norway spruce, both needle loss and needle discoloration were greater in older trees. The significance of this has yet to be determined.

The survey will be further extended in 1987 to include older Scots pine and Sitka spruce, together with oak and beech.

J. L. INNES

Reference

Innes, J. L., Boswell, R., Binns, W. O. and Redfern, D. B. (1986). *Forest health and air pollution: 1986 survey*. Forestry Commission Research and Development Paper 150. Forestry Commission, Edinburgh.

Advisory work

Advice on tree planting for reclamation, land fill, and particularly for sites contaminated with pollutants, has been given to a variety of agencies, suggesting that both commercial forestry and amenity woodland are land uses which are being increasingly considered for these types of site.

There has been no decrease in the number of enquiries relating to the effects of air pollution ('acid rain') on tree health; these were heightened by the publication in December 1986 of the report of the 1986 survey (Innes *et al.*, 1986).

W. O. BINNS, J. L. INNES, A. J. MOFFAT

SITE STUDIES (NORTH)

A new series of small, short-term drainage experiments is aimed primarily at light-textured gley soils in high rainfall areas. In spite of difficulties of terrain, these soils may offer better prospects for improvement than the clay soils which have proved so intractable.

Foresters are occasionally criticised by downstream users of water for increasing the turbidity of streams by ploughing and draining operations. While various modifications to practice which are now generally applied should reduce the likelihood of problems arising, it is necessary to obtain a better understanding of the process of sediment movement. A 3 year study is being commissioned from the Freshwater Biological Association, Windermere Laboratory.

Deep peats

Most of the establishment and maintenance problems of tree crops on deep peat soils have been solved, but uncertainties remain about the rooting depth and windfirmness of Sitka spruce, either pure or mixed with Lodgepole pine, which is itself capable of deep rooting on such soil. This subject, together with the silvicultural and hydrological implications of progressive drying of the peat under trees, is to be tackled in a joint project with the Macaulay Land Use Research Institute. There follows a summary of what is presently known about the effects of afforestation on the physical properties of blanket peat.

Blanket peat usually comprises three layers of which the middle one is the most variable in thickness. The upper layer of 10–40 cm is least decomposed (humification (H) value 2–5) and consists of strong *fibrous* material and varying amounts of *Sphagnum* moss together with live roots. Over a depth of 10–20 cm this gives way to *pseudofibrous* peat (H7–9) in which fibres are quite distinct but have lost much of their strength. When squeezed the peat mass is extruded between the fingers with little or no release of water. Pseudofibrous peat is initially reddish brown but darkens within minutes of being exposed to oxygen. The lowest blanket peat layer is *amorphous*, 50–100 cm thick, dark brown or black and denser than the overlying material. The amorphous layer usually contains ancient stumps and other material of pine or birch and merges with the organic-rich layer of mineral soil beneath.

The process of curing or ripening blocks of peat to make household fuel (amorphous peat is preferred) depends on the ability of peat to dry irreversibly. Treeless shallow blanket peats on the drier eastern hills commonly show that the phenomenon of irreversible drying is not limited to peat which is exposed to the sun and wind. In the amorphous layer there are shrinkage cracks several centimetres wide, which presumably form during droughts but which become permanent.

Shrinkage cracks developing in deeper blanket peats as a result of tree growth were first reported in the 1950s (Binns, 1968) occurring under the stands of Lodgepole pine planted in the 1920s. In the last decade the phenomenon has become widely distributed and it is now clear that it can be expected on all blanket peats under any species including deciduous ones.

The drying and consequent shrinkage is not appreciable, except on the plough ridge, until after canopy closure at 10–15 years. Thereafter it develops rapidly and may be fully developed by 20 years on moderately deep peat (Figure 10). The first cracks develop longitudinally in deep ditches, followed a year or two later by similar cracks in furrows and several years later by the reticulate pattern throughout the main peat mass (Plate 5). Cracking occurs in pseudofibrous and amorphous peats but not in the fibrous layer so cracks are not evident at the original ground surface.

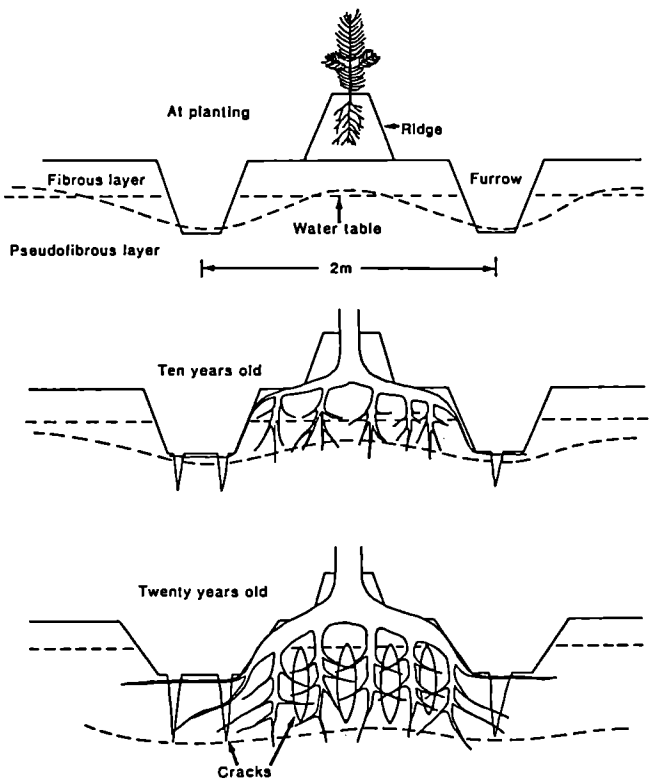

***Figure* 10. Progress of drying and cracking of blanket peat of medium depth (1.2 m) under Lodgepole pine.**

The early cracks in ditches and furrows differ from the later network; they occur in soft, very wet peat and are presumably the result of shrinkage of the whole peat mass between the ditches or furrows, the latter acting as lines of weakness to the tensile stress produced. Even at this early stage the ditches and furrows are wider than they were at planting. The cracks directly beneath the trees occur in peat which has lost much water and is fairly dense and firm.

In cracked peat the water table lies at the bottom of the cracked zone during summer and only rises a few centimetres in winter provided the ditches are still deep enough to lead the water away. Aeration of the fibrous layer improves as soon as the water table is lowered in the first few years after

ploughing. Pseudofibrous or amorphous peat remains almost saturated during the early stages of dewatering because shrinkage exactly matches the volume of water lost. Lodgepole pine seems capable of rooting into saturated peat and therefore to extend its rooting depth and drying effect more rapidly than Sitka spruce and other species.

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

Reference

Binns, W. O. (1968). Some effects of tree growth on peat. *Proceedings 3rd International Peat Congress*, 358–365.

GENETICS

Forest progeny tests

Open-pollinated families from 367 untested Corsican pine candidate trees were planted in seven experimental series over three sites in Thetford (Suffolk) and Dean & Three Counties Forest Districts. This is the largest number of Corsican pine families planted over more than one site and should identify within 8 years many superior parents which will more than double the breeding population.

Other progeny tests replicated across sites were planted and include: 47 single pair-matings between Sitka spruce clones already in the breeding population; screening of a further 81 open-pollinated families selected from candidate trees in Borgie (Highland) and Dunkeld (Tayside) for the 'Northern Breeding Population'; an investigation into the best source of White spruce pollen for use in the creation of F_1 hybrids with Sitka spruce; nine 6×6 Scots pine half-diallels; and 26 European larch mother trees crossed with a pollen mixture from selected Japanese larches.

Screening all Sitka spruce progeny tests over 15 years of age to identify open-pollinated families which combine good growth rate with acceptable wood density has begun following the preliminary work by Oxford University (*Report* 1986, p. 62). Density is measured indirectly and non-destructively using a 'Pilodyn' (Plate 7), a spring-loaded gun which fires a steel pin into an exposed area of wood; the penetration of the pin provides a measure of density.

S. J. LEE

Pollinations

Flowering in 1986 was the poorest for many years in larch, Sitka spruce and Lodgepole pine. No artificial pollinations were made in Lodgepole or Scots pines and in Sitka spruce the crossing programme was very small and restricted mainly to those clones which had been injected with $GA_{4/7}$ to stimulate flowering. This small programme allowed time for large-scale application of

$GA_{4/7}$ to all untested Sitka spruce clones and should result in heavier flower crops in 1987. A programme of polycrosses involving 68 larch clones was undertaken.

Provenance

During the year all provenance research on coniferous species was transferred from the Silviculture Branch to the Genetics Branch. A full review of all experiments is currently being carried out and all which have passed their useful life are being closed. Further work will mainly be concentrated on the series of Douglas fir, Sitka spruce, Lodgepole pine, Grand fir and Noble fir experiments established from seed collections arranged by IUFRO together with more recent experiments which compare the performances of different origins of *Picea glauca, Picea engelmannii, Abies amabilis* and *Pinus peuce*. The total number of active experiments will be reduced from 216 to approximately 120.

A. M. FLETCHER

Seed production

Seed stands and seed orchards

Twenty-nine stands were registered; 13 were refused registration and 32 were inspected under the 5-yearly cycle of reinspections. A summary of the National Register of Seed Sources is given in Table 9.

Table 9 Numbers and area of registered seed stands and seed orchards as at 31 March 1987

Species/hybrid	Seed stands		Clonal orchards	Seedling orchards
	Number	Area (ha)	Area (ha)	Area (ha)
Conifers				
Scots pine	33	1568*	17	3
Corsican pine	14	342	6	—
Lodgepole pine	29	272	—	35
European larch	15	189	—	—
Japanese larch	19	89	—	—
Hybrid larch	5	25	20	—
Douglas fir	18	97	1	—
Norway spruce	2	5	—	—
Sitka spruce	7	81	33	—
Miscellaneous	16	45	—	—
TOTAL	158	2713	77	38
Broadleaves				
Beech	21	179	—	—
Sessile oak	16	175	—	—
Pedunculate oak	29	302	—	—
Miscellaneous	9	18	—	—
TOTAL	75	674	—	—

* Mainly native pinewoods

R. FAULKNER

Biochemical variation

A computing integrator has been acquired to complement the gas chromatography equipment used in resin analysis. This facility (Trio: Trivector Systems International Ltd.) includes VDU and keyboard, high resolution printer/plotter, and floppy disc drive. Chromatograms are displayed in real time or post-run mode. Re-analysis can be carried out from raw data files stored on disc, or from raw data in memory simultaneously with data collection. Adequate facilities exist to optimise scaling and integration parameters prior to plotter print-out. The versatility of the system is of particular value when analysing conifer resin samples of high heterogeneity, and different method files can be used to control data collection and analysis of samples from different species or different sampling locations.

The increased efficiency of analysis has already become apparent in ongoing projects, notably the study of resistance to *Heterobasidion annosum*, and the variation in oleoresin composition during maturation of individual trees of various origins of Sitka spruce and Lodgepole pine.

G. I. FORREST

Computer-based information systems

All information on routine breeding work is now maintained on computer records, and all files, with the exception of those for seed and pollen stocks which are mounted on a microcomputer, are held on a mainframe computer. Each year the main database files are updated by adding recent information and resorting the combined data.

Specific details of the location and origin of all trees selected for breeding work are available, together with records of representative material maintained by vegetative propagation in clone banks or seed orchards. Two listings are issued, one sorted by clone and one by bank/orchard. When nursery stock is allocated to forest-stage progeny-tests, randomisation is carried out by computer. Layouts for use in the forest are produced together with a reference file of the unique plot numbers throughout the experiment which are associated with each entry in the test.

For each of the major species, a list of all families derived from each clone is produced, together with the same list extended to include the test-experiments in which each family is planted. The latter is then re-sorted by experiment to present the families allocated to each test. Further similar listings are produced for full-sib families and for general seed collections used either as controls in progeny-tests or in experiments to compare seed origins. After standard statistical analysis of progeny-test data, a set of overall means for each entry is stored for updating the files in which assessment and performance data are accumulated.

The national registers of seed stands, seed orchards and family mixtures used as the basis for bulk vegetative propagation are also maintained as computer files. These are issued annually throughout the Forestry Commission and specialised versions are produced in fulfilment of responsibilities to the EEC and OECD for controlling sources of reproductive material. A reference file of seed identification numbers is nearing completion.

C. J. A. SAMUEL

PHYSIOLOGY

Flowering

Coning can now be enhanced consistently on mature Sitka spruce grafts; flowering of younger trees would shorten the breeding cycle further. Gibberellin A_4/A_7 and cultural stress applied to 7-year-old potted seedlings were unsuccessful, even with $GA_{4/7}$ levels beyond those which stimulate flowering of mature grafts. However, 12-year-old trees in the field produce on average 20 seed cones and four pollen cones following $GA_{4/7}$ application and root pruning. The response probably reflects the trees' greater maturity, rather than the root pruning treatment, as the latter was unsuccessful on 6-year-old potted seedlings. The root pruning did not reduce leaf water potential during cone induction and although shoot growth and foliar nutrient concentrations were reduced there was evidence for renewed root growth in the treatment year. Flowering of 12-year-old trees could facilitate the assessments of the genetic component of tree vigour in F_1 progeny tests.

Collaborative research with physiologists at the Swedish University of Agricultural Sciences at Umeå has been started to examine changes in endogenous gibberellins in relation to flowering to extend fundamental knowledge and assist in selection of practical treatments.

Restocking

Early root growth of newly planted trees is crucial to successful establishment. A study has been initiated comparing root growth in Sitka spruce and Douglas fir. Root growth requires energy and in Douglas fir is dependent directly on photosynthesis, therefore requiring the stomata to be open (Ritchie and Dunlap, 1980). Experiments involving stem girdling, decapitation and analysis of carbohydrates indicated that Sitka spruce roots, by contrast, can begin to grow independently of current photosynthate, utilising starch reserves in the roots. Thus root growth could occur in Sitka spruce even if the shoots have suffered handling damage causing stomatal closure. These differences may help to explain why Douglas fir is more difficult to establish and more susceptible to handling damage than Sitka spruce.

J. J. PHILIPSON

Reference

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.

Adventitious rooting

A project to investigate the importance of adventitious root production in young plantations of Sitka spruce was initiated. Preliminary work indicated that such roots constitute a major component of the structural rooting system of transplants within a decade of planting. Experiments have been established to verify this and to examine the possibility of manipulating adventitious root production to the benefit of the crop.

C. WALKER

Vegetative propagation of oak

A new project was started using physiological methods to identify oak trees with desirable characteristics for use in an improvement programme. The first essential step was to develop a system for vegetatively propagating mature trees. Crown cuttings from mature trees did not root well, but success was achieved with epicormic shoots.

Suppressed epicormic buds were stimulated to grow by partially girdling the trunk during April and May. Cuttings could be taken from new epicormic shoots after leaf expansion had ended in June or July. Epicormic shoots were induced to grow out from sections of trunk or branch wood cut from the tree by standing them in water or partly burying them in a moist mixture of peat and sand and maintaining them in high humidity (Front Cover). Buds are dormant between June and September and although shoots can be forced at any other time of the year the best results were obtained in April and May. Samples collected in autumn were stored and used successfully in the spring.

When rooted under mist, cuttings from intact trees in the field gave 0–100 per cent rooting, those from logs standing in water 59–97 per cent and those from partially buried crown branches 11–50 per cent.

R. HARMER

Micropropagation

Juvenile explants of Sitka spruce can now be multiplied routinely *in vitro* and up to 80 per cent of the shoots thus produced can be rooted in conditions of high humidity in seed trays with a suitable rooting compost (*Report* 1986, p. 33). The techniques are now undergoing further development, and are being used to produce large numbers of stock plants from selected seed for the production of cuttings and to produce clonal rooted plants for studies of air pollution.

A. JOHN

Mycorrhizas

Third-season results for outplanting experiments with mycorrhizal Sitka spruce (*Report* 1986, pp. 33–34) were encouraging in new planting at Dornoch Forest District (Highland) but not at a restocking location in Kielder Forest District (Northumberland). In the former, previous height increases induced by a strain of *Thelephora terrestris* were maintained, the plants inoculated with this fungus being now approximately 29 per cent taller than the untreated controls. The Kielder experiment, however, failed to show a response to inoculation with any of the mycorrhizal fungi tested.

A second series of field trials with Sitka spruce was established at Dornoch and Kielder (*Report* 1986, p. 34). The first year results have not yet been analysed, but fruiting body production in the plots inoculated with *Laccaria proxima* indicated that the mycorrhizas had established and survived in the field.

Nursery work on mycorrhizas continues, but without success. Although mycorrhizas of *L. proxima* were established in the seedbeds, by the end of the transplanting period they had been largely replaced by naturally available fungi, and no growth differences could be detected.

C. WALKER

Behaviour of roots at discontinuities in the soil

Laboratory experiments and field observations have been started on the behaviour of the major lateral root tips of Sitka spruce on encountering discontinuities in the soil of the type caused by cultivation.

M. P. COUTTS

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

Reduced growth and bent top of Sitka spruce

Measurements on trees and their environment were continued on the 20 sites, covering a range of growth rates and tree health, in the area of forest decline in the South Wales Coalfield (*Report* 1986, p. 34). The water regimes of the main soil types have now been characterised. 1986 was even wetter than 1985, with more than 3000 mm rainfall. In August the water table was 10–20 cm below the soil surface for 2–3 weeks on some sites, inundating part of the root system.

In September/October extensive browning of older needles was observed in the lower crowns. Pathology (North) Branch has isolated *Lophodermium nanakii* from affected foliage. Defoliation associated with the fungus is followed by dieback of twigs which later become indistinguishable from that caused by the Green spruce aphid.

Analysis of the data for 1985 showed a 30 per cent increase in basal area increment compared with 1984, an increase in foliar N and a decrease in P and K. The relationship described previously between foliar K and N, and growth, was maintained. Foliar Mg increased in 1985 and the inverse relationship between Mg concentration and growth reported last year was no longer present. An experiment has been established to examine the effects of fertiliser application, including trace elements and higher than normal rates of N, P and K.

The Green spruce aphid was scarce during 1985 and spraying with malathion had no significant effect on tree growth. The insect caused appreciable defoliation of unsprayed trees on only one site in 1986.

Large variation is evident between the vigour of individual trees in crops in decline. Both vigorous and poorly growing trees have been successfully propagated by grafting and rooting cuttings to provide material for future experiments.

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PATHOLOGY

Advisory services

Scotland and northern England

The year ending March 1987 saw an unprecedented number of enquiries due in part to three extremely widespread phenomena: browning of Scots pine, winter desiccation injury and autumn frost injury. The first of these was the most dramatic and became noticeable throughout northern Britain in late winter and early spring 1986. The main agent was the needle pathogen *Lophodermium seditiosum* which had infected needles during 1985 (*Report* 1986, p. 36) when exceptionally wet weather apparently favoured the fungus. The effects of attack by *L. seditiosum* are usually confined to browning of the previous year's needles in late winter or spring. However, in a few cases, trees were partially or completely defoliated by early winter and in spring 1986 the majority of buds produced shoots only a few centimetres long. Some failed to flush at all, leading to shoot dieback.

In many cases the condition of affected pine stands, especially ones at higher elevation, was made worse by concurrent attacks by the shoot pathogen *Brunchorstia pinea* and the Pine shoot beetle *Tomicus piniperda.* Unusually for Britain, apothecia of *Gremmeniella abietina*, the perfect state of *B pinea*, were found in some profusion in one stand of Scots pine at high elevation (420 m) in a forest in southern Scotland.

Winter desiccation injury also became evident early in spring 1986 affecting a wide range of conifers but principally Sitka spruce, Lodgepole pine and Douglas fir. Although some damage was seen in trees 20 years old or more, it occurred mostly in trees less than 10 years old and was particularly serious in Sitka spruce planted in 1985 at higher elevations in western Scotland: in several such plantations a high proportion of trees were killed almost to ground level. The injury appears to have been caused by the weather of February and March. There was an unusually prolonged cold spell in February when, with little or no snow cover, the ground (and particularly plough ridges) became frozen in many western plantations. During this period winds were predominantly easterly or north-easterly. Although they may have caused some desiccation, there is evidence that the bulk of the damage followed an abrupt change to a mild south-westerly or westerly airflow early in March while the ground was still frozen. Winter injury is not uncommon in Douglas fir and Lodgepole pine (*Report* 1970, p. 118; 1979, p. 32; 1980, p. 35) but is unprecedented in our experience in young Sitka spruce. Damage of the same kind was also seen for the first time in young Norway spruce in a few exposed plantations.

Further climatic injury to young Sitka spruce occurred towards the end of the 1986 growing season when a series of frosts occurred in early September. In some areas grass minima below zero occurred every night between 8 and 19 September but the most damaging frost was probably on 9/10 September when a screen minimum of −4.3°C was recorded in the Fort William area and a grass minimum of −6.2°C in the Scottish borders. Sitka spruce was the species most widely affected and young trees in western and southern Scotland suffered severe foliage browning. In some cases lammas growth was also killed. Damage from the same frosts occurred on Douglas fir seedlings in

some nurseries and, most unusually, on 4 to 7-year-old Norway spruce in a Scottish plantation.

The year was also remarkable for the range of foliage damage that occurred. During the growing season, *Acer* spp. in particular suffered high levels of infection by a variety of fungi: *Rhytisma* sp., *Cristulariella depraedans* and *Phleospora aceris* were all found on sycamores, as were symptoms typical of infection by *Ophiognomonia pseudoplatani*. Foliage injuries from buffeting and desiccation by high winds were also common on *Acer* spp. and Horse chestnut. On conifers, two needle fungi, *Meria laricis* and *Rhizosphaera kalkhoffii*, which were recorded as noteworthy in 1985 (*Report* 1986, p. 36) recurred under unusual circumstances in 1986. The first, a well-known nursery pathogen, was responsible for browning in a number of thicket stage larch plantations in Scotland. *R. kalkhoffii* is not clearly established as a pathogen in Britain but it was consistently isolated in April from the brown tips of 1985 needles of Douglas fir at Tummel Forest District (Tayside). Later in the year a related species, *R. pini*, was associated with browning and loss of older foliage of Sitka spruce in Kielder Forest District (Northumberland). This is believed to be the first record of this fungus on Sitka spruce. Another notable record on Sitka spruce was the needle rust *Chrysomyxa rhododendri* which was found fruiting prolifically on severely infected trees in Kintyre. This rust is occasionally seen on Norway spruce but is quite rare on Sitka.

Among the nursery problems investigated was an unusually severe outbreak of *Botrytis cinerea* in large, 2-year-old Noble fir seedlings. The fungus had infected suppressed or injured lower side shoots in densely stocked seedbeds, spread into stem bases and girdled them causing the plants to die.

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

Southern England and Wales

As in the north, the low temperatures and northerly to easterly winds which occurred between late January and early March 1986 were followed by the appearance in April on many conifers of severe foliage browning, often strikingly directional. The most seriously affected species were Norway spruce, Douglas and Grand fir, *Sequoia sempervirens*, yew, certain Lawson cypress varieties and Leyland and Monterey cypress. Scots pine in Wales also showed browning but, as further north, this was consistently associated with the presence of the fungus *Lophodermium seditiosum*. Along roads, deicing salt spray undoubtedly contributed significantly to the browning of evergreens and during the summer many cases of dieback on broadleaves (mainly London plane) were also attributed to the winter use of deicing salt. In late August, Hurricane 'Charlie' caused much leaf browning and defoliation of broadleaves in the west of England and Wales. This and severe gales in southern England in late March 1987 blew down many trees.

In Wales and the Midlands, many 1985 shoots of Corsican pine were killed by *Brunchorstia pinea*. The cause of similar damage on Lodgepole pine in the same areas was not determined. Death of 1- to 4-year-old branches on 10-year-old *Pinus muricata* in Dorset appeared to be due to infections through 1-year-old needles or shoots during the 1984/85 dormant season. No fungi were isolated sufficiently frequently to be considered likely causes.

Spring 1986 was wet and the coldest since 1979, a fact which probably accounted for the numerous cases of *Gnomonia platani* on London plane and

willow scab *(Venturia chlorospora)*. Although the summer was generally cool, sunless and unsettled, symptoms corresponding to those caused by drought occurred in late summer and autumn on a number of cypress and *Thuja* species.

In 1985 and again in 1986 the death and severe stunting of many rising 1-year-old European and Japanese larch seedlings in a nursery in Sussex was associated with the use of a routine pre-emergence herbicide application of diphenamid, a practice not normally damaging. It is supposed that, in the very poor early growing season conditions, rootlets may have failed to extend quickly enough beyond the herbicide layer to escape injury.

In 1984 *Seiridium cardinale* was found to have been cankering branches on a 70-year-old Western red cedar in Dorset for at least 7 years, and a similarly infected 15-year-old tree was found in Surrey in 1986 – the first records of such damage to *Thuja* in Great Britain, although the fungus was seen on leaves of young plants in 1983 (*Report* 1984, p. 33). In 1985, several large, perennating cankers were examined on an unusually green-barked Common ash *(Fraxinus excelsior)* in Avon. The fungus *Phomopsis scobina* was fruiting profusely on the dead bark and was isolated from canker margins. Macdonald and Russell (1937) demonstrated the pathogenicity of *P. scobina* to ash but this is only our second record of the disease since 1953.

Occasionally over the last few years we have examined seedlings or seed growing in Japanese paperpots or germinating on blotting paper in germination tanks where the peat medium and the paper have been quickly overgrown by the white mycelium of *Peziza ostracoderma* Korf. The colour soon changes to fawn with the development of conidia, and then ochre-yellow. Observations have suggested that this is harmless at least to the principal species involved (Corsican pine).

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

Reference

Macdonald, J. A. and Russell, J. R. (1937). *Phomopsis scobina* (Cke) V. Hölm. and *Phomopsis controversa* (Sacc.) Trav. on ash. *Transactions of the Botanical Society of Edinburgh* **32**, 341–352.

Dutch elm disease

Origin of Dutch elm disease epidemics

Surveys to identify the geographical source of the different strains and races of the Dutch elm disease pathogen *Ophiostoma (Ceratocystis) ulmi*, thought to be in Asia, are continuing. In September 1986, samples were collected from two locations in Soviet Central Asia, with the assistance of the Forestry Ministry of the USSR. In the Tashkent area, Uzbekistan, where the disease was first reported in 1939 (Rovski, 1939), the EAN aggressive was predominant, and the non-aggressive also present (1 non-aggressive in 212 isolations) indicating that, as in Europe and North America (Brasier, 1983) a first epidemic caused by the non-aggressive subgroup of the fungus has more recently been superseded by a second epidemic caused by the aggressive subgroup. Both *Scolytus scolytus* and *S. multistriatus* vector beetles, together with *S. kirschi*, were plentiful in the area.

In the Dushanbe area, Tadjikistan, elms *(Ulmus androsowii, U. densa* and hybrids with *U. pumila)* were plentiful in the city, pastures and roadside plantations but no symptoms of Dutch elm disease, foliar or internal, were found. Breeding galleries of a *Scolytus* sp. close to *S. multistriatus* were present in stressed dying trees but no *O. ulmi* was obtained from the galleries. Hence this region may have escaped Dutch elm disease through being isolated by geographical barriers. However, an *Ophiostoma* sp. possibly close to *O. piceae*, found in association with scolytid beetles, was very similar to another *Ophiostoma* found in association with *S. scolytus* at Rubena, Spain in 1984 (see Table 10), and could represent an archetypal fungal associate of elm bark beetles.

Dynamics of the aggressive/non-aggressive interaction at current epidemic fronts

It has been postulated that the arrival of the aggressive subgroup of *O. ulmi* in an area results in a short-lived peak in the non-aggressive sub-group, followed by its decline and replacement (Brasier, 1983). Studies in central Spain in 1984 support this conclusion. In areas of endemic disease, elms were largely healthy and disease symptoms caused by the non-aggressive subgroup were difficult to find. By contrast, in epidemic outbreak areas, characterised by massive infection levels and rapid disease progress, the non-aggressive subgroup was present in abundance. At five sites (Table 10 a–e) it comprised between 31 and 87 per cent of the *O. ulmi* population; and at five more sites (f–j) was the only form of the fungus recorded. Resampling 6 weeks later at one of these latter sites (f) still failed to yield the aggressive subgroup from twigs but it was found on 9 out of 52 beetles associated with diseased bark. Thus evidence was provided that the recent arrival of the aggressive subgroup had led to an explosive build-up of the non-aggressive, resulting in multiple non-aggressive infections and in heavy tree mortality in which the non-aggressive was a major factor. The four sites at which only the non-aggressive was obtained may have represented a similar phenomenon, or may have been true local non-aggressive flare-ups.

Table 10 Recovery of non-aggressive isolates in twig samples from current epidemic outbreak areas in Spain, 1984

Site	Total† samples	% Non-aggressive
a. Guadalahara	51	43
b. Peñaranda	39	31
c. La Alamadilla	49	49
d. Rio-Frio	24	37
e. Casa de Campo	82	87
f. Rubena	27/92	100/100*
g. Aracena	29	100
h. Merida	16	100
i. Miraflores	38	100
j. Medinacelli	21	100

† Each twig sample from a separate diseased tree.
* Data from two sampling occasions (see text).

Other factors likely to influence the pattern of disease development in central and southern Europe are (i) high summer temperatures which will favour development of the non-aggressive subgroup of *O. ulmi* (Brasier, Lea and Rawlings, 1981), and also result in increased numbers of beetle generations per year; (ii) rapid breeding attack by *Scolytus kirschi* on stressed or diseased twigs and small branches; and (iii) the effect of tree stress resulting from fire, stubble burning, lowering of water tables, insect defoliation by *Galarucella* sp., etc.

C. M. BRASIER

Reference

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Brasier, C. M., Lea, J. and Rawlings, M. (1978). The aggressive and non-aggressive strains of *Ceratocystis ulmi* have different temperature optima for growth. *Transactions of the British Mycological Society* **76**, 213–218.

Resin top caused by *Peridermium pini*

A Scots pine provenance trial in Thetford Forest was clear felled and the trees assessed for *P. pini*. The analysis of results showed that within plots planted in 1932, five Scottish provenances and one east England collection were significantly ($p<0.001$) more susceptible than two provenances from Hungary and one from Italy. No significant differences could be demonstrated between the UK provenances. The experiment was very under-stocked due to past mortality caused by *Heterobasidion annosum*. As data on the incidence of *P. pini* were only available from the trees assessed at clear felling, the results should be interpreted with caution.

In a similar Scots pine provenance trial in Scotland, which included some provenances in common with the Thetford experiment, but for which fuller data were available, the Scottish provenance, Loch Maree and the Finnish provenance, Ahtari, had significantly higher ($p<0.001$) incidence of *P. pini* than three other provenances from Finland and the Baltic States and two from Scotland.

Control of *Armillaria* in stumps by fumigation

Preliminary results from trials using fumigants to control *Armillaria* in conifer stumps have given encouraging results. The fumigants were applied into holes (2.5 cm diameter) drilled vertically into infected stumps. The stumps were excavated after 2½ years and isolations were made from the roots and stumps to determine the presence of *Armillaria*. Results from three experiments are shown in Table 11.

Methyl bromide was only tested in one trial, but it completely eradicated *Armillaria* from the roots and stumps of Scots pine. Metham-sodium, as Sistan, gave good results in all three trials on both Scots pine and Lawson cypress. Dazomet, as Basamid, was less successful than metham-sodium, possibly because it is in granular form and may thus require more moisture to be effective.

B. J. W. GREIG

Table 11 Isolation of *Armillaria* from stumps treated with three fumigants

Treatment	% isolations from the stump body			% isolations from stump roots		
	Scots pine I	Scots pine II	Lawson cypress	Scots pine I	Scots pine II	Lawson cypress
Control	19.2	23.3	31.7	30.2	38.2	41.0
Sistan	0.0	6.6	0.8	5.6	9.7	1.8
Basamid	5.0	18.3	5.8	10.6	28.7	11.5
Methyl bromide	0.0	—	—	0.0	—	—

These data were transformed to angles before analysis. The transformed means show that all treatments differed significantly ($p<0.001$) from each other.

Beech health study

The study initiated in 1985 (Lonsdale, 1986a) was continued at 15 of the original 19 plots (Lonsdale, 1986b). The foliar yellowing observed in 1985 was largely absent, and there was a slight general improvement in crown density. These findings probably reflect the improvement in growing conditions in 1985, following the droughts of 1983 and 1984, and do not indicate any general trend.

Annual increments of twig growth in beech have proved to be a good indicator of overall health and can be traced back over many years to reveal the onset of any decline. Using this method, mature trees have been assessed in Staffordshire, Cornwall and the New Forest. In one of these areas, the New Forest, there was evidence of a general decline following the 1975/76 drought. The study is now being continued in a series of plots (initially 15) along a transect from East Anglia to Cornwall which represents a range of different 'pollution climates'.

D. LONSDALE

References

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Lonsdale, D. (1986b). *Beech health study 1986.* Forestry Commission Research and Development Paper 149. 22 pp. Forestry Commission, Edinburgh.

Arboriculture, Department of Environment contract

Decay in amenity trees

The improved protection of pruning wounds against decay fungi remains a major aim of this contract, and there has been further expansion of a series of trials involving the treatment of such wounds with the fungus *Trichoderma* as a biological control agent. The trees so far included in the trial are: beech, oak, cherry, birch, Lombardy poplar, Norway maple, sycamore and ash. All are being assessed for establishment and survival of the *Trichoderma* one year after the application of a spore suspension to the wounds, and it is intended to assess continued survival over about 4 years, at which time the incidence and severity of attack by decay fungi will also be measured.

As reported previously, establishment of *Trichoderma* has been very successful in the first five species of trees listed above. The first-year assessment for Norway maple has now shown 86 per cent establishment and survival. A

second-year assessment on Lombardy poplar has shown 63 per cent of wounds with the fungus still present in the outer wound tissue, following a first-year value of 83 per cent.

D. LONSDALE

Heartwood colour in Sitka spruce

During a pulping trial of Sitka spruce from Glen Massan, Cowal Forest District (Strathclyde), a pronounced pink or reddish coloration was observed in the heartwood of some logs. Since this feature might reduce the brightness of pulp if it was present in a sufficiently high proportion of trees, a survey was carried out in October 1986 to establish its incidence in living trees.

Five hundred and eighty Sitka spruce were felled in first rotation crops, approximately 30 years old, growing on a variety of soils in Mid Scotland and South Scotland Conservancies. Samples were cut from the butt of each tree and from an internode between 3 and 5 m above the butt. The colour of the heartwood was assessed in natural light by reference to a standard colour chart. Pink wood occurred in 78 per cent of trees at the butt but only extended as far as the upper sample point in 27 per cent of trees. These figures are high but the assessment was stringent and included even the lightest pink flush which could be detected in good light. There were no appreciable differences in incidence between the dominance classes of trees sampled, their geographical origin or between the soils on which they were growing.

Excluding compression wood, colours observed in the heartwood were principally yellow, various shades of brown and different intensities of pink. Other colours were rare. The greatest intensity of pink occurred at the boundary between the heartwood and sapwood. It decreased in intensity towards the pith where it merged into a central light brown zone. In the direction of the sapwood there was an abrupt change from pink to a narrow yellow zone, only a few millimetres wide, which can probably be interpreted as the transition zone between the heartwood and the sapwood.

Both infection by *Heterobasidion annosum* and physical injury to the bark can cause the formation of pink colour in heartwood but these factors were excluded in this survey by the method of sampling. Cultures made from a sample of affected trees suggested that neither fungi nor bacteria were involved. There are few references in the literature to the colour of healthy Sitka spruce heartwood but Brown (1978) describes it as usually having a pinkish tinge and Hansbrough and Englerth (1944) decribe it as commonly light pinkish or reddish-brown. Thus it seems likely that the formation of pink colour ia the heartwood of Sitka spruce is part of the natural process of heartwood formation. Although the incidence of the pink colour in trees is high it occurs principally at the base and the effect on the quality of pulp made from a normal mix of material is likely to be negligible.

D. B. REDFERN, S. C. GREGORY

References

Brown, W. H. (1978). *Timbers of the world. 7. North America.* Timber Research and Development Association, High Wycombe, Buckinghamshire, England. 91 pp.

Hansbrough, J. R. and Englerth, G. H. (1944). *The significance of the discolouration in aircraft lumber: Sitka spruce.* Forest Pathology Special Release No. 21. United States Department of Agriculture.

Plates 1 to 4 Douglas fir photographed in January 1987, 10 months after planting in a weeding experiment on a brown earth at Crumblands, Gwent Forest District, south Wales. Many of the trees with the glyphosate or polythene treatments made a second burst of growth in 1986 (see p. 19).

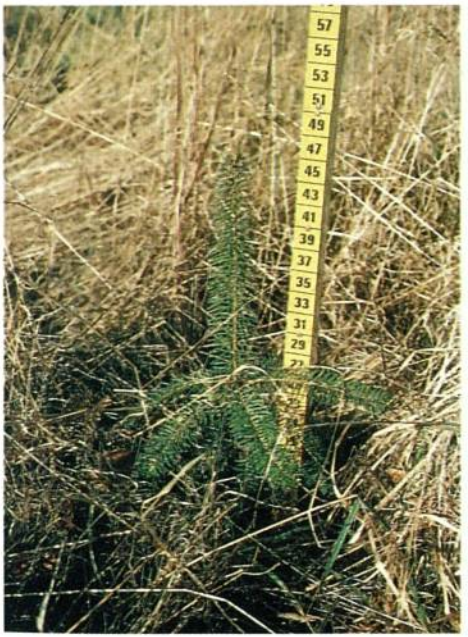

Plate 1 Tree which had no weed control. (*37574*)

Plate 2 Tree which had surrounding weeds mown. Mowing invigorated the grass. Notice the poor needle colour. (*37572*)

Plate 3 Tree which had weeds within a 1 × 1 m square killed with glyphosate. (*37575*)

Plate 4 Tree with a 1 × 1 m black polythene mulching mat. (*37577*)

Plate 5 Peat cracking exposed by removing the 30 cm thick fibrous layer. The cracked peat is of the amorphous type and is only 40 cm thick at this site. Note the long straight crack along each furrow. (about 50 cm in front of the spade and also near the bottom of the picture). Strathy Forest, Sutherland. (*J. Howell*)

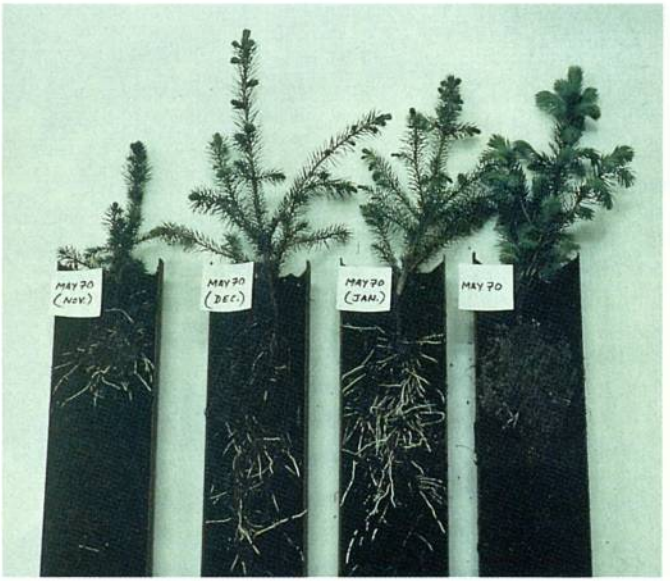

Plate 6 Transplants of Sitka spruce in root observation boxes following the 14 day root growth potential test in May. *Left to right:* cold-stored in November; cold-stored in December; cold-stored in January; freshly lifted.

Plate 7 Using a 'Pilodyne' for the indirect measurement of wood density in the outer sheath of timber.

Plate 8 The Epson HX-20 hand-held microcomputer being used to record field data in sample plots. Data can be transferred by microcassette tape to a mainframe computer for more detailed analysis. (*36676*)

Plate 9 Winter cold damage 1985/86 on *Nothofagus procera*.

ENTOMOLOGY

Further restructuring of projects took place this year. A new project on the biology of *Hylobius abietis* and *Hylastes* spp. aims to develop non-chemical management methods for control of these major pests. A report by the Forest Research Co-ordination Committee (FRCC) review group on biotic damage stressed the importance of research into plant resistance to pest attack. Existing research on this aspect carried out on *Elatobium abietinum* is being expanded in response to the FRCC report. University links were also strengthened through research studentships (Oxford, Coleraine) and through collaborative research projects (Cardiff, Imperial College).

H. F. EVANS

Great spruce bark beetle, *Dendroctonus micans*

Biological control of Dendroctonus micans

The mass rearing and release programme of *Rhizophagus grandis*, the predatory beetle specific to *D. micans*, was concluded in October 1986. Results of the 3 years of the work are summarised in Table 12. Cultures of the predator are being maintained by rearing in plastic containers of pulverised bark with *D. micans* larvae amongst which *R. grandis* breeds readily. Predatory larvae are fed-on to maturity on a diet of blow-fly larvae. This method (developed in Belgium) ensures a supply of predators for both contingency and research needs.

During the year three *D. micans* study plots were intensively sampled. Results showed that *R. grandis* was well established and actively breeding. Overall 34 per cent of *D. micans* broods were found to contain *R. grandis* at various stages of development. Local dispersal within forests by *R. grandis* was found to be efficient; long distance migrations of 1.2 and 4 km were also noted.

Table 12 Numbers of *Rhizophagus grandis* released in Britain in the period 1984 to 1986

Year	Number of *R. grandis* released	FC[a] locations	PW[b] locations	Total locations
1984	31 168	528	414	942
1985	39 392	206	449	655
1986	17 604	319	496	815
TOTALS	88 164	1053	1359	2412

[a] FC = Forestry Commission
[b] PW = Private Woodlands

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

Orientation of Rhizophagus grandis adults

In a walking bioassay conducted in a small wind tunnel, we obtained a 90 per cent response of young unmated male and female *Rhizophagus grandis* to fresh *D. micans* frass. These results confirm previous reports that frass is

highly attractive to this predator. Some chemicals assumed to be present in the frass were tested individually and in mixture in the wind tunnel. The best response was obtained to 10 000 μg of DL α-pinene to which about 60 per cent of both males and females responded. Forty to fifty per cent and about 30 per cent of insects responded to the + and − isomers respectively when presented alone at the same concentration.

D. WAINHOUSE, A. CLEAVER, D. CROSS

Interactions of D. micans and spruce

The lignin content of bark of both Norway and Sitka spruce was found to be a significant factor determining survival and growth rate of larval *D. micans* feeding on detached bark in the laboratory. On highly lignified bark, mortality of first instar larvae was higher and development time was about 70 per cent longer than on unlignified bark.

D. WAINHOUSE, D. CROSS, M. R. JUKES

The Pine beauty moth, *Panolis flammea*

Monitoring and control

Egg counts in May 1986 confirmed the need to treat a total of 2713 ha of Lodgepole pine plantations in the Highland Region of Scotland, including 294 ha in private ownership. Approximately 1500 ha had previously been sprayed in 1985; however the area requiring retreatment was considerably less than had been expected (*Report* 1986, p. 42). The season was exceptionally late and spraying was not begun until mid June. Three insecticides were used: fenitrothion (1456 ha); Dimilin (diflubenzuron) at two rates (632 ha) and several virus preparations as a field trial (625 ha). On the basis of pupal counts in the autumn periods of 1985 and 1986, Dimilin (oil dispersible concentrate formulation) even at the lower rate tested (17 g a.i. ha^{-1}) gave >99 per cent reductions in all except one location.

Aerial application of virus to a range of larval densities (100 to >300 per 3 metre tree in 1985 and 80 to >1000 per 4 to 10 metre tree in 1986) resulted in both high initial mortality (up to 90 per cent in 1985 and around 50 per cent in 1986) and substantial secondary epizootics giving almost total mortality in both years. Considerable virus persistence between 1985 and 1986 was observed resulting in high levels of mortality in mature larvae. Pupal counts in autumn 1986 show a possible need to treat 2600 ha, mainly in new areas although this is likely to be reduced following egg counts in the spring.

J. T. STOAKLEY

Population ecology

P. flammea populations on Lodgepole pine in the Elchies block of Speyside Forest (Grampian) continued to fall, reaching a level of only 0.3 pupae m^{-2}. Of these 37.5 per cent were parasitised giving a healthy pupal population of only 0.19 pupae m^{-2}. In the experimental plots no pupae were found in ironpan sites. Preliminary work on the abundance of arthropod predators indicated that natural enemies were less frequent in deep peat sites than in ironpan sites.

Field experiments (to monitor soil temperatures) at North Dalchork (Highlands) confirmed last year's laboratory work (*Report* 1986, p. 42) concerning the rate of adult eclosion in response to soil temperatures exceeding 6°C. Flight, egg laying and oviposition were also shown to be temperature dependent in the field.

Laboratory investigations indicated that sub-lethal applications of fenitrothion could delay emergence of adult *P. flammea* and reduce the fecundity of the females. Fecundity increased linearly over the temperature range 6–15°C and was lower at fluctuating temperatures than at the corresponding constant temperatures.

S. R. LEATHER

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

Further data have been obtained on the impact of defoliation by *E. abietinum* on subsequent growth of Sitka spruce. Some of these data were derived from discs collected from a line thinning in a Sitka spruce provenance experiment at Rhondda. These trees have an attack history that dates back to 1980. The basal area increments were calculated for five provenances up to 1986 using the method developed by Howell (*Report* 1979, p. 39) as a follow up to the annual height increments which were measured when the trees were smaller (Carter and Nichols, 1984). The data clearly show depressions in volume increment following *E. abietinum* defoliation, but these are not so marked as the effects on height growth (Carter, 1977). The Alaska and Masset, Q.C.I. provenances showed a depression in growth into the third growing season after attack, whereas Vancouver Island, North Oregon and California provenances appeared to have returned to the expected increment rate after the second growing season.

C. I. CARTER

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Carter, C. I. and Nichols, J. F. A. (in press). The Green spruce aphid and Sitka spruce provenances in Britain. *Proceeding of the IUFRO Sitka Spruce Provenance Meeting, Edinburgh, 1984.*

Effects of metal pollutants

Metal pollutants found in certain soils of the South Wales Coalfield have been shown by Burton *et al.* (1983) to adversely affect the growth of roots and shoots of Sitka spruce. The response of *Elatobium abietinum* to host plants grown in such conditions has not previously been studied. In preliminary studies over the last 2 years no effects on the aphid were noted until the second season. High cadmium levels (4 ppm) produced aphids with low fecundity and extended development time, while low cadmium levels (1 ppm) favoured aphid growth. High lead levels (25 ppm) also resulted in aphids with low fecundity, and reduced life span. Neither high (16 ppm) nor low (4 ppm) levels of copper affected *E. abietinum*. It seems from these studies that Sitka spruce growing in areas high in metal pollutants may well not support *E. abietinum* in any numbers.

J. F. A. NICHOLS, J. RIDER, A. BRAMMER

Reference

Burton, K. W., Morgan, E. and Roig, A. (1983). The influence of heavy metals upon the growth of Sitka spruce in south Wales forests. Greenhouse experiments. *Plant and Soil* **78**, 271–282.

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

Current investigations on protection against these insects fall mainly within the scope of the Upland Restocking Special Project Team initiated in January 1986 (see this Report p. 5).

Research over several years on the use of pyrethroids as an alternative to lindane (gamma-HCH) for pre-planting dipping is now being applied in forest practice with the recommendation that permethrin should be used at 0.8 per cent a.i. Only one permethrin product, Permit (Pan Britannica Industries), is currently approved for this purpose under the control of Pesticides Regulations 1986 and, for the present, only part of the overall programme of dipping may be with this insecticide.

Spraying Sitka spruce transplants in the forest with permethrin at 0.05 per cent a.i. has been found to give excellent protection for a whole season against both *H. abietis* and *Hylastes* spp. (*Report* 1986, p. 43) and was significantly better than the currently recommended treatment, lindane at 0.125 per cent a.i. (Table 13). No phytotoxic effects were found in this experiment or a similar one using Douglas fir. Approval is being sought for the use of permethrin for this purpose in forest practice.

J. T. STOAKLEY, S. G. HERITAGE

Table 13 The effects of various insecticide treatments on Sitka spruce mortality resulting from *Hylobius abietis* activity

Treatment	Percentage of plants killed by *H. abietis*
Untreated	66.5
Lindane (0.125%)	16.8
Permethrin (0.02%)	8.0
Permethrin (0.05%)	0*

* Significantly lower than 0.02% permethrin ($p<0.05$) and 0.125% lindane ($p<0.01$).

The European pine sawfly, *Neodiprion sertifer*

Following a survey in December 1986 of numbers of sawfly egg clutches, Virox, a commercial formulation of a nuclear polyhedrosis virus specific to this insect, was applied shortly after egg hatch in June to 310 ha of young Lodgepole pine plantations in Highland Region. Assessments of larvae showed at least 71 per cent of clutches severely affected by virus in each of the two blocks treated. Subsequent counts of egg clutches in January 1987 showed falls in numbers of 86 per cent and 96 per cent compared with the previous winter.

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

Genetic variation in insects

Techniques of isoenzyme electrophoresis using polyacrylamide and starch gels are being developed to examine genetic differences within British populations of *Panolis flammea*, and European populations of *Dendroctonus micans*. Of 30 enzyme systems examined so far, many from *P. flammea* were found to be polymorphic at one or more loci. The degree of polymorphism in *D. micans* appears to be much lower. For *P. flammea* a detailed study of one malate dehydrogenase locus provided evidence for distinct northern and southern populations (Wainhouse, Jukes and Rhind, 1987).

M. R. JUKES, D. WAINHOUSE

Reference

Wainhouse, D., Jukes, M. R. and Rhind, D. (1987). Genetic variation between populations of *Panolis flammea*. In, *Population biology and control of the Pine beauty moth*, 37–40, eds. S. R. Leather, J. T. Stoakley and H. F. Evans. Forestry Commission Bulletin 67. HMSO, London.

Pheromone trapping for exotic bark beetles

In this second year of the scheme 24 locations were monitored, consisting of docks, timber yards, ladder factories and forest sites. Only one exotic species was trapped: *Ips typographus* at a timber yard in Grangemouth, repeating the result obtained for this location in 1986.

Pine looper moth, *Bupalus piniaria*

Pupal surveys were carried out in 39 areas. Counts were low in all locations. Highest compartment mean at Sherwood IV fell from 24.4 m^{-2} in 1986 to 4.4 m^{-2} in 1987.

Research was started to identify the sex pheromone of *B. piniaria* for the purpose of developing a monitoring programme based on pheromone trapping. A C19 hydrocarbon compound was identified in extracts from female abdominal glands; however this did not attract male *B. piniaria* moths in the forest.

D. A. BARBOUR

Advisory and taxonomic services

Enquiries relating to sap-sucking insects increased up to fourfold from the previous year for the aphids *Cinara piceae* and *C. pilicornis* on spruce, *Phyllaphis fagi* on beech and the Horse chestnut scale *Pulvinaria regalis*. In the autumn the mite *Eotetranychus tiliarium* was widely reported in the south causing conspicuous sheets of silk on lime trees. Yellowing of Norway spruce needles by *Oligonychus ununguis* was reported by Christmas tree growers in southern and eastern England.

Larvae of *Euproctis chrysorrhoea* were found on *Prunus cerasifera* in Hampshire 50 km north of the coastal area where this insect is normally found.

Large numbers of the scolytid *Crypturgus subcribrosus* were found for the first time in Britain overwintering in galleries of another scolytid, *Orthotomicus laricis*, on a dead Norway spruce in Hampshire.

Forestry Commission plant health inspectors found *Ips typographus* on two occasions and *I. amitinus* once in spruce dunnage from Europe. *Crypturgus borealis* was intercepted for the first time in bark fragments on timber from western Canada.

T. G. WINTER

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

The relationship between the Green spruce aphid, *Elatobium abietinum*, and the volatile secondary chemicals in spruce foliage

The work reported last year (*Report* 1986, p. 44) has continued with bioassay studies on the leaf oil extracts from *P. glehnii, P. sitchensis* and *P. abies*. The results have shown that *E. abietinum* moved away from, and had a higher mortality when exposed to, the oil from *P. glehnii*, while the oils from the other two spruce species had no effect. The variation in chemical composition of the steam-distilled oils from individual trees of *P. glehnii*, collected from a trial plot at Rheidol, south Wales, was examined: comparison of the resultant gas chromatographs of these leaf oils showed no differences between the individual trees of *P. glehnii*.

J. F. A. NICHOLS, L. SUR

WILDLIFE AND CONSERVATION

The new structure and revised staffing of the Branch is almost complete with the recent appointment of a plant ecologist at Alice Holt. A complementary post will soon be filled at Northern Research Station.

Deer

Vantage-point counts, used successfully for estimating red deer densities (Ratcliffe, 1984), have been attempted with roe deer. Preliminary results in north Scotland appear promising. In three areas previously assessed subjectively as low, high, and medium density, vantage-point counts suggested that high densities occurred in all three. Continuing work will seek to check these densities by other methods.

The long term studies of the ecology and social behaviour of roe deer are continuing. A total of 148 roe deer have been caught and marked at Thetford between 1974 and 1987 and 308 roe deer caught and marked at Chedington (Dorset) between 1961 and 1987. Collars incorporating radio-transmitters have been used at Thetford and at Chedington since 1981 in order to aid tracking in the increasing proportion of thickets and older crops. One Sika hind and four calves were caught in the New Forest adding to the two calves marked previously. Two of the deer caught in February were found in a moribund state a few days after capture and release. Subsequent post-mortem examination showed that they were suffering from 'white muscle' disease which is sometimes caused by selenium deficiency. Parts of the New Forest are known to be selenium deficient and this disease requires further investigation. A detailed study of the social behaviour of Sika deer in the New Forest has been started in collaboration with a local naturalist.

The management of important plant communities may be in jeopardy owing to selective reduction or elimination of particularly sensitive plant species by high or uncontrolled numbers of deer. Densities of 3–5 deer km^{-2} can eliminate some plants from the herb layer and broadleaved trees. Where browsing effects are suspected the construction of 2 × 2 m exclosures will soon demonstrate any effects caused by grazing, prior to a consideration of increased shooting or temporary fencing.

P. R. RATCLIFFE, B. A. MAYLE

Birds

A study of the ways by which the tawny owl *(Strix aluco)* has adapted to extensive spruce forests in the uplands has concentrated on population ecology in relation to food supply, habitat structure and climate. The main food has been determined from an analysis of pellets and records of prey items in nests. Field voles *(Microtus agrestis)* are by far the most important food of tawny owls in Kielder and Glenbranter Forests. In 1986 a large proportion of the Kielder population failed to lay eggs (Table 14) and this was apparently related to the low overwinter vole population (Figure 11) and the particularly cold wet spring. The Glenbranter population was more successful, with broadly the same number of clutches recorded as in the previous two years.

Table 14 Productivity and survivorship of tawny owl clutches

	1984		1985		1986	
	K	G	K	G	K	G
Nests located (including repeat clutches)	43	21	45	20	4	19
Total eggs laid	148	61	130	49	10	48
Mean clutch size	3.44	2.90	2.89	2.45	2.50	2.53
Total young fledged	132	34	91	26	7	24
Mean young fledged	3.07	1.62	2.02	1.30	1.75	1.26

K = Kielder, G = Glenbranter.

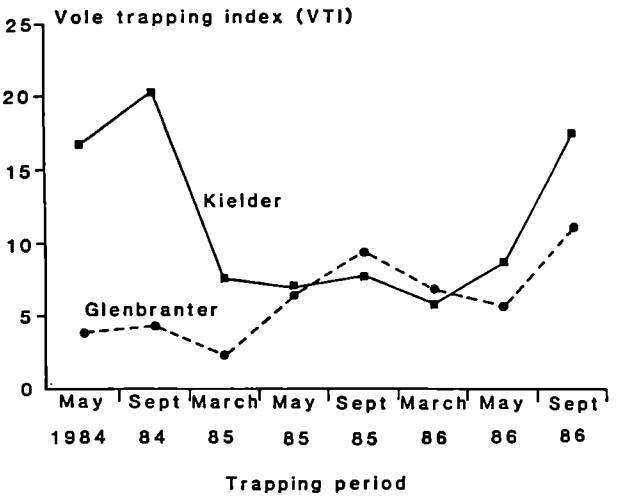


Figure 11. **Vole trapping index at Kielder and Glenbranter Forests.**

At Glenbranter six breeding females and 12 chicks were fitted with radio transmitters to investigate the post-fledging behaviour of juveniles. Eleven of the 12 juveniles died before they dispersed from their natal territories. This loss was considerably higher than expected. Deaths occurred either within a few days of fledging, when the birds spent most of their time on the ground because they flew poorly and were vulnerable to mammalian predators, or at about 2 months of age when they died of starvation. The one remaining chick appeared to become independent of its parents at about 80 days of age and thereafter increased its home range to encompass the territories of both its parents and the near neighbours.

S. J. PETTY

Bats

A review of the current knowledge of the habitat preferences and management of bats in woodlands is almost complete. Bat boxes of various designs are used by many species of bats throughout Europe but little is known of

their effect on population density or survival. The review will indicate the desirable directions of further research.

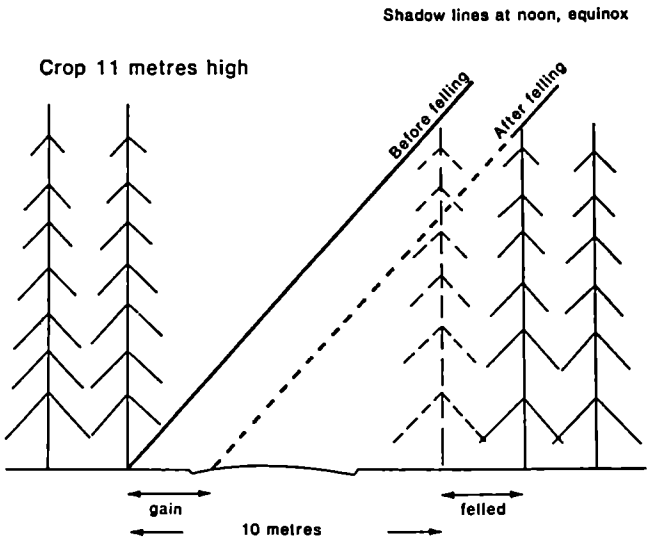
B. A. MAYLE

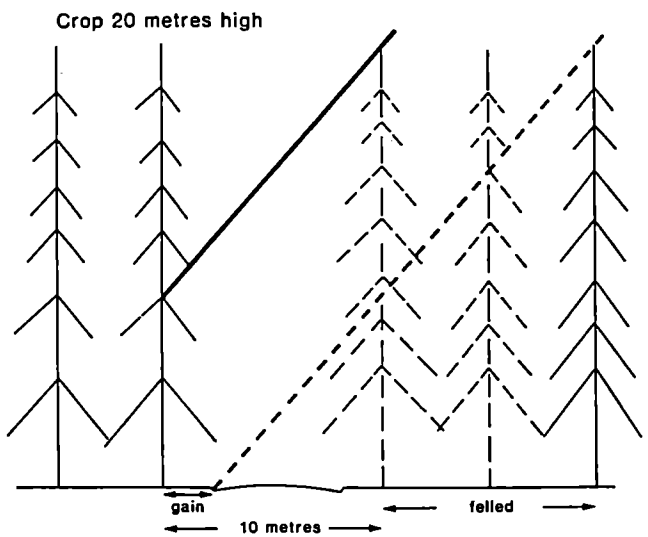
INTER-BRANCH REPORT: WILDLIFE & CONSERVATION AND ENTOMOLOGY

Vegetation management

Our new commitment to conservation research has begun with a project in lowland woodland on cutting back and shaping ridesides to benefit woodland plants and butterflies. Experiments have been set up to find the effects of cutting bays of various shapes and orientation in plantation edges. A useful criterion in planning the depth of cutting, or in selecting ready-made bays such as loading places, is the maximum length of shadow cast by edge trees at the equinoxes. Forming the new forest edge at this point ensures that light is provided for plants and insects during the growing season. Figures 12 and 13 show this criterion applied to two south-facing ride edges in crops 11 m and 20 m high respectively.

M. A. ANDERSON, C. I. CARTER





***Figures* 12 and 13. Ride widening decisions based on equinoctial shadow lengths.**

The diagrams show the shadow limits of tree crops at the start of the growing season (equinox). Dashed trees show the minimum widening needed on an east–west road if direct sunlight is to strike the ground at noon.

MENSURATION

Sample plots

One hundred and fifty five permanent sample plots were measured, the data being added to the computerised databank containing measurements of all sample plots. Ten new sample plots of Sitka spruce and Lodgepole pine were established to extend the range of sites, growth rates and treatments covered. Work has begun on the establishment of a respacing experiment in Bennan Forest (Dumfries and Galloway) to study the effects of different intensities of respacing on crop growth and timber yield and to compare chemical and mechanical respacing. The number of trees after respacing will range from 2500 down to 400 trees per hectare.

Yield modelling

Workshop on the effects of damage on tree growth

A two day workshop on the effects of damage on tree growth was held at Alice Holt Lodge in order to consider what is known about the effects of defoliation and other forms of damage on tree growth, to review measurement techniques and to explore how we might improve our knowledge. There were 41 participants who heard 16 speakers covering biotic damage, abiotic damage and measurement methods including tree ring analysis. There was general agreement that more needs to be done by way of quantifying both damage and tree response.

Thinning response

An investigation into the response of individual trees to thinning was carried out using data from thinning experiments. As the aim of the study was to investigate underlying trends in the data, some means of smoothing the fluctuations caused by seasonal effects was required. This was achieved by fitting a sigmoid function to the radial growth data. The resulting radial growth curves were converted to basal area curves. Figure 14 shows basal area curves for one sample plot for (a) the raw data, and (b) the fitted function. Annual basal area increment curves for individual trees were then calculated by differentiating the basal area function with respect to time. Figure 15 shows the basal area increments (a) for the raw data, and (b) after differentiating the basal area curves. The study has enabled some quantification of the response of trees of different sizes and ages to be made and has confirmed that thinning defers the culmination of increment of individual trees. The results of the study will be used in future work on growth modelling reported elsewhere (see page 68).

Sycamore, ash and birch yield tables

With an increase in demand for information on the yield of broadleaved species, a project has been started to separate the published yield table for sycamore, ash and birch into individual species tables. Although there are only a small number of permanent sample plots in these species, there is a considerable amount of data available on computer files from temporary plots established in the 1950s. A preliminary study of the data indicates that it should be possible to construct separate yield tables for sycamore and ash using available data.

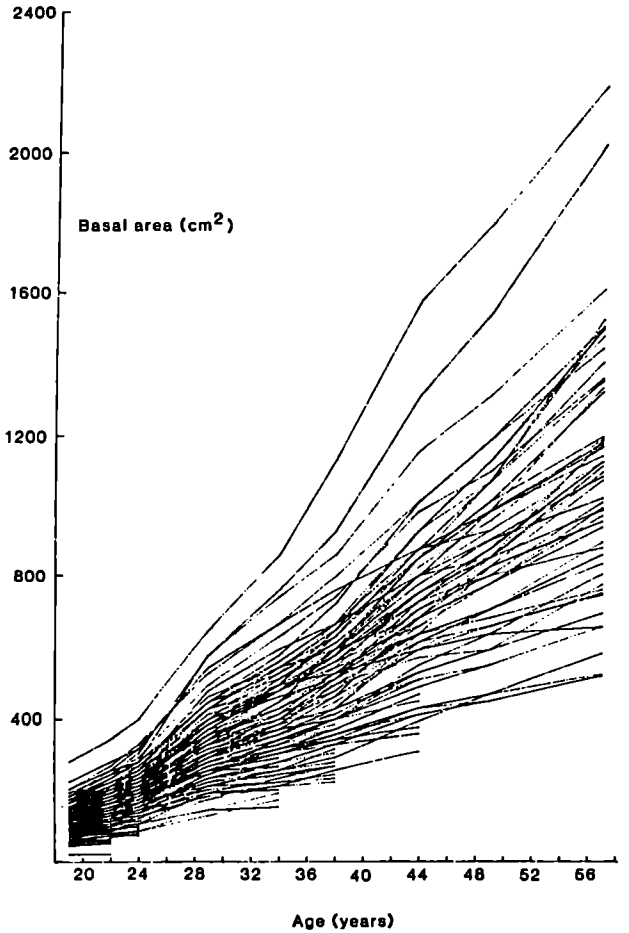


Figure 14. **Basal area curves for individual trees at Brendon Forest (Somerset). Intermediate thinning. a) raw data**

Height/diameter relationship

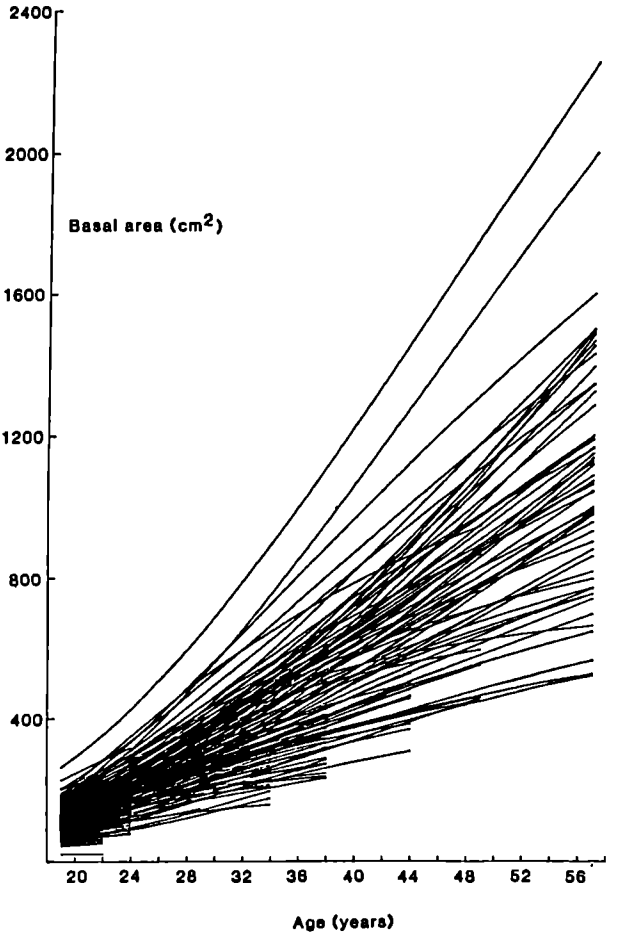
For the production of sample plot summary information it is convenient to find a relationship between the height of trees and their diameter. Until now the equation:

$$\text{height} = a\sqrt{d} + b$$

has been used, where d is breast height diameter and a and b are parameters. Concern about apparently poor fits to data in some cases led to a reappraisal of the method. The conclusion of the study has been that the present equation has some undesirable properties which have been improved upon by fitting an equation of the form:

$$\text{height} = a\, d/b + d$$

The estimation procedure is modified in certain cases, for example where all trees in a plot have been measured. The equation together with certain checks



b) fitted curves

on goodness of fit has been incorporated in the sample plot program for calculating summary information including estimates of top and mean height.

Measurement studies

A project to study the quantity of measurable timber (to 7 cm top diameter) remaining on clear fell sites indicated that approximately 10–15 per cent of the volume before felling remained after extraction. Only a small proportion of this material was potentially utilisable. Stump volume accounted for about one-third of the material, the remainder comprising other unutilisable material such as short lengths and damaged stemwood.

Management services

The computerised Tariff Checking and Assortment Forecasting Services have been well used; 573 tariffs were processed, an increase of 30 per cent on last year, and 200 assortment forecasts were run, an increase of 35 per cent on last year. Work is well in hand to distribute the Tariff Checking and Calculation

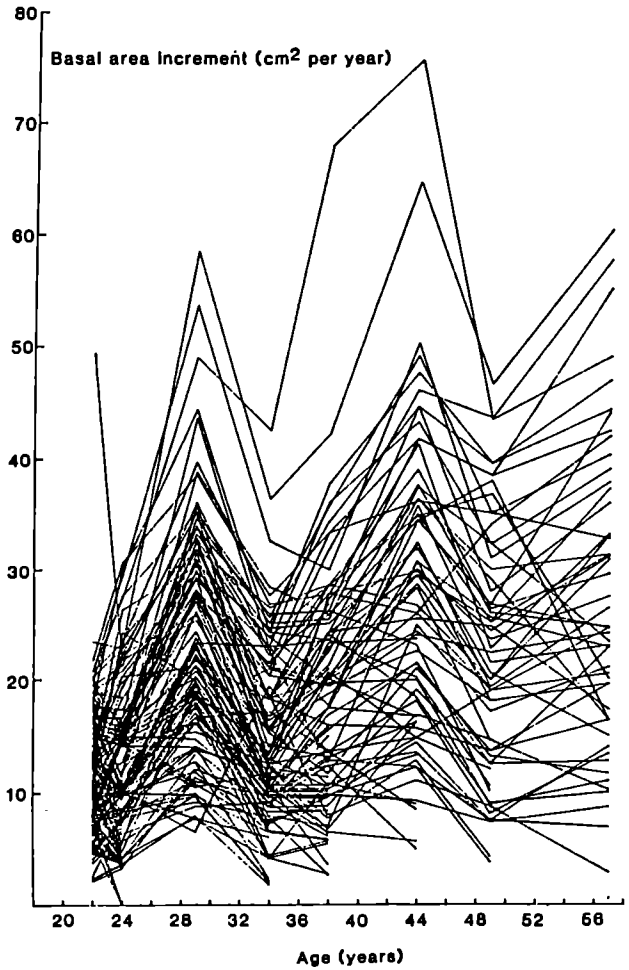


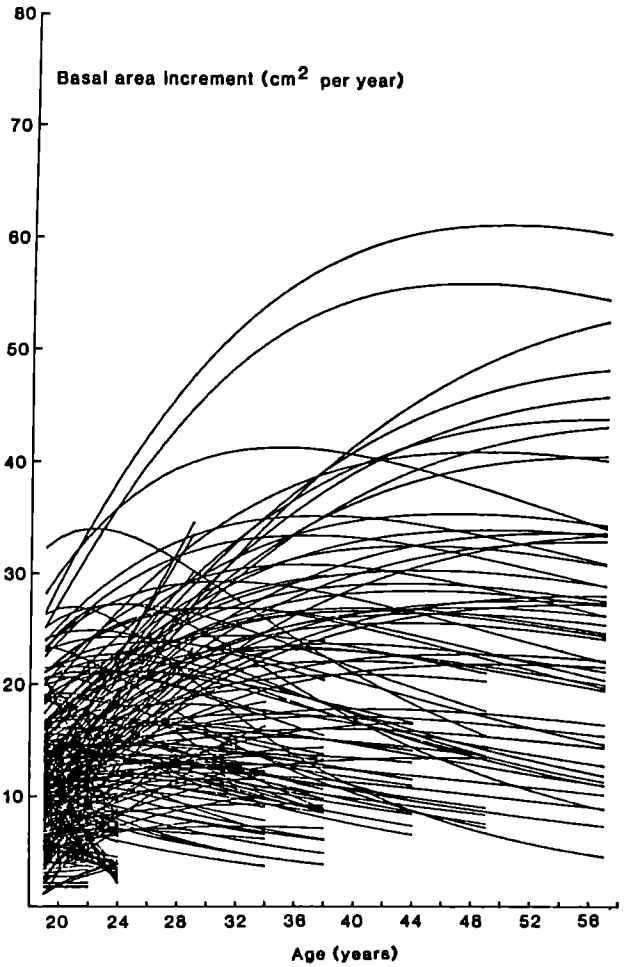
Figure 15. **Basal area increments for individual trees at Brendon Forest (Somerset). Intermediate thinning. a) raw data**

Program to the microcomputers in Forest District offices. The program being written by staff in Data Processing Division (Headquarters) to a specification supplied by Mensuration Branch is expected to be completed by the end of 1987.

T. J. D. ROLLINSON

Data terminals

The Epson HX-20 microcomputer (Plate 8) has again proved very reliable and the most appropriate machine for recording data in sample plots. All the necessary checks and intermediate calculations are done during plot measurement. The large display permits meaningful prompts and error messages to be given. The built-in printer gives instant hard copy of intermediate results and



b) fitted curves

the measurements collected, which are retained for back up. The microcassette provides an additional storage medium and a means of data transfer from the Epson to the Prime computer at Alice Holt. The main advantage of the new system is the increased speed of data processing. A tape received in the morning can have its data stored and processed on the Prime with the final results sent back to the field team by the afternoon. Accuracy has been greatly improved, partly because of the validation checks in the program but primarily because all copying phases have been eliminated. We are now confident that the same standards of measurement and recording will be followed by all field teams in Britain. Further program developments are being considered and new programs are planned, such as the selection of volume and height sample trees and the calculation of the thinning cut.

J. M. GAY

WOOD UTILISATION

Value enhancement of low quality hardwoods

Work began on the assessment of hardwood markets as a prelude to more precise studies. It is clear that:

1. there is a marked drop in value for grades just below the best qualities;
2. there has been a decline in the volume of hardwood sawlogs presented for sale in the last 10 years;
3. there has been no decline in demand for temperate sawn hardwoods from overseas in the last 10 years.

Studies have been initiated to assess the volumes and qualities of hardwoods which are or might be marketed, to establish the specifications for hardwoods currently consumed and those for any potential new uses.

Tree stake preservation treatments

A short-term study of simple treatments which might be applied in preserving tree stakes was begun in 1986. These stakes are expected to have a life of between 2 and 20 years. The work has been a joint exercise with the Timber Technology Group of Imperial College. Early studies by an undergraduate, Mr D. Thomas, examined samples of stakes currently in use for preservative distribution, studied potential preservation techniques in the laboratory and, in the light of results, prepared stake material by six different methods for further studies. Samples of these stakes are to be analysed for retention and distribution of preservative and biodegraded in the laboratory. A further sample will be taken from each treatment and used in a field trial.

Advice

During the year the Branch received a number of requests for advice; over 50 per cent of these concerned sawn wood and forest residues.

D. A. THOMPSON

INSTRUMENTATION

As in 1986 much effort has again been devoted to open-top chamber instrumentation. The demand for vernier girth bands continued. Aluminium frames for a greenhouse fogging unit, small tipping bucket rain gauges and perspex gel formers have all been completed. The small radio transmitters made by the Industrial Electronics Unit at Surrey University for tracking squirrels are now ready for field testing.

W. O. BINNS

STATISTICS AND COMPUTING

Statistics

Alice Holt

Several surveys to study the incidence of tree diseases have been designed. Among these was one to study the occurrence of dieback in hedgerow ash

trees in specific climatic/pollution zones in lowland Britain. Two hundred 10 km squares will be visited and approximately 20 trees will be assessed in each square. Information will be collected on current land use around each tree to allow relationships between land use and dieback to be tested.

A sampling experiment has shown that the statistical tolerances used by the International Seed Testing Association (ISTA) are not suitable for a number of tree seed samples. Seedlots which contain moderate or large quantities of empty seed will exceed the permitted tolerances for weight determination even if they are sampled correctly. This and related seed sampling problems will be discussed at an ISTA statistical seminar to be held in Budapest later in 1987.

New tests of the distribution of marked (e.g. diseased) trees in a mapped forest stand were devised and applied to stands affected by beech bark disease. The tests use the statistics of the 'minimum spanning trees' of random subsets of points in the plane.

In the analysis of the results of air pollution surveys contouring techniques have been used to display patterns of observed foliage discoloration and needle loss on maps of Great Britain; these have helped in the interpretation of the results and have indicated where additional samples would be most beneficial. Contouring methods have also been used to display the results of an investigation into the use of specially selected poplar clones to monitor air pollution levels. The results of an initial survey were used to design a more comprehensive survey of southern England for 1987. Contouring also helped in the study of the accumulation and melting of snow within open-top chambers built for air pollution experiments. Maps of snow depth within the chambers on successive days have shown where the snow remains longest, making it possible to allow for positional effects in future experiments.

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

Northern Research Station

The theory of generalised lattice designs, including the recovery of inter-block information, was studied with a view to writing a computer program to analyse any block design. Two methods of solving the normal equations and finding estimates of treatment effects were compared – iteration and matrix inversion. The iterative method was computationally more efficient but the matrix inversion provided more information. The iterative method is preferred for large, routine analyses.

In preparation for a new series of spacing experiments in a range of species, recently used experimental designs were reviewed and found to be unsatisfactory. In an attempt to overcome some of the difficulties, a design using a series of L-shaped plots with independent but restricted randomization in separate square blocks has been agreed. The analysis will involve the estimation of a spatial correlation effect.

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

Modelling

Alice Holt

A Biometric Modelling Section was established late in 1986. The first aim was to review and test the earlier work on the Integrated Forest Process Model of

Rennolls and Blackwell (1986). Work in this field is described in the inter-Branch report (p. 68).

At the request of North Scotland Conservancy a module simulating a clam-bunk skidder was added to the program simulating cable crane extraction.

A. R. LUDLOW, I. D. MOBBS

Reference

Rennolls, K. and Blackwell, P. (1986). *An integrated forest process model: its calibration and predictive performance.* Research and Development Paper 148. Forestry Commission, Edinburgh.

Northern Research Station

Modelling the spread of the fungus *Heterobasidion annosum* through a stand of Sitka spruce continued. A simulation program (in Fortran) was extended to model more than one rotation. The model was expressed in transition matrices. Expected numbers of infected and decayed trees at each thinning and at clear felling were calculated for several rotations of a crop and an equilibrium level of decay was investigated. The sensitivity of the model to changes in the values of the initial probabilities was studied.

A. C. BURNAND

Computing

Alice Holt

Because of consistent overloading of the Prime 550 processor (with two megabytes of memory) it was replaced during the year by a 9655 processor with four megabytes of memory. Three Olivetti microcomputers were purchased as 'IBM compatibles' respectively for database work at Westonbirt Arboretum, for the *Dendroctonus micans* field station at Ludlow and for general program development at Alice Holt.

The production forecasting system was thoroughly redesigned, written and tested using Turbo Pascal (Borland) on an Olivetti M24 micro before passing to the Sheffield University Pascal compiler on the Prime. The forecast module of the new system encapsulates the whole of the complex set of forecasting rules and allows separate 'back-end' attachments determined by the forms of output required. The short-term forecast back-end includes an analysis of felling in a quinquennium by species and average age; information not previously available. The improved articulation of the system enabled studies to be done on the long-term effects of premature felling. The valuation forecast back-end produces summaries by both breast height diameter and mean tree size. The output files were sent to Planning and Surveys Division for the 1987 valuation.

A decision to replace the Rapport database management system as soon as possible was taken during the year but the final choice of replacement system has not yet been made. A wide selection of IBM compatible micro software has been acquired and is being tested; it includes the Microcairs system for literature references and library management, Statgraphics for simple data analysis and Turbo Prolog (Borland) as a means of developing a pilot expert system for the identification of wood fungi in culture.

Programming of the Micromac on-site devices to be used for continuous data capture in open-top chambers for air pollution experiments has advanced to the stage of summarising the files output to the Prime to allow preliminary statistical analysis, graphical display and archiving.

The Culham Ghost 80 plotting library has been used to develop a command driven plotting program and a contouring program. Both these programs are proving very popular among research staff for their ease of use.

Microfin hand-held data loggers are used to record time study data for most forest operations. A new data processing program has been designed to allow more flexible use of this equipment.

G. J. HALL, B. J. SMYTH, L. M. HALSALL, R. C. BOSWELL

Northern Research Station

With the GP300 high-quality printer on the ERCC network and Scribe document layout available, experiment plans and final reports are being produced and stored on the mainframe so that they can be viewed from any terminal. The move to the new version of the EMAS operating system provided opportunities to make programs more efficient and easier to use. About 20 general-purpose programs were donated to the user-contributed library on EMAS.

A mainframe program was written in 'Imp' to prompt for treatment names and levels, number of blocks, plots, and (optionally) subplots. It produces a Genstat program to perform the appropriate analysis of variance. Intended for common designs, such as randomised blocks or split-plots with cross-classified treatment factors, it may encourage use of Genstat by those otherwise reluctant to undertake statistical analysis.

A program was written to retrieve information quickly on a particular experiment in the Experiment Register database, and to locate the relevant assessments in the computer's archive. It translates descriptive numeric codes to meaningful text. Utilities were written to facilitate queries, and to close old experiments or open new ones in the database.

From a description of experiments requiring foliar analysis, a program now automatically generates labels to go in the sample bags each year. In tests, Pathology's query records were successfully indexed and retrieved using the Catalog package on EMAS. A rewrite of the basal area increment analysis program was started so as to allow use of a database of previous assessment data. The Field Surveys Subcompartment database files were made more accessible and were increasingly used.

A program was written in UCSD Pascal for a micro, to allow a small digitising tablet to be used in conjunction with a microscope. The user can calculate areas and lengths of the objects on microscope slides. He is free to define a recording template or outline form on screen, using combinations of four data types (text, value, length or area).

A Nursery Stock Control Program was developed on a microcomputer to control allocations to forest experiments, other users (FC and external) or for lining-out for the next season. It should save time and errors.

R. W. BLACKBURN, K. P. DONNELLY, I. M. S. WHITE

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

The recently formed Biometric Modelling Section has continued the work on modelling forest growth described in *Report* 1985, pp. 51–53, and by Rennolls and Blackwell (*op. cit.*). The programs and data files have been reviewed and streamlined so that the model can be tested quickly against a wide range of data sets. The method of fitting the model has been altered slightly so that more of the available information in the data set is used.

The main aim of the project is to predict the consequences of management practices, such as thinning and fertiliser treatments. For new practices, this will involve extrapolating beyond the observed range of treatments and since extrapolation is always risky, a second model is being constructed so that the two models can be used to check each other's extrapolations. The new model is based on the simple assumptions that growth rate is proportional to the difference between income and expenditure of carbon for the tree, and that income is related to leaf area while expenditure depends on the volume of roots, foliage, etc. These volumes, in turn, are assumed to change to compensate for differences in site or competition. On a nutrient deficient site, for example, more may be invested in roots and less in foliage and wood. The approach is similar to that of McMurtrie (1986) although he worked with whole stands while our main interest is in the competition between individual trees. The growth function of the new model is more physiologically based than the original and the two models require different information about the site. The first extensive comparisons of the models are now being made.

A. R. LUDLOW, T. J. D. ROLLINSON

References

McMurtrie, R. E. (1986). Forest productivity in relation to carbon partitioning and nutrient cycling: a mathematical model. In, *Attributes to trees as crop plants*, eds. M. G. R. Cannell and J. E. Jackson, 194–207. Institute of Terrestrial Ecology, Abbots Ripton, Huntingdon.

COMMUNICATIONS

Library

A software package for information retrieval was installed on a microcomputer as a pilot for a larger system. The library acquired 365 new books and book loans amounted to 1484, journal loans 6400, photocopies 3600 and outside loans 1564. This totalled 13 048 items supplied in response to demand, representing an average annual increase of 6 per cent over the last 5 years.

Photography

The Commission's aircraft was sold at the end of the year. The Photographic collection was largely weeded and overhauled and programmes for the acquisition of new material were drawn up. A project was initiated to examine video as a vehicle for technology transfer. It is intended to compare the benefits of inhouse production and video produced by a contractor.

Publications

The following publications were published during the year ending 31 March 1987.

Report

Report on forest research 1986 (£7.85)

Bulletin

63 Census of woodlands and trees 1979–82, by G. M. L. Locke (£8.50)

Booklet

51 The use of herbicides in the forest, 2nd edition, by J. S. P. Sale, P. M. Tabbush and P. B. Lane (£2.50)

Forest Record

131 The fox, by H. G. Lloyd and R. Hewson (£2.70)

Research and Development Papers

139 IUFRO *Abies grandis* provenance experiments: nursery stage results, edited by A. M. Fletcher (£7.50)

146 Beech health study 1985, by D. Lonsdale (£1.85)

148 Forest health and air pollution: 1985 survey, by W. O. Binns, D. B. Redfern, R. C. Boswell and A. J. A. Betts (£1.50)

148 An integrated forest process model: its calibration and predictive performance, by K. Rennolls and P. Blackwell (£2.30)

149 Beech health study 1986, by D. Lonsdale (£2.30)

150 Forest health and air pollution: 1986 survey, by J. L. Innes, R. C. Boswell, W. O. Binns and D. B. Redfern (£1.75)

Miscellaneous

Wood as fuel – a guide to burning wood efficiently, 2nd edition, by G. D. Keighley (20p)

Research digest '86 (free)

The recognition of hazardous trees (free)

Practical work in farm woods (a series of eight free leaflets and a woodland checklist prepared jointly by the Agricultural Development and Advisory Service and the Forestry Commission).

1. Why manage farm woods?
2. Woodland survey and assessment.
3. Management for wood production.
4. Woodlands and farm resources.
5. Woodland management for wildlife and landscape conservation.
6. Woodland management for sport and recreation.
7. New planting.
8. Woodland operations.

Arboricultural Research Notes

65/86/SILS	Alternatives to simazine for weed control in transplant lines and shrubberies at time of planting, by J. S. P. Sale and W. L. Mason.
66/86/EXT	Planting success rates – standard trees, by D. N. Skinner.
67/87/ARB	A comparison of the survival and growth of transplants, whips and standards, with and without chemical weed control, by R. J. Davies.
68/87/PAT	Lightning damage to trees in Britain, by D. R. Rose.

Research Information Notes

106/86/COMM	Technical publications issued during the year ending 31 March 1986, by E. J. Parker.
107/86/SILS	Alternatives to simazine for weed control in transplant lines at time of lining-out, by J. S. P. Sale and W. L. Mason.
108/86/COMM	Research Information Notes issued since 1983.
109/87/SILN	The use of 'Mixture B' to enhance the effect of glyphosate herbicide on *Rhododendron ponticum* and coarse grasses, by P. M. Tabbush.
110/87/SILN	The use of co-extruded polythene bags for handling bare-rooted planting stock, by P. M. Tabbush.
111/87/SSS	Acid rain, air pollution and trees, by J. L. Innes.
112/87/PHYS	Treatment of Sitka spruce to enhance flowering. I. Container-grown grafts, by J. J. Philipson and Margaret A. Brown.
113/87/PHYS	Treatment of Sitka spruce to enhance flowering. II. Grafts in clone banks, by J. J. Philipson, A. M. Fletcher and R. B. Collins.
114/87/SILS	Provenance selection in *Nothofagus procera* and *N. obliqua*, by M. J. Potter.
115/87/SILN	Guidelines for monitoring and management of cold stores, by P. M. Tabbush and S. C. Gregory.

Visits, seminars and open days

There were 72 visits of parties or individuals to Alice Holt, involving 667 people, and 48 to NRS, involving 422 people. The annual visits of Timber Growers UK (TGUK) to the two stations were, once again, successful events and more research seminars of this type were mounted, ranging from a visit from the National Farming and Wildlife Advisory Group's county advisers to Alice Holt for the second year, to a seminar for senior operations' staff from all Conservancies. In response to demand, a seminar was mounted for TGUK at Alice Holt to deal specifically with research into air pollution. Open days at Westonbirt Arboretum, aimed at presenting the results of research in arboriculture, attracted 315 visitors from local authorities and the arboriculture trade.

Research Division's exhibit at the Chelsea Flower Show attracted over 20 000 visitors. It was entitled 'Planting trees for survival' and demonstrated results from research in establishment and weeding. The Royal Horticultural Society awarded the exhibit the Lindley Medal for special scientific and educational merit.

B. G. HIBBERD

OTHER HEADQUARTERS DIVISIONS

PLANNING AND SURVEYS

ECONOMIC PLANNING BRANCH

Forestry employment survey

A joint FC/TGUK survey was conducted during 1986 with support from organisations representing growers, merchants and processors. This revealed a total of nearly 40 000 man-years of employment in British forestry and related industries (Table 15). In addition an estimated 1500 temporary jobs were found to exist: these had been created through the Youth Training Scheme and other Manpower Services Commission schemes.

Previously published figures were founded on estimates from minimal information and this survey establishes a new baseline upon a rather more precise identification of the population. The survey enumerated jobs in the principal sectors of the timber industry, that is growing, haulage from forest to mill, and primary processing, but excluded academics and consultants, small woodworking and craft businesses, and those who supply goods and services to the forest industry (e.g. manufacturers or retailers of chain saws, fertilisers, fuel, fencing materials, etc.).

The numbers in the timber merchants' sector are considerable underestimates. Firms in this sector operate partly as contractors, in which capacity their employment has been identified in the growers' sector of the survey. However, they also harvest and process timber purchased standing from the growers and labour in this area has been included in the survey only if the firm is a member of one of the recognised organisations covering such firms. Many small firms may have been missed because they did not belong to such organisations.

J. THOMPSON

Table 15 Employment in British forestry and wood processing (1)

	England	Wales	Scotland	Great Britain
Forestry Commission	3000	1650	3600	8250
Private estates	9050	1600	3300	13950
Forest management companies	550	150	1800	2500
Timber merchants(2)	4050	1450	250	5750
Primary processing industries(3)	5500	1100	2600	9200
TOTAL	22150	5950	11550	39650

(1) Man-years of work; part-timers counted by actual time worked.
(2) Under-estimates – see text.
(3) Processing of British grown timber only (provisional data obtained from sources other than current survey).

FOREST SURVEYS BRANCH

Census of woodlands and trees

The final report on the Census of woodlands and trees 1979–82 was published as Bulletin 63 in February 1987. Enquiries for woodland information derived from the census continued at a steady rate throughout the year.

Contract work on the survey 'Monitoring landscape change' was completed shortly after the start of the year under review.

G. M. L. LOCKE

PART II

Work done for the Forestry Commission by Other Agencies

SILVICULTURE

Control of shake in oak

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

'Shakes' are splits that develop in the wood of standing trees, often causing serious reduction in the timber value of the British oaks *(Quercus robur* and *Q. petraea)*. Our previous surveys suggested that shakes develop when wood with an inherent weakness becomes stressed. The present work is, therefore, concerned with causes of such weak zones in the timber, and with the development of growth stresses. Weaknesses leading to shake are being investigated in samples from shaken and unshaken trees; cell dimensions and wood structure patterns are compared. Equipment is being developed to compare levels of growth stress in living trees by analysis of increment cores.

Epicormic bud dormancy in oak

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

Shading experiments showed that an 80 per cent reduction in light availability had no effect on the outgrowth of epicormic shoots which could only be suppressed by complete darkness. Thinning in stands of *Quercus robur* increased the amount of light available 1 metre above ground by about 15 per cent in spring and 70 per cent during summer in the first year after the operation. However, thinning had little effect on the number or growth of epicormic shoots over periods of 1 to 3 years, whether assessed in terms of shoot length or weight at three different sites.

Nutrition and forest soils

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

Nutrient cycling in second-rotation Corsican pine is being studied at Culbin Forest, Moray. This work forms part of a wider research programme with the following aims:

1. to measure changes in nutrient sources and sinks from crop establishment to canopy closure, and
2. to provide detailed information on growth and biomass partitioning within young trees and competing ground vegetation.

Sample analyses and data processing have continued for other experiments

including earlier work on spruce nutrition (Miller and Miller, in press) and catchment studies at Balquhidder in the Central Highlands (*Report* 1986, p. 61). A final report on the collaborative UK/Eire study of nutrient cycling within mixed stands (*Report* 1984, p. 62) supported by the EEC has now been prepared (Miller *et al.*, 1986). The nutrition advisory service to forest nurseries continues to operate.

References

Miller, H. G. and Miller, J. D. (in press). Nutrition of Sitka spruce. *Proceedings of the Royal Society, Edinburgh, Series B.*

Miller, H. G., Alexander, C. E., Cooper, J., Keenleyside, J., McKay, H., Miller, J D. and Williams, B. L. (1986). *Maintenance and enhancement of forest productivity through manipulation of the nitrogen cycle.* Final report to the European Research and Development Programme, Wood as a Renewable Raw Material, Contract Number BOS-093 UK.

SITE STUDIES

Effects of afforestation on water resources

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

Institute of Hydrology, Crowmarsh Gifford, Wallingford, Oxon

Balquhidder catchments (Central Region)

Detailed analysis of data, checks of the instrument networks and a hydrogeological study confirm that water use by the Kirkton catchment (35 per cent forest, 55 per cent upland grass, 10 per cent heather) is lower than the Penman evapo-transpiration estimate for grass, apparently caused by the low-temperature restriction of transpiration of grass at high altitude. Water use by the Monachyle catchment (heather/upland grass/bracken) is the same or greater than that predicted for grass alone.

Process studies

A physically-based model of snow interception by coniferous forest has been developed using results from Queens Forest, Aviemore. Using meteorological data as inputs, this model describes well the evaporation and melt of intercepted snow.

A 3-year study of the effects of line thinning on interception losses from Sitka spruce shows that any resulting change in loss is less than the year-to-year variations at the site.

GENETICS

Variation in wood characteristics between *Pinus contorta* seed origins

by D. J. MARSHALL and M. P. DENNE

Department of Forestry and Wood Science,
University College of North Wales, Bangor, Gwynedd

Trees have been sampled from the seed origin trial of *Pinus contorta* planted in 1938/39 at Wykeham (North Yorkshire). Information collected is intended

to aid selection and to provide guidance on variation on desirable sampling intensity. Nine trees have been sampled from each of seven seed origins. Each tree was sampled at five levels to investigate anatomical and physical wood properties within trees and between trees. Data are being collected on gross features such as sweep, bark thickness, eccentricity, ellipticality and heartwood:sapwood ratio, and on microscopic and physical characteristics such as ring width, tracheid length, compression wood, earlywood:latewood ratio, spiral grain and density.

PATHOLOGY

Brunchorstia pinea on conifers in northern Britain

by E. A. B. AITKEN

Department of Forestry, Aberdeen University

Brunchorstia pinea (Ascocalyx abietina) is well known as a cause of disease in Corsican pine but in the late 1970s it was associated with serious damage to Scots pine plantations in north England and south Scotland. Damage was most severe in plantations approximately 20 years old growing at relatively high elevations. *B. pinea* infects both buds and 1-year-old shoots but, in contrast to Corsican pine, infection in Scots pine is more common on shoots than on buds. Infection occurs during the growing season and symptoms develop during the following winter. In Scots pine, necrotic tissue from which *B. pinea* could be isolated was evident in buds at the beginning of November (the earliest date tried) and in shoots from December.

In a severely damaged stand of 30-year-old Scots pine in Rothbury Forest District (Northumberland) in which a high proportion of trees were dead or dying, a small number of individuals virtually escaped injury. Analysis of monoterpenes from cortical resin from 100 trees in each category showed that high levels of β-phellandrene occurred in a significantly higher proportion of 'healthy' trees than in severely damaged trees. Scions taken from 10 'healthy' trees with high levels of β-phellandrene and 10 'diseased' trees with low levels were grafted on to Scots pine rootstocks. One year later the grafts were inoculated with *B. pinea*. Grafts from trees with high levels of β-phellandrene were significantly less diseased than those from trees with low levels.

Additional evidence of variation in resistance in Scots pine was obtained from an inoculation experiment that showed that seedlings from individual mother trees in a stand of native Scots pine at Loch Maree were significantly more susceptible than those from 10 other stands. Inoculations also provided some evidence that site influences disease development but the effect may be complex and individual factors could not be identified.

ENTOMOLOGY

The influence of *Pinus sylvestris* chemistry on the population dynamics of the Large pine aphid, *Cinara pinea* Mordv.

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

The levels of individual amino acids and total phenols of *P. sylvestris* can account for the greater proportion of variation in aphid growth rates between trees. The amount of this variation increases through the season, from the beginning when conditions as reflected by aphid performance are most favourable, to mid-season when variation in both the chemicals and growth rates is greatest. Thus host plant nutrition becomes more limiting at a time which is important for the overall aphid population dynamics, namely at the downturn in numbers. This suggests that factors affecting the health of the tree such as site conditions, climate, other herbivore/pathogen attack and aerial pollution will influence its suitability for a given pest species and possibly also its ability to defend itself, which may then determine whether or not damaging levels are attained.

Acid mist can increase aphid damage potential to conifers

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

The responses of the needle feeding aphid *Schizolachnus pineti* to acid mist treatment of its host tree *Pinus sylvestris* were investigated in the laboratory. The results showed that the presence of acid mist increased the individual and population growth rates of aphids and promoted the production of alatae amongst adults. This suggests that acid mist or acid rain may increase conifer aphid populations in the field and promote the spread of infestation between trees. Heavy infestations of *Schizolachnus* are known to retard the growth rates of *P. sylvestris* and reduce its survival, so the results support the view that aphid populations may have an important role to play in the interactions between air pollution and tree health.

G. B. Lewis is supported by both NERC and the Forestry Commission in the two projects reported above.

WILDLIFE AND CONSERVATION

An assessment of the effectiveness of ultrasonic sound as a deterrent to deer and squirrels

by S. FAWKES
Department of Forestry and Wood Science,
University College of North Wales, Bangor, Gwynedd

Two high-frequency sound generators, the Buzz Bird Sonic Pest Control Unit, manufactured by Demion Electronics, and the Buzz Box produced by the Forestry Commission, were tested to assess their value as deterrents to

squirrels and deer. The Buzz Bird unit was ineffective in deterring squirrels and deer from bait points. The Forestry Commission Buzz Box was 100 per cent effective in preventing roe deer moving through a gateway. Further field trials are planned.

The effects of stress on the behaviour and physiology of red squirrels

by D. J. INKPIN
Queen Mary College, University of London

Red squirrels are fully protected by law and if licences are issued for their control it is often a condition that they are not killed. A solution is the translocation of squirrels into areas where they are scarce or absent and this is now being seriously considered as a red squirrel conservation strategy. The responsible and humane translocation of wild animals demands a knowledge of the effects of stress on their behaviour and physiology. Both red and grey squirrels suffer stress following capture and confinement, and this may result in death. Initial results suggest high stress following capture is manifested by long periods of immobilisation, altered daily feeding patterns and displacement behaviour. High preference foods such as hazelnuts and apples are eaten within a few hours of capture, but low preference foods such as sunflower seeds, maize and peanuts are not eaten until up to 72 hours following capture. This project is funded by SERC and the Forestry Commission.

Squirrel ecology in Thetford Forest

by M. J. R. JORDAN
Queen Mary College, University of London

Grey squirrels in Thetford Forest were originally associated with the amenity belts of beech and oak. They now occur throughout the forest even in the largest blocks of pure conifers. The maximum density encountered is 0.8 ha^{-1}, approximately 10 times lower that in a good broadleaved tree habitat. The red squirrel population in the forest is apparently at very low density and animals are very difficult to trap. Red squirrels are most frequently seen in or near the densest stands of trees, especially conifers between 20 and 40 years old, or in areas with thick dense understoreys.

WOOD UTILISATION

Joint research programme on British-grown timber

by T. HARDING
Princes Risborough Laboratory, Building Research Establishment, Department of the Environment

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

Data from 13 plots sampled to examine the effect of planting distance on structural wood yields from unthinned stands of Sitka spruce have been ex-

amined to determine the characteristics of growth which influence structural performance. Two factors were of special importance – log straightness and size of the largest knots – both of which are adversely affected by wider planting spacings and are associated with the incidence of cross-grain in sawnwood. Density was not especially important but logs from unthinned stands had a high proportion of juvenile wood, which is characteristically low in strength and stiffness compared with that of more mature growth.

No further work on unthinned Sitka spruce is planned and attention is now directed at thinned plantations.

Effect of wood characteristics on machine grading of Sitka spruce

A model to predict the effect of growth features on the performance of Sitka spruce in machine grading has been developed and is being evaluated. Encouraging results have been obtained from preliminary statistical analyses which have been carried out on two sub sets of data, each comprising approximately 200 machine-graded 900 mm spans, with in excess of 50 parameters describing each span. The number of battens measured is now being increased to produce a significantly larger set of data on which to develop and validate the model. Consideration has been given to the interaction of several timber growth features in their effect on the machine graded value of each span. Weighting techniques have been developed to take into account the position of growth features both within the cross section of the batten and within the 900 mm span.

Conversion of British-grown timber

Studies on sawmilling accuracy have indicated that greater care is needed in converting British softwood. However, further investigations have shown that, under favourable conditions, it is possible to achieve a within-piece sawing accuracy comparable to that being achieved by the better overseas mills. Both sawblade and timber/log parameters have been found to be important. Work is underway to identify and quantify the parameters in order to produce guidelines which will enable British sawmillers to check their procedures and optimise the accuracy of conversion.

Drying and use of British-grown timber

by C. J. GILL

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

Drying and presentation of British-grown softwood

A steering committee was formed during 1986 which decided that an investigation of drying Sitka spruce at temperatures up to 102°C should continue. Acceptably low levels of distortion had been achieved using various combinations of restraint, distorted beds and conditioning at temperatures above 90°C. All the timber required for the small-scale drying trials has now been received and has been allocated to one of three categories based on weight. The steering committee also agreed that an investigation of high temperature drying be initiated. A literature review has been completed. A tour of in-

stallations for high temperature drying in Australia and New Zealand was made in March 1987, part-funded by the Department of Trade and Industry. A review of the published literature on air drying was completed and submitted to the Forestry Commission.

Use of sawn British timber in packaging

Work started on abstracting timber strength data for British-grown species and its conversion into suitable formats for comparison with the tables in BS1133 *Packaging code: Section 8, Wooden boxes, cases and crates.* The information gained will be incorporated in a revision of this British Standard. Design and construction of the test equipment to be used on box panels has been completed.

APPENDIX I

Publications by Forestry Commission Staff

ANDERSON, A. R. and PYATT, D. G. (1986). Interception of precipitation by pole-stage Sitka spruce and Lodgepole pine and mature Sitka spruce at Kielder Forest, Northumberland. *Forestry* **59** (1), 29–38.

The average interception loss was 29 per cent for both pole-stage crops and 49 per cent for mature Sitka spruce. The ratio of stemflow to throughfall was 0.18:0.82 for pole-stage spruce, 0.14:0.86 for pole-stage pine and 0.02:0.98 for mature spruce.

ANDERSON, M. A. (1986). Conserving soil fertility: application of some recent findings. In, *Forestry's social and environmental benefits and responsibilities.* Proceedings of a discussion meeting held at Oxford Forestry Institute, April 1986, ed. R. J. Davies, Institute of Chartered Foresters, 65–73.

Foresters can regulate the effects of forest crops on soil fertility by species choice, by spacing and thinning practices, and by harvesting methods. The paper ranks widely-used tree species by their effects on soil nutrient stocks and compares the effects of thinning and spacing on nutrient accumulations in the surface of lowland soils. Means of alleviating soil damage from harvesting, and the conflicts between conservation for wildlife or soil fertility are discussed.

BALDWIN, E. and MASON, W. L. (1986). An early trial of Sitka spruce cuttings. *Scottish Forestry* **40** (3), 176–184.

Cuttings of Sitka spruce were propagated in 1949 and planted in a forest experiment in 1953. Survival of cuttings was high and subsequent growth has been as good as transplant controls.

BARBOUR, D. A. (1986). Why are there so few butterflies in Liverpool? An answer. *Antenna* **10** (2), 72–75.

The number of butterfly species in Britain falls off progressively from south to north. Major exceptions to this occur around industrial and urban areas of England, where up to 22 species of butterflies have become extinct. The pattern of decline resembles that of many lichen species, and is strongly correlated with atmospheric sulphur dioxide levels.

BARBOUR, D. A. (1986). Expansion of range of the speckled wood butterfly *Pararge aegeria* L. in north-east Scotland. *Entomologist's Record and Journal of Variation* **98** (5–6), 98–105.

The distribution of the speckled wood in N.E. Scotland has been expanding steadily for about 30 years since its first appearance near Inverness. The spread is mapped by 6-year periods, and ecological reasons for the change are discussed.

[BATEMAN, R. M.] and MOFFAT, A. J. (1987). Petrography of the Woolwich and Reading formation (late Palaeocene) of the Chiltern Hills, southern England. *Tertiary Research* **8** (3), 75–104.

Petrographic study of the Woolwich and Reading formation in the Chiltern Hills suggests three stratigraphical units: bottom bed, sands and clays. The bottom bed represents a transgressive event and is largely composed of re-worked material. It is succeeded by sands and clays that were probably deposited in a complex series of sub-environments associated with a lagoon. A zircon+tourmalines+rutile+staurolite+kyanite mineral assemblage occurs throughout the formation.

[BAYES, C. D., DAVIES, J. M.] and TAYLOR, C. M. A. (1987). Sewage sludge as a forest fertiliser: experiences to date. *Journal of the Institute of Water Pollution Control* **86** (1), 158–171.

Description of current research work on the use of sewage sludge as a forest fertiliser. The background to this project is explained and initial experimental results are presented. Although the results were not always positive, this work has stimulated enough interest to warrant further investigation.

BINNS, W. O. (1986). Forestry and freshwaters: problems and remedies. In, *Effects of land use on freshwaters: agriculture, forestry, mineral exploitation, urbanisation*, eds. J. F. and L. G. Solbé, 364–377. Ellis Horwood Ltd., New York.

Forests reduce water yield, though in Britain effects are local rather than regional. Upland forests appear to acidify freshwaters but this only seems important over hard acid rocks. Undesirable effects of forestry on water quality may be mitigated by changes in cultivation and drainage practice, by leaving stream-sides unplanted, and by good control of roading and harvesting operations. Final conclusions on the causes of acidification and the best remedies must await the results of research.

BINNS, W. O. (1987). Surveys of forest health in relation to air pollution. In, *The effects of acid rain and air pollution in northern Europe.* Proceedings of a scientific seminar organised by Friends of the Earth, April 1986, eds. A. Markham and L. Blundell, 105–117.

Surveys of forest health in relation to air pollution. The surveys of 1984 and 1985 were designed to detect changes, over a number of years, in the condition of three of the most important conifers in British forestry, and to relate any changes found to environmental factors. Crown density, average needle life and needle colour appeared normal. Regression analaysis revealed few significant (or meaningful) correlations. Foliar analysis showed reasonable concentrations of major nutrients, with some samples low in N and P.

BINNS, W. O., REDFERN, D. B., BOSWELL, R. and BETTS, A. J. A. (1986). *Forest health and air pollution: 1985 survey.* Forestry Commission Research and Development Paper 147. Forestry Commission, Edinburgh.

The 1985 survey followed the lines of the 1984 survey; nine plots were added in north Scotland. Crown density and average needle life were slightly higher. Analysis of 7th whorl foliage showed generally satisfactory concentrations of K, Ca, and Mg; a few samples were low in N and P. Regression of crown characters on environmental and geographic variables showed few significant terms, and these accounted for a rather small proportion of the variance. Between-assessor variation was unacceptably high, requiring changes in procedure.

BRASIER, C. M. (1986). A comparison of pathogenicity and cultural characteristics in the EAN and NAN agrressive sub-groups of *Ophiostoma ulmi. Transactions of the British Mycological Society* **87**, 1–13.

EAN aggressive isolates are on the average slower growing and have a different colony morphology from NAN aggressives. The EAN also exhibits a characteristic mycelial-mycelial dimorphism condition by the *'up-mut'* factor. EAN isolates show a greater range of pathogenicity and a lower mean pathogenicity than NAN. The role of the *up-mut* factor in EAN behaviour, in the outcome of the EAN/NAN interaction in the current epidemics and in the evolution of *O. ulmi* is discussed.

BRASIER, C. M. (1986). The d-factor in *Ceratocystis ulmi*: its biological characteristics and implications for Dutch elm disease. In, *Fungal virology*, ed. K. W. Buck, 177–208. C.R.C. Press, Florida, USA.

Describes the distribution of the mycovirus-like d-factor in the three *C. ulmi* subgroups, the characteristics of 'd-reaction', cytoplasmic location and spread of d-factors, their detrimental effects on growth and reproduction, mechanisms of regulation of transmission, and effect on pathogenicity of *C. ulmi* isolates. Assesses the potential impact of d-factors in various phases of the pathogen within the Dutch elm disease cycle and the potential impact of d-factors on *C. ulmi* populations and in disease control.

BRASIER, C. M. (1986). The population biology of Dutch elm disease: its principal features and some implications for other host-pathogen systems. In, *Advances in Plant Pathology* **5**, eds. D. S. Ingram and P. H. Williams, 55–118. Academic Press, New York.

Discusses the population biology of the Dutch elm diseases pathogen *Ophiostoma ulmi*, in terms of selection components, fitness parameters, gene flow regulation mechanisms and population partitioning effects in the context of the current epidemics of Dutch elm disease and their causes. Presents conceptual models for rapid evolution of plant pathogens in response to environmental pressures and considers implications of the population structure of *O. ulmi* for crop breeding and disease control, including the possibility of breeding the pathogen itself.

BRASIER, C. M. (1987). Recent genetic changes in the *Ophiostoma ulmi* population: the threat to the future of the elm. In, *Populations of plant pathogens,* eds. M. S. Wolfe and C. E. Caten, 213–226. Blackwells, Oxford.

Discusses the role of the non-aggressive, EAN aggressive and NAN aggressive subgroups of *O. ulmi* in the current Dutch elm disease epidemics. Considers evidence for the likely replacement of the non-aggressive by the aggressive and for a natural decline in pathogenicity of the aggressive subgroup. Presents a theoretical prognosis for the future of the elm populations of Europe and North America.

BRASIER, C. M. (1987). Some genetical aspects of necrotrophy with special reference to *Ophiostoma ulmi*. In, *Genetics and plant pathogenesis*, eds. P. R. Day and G. J. Jellis, 297–310. Blackwells, Oxford.

Discusses the genetics of pathogenicity in pathogens causing fine root rots, stem cankers, bark necroses, massive root and collar rots and vascular wilts. Examines evidence for the broad genetic architecture of aggressiveness including polygenic and major gene involvement, role of regulatory genes, and impact of genetic divergence and effects of environment on expression. Considers evidence for the genetic control of enzyme, toxin and growth components of necrotrophy.

BRASIER, C. M. and KIRK, S. A. (1986). Maternal inheritance of chloramphenicol tolerance in *Ophiostoma ulmi*. *Transactions of the British Mycological Society* **87**, 460–462.

Isolates of *O. ulmi* tolerant to 0.4–1.0 per cent chloramphenicol in the base medium had a relatively normal colony morphology. Tolerance, stable over 10 serial mass subcultures, was transmitted to single-spore derivatives, and was classically maternally inherited in reciprocal crosses. The locus concerned is presumed to be located on the mitochondria.

BURDEKIN, D. A. (1986). European plant health requirements for forest pests. *EPPO Bulletin* **16**, 509–512.

There is a need to establish and update lists of potentially dangerous forest pests in order that appropriate preventive measures can be introduced. However, it is important to recognise that lists of potentially dangerous organisms can never be complete. In effect, this is recognised by the provisions of the EC directive but not so far in EPPO recommendations.

CARNELL, R. and ANDERSON, M. A. (1986). A technique for extensive field measurement of soil anaerobism by rusting of steel rods. *Forestry* **59** (2), 129–140.

Steel rods inserted into the soil for 3 months or more demonstrated limits of anaerobism by colour differences in reaction products. Rods corroded consistently to give a surface brown/orange zone and a mat grey zone at depth. The sharp boundary between zones corresponded with: (i) the top of the capillary fringe; (ii) the lower limit of oxygenation as indicated by polarography; and (iii) the limit of Sitka spruce seedling root mats.

COUTTS, M. P. (1986). Components of tree stability in Sitka spruce on peaty gley soil. *Forestry* **59** (2), 173–197.

Measurements were made on the anchorage of the trees in terms of the soil resistance, the weight of the root-soil plate, and the contributions made by different parts of the root system. The importance of these components changed during the course of uprooting. Changes in the displacement of the stem and crown were also recorded.

DAVIES, R. J. (ed.) (1986). *Forestry's social and environmental benefits and responsibilities*. Proceedings of a discussion meeting held at Oxford Forestry Institute, April 1986. Institute of Chartered Foresters.

[DOYLE, C. J.], EVANS, J. [and ROSSITER, J.] (1986). Agroforestry: an economic appraisal of the benefits of intercropping trees with grassland in lowland Britain. *Agricultural Systems* **21**, 1–32.

EVANS, H. F. (1986). The ecology and epizootiology of baculoviruses. In, *The biology of baculoviruses*. Vol II. *Practical application for insect control*, eds. R. R. Granados and B. A. Federici, 89–132. C.R.C. Press, Florida, USA.

A review article dealing with the ecology of insect baculoviruses. Basic ecology, infectivity, specificity, transmission and persistence of baculoviruses are discussed as a background to their use in pest management programmes.

EVANS, J. (1986). A re-assessment of cold-hardy eucalypts in Great Britain. *Forestry* **59** (2), 223–240.

A few species of eucalypts in Great Britain are both hardy and fast growing. Although in 1981/82, nearly all species were killed in the temperatures of between −19°C to −23°C, it was found that some provenances of *E. gunnii* and the snow gums *E. debeuzevillei* and *E. niphophila* did possess sufficient cold-hardiness to survive well. In the long term, eucalypts could be considered a short-fibre pulp species for moderately exposed upland sites where yield classes of 12 to 16 on 10 year rotations could be expected. Their biomass potential appears at least comparable to that of poplars and willows.

EVANS, J. (1986). Nutrition experiments in broadleaved stands: I. Pole-stage oak and ash. *Quarterly Journal of Forestry* LXXX (2), 85–94.

With ash, breast height diameter increment was significantly increased by nitrogen fertilising for at least the first 3 years after application. Potassium fertilising significantly increased diameter increment on one site. No responses were recorded to fertiliser application in any of the oak experiments, thus adding weight to the view that nutrient supply is unlikely to be an important limiting factor to growth on sites where oak is generally grown in Britain.

EVANS, J. (1986). Nutrition experiments in broadleaved stands: II. Sweet chestnut and stored oak coppice. *Quarterly Journal of Forestry* LXXX (2), 95–104.

Coppicing leads to depletion of soil nutrients if practised over long periods. Leaf nutrient levels can sometimes be significantly increased by adding fertilisers but in only one experiment (phosphate in 10-year-old Sweet chestnut) was growth rate improved. Liming significantly depressed growth. Foliar analysis showed considerable year-to-year variation in leaf nutrient levels for the same trees and generally low levels of phosphate (0.12 to 0.14 per cent oven-dry weight) which appear satisfactory for growth.

FAULKNER, R. (1986). Are our tree seed and plant regulations working well? *Forestry and British Timber* **15** (9), 15–18.

A synopsis of the main features of the British forest reproductive materials regulations and their main objectives; the probable benefits of using seed and plants derived from selected seed sources; and some of the problems which arise when there is a shortfall of 'home' collected seeds from selected stands.

FAULKNER, R. (1986). The registration and certification of forest reproductive material from sources other than seed stands and seed orchards. Materials derived from hand pollinated flowers in young tested orchards, or tested clones in clonal archives, plants from which are bulked-up by vegetative propagation. *Mitteilungen der Bundesforschungsanstalt für Forst und Holzwirtschaft* **154**, 50–53.

Presents the main problems of seed production from clonal orchards and the benefits of producing limited amounts of seed from hand pollinations and the subsequent bulking-up of plant material using vegetative means. Provision will have to be made to modify existing EEC and national regulations in order to cater for this class of material and other products expected from some of the new biotechnological developments in gene manipulation and plant production.

FLETCHER, A. M. (1986). *IUFRO Abies grandis provenance experiments: nursery stage results.* Forestry Commission Research and Development Paper 139. Forestry Commission, Edinburgh.

A joint production by members of the IUFRO Working Partry (S2.02.14) on *Abies* provenances, which deals with the nursery stages of the seed collections made throughout the natural distribution of *Abies grandis* in north-west America. Contributions from 10 countries covering 12 research organisations are included in the publication.

GIBBS, J. N. and WAINHOUSE, D. (1986). The spread of forest pests and pathogens in the northern hemisphere. *Forestry* **59** (2), 142–153.

There are four main forest regions in the northern hemisphere, each containing many of the same genera of trees. An organism living in balanced relationship with its host tree in one of these forest regions may cause major damage if moved to another. Examples of pest and disease problems analysed include Chestnut blight, White pine blister rust, Gypsy moth, Balsam woolly aphid, Dutch elm disease, Pine wilt disease and Beech bark disease.

GREGORY, S. C. (1986). The development of stain in wounded Sitka spruce stems. *Forestry* **59** (2), 199–208.

The upward extent of stain in wounded Sitka spruce stems was positively correlated with wound surface area and length. Most stain was of a light type which usually constituted an insignificant defect. Heavy stain, a more serious defect, extended above less than half of all wounds but was common above wounds exceeding 300 cm^2 surface area. The wounds studied were between 8 and 14 years old and most had been made by red deer.

GREIG, B. J. W. (1986). Further experiments with Thiabendazole (TBZ) for control of Dutch elm disease. *Arboricultural Journal* **10** (3), 191–201.

In trials on elms showing early symptoms of Dutch elm disease, additional evidence was obtained on the efficacy of 60 g TBZ per 30 cm circumference when applied as 20:1 of 0.3 per cent a.i. Reduced volumes with the same dosage of fungicide gave inconclusive results. In a protective trial the 60 g treatment completely prevented disease symptoms in artificially inoculated trees, while with a lower rate (20 g) inoculated branches wilted but the trees subsequently recovered.

[HANSEN, E. M.], BRASIER, C. M., [SHAW, D. S. and HAMM, P. B.] (1986). The taxonomic structure of *Phytophthora megasperma:* evidence for emerging biological species groups. *Transactions of the British Mycological Society* **87**, 557–573.

In a comparison of 93 isolates of *Phytophthora megasperma*, a ubiquitous plant pathogen, on the basis of morphological characters, growth rate, protein electrophoretic patterns, chromosome numbers and nuclear DNA content, nine distinct subgroups were distinguished. The groups were largely associated with host plant specificities ranging from legumes to trees. Two broad lines of evolution are hypothesized, a legume line and a broad host range line. Subgroups within each line may reflect biological species emerging under influence of crop monoculture.

HARMER, R. [and ALEXANDER, I.] (1986). The effect of starch amendment on nitrogen mineralisation from the forest floor beneath a range of conifers. *Forestry* **59** (1), 39–46.

Samples from the LF and H horizons of the forest floor collected beneath 16 coniferous species growing at the same site were incubated in the laboratory with or without starch amendment. When starch was added material from 11 species showed significantly greater accumulation of mineral nitrogen. Addition of starch to LFH from Sitka spruce increased rates of mineralisation regardless of yield class, rates being greatest in the most productive stands.

HARPER, W. C. G. (1986). Factors affecting the selection of the economically optimum thinning regime. In, *The influence of spacing and selectivity in thinning on stand development, operations and economy.* Proceedings IUFRO Project Group P4.02.02, Dublin, Ireland.

The choice of thinning regime was considered in relation to site factors, stand growth pattern and price assumptions. The main conclusions were:

1. Wind is the dominant site factor influencing thinning. Some 35 per cent of Forestry Commission stands will not be thinned because of the risk of windblow.
2. On stable sites, the faster a stand is growing, the more likely that thinning will be optimal. On unstable sites the reverse is true.
3. Optimal thinning regime is very sensitive to price level and to the slope of the price-size curve.

The decision to start thinning can be made by comparing the expected surplus with a calculated required minimum.

HARPER, W. C. G. (1986). The Forestry Commission Forest Investment Appraisal Package. *ECE/FAO/ILO Joint Committee on forest working techniques and training of forest workers.* Seminar on the preparation and implementation of forest management plans. Oosterbeek, The Netherlands, 26–31 May 1986.

This package provides the forest manager with a tool to help in evaluating management decisions. The use of a computer based system removes the need for length of calculations and allows more time to be spent considering the results of appraisals.

HARPER, W. C. G. (1986). To thin or not to thin – optimising present and future returns to grower. *Forestry and British Timber* **15** (12), 22–27.

This paper outlines current Forestry Commission thinning policy, and discusses the assumptions on which it is based.

HATFIELD, G. R. (1986). Forestry as an alternative crop. *The Agronomist* **3**, 4–5.

Afforestation in this country has long been confined to agriculturally marginal land, but in a climate where surpluses are stimulating a search for alternatives, a less restrictive approach to forestry could be adopted. The UK imports most of its timber requirement so greater output, both from farm forestry and transfer of land to the forestry sector, would find a ready market. Compensatory payments for the loss of annual income from land planted will be an important factor for farmers. The best land is likely to remain more profitable in farming. Regional and local effects of a less restrictive approach to forestry are difficult to predict because the means of curtailing agricultural output is not yet clear.

[HEADLEY, M. V.] and THOMPSON, D. A. (1986). Forest management in Jamaica. In, *Forests of Jamaica*, eds. D. A. Thompson, P. K. Bretting and M. Humphreys, Jamaican Society of Scientists and Technologists, Kingston, Jamaica, 91–96.

Brief descriptions are given of the organisation of forest management in Jamaica up to 1985. The practice of silviculture and harvesting methods are described followed by an outline of the economics of tree growing in the island.

HIBBERD, B. G. (1986). Sitka celebrated – species chosen to mark Edinburgh anniversary. *Forestry and British Timber* **15** (12), 29–30.

An account of the symposium on Britain's most common plantation tree which marked Edinburgh Botanical Society's 150th anniversary.

INNES, J. L. (1986). The size-frequency distributions of the lichens *Sporastatia testudinea* and *Rhizocarpon alpicola* through time at Storbreen, south-west Norway. *Journal of Biogeography* **13**, 283–291.

Populations of two lichen species show evidence of ageing and changes in recruitment. Colonization occurred during a limited period and is apparently restricted at the present time, even on relatively young surfaces.

INNES, J. L. (1986). Dating exposed rock surfaces in the Arctic by lichenometry: the problem of thallus circularity and its effects on measurement errors. *Arctic* **39** (3), 253–259.

Errors involved in the use of the largest inscribed circle method of measurement are significantly greater than those associated with the measurement of the longest axis. The use of inscribed circle diameters will underestimate the maximum growth rates of lichens on older surfaces.

INNES, J. L. (1986). Influence of sampling design on lichen size-frequency distributions and its effect on derived lichenometric indices. *Arctic and Alpine Research* **18** (2), 201–208.

Late-lying snowbanks and altitude both affect the nature of lichen size-frequency distributions. The measurement interval is important when applying population models to the distributions.

INNES, J. L. (1986). The use of percentage cover measurements in lichenometric dating. *Arctic and Alpine Research* **18** (2), 209–216.

Subjective estimates of cover are subject to systematic error and the results obtained by different observers are not reproducible. Percentage cover is extremely sensitive to environmental variations and this poses problems for its use as a dating technique.

INNES, J. L. (1986). Textural properties of regoliths on vegetated steep slopes in upland regions, Scotland. *Transactions of the Royal Society of Edinburgh: Earth Sciences* 77, 241–250.

There are substantial variations in the textural properties of regoliths derived from different parent lithologies, although the majority are dominated by the coarser fractions and are poorly sorted. Most particle size distributions show some degree of fit with both Rosin and log-normal probability distributions. Differences from these can be ascribed to the processes operating on steep slopes, namely the colluvial inwash of sand and silt-sized material and the removal of clay-sized material by leaching.

INNES, J. L. (1987). What causes forest damage? Forestry Commission looks at air pollution. *Forestry and British Timber* **16** (2), 17–18.

Current research on the interaction of air pollution and forestry is summarised.

INNES, J. L., BOSWELL, R., BINNS, W. O. and REDFERN, D. B. (1986). *Forest health and air pollution 1986 survey.* Forestry Commission Research and Development Paper 150. Forestry Commission, Edinburgh.

A general decline in tree health is apparent from the survey data. This can be partly attributed to the effects of observer training and is therefore artificial. However, it is likely that the very cold conditions in early 1986 combined with severe *Lophodermium* infections and *Brunchorstia* infestations also influenced tree health, resulting in a real decline in health. The survey will be repeated and extended in 1987.

INSLEY, H. (1986). Incentives for private forestry in Great Britain. In, *Proceedings of 11th Seminar on Multipurpose Agriculture and Forestry,* University of Padove, 28th April–3rd May 1986, 331–340.

Describes the incentives available to private woodland owners under income tax, capital expenditure allowances and the ability to transfer from schedule B to schedule D as well as the special concessions under capital transfer tax and capital gains tax. Grant schemes open to private woodland owners are listed. Examples are given to show the net effect of the incentives on the net present value of a rotation of Corsican pine in east England.

INSLEY, H. [and BUCKLEY, G. P.] (1986). Causes and prevention of establishment failure in amenity trees. In, *Ecology and design in the landscape;* 24th Symposium of the British Ecological Society, ed. A. D. Bradshaw, 127–141. Blackwells Scientific Publications, Oxford.

The survival and growth of young broadleaved trees are affected by (i) their physiological condition at the time of planting and (ii) the ecological situation, determined by the plant communities and site conditions into which they are planted. These influences were investigated in a series of experiments in both glasshouse conditions and on motorway verges in England and Wales. These are described together with and conclusions drawn about the practical application of the results for improving the success of tree planting schemes.

JOHN, A. (1986). Test tube trees – potential of micropropagation. *Forestry and British Timber* **15** (5), 10–11.

The techniques used for the micropropagation and rooting of juvenile Sitka spruce shoots are discussed briefly in relation to their possible use in commercial forestry.

JOHN, A. [and WEBB, K. J.] (1987). Sitka spruce. In, *Cell and tissue culture in forestry.* Volume 3. *Case histories: gymnosperms, angiosperms and palms,* eds. J. M. Bonga and D. J. Durzan, 30–41. Martinus Nijhoff, Dordrecht, The Netherlands.

The various techniques used for the micropropagation and rooting of Sitka spruce shoots are discussed in detail.

[KING, J. A., SMITH, K. A. and] PYATT, D. G. (1986). Water and oxygen regimes under conifer plantations and native vegetation on upland peaty gley soil and deep peat soils. *Journal of Soil Science* **37**, 485–497.

The soil water regime and aeration were improved as a result of tree growth on both soils. Lodgepole pine had greater effects than Sitka spruce on the deep peat and on the peaty gley in summer but in winter the water regime of the peaty gley was similar under both species.

[KOSKE, R. E. and] WALKER, C. (1986). Species of *Scutellospora* (Endogonaceae) with smooth-walled spores from maritime sand dunes: two new species and a redescription of the spores of *Scutellospora pellucida* and *Scutellospora calospora. Mycotaxon* **27**, 183–194.

Examination of soil samples from sand dunes on the eastern seaboard of the USA revealed two undescribed species of *Scutellospora* with smooth outer walls. *Scutellospora weresubiae* is characterized by its translucent pink spores with a complex wall structure, and *S. fulgida* produces hyaline spores with three walls. The species are described in this paper, and comparisons drawn with two other similar smooth-walled species, *S. pellucida* and *S. calospora*, which are illustrated and redescribed with a standardized wall terminology.

LEATHER, S. R. (1986). Insect species richness of the British Rosaceae: the importance of host range, plant architecture, age of establishment, taxonomic isolation and species-area relationships. *Journal of Animal Ecology* **55**, 840–860.

The number of species of Lepidoptera, Hymenoptera, Homoptera and Diptera 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. Within the Rosaceae, trees support more insect species than shrubs which in turn support more insect species than herbs. In addition, trees have more insect species within each insect guild and taxonomic grouping associated with them.

LEATHER, S. R. (1986). Host monitoring by aphid migrants: do gynoparae maximise offspring fitness? *Oecologia (Berlin)* **68**, 367–369.

Gynoparae (autumn migrants) of the Bird cherry-oat aphid, *Rhopalosiphum padi* (L.) were not found to land randomly on their primary host, *Prunus padus* L. Some trees, although within a few metres of heavily infested trees, were not colonized at all. This phenomenon occurs regularly from year to year. Trees in Scotland and Finland were examined and the hypothesis developed that the gynoparae of *R. padi* show maternal care in selecting hosts that favour their offspring's survival and reproduction.

LEATHER, S. R. (1986). Insects on Bird cherry. I. The Bird cherry ermine moth *Yponomenta evonymellus* (L.) (Lepidoptera:Yponomentidae). *Entomologist's Gazette* **37**, 209–213.

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

LEATHER, S. R. (1986). The effect of neonatal starvation on the growth, development and survival of larvae of the Pine beauty moth, *Panolis flammea* (D & S). *Oecologia (Berlin)* **71**, 90–93.

Mortality of neonatal Pine beauty moth larvae varied depending on the duration of food deprivation and temperature. At 20°C and 100 per cent RH all larvae had died by the fourth day of food deprivation whereas at 10°C and 100 per cent RH larvae survived for 12 days without food. Although larvae were able to survive at 15°C for up to 7 days without food, establishment on their host at this temperature was seriously affected by 3 days of starvation.

LEATHER, S. R. (1986). Keep an eye out for the Vapourer moth. *Forestry and British Timber* **15** (7), 13.

Brief descriptions of the Vapourer moth *(Orgyia antiqua)*, its life cycle and damage effects to Lodgepole pine and Sitka spruce are presented.

LEATHER, S. R. (1986). *Panolis flammea* – a threat to Scottish forestry. *Antenna* **10**, 167–170.

Pine beauty outbreaks since 1976 are discussed, a brief review of the life cycle and control methods used presented, and the direction of future research indicated.

LEE, S. J. (1986). Tree breeding in Britain. *Forestry and British Timber* **15** (6), 22–23; **15** (7), 31–32; **15** (8), 24–25.

Three part series covering (i) the concept of tree breeding, (ii) its application in Britain, and (iii) future prospects.

LOCKE, G. M. L. (1987). *Census of woodlands and trees 1979–82.* Forestry Commission Bulletin 63. HMSO, London.

This report describes the survey methods used for a census of woods and trees in Great Britain which was carried out between 1979 and 1982. It also discusses the main results of the investigation and compares them with those of past surveys. It supplements the area and volume results which have already been published for counties and conservancies in England and Wales, for regions and conservancies in Scotland, for the three countries and for Great Britain as a whole.

LONSDALE, D. (1986). *Beech health study 1985.* Forestry Commission Research and Development Paper 146. Forestry Commission, Edinburgh.

In a study of about 450 beech trees in 19 plots throughout Great Britain the incidence of 'Waldsterben' symptoms, of the type decribed from Central Europe, was generally low in the younger plots (minimum age 31 years) and somewhat higher in several older plots (maximum age *c.* 120 years). For the three major symptoms foliar yellowing, crown thinness and abnormal branching, a composite index (0–100 scale) gave scores ranging from below 1 to 17.

LONSDALE, D. (1986). *Beech health study 1986.* Forestry Commission Research and Development Paper 149.

The second annual assessment of the trees in this study showed no underlying changes in health. Foliar yellowing was, however, much less prevalent than in 1985, perhaps because the trees were recovering from the effects of drought in 1983 and 1984. Reports from two West German research workers Drs K. J. Lang and A. Roloff, who visited British beech stands in 1986, are appended.

LOW, A. J. (1986). Tree planting in the Falkland Islands. *Forestry* **59** (1), 59–84.

Tree planting prospects were appraised during a visit to the Falkland Islands in 1983. The creation of effective shelterbelts appeared feasible, the most promising species being *Cupressus macrocarpa, Picea sitchensis* (QCI), *Pinus contorta* (coastal origins), *Pinus radiata* and *Nothofagus betuloides.* Using the same species, limited planting for wood production may also be possible on a very few sheltered, moist, accessible sites.

[McKILLOP, I. G.], PEPPER, H. W. [and WILSON, C. J.] (1986). Specification for wire mesh fences to exclude the European wild rabbit from crops. In, *Proceedings of the 12th Vertebrate Pest Conference*, San Diego, USA, 147–152.

The sizes of hexagonal and rectangular meshes needed to exclude all age classes of rabbits *(Oryctolagus cuniculus)* are 31 mm and 50 × 25 mm respectively. Fences 0.75 m high excluded >90 per cent of adult rabbits, a similar percentage to that obtained using the commonly accepted height of 0.9 m. The 0.75 m high fence is more cost-effective.

MASON, W. L., MANNARO, P. M. and WHITE, I. M. S. (1966). Growth and root development in cuttings and transplants of Sitka spruce 3 years after planting. *Scottish Forestry* **40** (4), 276–284.

Cuttings of Sitka spruce were taller and had greater dry weights than transplants. There was no difference in the uniformity of the root system of the two plant types.

MASON, W. L. and GILL, J. G. S. (1986). Vegetative propagation of conifers as a means of intensifying wood production in Britain. *Forestry* **59** (2), 155–172.

Reasons for current interest in vegetative propagation are reviewed. Three preconditions are proposed for commercial propagation programmes. These are use of juvenile material, propagation of tested material only, and use with material in short supply. At present, only Sitka spruce and possibly Hybrid larch meet these preconditions.

MASON, W. L. (1987) Control of simazine resistant weeds in forest nurseries. *Forestry and British Timber* **16** (2), 27–28.

Simazine resistant weeds have become an increasingly serious problem in British nurseries. Research has been carried out to identify alternative herbicides. Oxadiazon, oryzalin, napropamide and diphenamid show promise in controlling resistant weeds.

[MATTHEWS, J. A.], INNES, J. L. [and CASELDINE, C. J.] (1986). ^{14}C dating of palaeoenvironment of the historic 'Little Ice Age' glacier advance of Nigardsbreen, south-west Norway. *Earth Surface Processes and Landforms* **11**, 369–375.

Moss and grass remains associated with a well-developed *in situ* palaeosol buried beneath a moraine ridge in front of Nigardsbreen (south Norway) have been ^{14}C dated. Pollen preserved with the plant remains suggest the existence of an agricultural landscape prior to the deposition of the moraine. This accords with documentary evidence.

MILLER, K. F. (1986). Recent aeromechanical research in forest plantations. In, *Minimising wind damage to coniferous stands.* Proceedings of a workshop organised jointly by the Danish Forest Experiment Station and the Commission of the European Communities, 3–7 March, Denmark, 7–10.

Useful progress has been made in quantifying wind structure over forests, and the dynamic response characteristics of trees under windloading. This paper reviews the main elements of this research, with particular reference to commercial conifer plantations. Knowledge of the mechanisms involved during tree failure in strong winds may facilitate the development and selection of silvicultural techniques that delay or restrict the incidence of damage.

MILLER, K. F. (1986). Windthrow hazard classification of forest land. In, *Minimising wind damage to coniferous stands.* Proceedings of a workshop organised jointly by the Danish Forest Experiment Station and the Commission of the European Communities, 3–7 March, Denmark, 27–29.

Endemic windthrow in Britain currently affects around 5000 ha of conifer plantations a year, with an estimated economic loss of about £3 million. A programme of systematic observation of windthrow in selected forest areas has enabled the development of a simple system of windthrow prediction, known as the Windthrow Hazard Classification. Current research is attempting to refine the predictive precision of the Classification to include wind damage extension rates and the influence of alternative site preparation techniques.

MILLER, K. F. (1986). Windthrow hazard in conifer plantations. *Irish Forestry* **43** (1), 66–78.

Describes the development and applications of the Forestry Commission's Windthrow Hazard Classification and outlines current research aimed at improving the prediction of windthrow in spruce plantations. A preliminary wind zonation of Ireland is also presented.

MITCHELL, A. G. (1987). Characterization of iprodione tolerance in *Ophiostoma ulmi. Transactions of the British Mycological Society* **88** (2), 283–288.

Iprodione tolerance in *Ophiostoma ulmi* appears to be conferred by allelic or closely linked single-locus mutations. The characteristics of three stable iprodione-tolerant phenotypes are described.

MOFFAT, A. J. (1986). Quartz signatures in Plio-Pleistocene gravels in the northern part of the London basin. In, *Clast lithological analysis*, ed. D. R. Bridgland, Quaternary Research Association Technical Guide 3, 117–128.

This paper demonstrates that detailed examination of gravel size distribution and their components for Plio-Pleistocene gravels on the Chiltern Hills can elucidate mode of deposition and provenance. The quartz component is shown to be particularly important, differentiating gravels with a likely marine origin from those deposited under fluvial conditions.

MOFFAT, A. J. [and CATT, J. A.] (1986). A re-examination of the evidence for a Plio-Pleistocene marine transgression on the Chiltern Hills. III. Deposits. *Earth Surface Processes and Landforms* **11**, 233–247.

A petrological re-examination of the deposits that Wooldridge and Linton used as evidence for a Plio-Pleistocene marine transgression on the Chiltern Hills indicates that many are fluvial and some have been reworked in a periglacial climate. However, those from Little Heath and Rothamsted, Hertfordshire and Lane End, Buckinghamshire are confirmed as marine and Plio-Pleistocene. Subsidence during the Pleistocene is suggested by the northeasterly decline in height of the few truly marine deposits.

PEPPER, H. W. (1986). Spring steel wire – the versatile system. *Forestry and British Timber* **15** (6), 7.

Describes the application of spring steel wire to fencing.

PEPPER, H. W. (1986). The protection of broadleaved woodlands against bark-stripping damage by grey squirrels. *The Game Conservancy Annual Review No. 17*, 106–111.

Bark-stripping damage by grey squirrels especially on broadleaved woodlands is a major problem. The Forestry Commission's recommended methods of protection and their application are discussed.

PETTY, S. J. and ANDERSON, D. (1986). Breeding by Hen harriers *Circus cyaneus* on restocked sites in upland forests. *Bird Study* **33**, 177–178.

In the British Isles, the Hen harrier breeds mainly on heather moorland and in young, first generation conifer plantations in the uplands. This paper records one successful and a number of failed breeding attempts on restocked sites in the English/Scottish border region. These are discussed in relation to current forest management.

PETTY, S. J., [LITTLE, B. and] ANDERSON, D. (1986). Incestuous breeding and abnormal movement by a female Barn owl *Tyto alva. Ringing and Migration* **7**, 23–24.

A Barn owl was caught and ringed as a breeding female at a nest site in Wark Forest, Northumberland in 1982. She was recaptured at the same site in 1983 and 1985. In each of these years she reared chicks. In 1985 she was caught at another nest site 24 km away, where she failed in a breeding attempt with her son of 1984. Incestuous matings in birds of any species are rare and a movement of this distance for an established female Barn owl is abnormal.

POTTER, M. J. (1986). Major innovations mark the 1986 treeshelter scene. *Forestry and British Timber* **15** (10), 19.

Upright plastic tubes, often with trees, sprouting from their tops, have become a common sight in the British countryside. Since their conception in 1979 treeshelters have consistently demonstrated their potential for enhancing height growth and improving survival of young transplants.

PYATT, D. G. (1986). Forest drainage in the uplands. *Timber Grower* **101**, 22.

A review of the purpose and benefits of forest drainage has indicated that drainage is unlikely to improve growth but may improve crop stability. Minimising soil erosion and sediment transport to streams requires careful planning of the drainage system.

PYATT, D. G. (1987). Afforestation of blanket peatland – soil effects. *Forestry and British Timber* **16** (3), 15, 17.

The highly decomposed layers of peat beneath the thin fibrous layer progressively dry out after afforestation and after about 15 years large shrinkage cracks form a continuous network, greatly improving the permeability, aeration and rooting depth of the soil. Root spread is restricted by furrows in the first rotation but prospects for growth and crop stability are better for the second rotation.

PYATT, D. G. and ANDERSON, A. R. (1986). Increased streamflow after clear felling a spruce plantation. In, *Effects of land use on fresh waters*, eds. J. F. and L. G. Solbé, Water Research Centre, 538–540.

Clear felling three 2 ha plots increased annual runoff by about 360 mm in the first year compared with previous years or with a control (not felled) plot.

RATCLIFFE, P. R. (1986). Forestry, conservation and the Japanese Sika deer. *Deer* **7** (1), 15–17.

Summarises a more complete review of the problems associated with the continuing expansion in range of Sika deer published in *Mammal Review* **17** (1), 39–58.

RATCLIFFE, P. R. (1987). Distribution and current status of Sika deer, *Cervus nippan*, in Great Britain. *Mammal Review* **17** (1), 39–58.

Introduced populations of Sika deer are established in many parts of Great Britain and some are expanding their range. The taxonomy of Sika and the timing and location of introductions are reviewed and current information on range expansion and hybridisation with red deer is provided. The introduction of Sika deer to red deer areas is considered to be irresponsible due to the likelihood of hybridisation and the threat to the genetic integrity of the red deer.

RATCLIFFE, P. R., HALL, I. and ALLEN, J. (1986). Computer predictions of sequential growth changes in commercial forests as an aid to wildlife management with reference to red deer. *Scottish Forestry* **40** (2), 79–83.

Sequential growth stages in commercial forests influence successional changes occurring in associated plant communities, which in turn have important consequences for the capacity of forests to support wildlife. A method of predicting such changes from a computerised forest inventory database is described.

RATCLIFFE, P. R. and PETTY, S. J. (1986). The management of commercial forests for wildlife. In, *Trees and wildlife in the Scottish uplands*, ed. D. Jenkins, Institute of Terrestrial Ecology Symposium 17, 77–187.

Describes the birds and mammals associated with the sequential growth stages of conifer forests in upland Scotland, and discusses management options and habitat improvements which might maximise this wildlife while maintaining the profitability of the timber crop.

RAY, D., PYATT, D. G. and WHITE, I. M. S. (1987). The effect of the frequency of sampling on the observed concentration of oxygen in an afforested peat soil. *Journal of Soil Science* **38**, 115–122.

Samples of air or water were extracted daily from porous pots buried within the rooting zone of trees planted on a deep peat soil. For most pots, the O_2 concentration in the fluid increased with the number of samples taken each day, presumably because air was drawn into the pot from shallower depth.

RENNOLLS, K. [and BLACKWELL, P.] (1986). *An integrated forest process model: its calibration and predictive performance.* Forestry Commission Research and Development Paper 148. Forestry Commission, Edinburgh.

A general family model of the growth of an individual tree is developed. The model takes into account the age-layered canopy, litter fall and its decomposition in the litter layer and in a general way the cycling of nutrients in the tree. The growth (and depth) of a tree is made to depend not only on its nutrient status but on its competitive status relative to its neighbours.

RENNOLLS, K. and PEACE, A. J. (1986). Flow models of mortality and yield for unthinned forest stands. *Forestry* **59** (1), 47–58.

Previous work on the modelling of forest mortality due to self thinning is reviewed and discussed. Unthinned sample plots of Scots pine are used as a basis for deriving new families of unthinned forest mortality and yield models.

[ROGERS, H. J., BUCK, K. W. and] BRASIER, C. M. (1986). The molecular nature of the d-factor in *Ceratocystis ulmi.* In, *Fungal virology*, ed. K. W. Buck, 209–220. C.R.C. Press, Florida, USA.

Describes the association of specific dsRNA segments with the d^2-factor in *C. ulmi,* including correlated transmission of the d^2-factor and dsRNA segments, loss of d^2 phenotype and of dsRNA segments in ascospore progeny, and loss of d^2 phenotype and dsRNA segments in *C. ulmi* isolates inoculated into elm. Compares the behaviour of the d-factor in *C. ulmi* with hypovirulence in *Endothia parasitica* and discusses other reports of dsRNA and plasmids in *C. ulmi.*

[ROGERS, H. J., BUCK, K. W. and] BRASIER, C. M. (1986). The d^2-factor in *Ophiostoma ulmi:* expression and latency. In, *Biology and molecular biology of plant-pathogen interactions,* ed. J. A. Bailey, 393–400. Springer Verlag, Berlin and Heidelberg.

Gives account of the association between phenotypic expression of d^2-factor and specific segments of dsRNA, and discusses experiments on reversion of latently d^2-infected isolates to overt d-infection.

[ROGERS, H. J., BUCK, K. W., and] BRASIER, C. M. (1986). Transmission of double stranded RNA and a disease factor in *Ophiostoma ulmi. Plant Pathology* **35**, 277–287.

A diseased or d^2-infected isolate of *O. ulmi* contained 10 dsRNA segments whereas seven healthy isolates contain no dsRNA or up to four dsRNA segments. Ascospore progeny of the diseased isolate were healthy and contained no dsRNA or only one segment. When diseased isolates were reisolated from elm trees after inoculation some were healthy and retained only two to seven segments, while others were diseased and retained all 10 segments. Healthy conidial derivatives of the diseased isolates usually carried the d^2-factor in latent form.

ROLLINSON, T. J. D. (1986). Field data collection using a portable microcomputer. In, *Environmental influences on tree and stand increment*, eds. D. S. Solomon and T. B. Braan, Maine Agricultural Experiment Station, University of Maine, Miscellaneous Publication 691, 133–136.

Epson microcomputers are being used for entering, checking and summarising measurements from permanent sample plots. As prices fall and memory sizes increase wider use of data capture devices can be expected in both research and management applications.

ROLLINSON, T. J. D. (1987). Don't forget production class. *Scottish Forestry* **40** (4), 250–258.

The production class system provides the means by which the deficiences of height growth alone as an index of volume production can be remedied so that General Yield Class tables can be converted into Local Yield Class tables.

ROLLINSON, T. J. D. (1987). Thinning control of conifer plantations in Great Britain. *Annales des Sciences Forestières* **44** (1), 25–34.

Describes current thinning practice in the Forestry Commission based on assessments of the likelihood of wind damage and the costs and revenues of thinning operations. The various elements which comprise a thinning regime are described together with the control system used when marking a stand for thinning.

ROLLINSON, T. J. D. and EVANS, J. (1987). *The yield of Sweet chestnut coppice.* Forestry Commission Bulletin 64. HMSO, London.

Reports an investigation into the growth and yield of Sweet chestnut coppice in relation to site and various stand characteristics and shows how volume or weight per hectare may be predicted from simple field measurements.

[SHI, J. L. and] BRASIER, C. M. (1986). Experiments on the control of Dutch elm disease by injection of *Pseudomonas* species. *European Journal of Forest Pathology* **16**, 280–292.

Bacteria of the genus *Pseudomonas* were screened for antagonistic activity towards *Ceratocystis ulmi in vitro*. Selected bacteria were then tested for their ability to suppress symptoms of Dutch elm disease in English elm (*Ulmus procera*) and Commelin elm (*U.* × *hollandica* 'Commelin') *in vivo*. In a series of preventive bacterial injection experiments on English elm, no reduction in disease levels was obtained by comparison with non-injected controls. In curative injections of Commelin elm, only a slight reduction of disease recurrence in treated trees was indicated.

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

Repeated dropping of bags of Sitka spruce transplants significantly depressed their root growth potential and 1 year survival. In another experiment, Sitka spruce and Douglas-fir transplants were dropped 10 times then, together with control plants, were placed in root observation boxes at different soil temperatures. The number of new roots increased with soil temperature, and was generally greater in Sitka spruce. In both species, root growth was sharply reduced by mechanical shock treatment, which also depressed mycorrhizal development and resulted in a significant lowering of predawn water potential in Douglas-fir.

TABBUSH, P. M. and WILLIAMSON, D. R. (1987). Terbuthylazine to fight grass weeds – new product is on the way. *Forestry and British Timber* **16** (2), 21–23.

Possible uses for a terbuthylazine based herbicide in the forest and nursery are reviewed. In many circumstances, both coniferous and broadleaved trees tolerate overall sprays of terbuthylazine at rates sufficient to destroy a broad spectrum of grass and herbaceous broadleaved weeds. Properties, crop tolerance and rates and dates of application are briefly summarised.

TAYLOR, C. M. A. (1986). Forest fertilisation in Great Britain. *Proceedings No. 251, The Fertiliser Society, London.*

Summary of forest fertilisation practice including indications of where and when to fertilise, method of application and type of fertilisers used. There are also sections on recognition of nutrient deficiency, environmental effects of fertilisation and effects on wood quality.

TAYLOR, C. M. A. (1986). Nutrition prospects in upland restocking. *Timber Grower* 101, 23.

Although nutrition investigations of second rotation sites are at an early stage the results so far are very encouraging. It is generally true that replacement crops do not require fertiliser at planting, in contrast to the first rotation, and inputs over the whole rotation may well be substantially reduced.

THOMPSON, D. A. (1986). *Leucaena leucocephala and other fast growing trees.* Organisation of American States, Kingston, Jamaica.

The first part of this publication consists of technical sheets describing the various factors involved from planning through planting and maintenance to harvesting fast growing trees. The second part is a series of fact sheets covering nine species including *Leucaena leucocephala, Calliandra calothyrsus, Acacia auriculiformis* and *Cassia siamea.*

THOMPSON, D. A. (1987). Adding value to low quality hardwoods. *Timber Grower* 102, 15–16.

Considers state of the hardwood market in the UK and makes suggestions for adding value.

THOMPSON, D. A., [BRETTING, P. K. and HUMPHREYS, M.] (Eds.) (1986). *Forests of Jamaica.* Jamaican Society of Scientists and Technologists, Kingston, Jamaica.

The first section is a series of articles on the various natural forest types found in Jamaica. It is followed by a section on aspects of forest use including watershed management and agroforestry. The final part includes the Forests Acts of Jamaica, species lists for different forest types and information on the four day seminar in 1983 from which the papers evolved.

THOMPSON, D. A., WRIGHT, D. L. and EVELYN, O. (1986). Forest resources in Jamaica. In, *Forests of Jamaica*, eds. D. A. Thompson, P. K. Bretting and M. Humphreys, Jamaican Society of Scientists and Technologists, Kingston, Jamaica, 81–90.

Separate descriptions are given of the total woodland area, the forest reserve and forest plantations. The distribution of woodland by life zones and forecasts of production are included.

WALKER, C. (1986). Mycorrhizas in forestry – has inoculation a future? *Forestry and British Timber* **15** (5), 20–21.

After a brief popular introduction to the different kinds of mycorrhiza, the potential benefits of using ectomycorrhizas to enhance Sitka spruce growth are discussed. It is concluded that, although benefits are possible, the time is not yet right for commercial use of mycorrhizas in British forestry.

WALKER, C. (1986). Problems in taxonomy of mycorrhizal fungi. In, *Physiological and genetical aspects of mycorrhizae*, eds. V. Gianinazzi-Pearson and S. Gianinazzi, 605–609. INRA, Paris.

The problems associated with identifications of mycorrhizal fungi are discussed and ways of overcoming some of them are suggested.

WALKER, C., BIGGIN, P. and JARDINE, D. (1986). Differences in mycorrhizal status among clones of Sitka spruce. *Forest Ecology and Management* **14**, 275–283.

Cuttings of Sitka spruce clones with the same maternal parentage were rooted under mist and examined after they had been grown for a year in a forest nursery. All short roots were found to be mycorrhizal, but one clone differed from the others in the proportion of the roots colonised by different mycorrhizal fungi. Substantial clonal differences in root morphology were partially explained by these mycorrhizal differences. The significance of the host-fungus genotype interaction is discussed.

WALKER, C. [and SANDERS, F. E.] (1986). Taxonomic concepts in the Endogonaceae: III. The separation of *Scutellospora* gen. nov. from *Gigaspora* Gerd. & Trappe. *Mycotaxon* **27**, 183–194.

The genus *Gigaspora* is split into two genera, *Gigaspora* Gerd. and Trappe emend. Walker & Sanders and *Scutellospora* gen. nov. This separation is based principally on details of spore germination, although other characteristics are also used. The factors that characterise and separate the two genera are detailed.

WEBBER, J. F., MITCHELL, A.G. [and SMITH, F.] (1986). Linkage of the genes determining mating type and fungicide tolerance in *Ophiostoma ulmi*. *Plant Pathology* **35**, 512–516.

Two allelic mutations conferring high and low levels of *in vitro* tolerance to the fungicide methyl benzimidazole-2-yl carbamate (MBC) were identified in the elm pathogen *Ophiostoma ulmi*. Variants expressing a third and intermediate level of tolerance were also identified. The locus for fungicide tolerance was linked to the mating type locus in both the aggressive strains of the fungus.

WILLSON, A. (1986). The use of soil phosphate measurements to predict the growth of conifers. *Journal of the Science of Food and Agriculture* **37** (1), 9–12.

Soil chemical parameters are measured by routine laboratory methods but do the results relate to the response of conifers to available nutrient levels? The results from a wide range of soil types

are compared. Only adsorption isotherms were able to distinguish between different horizons and soil types. The response of conifer seedlings growing in P deficient soils to added phosphate can be determined from isotherms but not from assessments of extractable P.

WILLSON, A. (1986). Do air pollutants affect our trees? *Timber Grower* **100** (2), 30.

Describes the experiments using open-top chambers to investigate the effects of air pollutants on trees in rural areas of Britain.

WINTER, T. G. [and HYND, W. R. B.] (1986). *Chrysopadorsalis* Burmeister (Neuroptera: Chrysopidae) in Hampshire. *Entomologist's Gazette* **37**, 86.

A single specimen of this lacewing caught in the Rothamsted light trap at Alice Holt Lodge in August 1983 is the second record of this insect in Hampshire.

WINTER, T. G. (1986). *Drepanepteryx phalaenoides* (L.) (Neuroptera:Hemerobiidae) in Surrey. *Entomologist's Gazette* **37**, 91.

A specimen of this lacewing was recorded in the Rothamsted light trap at Haslemere in June 1978.

WINTER, T. G. (1986). A second record of the Brown-tail moth: *Euproctis chrysorrhoea* (L.) in north Hampshire. *Entomologist's Record and Journal of Variation* **98**, 209.

A single moth was recorded in the Rothamsted light trap at Alice Holt Lodge on 25 July 1985.

WINTER, T. G. (1986). First record of the triangle: *Heterofenea asella* (D & S) in north Hampshire. *Entomologist's Record and Journal of Variation* **98**, 210.

A single specimen caught in the Rothamsted light trap at Alice Holt Lodge in July 1985 is the first record of this moth in north Hampshire.

APPENDIX II

Research Division Branches and their Project Groups‡

Seed	Project leader(s) at 31/3/87
Research	P. G. Gosling
Service	P. G. Gosling
Silviculture (South)	
Plant production	J. Jobling, D. R. Williamson
Species	M. J. Potter
Establishment	M. J. Potter
Farm forestry	H. L. Davies
Contracts: arboriculture advisory and information service	D. Patch
arboriculture research	R. J. Davies
short rotation coppice	T. C. Booth
Silviculture (North)	
Plant production	W. L. Mason
Species	C. M. A. Taylor
Planting	P. M. Tabbush
Nutrition	C. M. A. Taylor
Cultivation	C. P. Quine
Stability	B. A. Gardiner, C. P. Quine
Farm forestry	C. M. A Taylor
Site Studies (South)	
Effects of trees on sites	W. O. Binns
Lowland production forestry	A. J. Moffat
Reclamation	A. J. Moffat
Upland production forestry	Vacant
Air pollution	W. O. Binns, J. L. Innes, A. Willson
Chemical analysis	A. Willson
Instrumentation	Vacant
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
Genetics	
Testing progeny and provenances	S. J. Lee, A. M. Fletcher
Production: clone banks and orchards	A. M. Fletcher, R. Faulkner
Stands: registration of seed sources	R. Faulkner
Biochemical variation	G. I. Forrest
Biometrical studies	C. J. A. Samuel
Physiology	
Root growth and form	M. P. Coutts
Flowering	J. J. Philipson
Bent top	M. P. Coutts
Micropropagation	A. John
Rejuvenation	A. John, A. M. Fletcher
Mycorrhizas	C. Walker
Development of rooting patterns	C. Walker

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

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

APPENDIX III

Net Expenditure of Research Division 1986/87

£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	86	24	—	110
Silviculture (South)	730	89	32	851
Arboreta	388	—	—	388
Silviculture (North)[f]	1496	25	29	1550
Site Studies (South)[g]	488	−14	6	480
Site Studies (North)	94	44	—	137
Genetics	617	63	13	693
Physiology	249	67	24	341
Pathology	421	83	10	514
Entomology	462	45	25	531
Wildlife and Conservation	189	36	1	226
Mensuration	126	134	—	260
Wood Utilisation	46	5	201	253
Statistics and Computing (South)	356	−327	—	29
Statistics and Computing (North)	164	−164	—	—
Communications	317	−97	—	220
Total[e]	6229	14[h]	341	6584

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 £1293(000), plus Forestry Commission headquarters overheads for common services of £377(000), net of income of £210(000) for contract services provided to outside parties.

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

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

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

(f) Including Experimental Workshop (North).

(g) Including Experimental Workshop (South).

(h) Net value of services provided by Branches of other Divisions, namely Forest Surveys and Work Study, equals £14(000).

APPENDIX IV

Staff Engaged in Research

As at 31 March 1987

The main centres for research are:

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

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

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

RESEARCH DIVISION

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

Chief Research Officer (South) ..... D. A. Burdekin, B.A., Dip.Ag.Sci. (*Alice Holt*)

(With general responsibilities for research south of the Mersey/Humber line, and with specific responsibilities throughout Britain for research in arboriculture, seed, pathology, entomology, wildlife and conservation, in silviculture and site studies in the lowlands, instrumentation and technical aspects of legislation relating to plant health.)

Chief Research Officer (North) ..... S. A. Neustein, B.Sc., F.I.C.For. (*Northern Research Station*)

(Head of the Northern Research Station with general responsibilities for research north of the Mersey/Humber line, and with specific responsibilities throughout Britain for research in silviculture and site studies in the uplands and for research in tree physiology and genetics.)

STAFF AT ALICE HOLT LODGE

SEED BRANCH

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

Miss A. M. Bolster, Mrs P. J. Rigg, Mrs Y. K. Samuel, D. C. Wakeman

SILVICULTURE BRANCH (SOUTH)

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

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

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

SITE STUDIES BRANCH (SOUTH)

W. O. Binns, O.B.E., M.A., B.Sc., Ph.D., F.I.C.For., Head of Branch
P. G. Crow, D. W. H. Durrant, B.A., J. L. Innes, M.A., Ph.D., Miss S. J. Lee, A. J. Moffat, B.Sc., Ph.D., C. J. Roberts, B.A., Mrs D. A. Waddell, E. Ward, B.Sc., M.Sc., A. Willson, B.Sc., Ph.D.

INSTRUMENTATION SECTION (SOUTH)

Vacant

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

PATHOLOGY BRANCH (with Section at Northern Research Station)

J. N. Gibbs, M.A., Ph.D., Sc.D., Head of Branch
C. M. Brasier, B.Sc., Ph.D., D.Sc., Miss S. E. Chuter, B.Sc., B. J. W. Greig, M.I.C.For., I. T. Hickman, B.Sc., Mrs S. A. Kirk, D. Lonsdale, B.Sc., Ph.D., Mrs T. C. Reffold, D. R. Rose, R. G. Strouts, Ms J. F. Webber*, B.Sc., Ph.D.

ENTOMOLOGY BRANCH (with Section at Northern Research Section)

H. F. Evans, B.Sc., D.Phil., F.R.E.S., Head of Branch
D. A. Barbour, B.Sc., Ph.D., F.R.E.S., C. I. Carter, MSc., C.Biol., M.I.Biol., F.R.E.S., N. J. Fielding, M. R. Jukes, C.Biol., M.I.Biol., C. J. King, T. O'Keefe, Miss J. F. A. Nichols, B.Sc., M.Phil., C.Biol., M.I.Biol., F.R.E.S., D. Wainhouse, M.Sc., Ph.D., F.R.E.S., T. G. Winter, F.R.E.S.

WILDLIFE AND CONSERVATION RESEARCH BRANCH

P. R. Ratcliffe, B.Sc., C.Biol., M.I.Biol., M.I.C.For., Head of Branch
M. A. Anderson, B.Sc., A. Chadwick (*Cowal, Strathclyde*), Mrs B. A. Mayle, H. W. Pepper, S. J. Petty (*Cowal, Strathclyde*), L. A. Tee

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

MENSURATION BRANCH

T. J. D. Rollinson, B.Sc., M.I.C.For., Head of Branch
E. J. Fletcher, Miss J. M. Gay, B.Sc., A. F. Martin, B.Sc.(For.), R. W. Matthews, B.Sc., M.Sc.

WOOD UTILISATION BRANCH

D. A. Thompson, B.Sc., M.I.C.For.

STATISTICS AND COMPUTING BRANCH (SOUTH)

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

COMMUNICATIONS BRANCH

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

RESEARCH INFORMATION SECTION

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Mrs E. M. Harland, M.A. (Librarian)

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STAFF CHANGES

Transfers in: A. T. Armstrong (Forest Officer IV) from Lorne Forest District to Silviculture South, Alice Holt. J. Boluski (Forest Officer IV) from Forest Surveys to Silviculture North, Lairg. A. H. Chadwick (Forest Officer IV) from York Forest District to Wildlife and Conservation Research, Cowal. J. A. McIntyre (Forest Officer III) from Wiltshire and Avon Forest District to Silviculture South, Bedgebury. T. O'Keefe (Forest Officer IV) from Brechfa Forest District to Entomology, Alice Holt. D. J. Pitt (Forest Officer IV) from Ayrshire Forest District to Silviculture North, Northern Research Station. C. P. Quine (Forest Officer I) from Newton Stewart Forest District to Silviculture North, Northern Research Station. M. Riley (Forest Officer IV) from Ardgarten Forest District to Silviculture North, Mabie. Mrs F. Snaith (Executive Officer) from Mid Scotland Conservancy Office to Administration, Northern Research Station. D. M. Watterson (Forest Officer III) from Kielder Forest District to Silviculture North, Mabie. Miss E. R. Wells (Executive Officer) from West England Conservancy Office to Establishments, Alice Holt. D. R. Williamson (Forest Officer II) from Suffolk Forest District to Silviculture South, Alice Holt.

New appointments: B. A. Gardiner (Senior Scientific Officer) Silviculture North, Northern Research Station. J. L. Innes (Senior Scientific Officer) Site Studies South, Alice Holt. A. R. Ludlow (Principal Scientific Officer) Statistics and Computing, Alice Holt. R. W. Matthews (Scientific Officer) Mensuration, Alice Holt. M. A. Mellergaard (Scientific Officer) Statistics and Computing, Alice Holt. T. J. Randle (Scientific Officer) Statistics and Computing, Alice Holt. E. Ward (Scientific Officer) Site Studies South, Alice Holt.

Transfers out: R. D. Butt (Professional and Technology Officer III) from Instrumentation, Alice Holt to East England Conservancy. P. Harrison (Forest Officer III) from Silviculture North, Northern Research Station to Nithsdale Forest District. P. A. Lodge (Executive Officer) from Establishments, Alice Holt to Manpower Services, Bolton. I. D. S. Macleod (Executive Officer) from Administration, Northern Research Station to Headquarters. K. F. Miller (Forest Officer I) from Silviculture North, Northern Research Station to Lorne Forest District. R. E. Preston (Forest Officer IV) from Silviculture South, Bedgebury to Weald Forest District. J. S. P. Sale (Forest Officer I) from Silviculture South, Alice Holt to East England Conservancy Office. M. J. Scott (Forest Officer IV) from Silviculture South, Bedgebury to Forest Surveys, North Devon and Cornwall.

Promotions: C. M. Brasier (Pathology, Alice Holt) to Senior Principal Scientific Officer on merit. M. P. Coutts (Physiology, Northern Research Station) to Senior Principal Scientific Officer on merit. S. C. Gregory (Pathology, Northern Research Station) to Grade 7. I. T. Hickman (Pathology, Alice Holt) to Forest Officer III. A. John (Physiology, Northern Research Station) to Senior Scientific Officer. Miss G. A. MacAskill (Pathology, Northern Research Station) to Scientific Officer. D. Patch (Arboriculture, Alice Holt) to Grade 7. T. G. Winter (Entomology, Alice Holt) to Senior Scientific Officer.

Resignation: J. G. Whyatt (Forest Officer IV) Silviculture North, Northern Research Station.

Retirement: R. Lines O.B.E. (Principal Scientific Officer) Silviculture North, Northern Research Station.

Death: R. Carnell (Senior Scientific Officer) Site Studies South, Alice Holt.

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GLOSSARY

Latin names of trees cited by common name in this Report

Broadleaves

Alder, Common	*Alnus glutinosa*
Ash	*Fraxinus excelsior*
Beech	*Fagus sylvatica*
Birch, Silver	*Betula pendula*
Cherry, Bird	*Prunus padus*
Wild	*P. avium*
Chestnut, Horse	*Aesculus hippocastanum*
Sweet	*Castanea sativa*
Lime, Common	*Tilia* × *europaea*
Small-leaved	*T. cordata*
Maple, Norway	*Acer platanoides*
Oak, English (Pedunculate)	*Quercus robur*
Sessile	*Q. petraea*
Plane, London	*Platanus* × *hispanica*
Poplar, Lombardy	*Populus nigra* 'Italica'
Rowan	*Sorbus aucuparia*
Sallow	*Salix caprea*
Sycamore	*Acer pseudoplatanus*

Conifers

Cedar, Western red	*Thuja plicata*
Cypress, Lawson	*Chamaecyparis lawsoniana*
Leyland	×*Cupressocyparis leylandii*
Monterey	*Cupressus macrocarpa*
Fir, Douglas	*Pseudotsuga menziesii*
Grand	*Abies grandis*
Noble	*A. procera*
Larch, European	*Larix decidua*
Hybrid	*L.* × *eurolepis*
Japanese	*L. kaempferi*
Pine, Corsican	*Pinus nigra* var. *maritima*
Lodgepole	*P. contorta*
Scots	*P. sylvestris*
Spruce, Norway	*Picea abies*
Sitka	*P. sitchensis*
White	*P. glauca*
Yew	*Taxus baccata*

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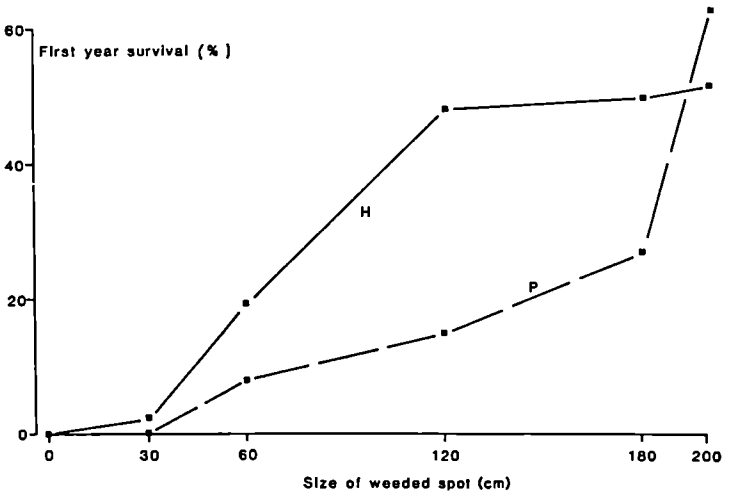

Figure 4. **The effect of different sized herbicide spots (H) and polythene mulches (P) on the survival of poor quality oak transplants at Quedgeley, Gloucestershire. See caption to Figure 3 for explanation of treatments.**

Enquiries relating to this publication should be addressed to the Technical Publications Officer, Forestry Commission Research Station, Alice Holt Lodge, Wrecclesham, Farnham, Surrey, GU10 4LH.

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