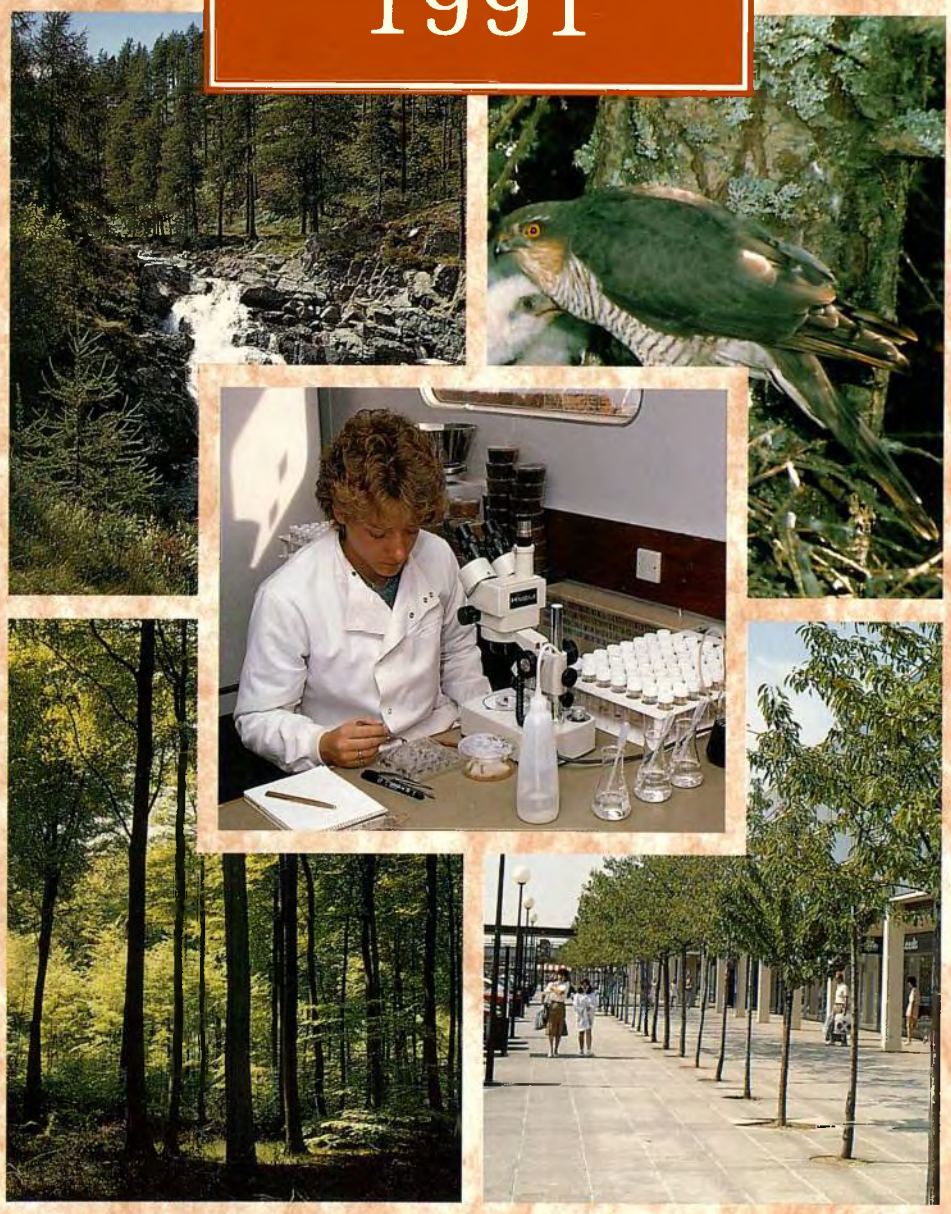
Forestry Commission

REPORT ON FOREST RESEARCH 1991



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REPORT ON FOREST RESEARCH

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INTRODUCTION

by D.A. Burdekin
Director of Research

Different aspects of forest research attract attention in succeeding years. Although in the long term effects of climate change are still very much in mind, the particular conditions in 1990 deserve special mention. The very hot weather in late July and early August was particularly marked in central and southern England. A number of tree species showed signs of stress, particularly beech but also cherry, hawthorn, rowan, sweet chestnut, field maple and sycamore. Paradoxically the winter of 1990/91 had a particularly cold spell in February and this resulted in the application of large quantities of salt to roads. As a consequence of reviewing the literature and of past experiences with salt damage (under contract to the Department of the Environment) we are strongly recommending that greater care is taken in the application of appropriate and not excessive quantities of salt.

As financial strings become tighter, the need to attract funds for contracts becomes more important. A small contract for a review of salt damage to trees is an example of the type of work which we are well able to undertake. Another area which has attracted attention is the use of peat in association with motorway tree planting, indeed a situation found in many arboricultural and horticultural locations. Our research has indicated that much less peat is needed and that alternative materials may be used.

ADVISORY COMMITTEE ON FORESTRY RESEARCH

During the course of the year visiting groups examined the work of two branches in the Research Division. For the first time the whole of Silviculture (North), as opposed to separate aspects, was visited. The chairman of the Group was Professor G.D. Holmes (previous Director General, Forestry Commission) and the three members were Professor H.G. Miller (Aberdeen University), Professor I. Cunningham (previous Director, West of Scotland Agriculture College) and Mr S.A. Neustein (Conservator of Forests, North England). The Group undertook this enormous task with enthusiasm, determination and skill and made a number of important recommendations for the long-term future of the branch. New areas of work were recommended to replace current activities and organisational changes were proposed. These new thoughts are now being introduced in practice.

The second Group, chaired by Mr R. Kempton (Scottish Agricultural Statistics Service) with Mr A. Windram (Rothamsted Experimental Station) and Mr H. Wright (Oxford Forestry Institute) examined the work of the two Statistics Branches (North and South). An important consideration at the Northern Research Station was the likely reduction in the services provided by the Edinburgh University Computing Centre. A major recommendation of the Group was to install a new local area network system to provide the hardware needed for the statistical and computing requirements of the Station. This recommendation was accepted and after intense pressure, funding was found within this financial year.

RESEARCH HIGHLIGHTS

The following are a selection of achievements in the Research Division during the year.

Windthrow. Research on windthrow has become much more sophisticated. Not only are studies being undertaken to predict windthrow of trees but computer models to predict windspeed in different situations in the forest are also being developed. Windspeeds have been measured across the long Kintyre peninsula (west Scotland), both on the western windward side, in the valleys and on the leeside. A large-scale airflow model has been developed and predictions of windspeed within Rivox Forest have been made.

Broadleaves. Research on oak extends from studies of branching patterns of clonally propagated material to natural regeneration of oak in the uplands. In the latter case, fencing to exclude browsing mammals, soil cultivation and canopy opening are likely to promote natural regenera-

tion. Branching patterns in oak may depend to some extent on the occurrence of lammas growth. Such growth has a tendency for its terminal buds to fail and therefore to lead to more branch formation from axillary buds.

In joint studies with MAFF, on the genetic improvement of broadleaves for farm forestry, seed of sycamore has been collected from 'good' stands and vegetative material from ash and sycamore stands has been collected for propagation at Alice Holt. This project aims at selecting better and known sources for propagating purposes.

Nurseries. Investigations into the quality of plants after cold storage have shown that a technique to measure electrolyte leakage from fine root systems can be extremely useful in predicting survival. Thus it has been demonstrated that Douglas fir and Scots pine were tolerant to only –5°C from December to March, whereas Japanese larch and various provenances of Sitka spruce could stand temperatures below –10°C.

Poplars. Poplars have become more popular in recent years, especially with the approval for planting of new disease resistant clones from Belgium. The so called 'UNAL' clones have been established on two experimental sites and growth rates at one, the wetter, are proving very good. More clones are being planted on an experimental basis to check on their performance at a range of sites in Britain.

In addition to their use as timber trees, from pulp to sawn timber, poplar clones have attracted a lot of attention as a source of renewable energy in short rotation coppice. Trials have been commissioned by the Department of Energy and some of the new Belgian clones are being tested under a coppice regime.

Health survey. The climate continues to have a major impact on the health and growth of trees in Britain. The annual survey of forest condition showed an improvement in the crown densities of Sitka spruce and oak with little change in Norway spruce and Scots pine. However, beech is particularly susceptible to drought and the 1989 and 1990 dry summers contributed to a deterioration in beech health.

Pests. *Hylobius abietis* is a major pest in conifer forests and new techniques for control are being explored. As well as chemicals, the possible use of entomogenous nematodes is showing some promise.

Conservation. There are a number of studies aimed at enhancing conservation values in upland forests. One is concerned with promoting the germination and growth of junipers. This is a native conifer and may be suitable as an understorey in mature Scots pine stands. Deer browsing is often a constraint on the growth of juniper and treeshelters may provide some protection. However, experiments to test this have not shown a particularly positive result.

FORESTRY RESEARCH CO-ORDINATION COMMITTEE (FRCC)

The FRCC plays an important role in co-ordinating the research activities of a number of different government departments and agencies. The special programme concerned with farm forestry funded by three FRCC members – Department of the Environment, Forestry Commission and Natural Environment Research Council (NERC) – has completed its first year. A seminar in London heard interesting results reporting the correlation between farm woodland size and biodiversity, farmers preferences and attitudes towards woodlands in the Scottish central lowlands, alternating cycles of regeneration between ash and sycamore, the role of the farm woodland environment for supporting bumble bee populations, etc. The programme has just under 2 years to run and these and other research areas in the special topic will be the subject of a conference which will probably be held in the autumn of 1992.

The annual collation of total expenditure on forestry research in Britain has shown that, for the second year, spending has exceeded £20 million when the commitment to tropical subjects is included. The trend towards increased research involving broadleaved species and effort devoted to genetics and environmental matters continues and climate change has begun to displace air pollution as the main area for new research. Research on economic and social issues of forestry, especially in connection with farm woodlands, has also increased, reflecting the strong support given by the three FRCC members mentioned above.

THANKS

Finally, none of the achievements mentioned above or in the body of the report could have been made without the commitment and dedication of the whole staff. This is very gratefully acknowledged.

PART I

THE WORK OF THE FORESTRY COMMISSION

RESEARCH DIVISION

PLANT PRODUCTION

During 1990/91 the former Seed Branch expanded to become Plant Production Branch. The principal change was the transfer of Dr Richard Jinks from Silviculture (South) Branch, as nursery research project leader. The new Branch continues to act as the British Official Seed Testing Station for trees and shrubs and offers an advisory testing service on broadleaved species, but the conifer advisory service has been withdrawn.

The Branch's research programme now spans seed collection, processing, storage, testing and dormancy breakage for all tree species; and open and intensive plant production methods of lowland forestry species (mainly broadleaves but also Corsican pine).

In March 1991 the Branch took a lead role in organising a 2 week course sponsored by the World Bank for four Pakistani forest officers, principally on seed and tree improvement.

NURSERIES

Several of the buildings on the open nursery at Headley and the intensive nursery at Alice Holt were modernised and extended to improve facilities for both the staff and for the storage and mixing of chemicals. Two additional Conviron S1OH growth cabinets were installed on the intensive nursery for assessing Root Growth Potential of seedling stock. A new glasshouse was also built to provide propagation and growing-on facilities for Tree Improvement Branch and a 0.1 ha site was prepared for holding stock plants of selected clones of broadleaved species. Six hundred and fifty new stools of poplar clones were established at Headley to provide supplies of cuttings for field trials.

Nearly 10 000 softwood cuttings were taken for research experiments on vegetative propagation of broadleaved trees and for producing plants for other researchers. Species included ash, sycamore, sweet chestnut, small-leaved lime, elms, yew, larch and clones of Leyland cypress. New accessions of *Nothofagus procera, Nothofagus obliqua, Metasequoia glyptostroboides* and *Ceanothus thyrsiflorus*, which had been imported from abroad, were successfully raised in containers for use by other researchers. The nurseries supplied over 110 000 bare-root stocks and 5000 poplar cuttings for use in experiments and trials.

Research on the production of tree seedlings in containers continued. Applying nutrients as a solution through the irrigation system is a common method for fertilising container tree seedlings. An alternative is to incorporate a coated controlled release fertiliser (CRF) in the growing medium. Until recently the only available CRFs had relatively large granule sizes and this limited their use with modular containers because of the difficulty of obtaining an even distribution of the few granules required in each cell. Two formulations of Osmocote (Osmocote Mini 18-6-12 with 2-3 month longevity and Osmocote Mini 18-6-11 with 5-6 month longevity) are now available; these have a much smaller average granule size and so are more suitable for use in tree seedling containers. Trials suggest that both Osmocote Mini fertilisers may be useful for raising tree seedlings in containers, however the manufacturer's rates should not be exceeded in order to avoid either damaging conifer seedlings such as Corsican pine or promoting excessive growth of broadleaved species, particularly if they are grown in small containers.

R.L. JINKS, A.R. HALL

IMPROVING SEED QUALITY AND PERFORMANCE

The need for Corsican pine seed lots with 90+% germination is becoming increasingly important with the use of modular plant production systems and a shift to precision sowing in open nurseries. Last year (*Report* 1990, p.2) we reported using IDS (see below) to improve the quality of one Corsican pine seed lot by selectively removing dead seed. Research has now been scaled-up,

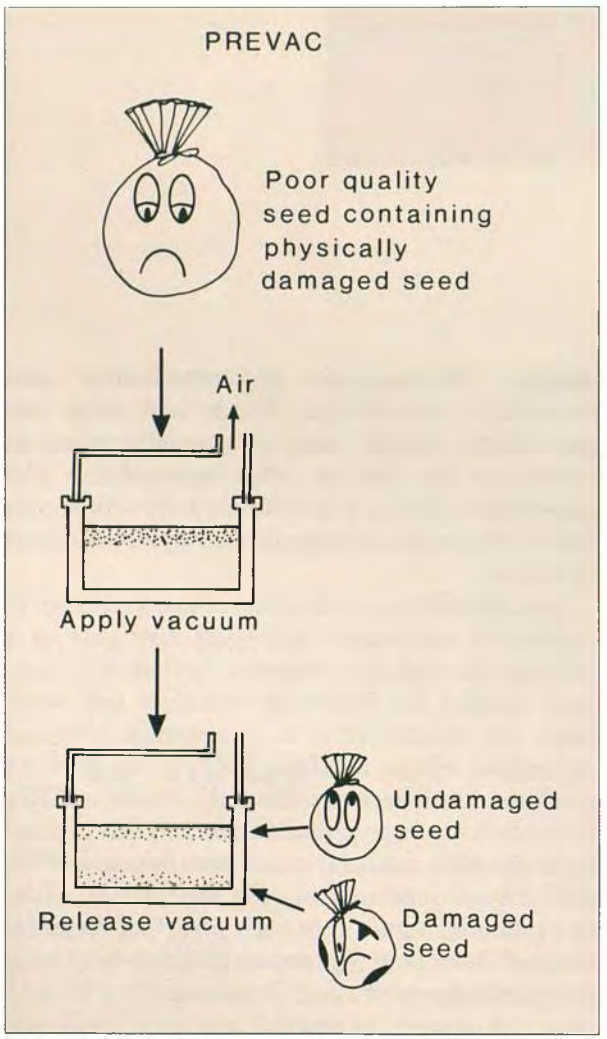


Figure 1. PREVAC – a pressure/vacuum technique used to improve the quality of tree seed lots by separating out damaged seed.

extended to other seed lots and aimed at removing physically damaged as well as dead seed.

Three techniques were tested: IDS (Imbibition, Drying and Separation) described in *Report* 1990, SG (Specific Gravity) described in *Report* 1986, and PREVAC (PREssure/VACuum; Figure 1) separations. SG separation is a very widely used technique for improving the quality of most tree seed lots; IDS and PREVAC have been developed in Sweden and have previously only been applied to Scots pine, lodgepole pine and Norway spruce. Each method was applied to four seed lots of Corsican pine seed varying in initial germination capacity between 30-70%.

None of the three techniques raised any of the four seed lots to the desired 90+% germination. IDS was particularly disappointing. Attempts to scale-up last year's encouraging results were unsuccessful and for all four Corsican pine lots the I-stage was actually harmful and reduced germination by as much as 41%. SG and PREVAC both had beneficial effects and raised germination percentages by up to 25-30 percentage points for the seed lots with the lowest initial quality.

Investigations continue to examine whether undamaged and physically damaged Corsican pine have different sensitivities to imbibition damage by applying PREVAC followed by IDS.

S.K. JONES, P.G. GOSLING, J. VIRGO*
* Bath University sandwich student

SEED TESTING

Five hundred and eighty two tree seed samples were tested: 420 of the Forestry Commission's own seed lots, 94 from seed merchants and nursery managers, 68 from the Oxford Forestry Institute.

P.G. GOSLING, Y.K. SAMUEL

SILVICULTURE (SOUTH)

ARBORETA

The arrangements for administering the Commission's two most comprehensive arboreta, at Westonbirt and Bedgebury, have been reviewed in the light of their expanding roles in education and recreation. To ensure the proper development of these roles, while safeguarding the scientific integrity of the collections, management responsibility will be transferred to West and East England Conservancies respectively from 1 April 1991. Research Division will retain a core of arboretum staff, including the dendrologist, a database manager and two propagators.

The arboretum database will be retained at Westonbirt using the International Transfer Format (ITF). All major Forestry Commission tree collections will be recorded in this way in due course. The advantages of this are automatic checking of nomenclature with a central register, and a single reference point for the whole of the ornamental tree holding which could be available to other ITF users worldwide.

The propagation units at Westonbirt and Bedgebury have been upgraded and considerably improved. In addition to meeting the needs of their own collections they will increasingly be able to supply plants required in Forestry Commission arboreta elsewhere. This year trees have been sent out to Lynford, Speech House and Kilmun as part of the Arboreta Project, which sets out to establish ornamental and exotic trees on sites where they will grow best.

J.E.J. WHITE

POPLARS

Poplar silviculture: clone/site trials

In late winter nine clone/site trials were planted with 25 cm cuttings inserted to full length at 3 x 3 m spacing. The objective is to assess the performance of newly introduced poplar clones on a wide range of site types throughout Britain. Sites have been selected from Somerset to Aberdeenshire and from central Wales to the East Midlands so as to test performance within the likely climatic and edaphic range of poplars. All sites are on uncultivated agricultural land.

Trials of UNAL clones

The earliest trials in the present series were planted in 1987 at Ampthill, Bedfordshire, on a compacted, sandy soil, and at Bedgebury, Kent on a more fertile sandy loam, using stumped, rooted plants protected by treeshelters. Four-year heights and diameters are presented in Figure 2. Growth has been slow at Ampthill with UNAL, the fastest cultivar, achieving a mean height of only 3.2 m in 4 years. At Bedgebury the fastest clone 'Boelare' has achieved a mean height of 6.5 m and a mean diameter of 8.8 cm in the same period. The order of ranking at Bedgebury between hybrid groups has remained much the same as in the previous year: *P.* x *interamericana* clones are clearly faster than *P.* x *euramericana* clones whilst the two *P. trichocarpa* clones 'Trichobel' and 'Columbia River' are intermediate in performance.

A further 20 new clones were imported from the Poplar Research Station at Geraardsbergen in Belgium in February 1991. Twelve are *P. trichocarpa* intraspecific hybrids, the remainder are interspecific hybrids between *P. trichocarpa, P. deltoides* and *P. maximowiczii.* Excluding the original UNAL cultivars, 49 new clones have been received from Belgium for trial in the past 2 years. These are being screened for disease resistance.

A. BEATON

STAND SILVICULTURE

Significant areas of broadleaves have been planted since the announcement of the broadleaves policy in 1985. However, a large propor-

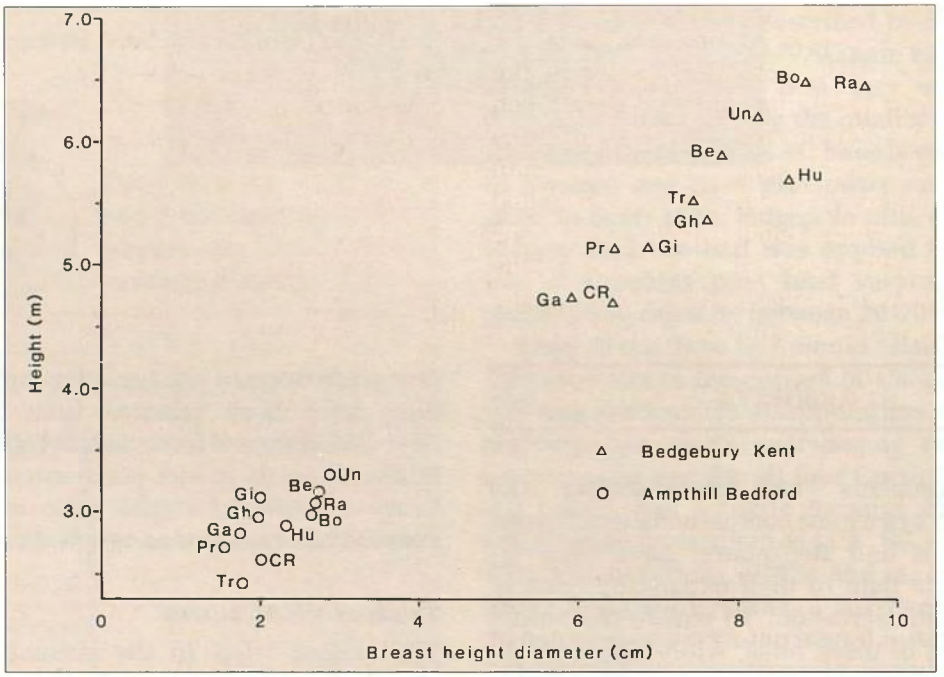


Figure 2. Four-year mean height v. dbh for UNAL clones at Bedgebury and Ampthill.

tion has been at spacings of 3 x 3 m (1100 stems per hectare). It is important to obtain silvicultural knowledge on how timber quality can be maintained if an initial decision to plant at these wide spacings has been made. One method is to utilise natural regeneration which will occur on restock sites, a second more direct method is to prune. Five experiments have been established (four on oak, one on wild cherry) to determine the change in stem straightness and branchiness of young pre-canopy closure trees derived following pruning treatments of different intensities.

G. KERR

In addition the same pruning treatments will be applied to two Dutch provenances of oak, 'Ede de Klomp' which is known to be a good provenance, and 'Wolfheze' which is a poor provenance.

G. KERR, R. HARMER*
*Tree Improvement Branch

Pruning is a traditional method of controlling epicormic shoots but is labour intensive and consequently expensive. Past research has compared direct methods of controlling epicormics such as herbicides, stem wrapping, etc., which have had limited success and little transfer to field practice. Hence, despite the cost of pruning it remains the most common method of control. Two experiments have been established to investigate what combination of pruning regime and time of pruning will give the most cost-effective control.

G. KERR

A trial has been established in the Forest of Dean comparing three different methods of treating oak natural regeneration, 2-3 m tall (see Plate 1). The treatments are: removal of wolves, de-wolfing and respacing, and a control. For the purposes of this experiment wolves are identified using the following criteria.

1. The largest 10% of trees in terms of diameter at breast height are classed as potential wolf trees.
2. Trees are only actual wolf trees if they also satisfy one of the following criteria:
   i. forked or multi-stemmed below a height of 5 m and each fork is equal in diameter 10 cm above the split;
   ii. a crown diameter greater than two-thirds total height;
   iii. lacking a very strong central axis.

The objective is to determine if any of the methods significantly affects the growth or quality of the stand.

G. KERR, A. RUSSELL

FOREST WEED CONTROL

The recent changes to the pesticide regulations have lead to a reduction in the number of

candidate herbicides becoming available for screening to test their potential for use in the forest. Therefore, the opportunity has been taken to expand our knowledge regarding the tolerance of tree species to herbicides already in common use. Crop tolerance trials have been established to test the tolerance of Douglas fir to hexazinone and triclopyr. Work is also taking place to test the tolerance of a wide range of broadleaved tree species to overall application of Asulox.

D.R. WILLIAMSON

FARM WOODLANDS

Many of the herbicides commonly used in traditional forestry will not control the wide range of weed species found on ex-arable land. Herbicides that do control arable weeds are already in common use in agriculture but the effects of these products on trees are not known. A large-scale screening trial is therefore underway to establish which agricultural herbicides can be used safely over trees.

Systems for establishing woodlands on ex-arable sites rely on good weed control around the trees and the management of the vegetation between the weed free spots or strips. This series of trials is demonstrating the need to manage the ground vegetation on fertile lowland sites and the potential for satisfying multiple objectives during the establishment phase. Many farm woodlands are planted to provide cover for game birds. By sowing a cover crop between the tree rows game birds can be attracted and held very early in the life of the woodland. The cover crop will also suppress the weeds. Alternatively, a herb-rich meadow can be established; this not only looks attractive but excludes the weeds and has a high conservation value.

D.R. WILLIAMSON

SHORT ROTATION COPPICE: DEPARTMENT OF ENERGY (ETSU) CONTRACT

Four experiments are now being managed under this contract, at Alice Holt (Hampshire); Mepal (Norfolk) and Long Ashton (Avon), and Aberfoyle (Central Region). Unsuccessful species (*Report* 1989) were replaced with three of the UNAL poplar clones, 'Beaupré', 'Boelare' and 'Trichobel' at the English sites. The original clone (RAP) has been grubbed out at Long Ashton, but will be retained at Alice Holt and Mepal for the assessment of dry matter production from third and subsequent coppicings.

P.M. TABBUSH, C.J. NIXON*
* Silviculture (North) Branch

URBAN TREES AND TREES IN COMMUNITY FORESTS: DEPARTMENT OF THE ENVIRONMENT CONTRACT

Plant quality at establishment

Work is underway to develop means of predicting the quality and outplanting performance of broadleaves while they are still dormant. The first winter of work using moisture stressed plants has indicated that assessment of electrolyte leakage through fine root cell membranes shows the greatest potential.

Stock type for tree establishment in the lowlands

Comparisons of cell grown and bare-root stock are being made. There is no clear and consistent evidence to suggest that cell grown stock establishes more successfully than well-handled bare-root stock, even when planted outside the normal planting season, although bare-root stock may be more vulnerable to abuse.

Site amelioration for tree establishment

Three large trials were established in March 1991, on contract to the Department of Transport, to assess the establishment of oak transplants on three contrasting trunk road sites using seven planting pit ameliorants; one peat based and six derived from organic waste products.

A container trial established in April 1991 is designed to evaluate the potential of calcium peroxide as an oxygen source for trees planted into waterlogged soils.

Tree establishment demonstration areas

As well as the 17 tree establishment demonstration plots, the first of a new type of demonstration woodland has been established in the West Midlands (Plate 2). This 1.5 ha woodland demonstrates the potential for tree planting in urban areas as well as specific techniques for overcoming the constraints imposed by degraded man-made sites and 'people pressures'.

Growth improvement of established amenity trees

Research has investigated the benefit of weed control, fertiliser application and soil augering as well as compressed air soil injection and 'Mauget' nutrient tree injection. None of the treatments consistently improved tree growth and condition. Soil augering did not improve tree growth but compressed air injection did relieve a perched water table to the benefit of London plane in grass sward. On sites where soil physical conditions are not limiting, weed control generally results in improved growth. However, semi-mature trees can respond well to high nitrogen fertiliser alone. 'Mauget' nutrient injection had no effect on the condition and growth of red oak or sycamore street trees.

S. J. HODGE

ARBORICULTURAL ADVISORY AND INFORMATION SERVICE: DEPARTMENT OF THE ENVIRONMENT CONTRACT

In 1990, in order to rationalise workloads, it was decided that the Forestry Commission's Disease Diagnostic and Advisory Service should no longer accept enquiries in respect of privately owned amenity trees. The Arboricultural Advisory and Information Service undertook to act as a 'clearing house' for these enquiries, and this has contributed to a 13% increase in the number of enquirers receiving replies, raising the annual total to 3800.

The dry weather during the 1990 summer again highlighted the threat of foundation failure as a result of clay movement. Many enquiries were received from tree and property owners, consultants and engineers requiring guidance on individual situations and the threats posed by trees.

Demand for Arboriculture Research Notes was sustained during the review period. Twelve new titles published were:

84/90/ARB	The ultimate spread of trees commonly grown in towns.
85/90/SILS	Propagation of lowland willows by winter cuttings.
86/90/ARB	Organic soil amendments for tree establishment.
87/90/ARB	Watermark disease of willows.
88/90/SILN	Inoculation of alder seedlings to improve seedling growth and field performance.
89/90/WILD	Bats and trees.
90/90/ARB	The establishment of trees in new hedgerows.
91/90/ARB	The establishment of trees in existing hedgerows.
92/90/ARB	The use of water retentive materials in tree pits.
93/90/ARB	The influence of nursery spacing on outplanting performance of amenity trees.
94/91/PATH	Dieback of flowering cherry, *Prunus* 'Kanzan'.
95/91/EXT	The management of ancient beech pollards in wood pastures.

In addition, the texts of three earlier titles were revised and re-issued. These were:

1/91/ARB	Control of conker formation.
39/90/PATH	Coryneum canker of Monterey cypress and related trees.
74/90/ARB	Protecting trees from field voles.

D. PATCH, F.R.W. STEVENS

SILVICULTURE (NORTH)

PLANT PRODUCTION

Root architecture of containerised seedlings

Previous *Reports* (1988, p.16; 1990, p.15) have referred to the increasing interest in the use of containerised planting stock in British forestry. Early results have shown the forest performance of containerised conifer seedlings to be similar to that of good quality bare-root plants. However, these tentative conclusions have ignored the patterns of root development post-planting. A preliminary investigation was carried out in a 3-year-old experiment with Douglas fir planted on a brown earth soil in the North York Moors. The experiment contained six plant types; two were produced as 2-year-old bare-root stock either as transplants (T) or as undercuts (U); the remainder were produced as one-year-old containerised seedlings in Rootrainers (SLT), Styroblocks (STY), Ecopot 508 (E5) or Ecopot 515 (E15). Results are shown in Table 1.

The significant differences in survival conformed with previous results for Douglas fir (e.g. Mason and Hollingsworth, 1989) with undercut plants and containerised seedlings having better survival than transplants. The only other significant difference was in root deformation where the roots of all the types of containerised seedlings showed a greater incidence of spiralling and a lower incidence of lateral roots than the bare-root stock. It is of some concern that this deformation occurred even in types of container with ribs or grooves to prevent root spiralling (Rootrainers and Styroblocks). The importance of this finding for the long-term stability of different plant types is as yet unclear. Further studies of root development are being made in other experiments in this series to see if similar trends can be discovered.

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

REFERENCE

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

Comparison of birch plant types

There is increasing interest in the use of birch (both *Betula pendula* and *B. pubescens*) for

Table 1. Survival, height, root collar diameter (RCD) and rooting development of six plant types of Douglas fir 3 years after planting

Teatment code[1]	*Survival (%)*	*Height (cm)*	*RCD (mm)*	*Rooting depth (cm)*	*Deformation*[2]	*Root*[3] *stock dry weight (g)*
T	66.2	125.3	28.9	57.8	1.34	47.7
U	97.5	115.9	29.1	54.4	1.73	45.8
SLT	83.7	126.9	32.6	58.1	3.77	78.5
STY	88.7	117.4	30.1	58.3	3.60	60.7
E5	86.9	116.2	30.2	58.8	4.38	66.4
E15	91.2	127.1	36.3	59.7	4.16	81.7
Significance	***	ns	ns	ns	***	ns
SED	5.4	18.3	4.6	4.5	0.29	19.8

Notes:

1. For details of treatment codes see text. Volume of containers: SLT=350 cc; STY=65 cc; E5=103 cc; E15=306 cc.
2. Deformation was assessed on a score basis: 1=negligible deformation to 5=severe deformation with root spiralling.
3. Root stock is defined as the central core of roots once the laterals have been cut off.

planting in upland Britain. Two experiments were established in 1990 to compare the performance of a range of 12 different plant types (i.e. bare-root stock or containerised seedlings) of both birch species available from commercial nurseries. One experiment was in the North York Moors on an ironpan soil while the other was on a brown earth on the island of Mull (Strathclyde). Both sites were cultivated before planting. Detailed results for eight treatments planted at both sites are shown in Table 2. Survival was generally high throughout with the exception of two poorer bare-root lots which performed poorly at both sites. However, there were no significant differences in survival between the mean of the containerised plants and the mean of the bare-root stock at either site. The only significant difference between the plant types was on Mull where the height increment of the containerised plants was greater ($P< 0.05$) than that of the bare-root stock. In North York Moors experiment, the height increment of the *B. pendula* plants was significantly greater ($P< 0.01$) than was found with *B. pubescens*. The implications of these early results are that birch can be satisfactorily established using either bare-root or containerised planting stock.

W.L. MASON, R.E.J. HOWES, D.R. TRACY

ESTABLISHMENT

Forest herbicides

Results from a 1986 experiment on heather control on mineral soils showed that after 4 years the currently recommended application rate for glyphosate of 6 litres ha^{-1} (Williamson and Lane, 1989) is the lowest rate which gives an acceptable level of long-term control. In addition, application by Herbi (ULV) gives much better long-term control than application by knapsack sprayer (at VLV).

Application of Dicamba for bracken control in a thin stream of product at 2 m intervals resulted in poorer ($P < 0.05$) overall control of bracken regrowth compared with Asulam applied at the standard rate and time (Williamson and Lane, 1989).

D.G. NELSON, D.R. TRACY, R.E.J. HOWES

REFERENCE

WILLIAMSON, D.R. and LANE, P.B. (1989). *The use of herbicides in the forest*. Forestry Commission Field Book 8. HMSO, London.

Cultivation, plant handling and weeding

The interactions between cultivation, plant handling and weeding on survival and early growth of Sitka spruce were investigated for 2 years on a weedy, surface-water gley restock site in the Forest of Ae. The 17–27 cm tall undercut stock were: either planted on small (50 X 50 X 30 cm high) mounds which, having been prepared the previous spring, were being recolonised by grasses (*Holcus mollis* and *Deschampsia caespitosa*), or notched directly into uncultivated weedy ground; either handled carefully or roughly (dropped five times from 3 m, dipped in Permethrin and left in bags for 10 days and then dropped another five times from 3 m); and either left unweeded or had the grass weeds controlled by application of Gardoprim A (terbuthylazine and atrazine) at 15 litres product $hectare^{-1}$ after planting. The rough handling treatment very significantly ($P< 0.001$) reduced the mean RGP

Table 2. Survival and first year height growth of eight different plant types of birch

	B. pendula					*B. pubescens*			
	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*5% LSD*
North York Moors									
Survival (%)	96.0	97.0	98.0	59.0	98.0	61.4	95.0	98.0	16.0
Height increment (cm)	33.7	22.6	51.0	21.5	61.7	19.3	29.4	30.6	9.6
Mull									
Survival (%)	100.0	100.0	98.0	88.0	99.0	89.2	60.6	97.0	11.4
Height increment (cm)	2.8	3.4	11.5	6.9	18.5	1.3	3.8	7.2	4.9

Notes:

1. A, B, F were produced as 1+1 transplants; C, D, G as 1/2 u1/2 undercut stock; E, H as containerised seedlings.
2. Growth on Mull was poorer because the cultivation was a year old at planting.

Plate 1 (left) *Silvicultural treatment trial of oak natural regeneration, Forest of Dean.* (G. Kerr).

Plate 2 (above) *Tree establishment demonstration site in a community woodland.* (G. L. Gate).

Plate 3 (below) *Natural regeneration of an upland oakwood.* (C. J. Nixon).

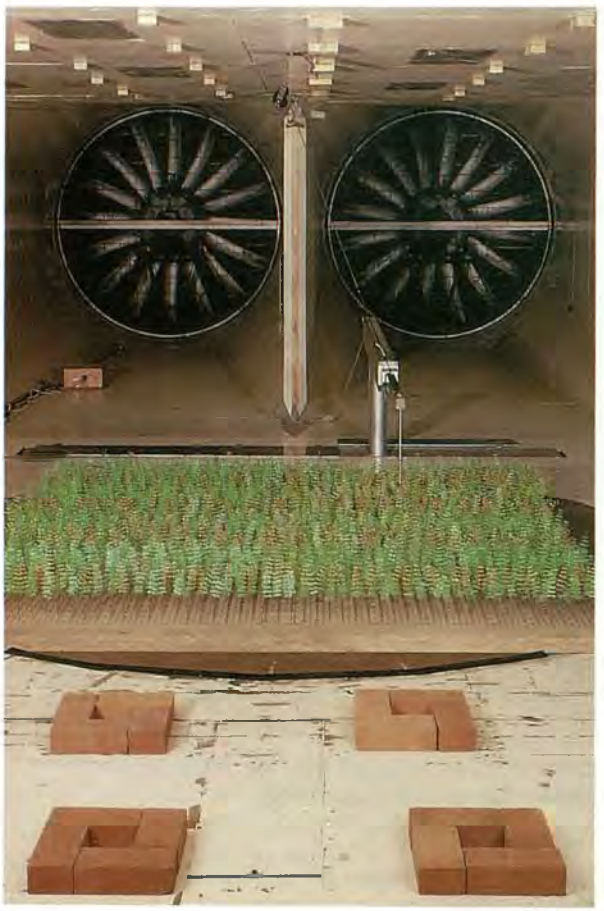


Plate 4 Model trees in the wind-tunnel at Oxford University. (39288).

Plate 5 A windthrown pocket of Sitka spruce in Tywi Forest (see also Figure 9). (C. P. Quine).

from 17.8 (range 1–51) to 2.1 (range 0–10). The first growing season after planting was very dry.

The survival of the carefully handled plants after 2 years was significantly ($P< 0.001$) greater than that of the roughly handled ones. The lower survival ($P< 0.05$) on the mounds compared to flat planting is probably a result of the lack of available soil moisture, with survival being much poorer on the mounds where weed control was not carried out. Overall, the grass weeding significantly ($P< 0.01$) improved survival.

Height increment up to age 2 (Table 3) also showed benefits from careful handling ($P< 0.05$) and weed control ($P< 0.001$), but the growth of the trees on mounds was significantly ($P< 0.01$) *less than those notched directly into the ground.*

These results show that it is possible to successfully restock grassy surface-water gley soils with Sitka spruce without cultivation (see also Nelson, 1990). Plants need to have a high root growth potential and to have been carefully stored, handled and planted, and be kept free from competition by grasses for the first growing season after planting. Under dry conditions, planting on older mounds being reinvaded by grasses and without subsequent weed control can result in poorer survival and growth.

D.G. NELSON, D. WATTERSON

REFERENCE

NELSON, D.G. (1990). Restocking with Sitka spruce on uncultivated gley soils – the effects of fencing, weeding and initial plant size on survival and growth. *Scottish Forestry* **44**(4), 266–272.

Root pruning of planting stock after lifting

Undercut, sidecut and regularly wrenched precision sown Douglas fir have proven superior to transplants in terms of both survival and early growth (Mason, 1988). The absence of any cross cutting operation in the nursery bed leads to a high proportion of the plants having long (up to 40 cm) roots, which makes planting more difficult. If not planted properly, there could be an adverse effect on future stability. An experiment investigated the effects of different intensities of root pruning on subsequent survival and early growth of undercut stock of Douglas fir and Japanese larch. The plants spent 4 weeks in a canopy store before being root pruned and planted in a freshly ploughed ironpan soil in late March.

The results (Table 4) indicate that with dormant plants of both species removal of the long roots outside the root mass has not markedly reduced the survival after one growing season.

D.G. NELSON, R.E.J. HOWES

REFERENCE

MASON, W.L. (1988). *Precision sown and undercut conifer planting stock. I. Quality and performance.* Forestry Commission Research Information Note 129.

Table 4. First year survival of root pruned Douglas fir and Japanese larch undercuts

Treatment	Species	
	Douglas fir	*Japanese larch*
No pruning	90.0	87.5
Long roots only	95.0	87.5
Prune roots		
15 cm below root collar	93.3	95.0
9 cm below root collar	80.0	80.0
5 cm below root collar	40.0	75.0
5% LSD	20.1	24.6

Table 3. Height increment (cm) of Sitka spruce planting stock over 2 years after different handling and establishment treatments

	Handling treatment			
	Careful		*Rough*	
Weed control:	*Nil*	*Weeded*	*Nil*	*Weeded*
Cultivation treatment				
Mounded	24.3	32.8	25.9	30.1
Flat planted	39.1	47.5	28.2	40.5
5% LSD	8.3			

INOCULATION OF ALDERS

Collaborative work with Glasgow University and the Institute of Terrestrial Ecology has previously shown that nursery and forest performance of red alder seedlings can be improved by inoculation with either commercial strains of *Frankia* or crushed nodules collected from healthy mature trees (McNeill *et al.*, 1989). These improvements were particularly notable on reclamation sites for the first 3–4 years after planting. In order to investigate nodule development on these sites, root systems of inoculated and uninoculated treatments were excavated from one of the oldest field trials. These investigations showed that *Frankia* had gradually dispersed throughout the experimental site from the inoculated plots. Nitrogen content of leaf samples was correlated with nodule biomass in the uninoculated trees but not in the inoculated trees. This reflected the greater age of nodule biomass in the inoculated trees with large amounts of woody and senescent tissue. These findings explain the gradual disappearance of early height differences between the inoculated and uninoculated plots as a result of 'levelling out' of nitrogen input within the site.

J.D. McNEILL, C.T. WHEELER

REFERENCE

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

NUTRITION

Sewage sludge

The collaborative research programme with the Water Research Centre into the use of sewage sludge as a forest fertiliser has now shown positive growth responses to sludge application at four sites. At Ardross, where sludge was applied (360 and 720 m^3 ha^{-1}) to a heathland site prior to planting with Sitka spruce, the height of the trees at age 7 is at least equivalent to those trees which received standard rates of inorganic phosphate and nitrogen fertilisers. An experiment on a restock site at Speyside is investigating the response of Sitka spruce to a pre-planting application of liquid sludge at 200, 400 and 800 m^3 ha^{-1}. Results to date show that at 2 years the trees are showing significantly ($P < 0.05$) better growth as a result of the sludge treatment. Two experiments on a reclamation site at Clydesdale demonstrate positive growth responses to both liquid sludge (100 and 200 m^3 ha^{-1}) and to solid 'cake' sludge (200 and 400 t ha^{-1}).

At a fifth site in Angus, where sludge was applied to a pole-stage Scots pine crop at 240, 480 and 720 m^3 ha^{-1}), growth was not enhanced by the sludge treatment. This is considered to be due to the high rates of sludge used resulting in anaerobic conditions and possible fine root death. The experiment was repeated last year in Moray Forest District using lower application rates (125 and 250 m^3 ha^{-1}). The crop at the Angus site has now been felled and replanted with Sitka spruce which will be assessed for any carry-over effect of the sludge application to the next rotation.

Further collaborative work will concentrate on possible environmental effects of sludge application to forests. An experiment is underway where sludge has been 'spiked' with additional heavy metals at varying rates. After a period of incubation, the sludge will be applied to small plots in a pole-stage Scots pine crop. This will allow studies to assess whether the maximum loading of heavy metals in forest soils, at present based on agricultural values, are suitable.

Draft guidelines for the application of sludge to forests are being prepared in collaboration with staff of Silviculture Division at Forestry Commission Headquarters.

J.C. DUTCH

NUTRITION OF TREES ON RESTOCK SITES AND IN THE FOREST NURSERY

There are two projects on tree nutrition being run jointly by the Macaulay Land Use Research Institute and the Forestry Commission. The first aims to quantify the physical and nutritional roles of harvest residues during the growth of Sitka spruce on restock sites. Tree growth in an age-series of five stands is being quantified and related to the cycling of nutrients within a range of residue treatments. Study areas are all on peaty gley soils in Kielder Forest, Northumberland and early results have shown tree growth to be better when residues are retained on site. Investigations are now focused on the mechanisms responsible for the relatively poorer tree growth on sites where the residues have been removed.

A second project aims to improve nitrogen top-dressing regimes in forest nurseries. A combination of polyhouse, laboratory and field exper-

iments are being used to study the relationships between nitrogen supply, plant demand and plant growth. Predictive models will then be developed to identify fertiliser regimes suitable for manipulating plant characteristics according to specified management criteria such as plant size, root:shoot ratio and physiological condition. During the first year a preliminary study quantified the nitrogen uptake profiles for a range of species grown as containerised seedlings in a polyhouse (Figure 3). These results are now being compared to values for open-grown seedlings at Newton Nursery, Moray. Model predictions of soil nitrogen availability are being tested against actual uptake values for different species.

M.F. PROE*, J.C. DUTCH, W.L. MASON
*Macaulay Land Use Research Institute, Aberdeen

THE NATURAL REGENERATION OF UPLAND OAKWOODS

A comprehensive literature review of the subject has been completed (Nixon and Worrell, 1991). The main conclusions are that, although seedlings occur irregularly with anything from 5-7 years between heavy seed years, upland oakwoods (Plate 3) produce sufficient seed to allow natural regeneration to take place. In very good years, ground densities of up to 700 000 acorns ha^{-1} have been recorded. The major reason for the subsequent loss of acorns is predation, with the major losses being attributed to squirrels, birds, mice and voles. Only around 0.5% of acorns survive to produce first year seedlings. The subsequent growth of seedlings following germination is strongly influenced by vegetation type due to its effect on shading and competition. Fencing, soil cultivation and the opening up of the canopy are regarded as the most important silvicultural measures for promoting regeneration. Fencing alone has been shown to be effective on upland acid site types but it will seldom be sufficient if canopy gaps do not exist or if vigorous weed competition occurs within any gaps.

A survey of climatic and crop factors, e.g. site elevation, soil type, rainfall, tree stocking density and ground vegetation, and their influence on natural regeneration has been conducted in over

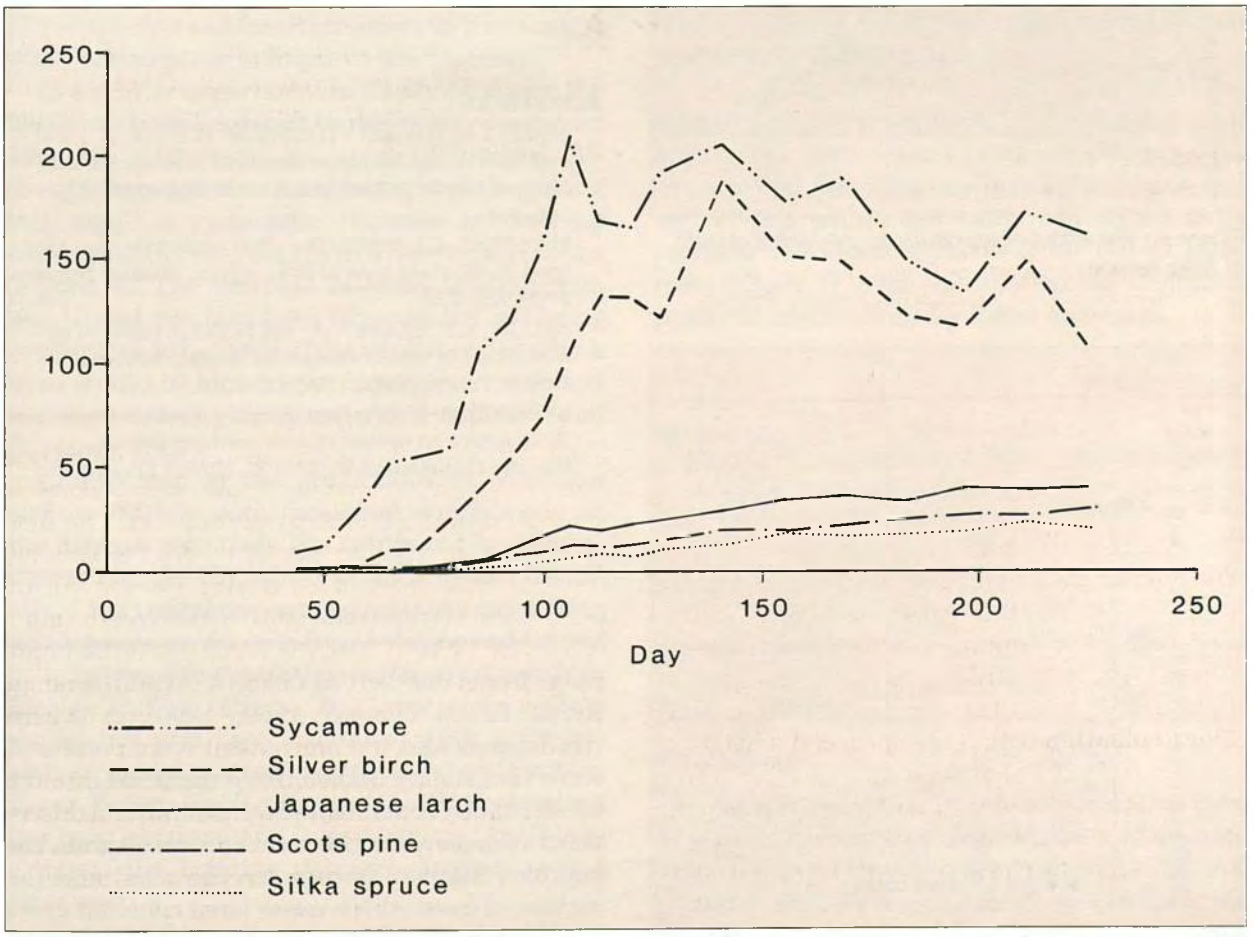


Figure 3. Nitrogen content (mg N per tree) for a range of tree species grown as containerised seedlings in a polyhouse.

50 woodlands in North Wales. The data collected are currently being analysed.

Experimental work has started to investigate the efficacy of a number of protection and ground preparation techniques in promoting regeneration in an oakwood at Brechfa Forest in mid Wales.

C.J. NIXON, R. WORRELL

REFERENCE

WORRELL, R. and NIXON, C.J. (1991). *Factors affecting the natural regeneration of oak in upland Britain.* Forestry Commission Occasional Paper 31.

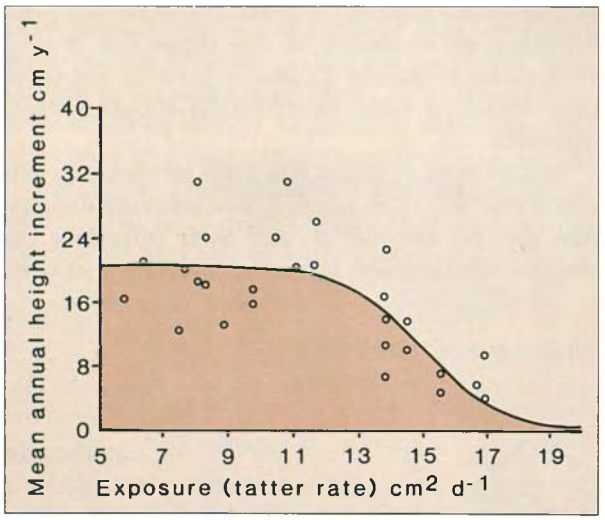


Figure 4. The effect of exposure on the height growth of Sitka spruce.

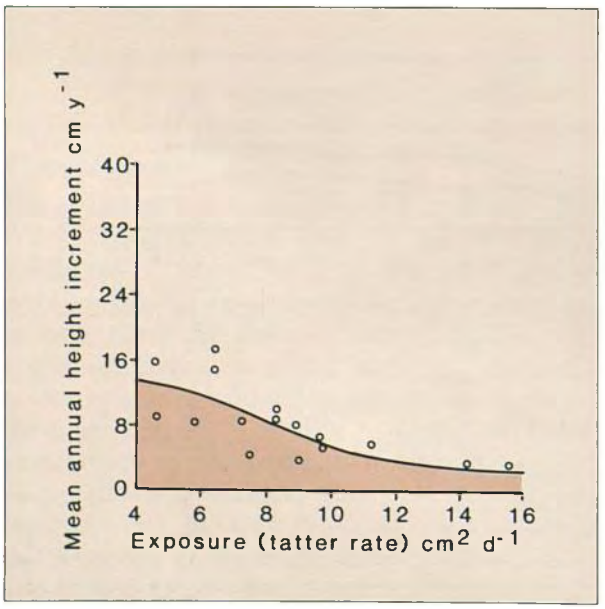


Figure 5. The effect of exposure on the height growth of Scots pine.

FOREST TRIAL PLOTS AT HIGH ELEVATIONS

The results from a larger number of trial afforestation plots located at high elevations have been analysed. In Britain's oceanic climate, exposure is the overriding factor limiting tree growth. At each of the trial sites the level of exposure was measured using tatter flags (Miller *et al.*, 1987). A number of previous studies (Malcolm and Studholm, 1962; Mayhead, 1973; Worrell, 1987) have described a linear relationship between the growth of Sitka spruce and elevation. However, the results from this study which concentrated on the growth of Sitka spruce and Scots pine at or near the tree-line has revealed an exponential decline in the rate of tree growth as the upper exposure limit is reached (Figures 4 and 5). It is clear that at these extreme limits, tree extension growth becomes increasingly restricted by the combination of cold temperatures and high windspeeds. Mutual shelter between trees and forest blocks could be very significant in helping to ameliorate the adverse site conditions and in promoting faster growth.

C.J. NIXON, A.L. TYLER

REFERENCES

MALCOLM, D.C. and STUDHOLM, W.P. (1972). Yield and form in high elevation stands of Sitka spruce and European larch in Scotland. *Scottish Forestry* **26**(4), 296–308.

MAYHEAD, G.J. (1973). The effect of altitude above sea level on the yield class of Sitka spruce. *Scottish Forestry* **27**(3), 231–237.

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

WORRELL, R. (1987). *Predicting the productivity of Sitka spruce on upland sites in northern Britain.* Forestry Commission Bulletin 72. HMSO, London.

AEROMECHANICS AND AIRFLOW

Data from the aeromechanics experiment in Rivox Forest (*Report* 1989, 1990) in which windspeeds and tree movement were measured show that energy transfer from the wind into the forest canopy is dominated by intermittent downward sweep events. These events result from the complex interaction between the wind and the motion of trees which cause large coherent gusts to form and move across the forest. The impact of these gusts on the trees is worse than a steady wind. Understanding their formation and the role

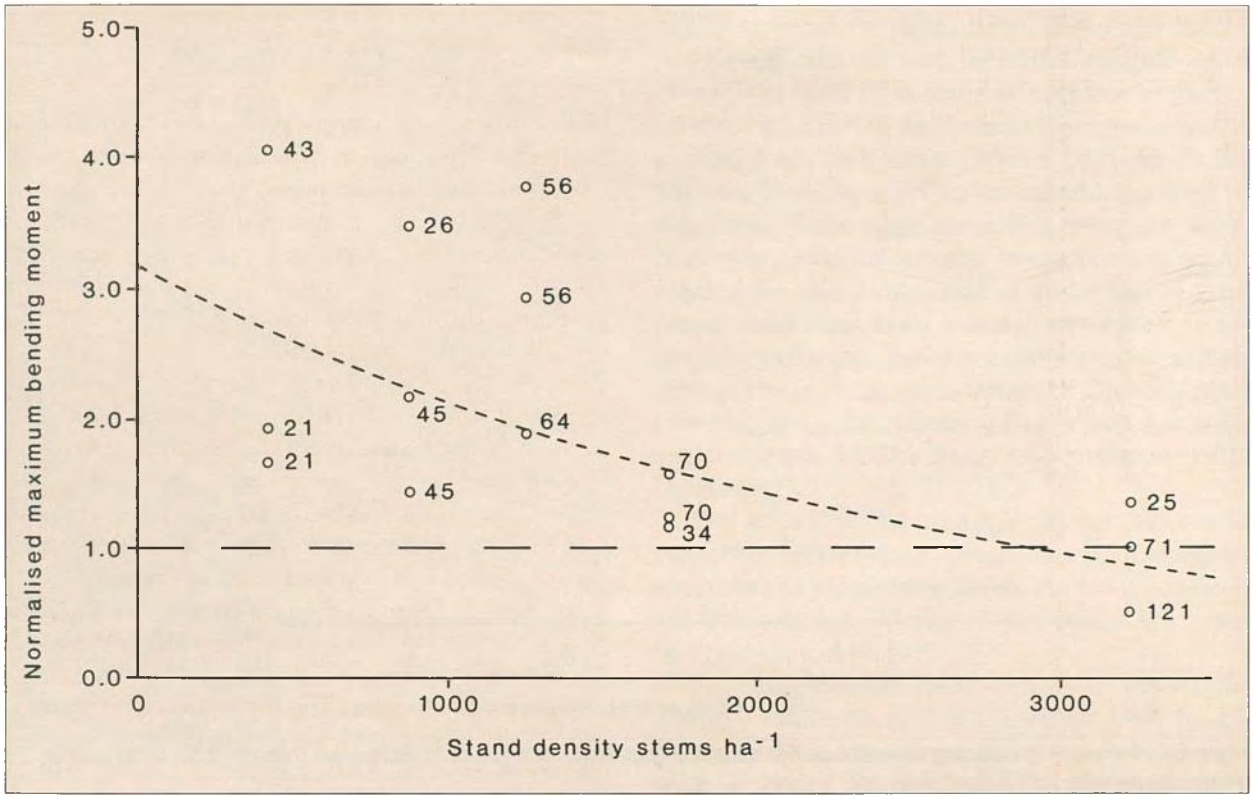


Figure 6. Change in bending moment with stand density. Values are normalised against bending moment for tree 71.

of tree spacing and forest structure will be a major goal in attempting to improve tree stability.

In a similar experiment in Kershope Forest the forces on trees respaced to densities of between 400 and 3500 stems ha^{-1} were compared. Although the number of trees tested at each spacing was small a systematic increase in bending moment with a decrease in tree density is obvious (Figure 6). The increase in wind loading with windspeed has also been investigated, allowing predictions to be made of the windspeed at which trees would be blown over based on comparison with earlier tree pulling experiments (Fraser and Gardiner, 1967).

Comparison of the predictions of computer airflow models with measured windspeeds on the Kintyre peninsula has continued in collaboration with the University of Manchester. Generally, the models are good at predicting windspeeds on the windward slopes and tops of hills but tend to overestimate the windspeeds in the lee and in valleys. The large scale airflow model has also been combined with a canopy airflow model to predict the windspeeds within Rivox Forest. Good agreement with observation has been obtained and it is becoming possible to estimate the bending moment on trees over a large area.

A series of experiments were carried out in the Oxford University wind-tunnel on a 1:75 scale model forest consisting of 11 000 plastic trees (Plate 4). The wind forces on forests of different spacings, different thinning patterns and with a variety of edge treatments were compared. The effect of wind direction and the size of gaps within the forest were also considered. The experiments have shown how introducing any sort of gap within the forest can significantly increase the bending moment on the exposed trees (Figure 7). Such information has important practical implications for forest managers.

B.A. GARDINER

REFERENCE

FRASER, A.I. and GARDNER, J.B.H. (1967). *Rooting and stability in Sitka spruce.* Forestry Commission Bulletin 40. HMSO, London.

STABILITY

Windthrow

The windthrow monitoring areas (Quine and Reynard, 1990) are now yielding data with which to validate and improve the Windthrow Hazard Classification (WHC). The WHC predicts the stand top height when 3% stems are windthrown (critical height) and when 40% stems are windthrown (terminal height). Predicted damage

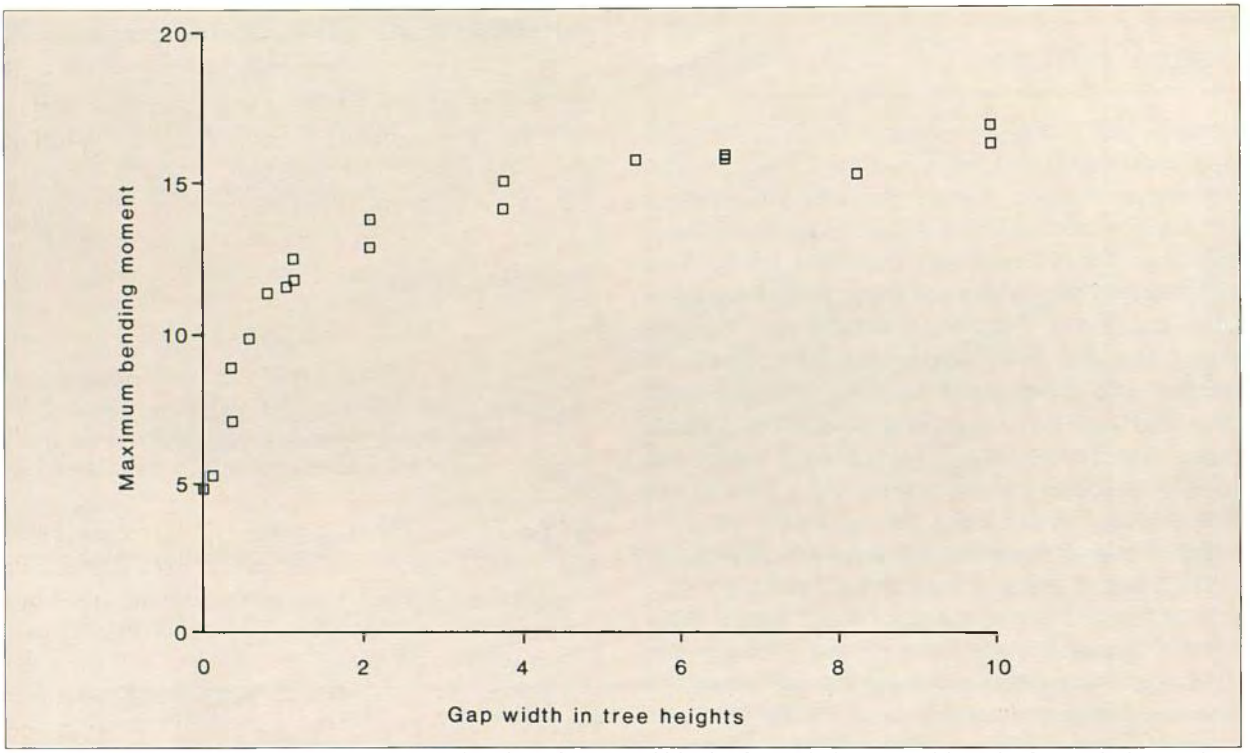


Figure 7. Increase in bending moment as the size of a gap within the forest in increased (results from wind-tunnel experiments with 1:75 scale trees.

(< 3%, 3-40%, > 40%) was compared with the percentage of trees actually windthrown within 0.01 ha ground survey plots. The WHC correctly predicted the damage class in 51% of plots, over-predicted damage in 33% of plots, and under-predicted damage in 16% of plots. The over-predictions and under-predictions tended to occur in different monitoring areas, indicating scope for improving the performance of the WHC by revising scores. This test at plot level assumes wind damage to be evenly dispersed through stands, whereas in practice it is frequently clustered. We plan to extend the test to the stand and compartment level.

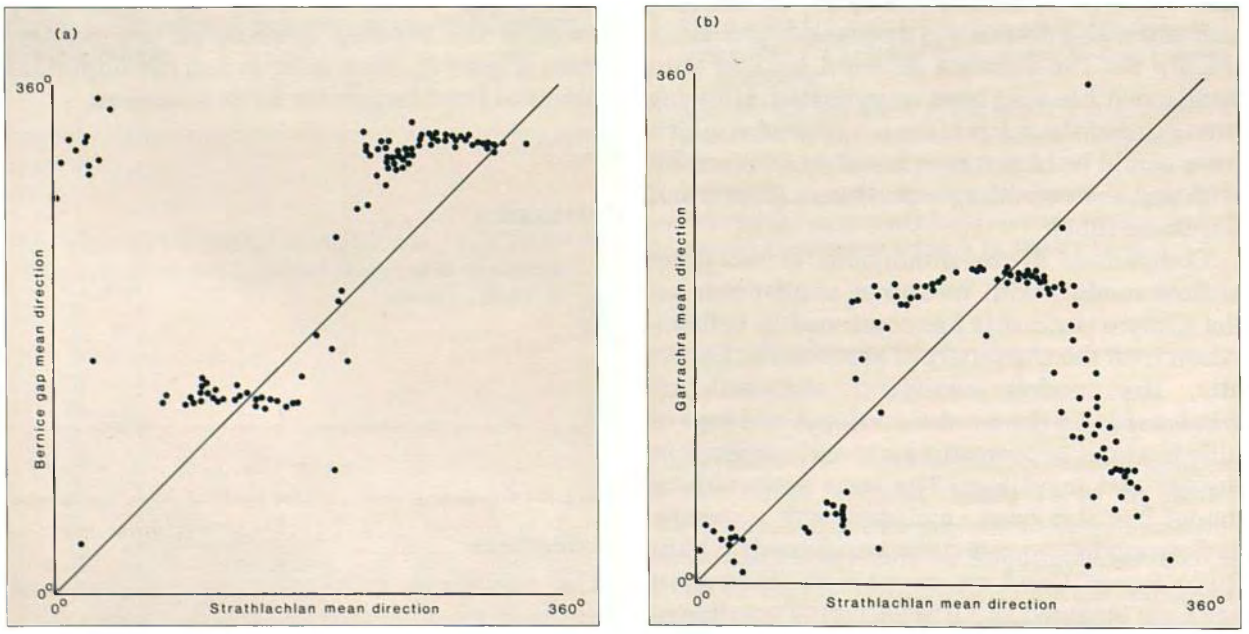


Figure 8. Twelve-hourly mean wind direction for a 4 month period at a hilltop site (Strathlachlan) compared with those at valley sites Bernice (Figure 8a) and Garrachra (Figure 8b). If wind directions were always the same at the sites the points would cluster along the diagonal line. However, although a wide range of wind directions are represented in the hilltop data, in the valleys most wind is funnelled along the valley axis only (Bernice 140°–320°, Garrachra 215°–35°).

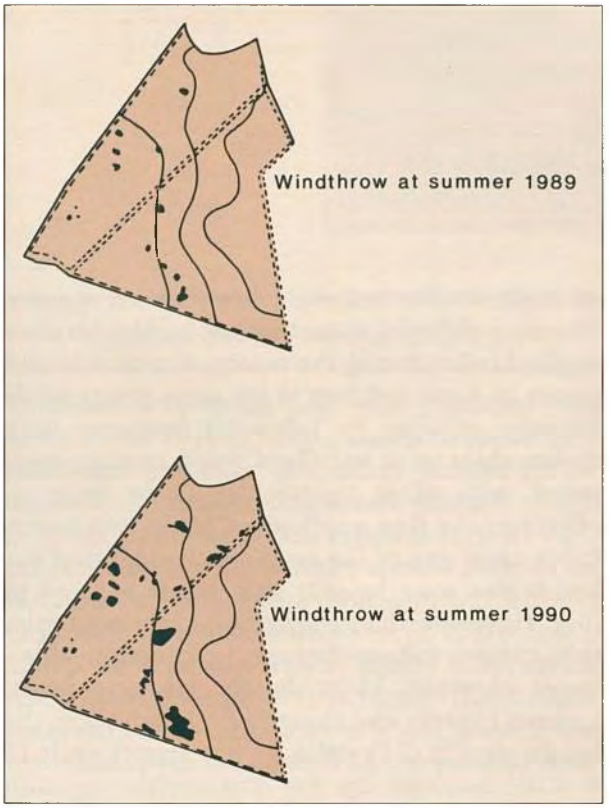


Figure 9. Progression of windthrow in part of the Tywi Windthrow Monitoring Area. Note no damage was apparent on aerial photography taken in summer 1988. The forest is unthinned Sitka spruce, top height 11.7 m in 1990, Windthrow Hazard Class 5.

Ground survey data have also been incorporated into a Geographic Information System (GIS) study of the Kintyre monitoring area in collaboration with the Macaulay Land Use Research Institute, Aberdeen. This study has explored the dataset combining capabilities of GIS to produce WHC maps, maps of years to predicted critical and terminal heights, and characterisation of existing windthrow pockets.

Wind-measuring equipment from the detailed airflow study in Kintyre (*Report* 1990, pp.19-20) has now been deployed in the monitoring areas to supplement the high elevation reference sites. Nineteen locations are now instrumented, representing an elevation range of 10 to 500 m. The recent sites have been selected to explore topographic variation, and we have a cluster of five sites in the very complex terrain of Cowal, Argyll (see Figure 8). An exposure flag is flown at each site to enable further study of wind/tatter relationships.

The annual aerial photography programme is revealing the onset and progression of damage in a number of monitoring areas. An example from the Cwm Berwyn block of Tywi Forest is shown in Figure 9 and Plate 5.

The most notable forest damage of the winter 1990/91 occurred on 7/8 December 1990 in the North York Moors, where strong winds combined with a heavy snowfall led to approximately 75 000 m^3 timber being thrown or snapped. Pre-thicket stands were also damaged. The general pattern of the damage is being investigated in conjunction with the Department of Geography, University of Edinburgh utilising GIS techniques.

C.P. QUINE, A.L. MACKIE

REFERENCE

QUINE C.P. and REYNARD, B.R. (1990). *A new series of windthrow monitoring areas in upland Britain.* Forestry Commission Occasional Paper 25.

INTER-BRANCH REPORT SILVICULTURE (NORTH) AND PHYSIOLOGY

HANDLING AND STORAGE OF PLANTING STOCK

'Tree G' shock recorder

To enable researchers and managers to objectively measure both the levels of force and the temperatures to which plants have been subjected during handling and transport, a 'Tree G' recorder has been designed. The recorder is battery powered and records the air temperature and maximum force every 30 seconds, giving a print-out at the end of the journey. This means that transport and handling systems can be compared. Work is under way to establish a relationship between the size and/or frequency of shocks and the effect that this has on root electrolyte leakage values (*Report* 1990, p.43) and subsequent plant survival and early growth.

D. G. NELSON, H. M. McKAY, B. A. GARDINER

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

NURSERY HERBICIDES

Seedbeds

Further experiments were carried out at Bush (Lothian) and Headley (Hampshire) nurseries to test the efficacy of repeat low-dose post-emergence applications of a range of herbicides (*Report* 1990, p.9) for maintaining weed-free conditions in first-year seedbeds. Results were similar at both nurseries. The most effective herbicides for repeat low-dose application were napropamide, oryzalin and metazachlor applied at between one-quarter and one-half of the recommended transplant rate (Williamson and Mason, 1989). These herbicides had no effect upon crop growth and survival. Weed control was most effective when the repeat low-dose regime had been preceded by partial soil sterilisation the previous autumn and a standard pre-emergence application of diphenamid. The repeat low-dose regime would appear to have great potential for use in commercial nursery management.

Transplant and undercut stock

In a continuation of previous work (*Report* 1990, p.9), eleven herbicides and herbicide mixtures were tested for crop tolerance and weed control on eight conifer and eight broadleaved species. The main difference was that test herbicides were applied twice during the season, first to dormant plants in April and then to the same plants while actively growing in July. All mixtures with metazachlor gave excellent weed control compared with other treatments. There were no effects of the first application of the test herbicides upon any of the crop species. Most of the herbicides were equally safe when applied in July. However, the metazachlor-clopyralid mixture caused foliage damage in common alder, sweet chestnut, birch, beech, Japanese larch, Lawson cypress and Douglas fir. In addition, the height growth of Douglas fir was significantly ($P < 0.05$) reduced by the metazachlor-oryzalin combination. However, the results were generally encouraging and confirm that there are a wide range of herbicides which may be used to control weed competition in transplant lines.

W.L. MASON, D.R. WILLIAMSON

REFERENCE

WILLIAMSON, D.R. and MASON, W.L. (1989). *Forest nursery herbicides*. Forestry Commission Occasional Paper 22.

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

RECLAMATION OF UPLAND SITES

At Benbain opencast coal site (Ayrshire and Arran Forest District) experiments to investigate nutritional problems of conifers planted on reclaimed land subjected to severe climatic conditions are continuing. One experiment tests various nitrogen inputs to Sitka spruce planted on traditional mineral restoration with and without a top layer of redistributed peat (1 metre deep). After 5 years, growth is significantly better on the peat ($P<0.01$) (see Table 5). Although the nitrogen treatments have produced a slight growth improvement over the control on the mineral area, all treatments, including the untreated control remain equally good on the peat area, indicating a continuing benefit from the peat.

These results continue to show the benefit of peat as a topsoil on reclamation sites and the data have been used to convince site operators to make use of available peat in South Scotland and South Wales. One experiment has recently been established in South Wales (Derlwyn, Morgannwg Forest District) comparing the performance of eight tree species on pure shale, shale mixed with peat/soil and pure peat (1 metre in depth).

J. D. McNEILL, A. J. MOFFAT

Table 5. Height and increment of Sitka spruce planted on opencast spoil with and without a top layer of peat

*Treatments		Height (cm)				Increment (cm)	
		At planting		5 years		5 years	
		Peat	Mineral	Peat	Mineral	Peat	Mineral
O	- no nitrogen	39.0	39.9	164.1	89.2	125.1	49.3
NVM	- legume (maku) sown	38.7	37.5	163.6	105.4	124.9	67.9
NVM+P	- above + added phosphate	36.5	38.3	170.1	104.1	133.6	65.8
NVA	- interplanted with *Alnus rubra*	35.3	38.3	152.1	114.3	116.8	76.0
NFR	- biennial urea (2 applications to date)	37.7	43.8	163.3	112.8	125.6	69.0
NFP	- periodic urea (1 application to date)	35.4	38.5	164.1	97.9	128.7	59.4
	Mean	37.1	39.4	162.9	103.9	125.8	64.5

*Standard phosphate/potash fertiliser application to all plots at planting.

SITE STUDIES (SOUTH)

CHEMICAL ANALYSIS

During the year 6900 foliar samples were submitted for analysis of major nutrients. Of these, 650 were from private forestry and 220 from the Forest Enterprise. Recent changes made to the software controlling the instrument used to quantify metal concentrations in foliage have led to an improved confidence in the results produced. Small changes in the submission procedure now allow samples to be processed according to their priority. Six hundred samples were analysed for chloride, other anions, calcium and magnesium for a project investigating the effects of de-icing salt (sodium chloride and calcium magnesium acetate) on common urban tree species. Investigations were started on the pigment concentrations of trees grown in ambient air or in clean air at the three open-top chamber sites. Additionally, 100 foliar samples were submitted for starch and total sugar determinations.

E. WARD, P. G. CROW, J. E. STONARD

RECLAMATION

Tree establishment and growth on waste products from coal burning power stations

The research under a contract from the Central Electricity Research Laboratories (now National Power Technology and Environmental Centre) (see *Report* 1989, p.27) has been completed. A detailed study of the rooting habit of common alder, Lombardy poplar, false acacia and grey sallow into various layers of gypsum and PFA (pulverised fuel ash) materials has been valuable in identifying disposal strategies to optimise tree rooting and growth. White poplar has been established on a mound of gypsum at West Burton Power Station, Nottinghamshire (Plate 6).

A. J. MOFFAT, N. P. HAYWARD

Evaluation of spoil placement and cultivation techniques

Soil compaction is an inevitable consequence of soil movement, but recent research at Bramshill on restored sand and gravel workings, and at the Maesgwyn restored opencast coal site in South Wales, has shown that 'loose tipping' (*Report* 1985, 1986) may produce the best substrate for tree establishment and growth. Examination of loose tipped ground using a soil penetrometer shows that this method produces a deep, uncompact substrate for tree rooting. In comparison, cultivation using the winged tine and 'Neath' plough merely loosens the surface, and the disturbed material begins to recompact within one season (Figure 10).

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

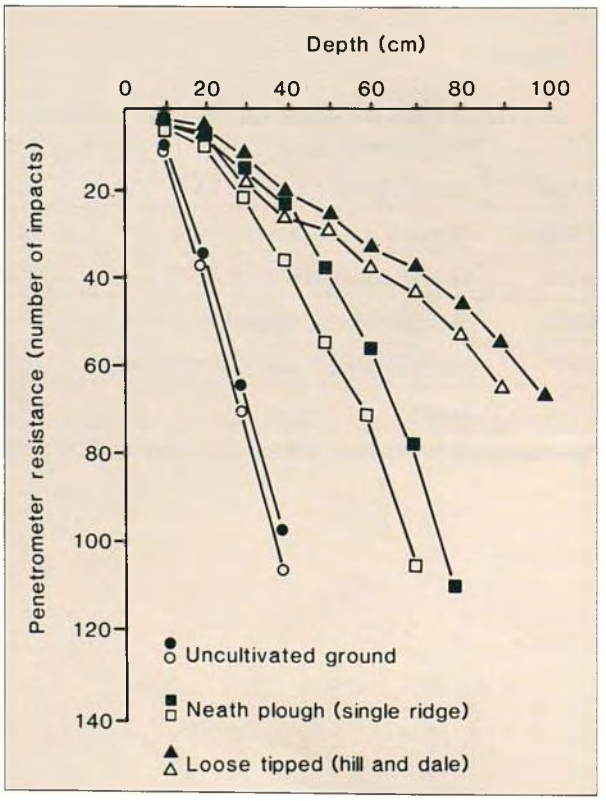
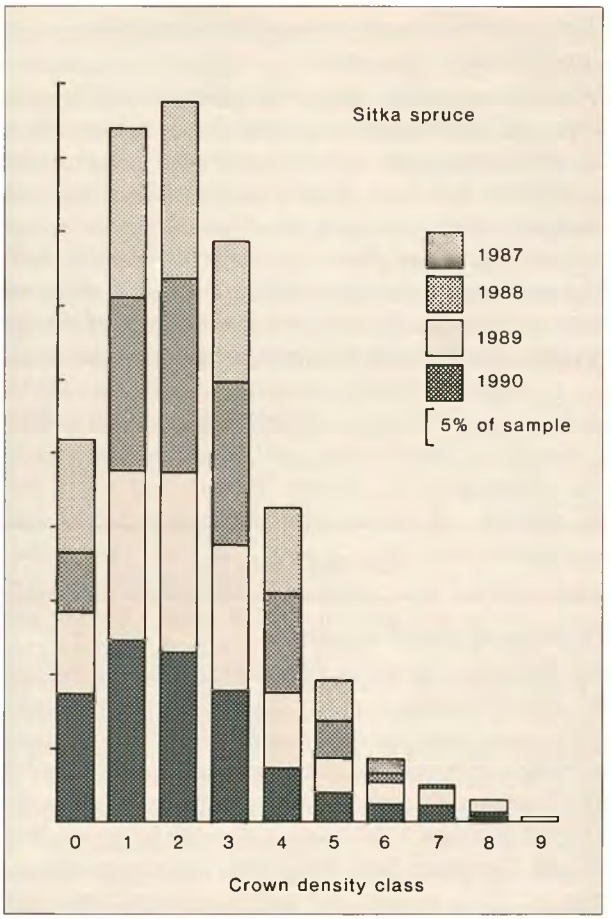


Figure 10. The effects of cultivation technique on soil compaction measured using penetrometer resistance tests.


Sitka spruce
1987
1988
1989
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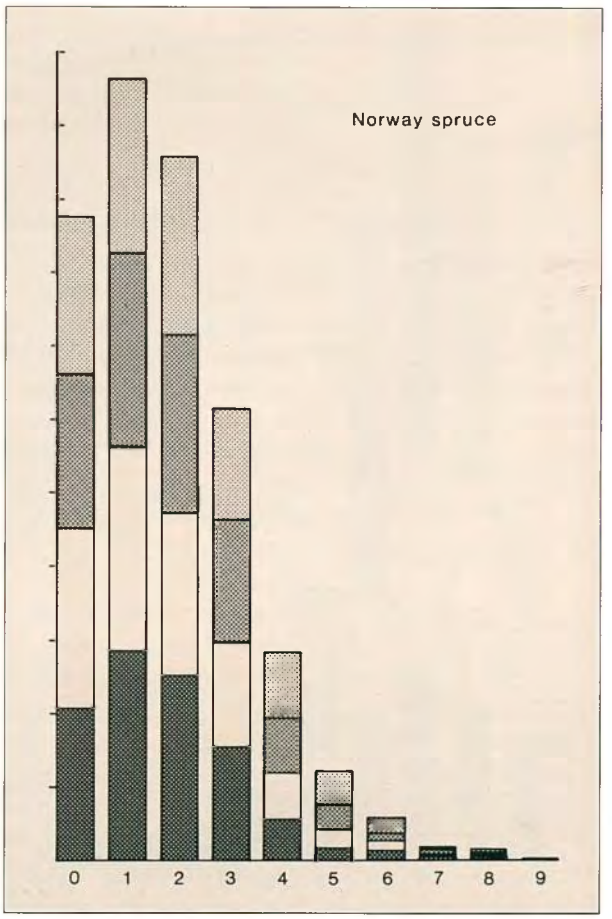
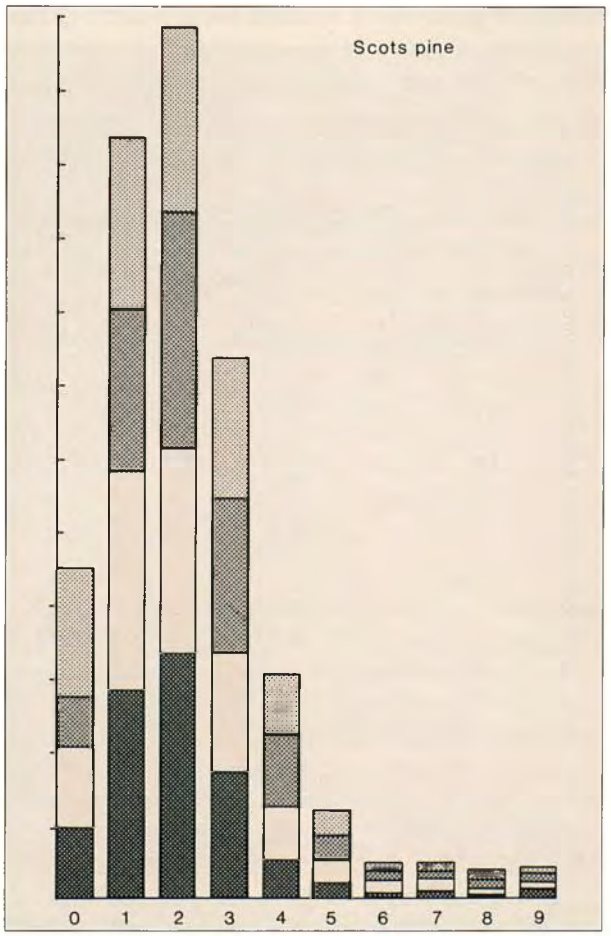
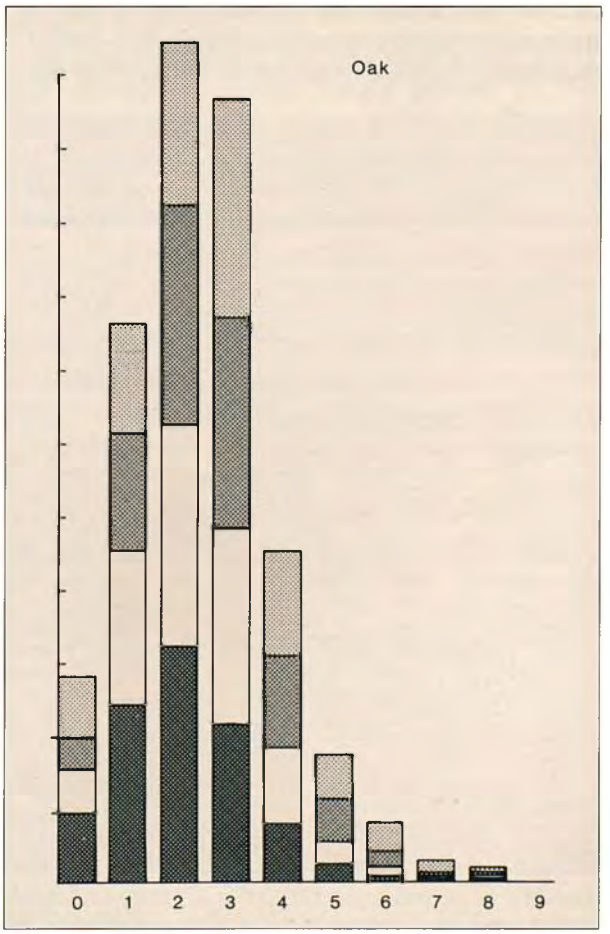
5% of sample
0 1 2 3 4 5 6 7 8 9
Crown density class


Norway spruce
0 1 2 3 4 5 6 7 8 9


Scots pine
0 1 2 3 4 5 6 7 8 9


Oak
0 1 2 3 4 5 6 7 8 9

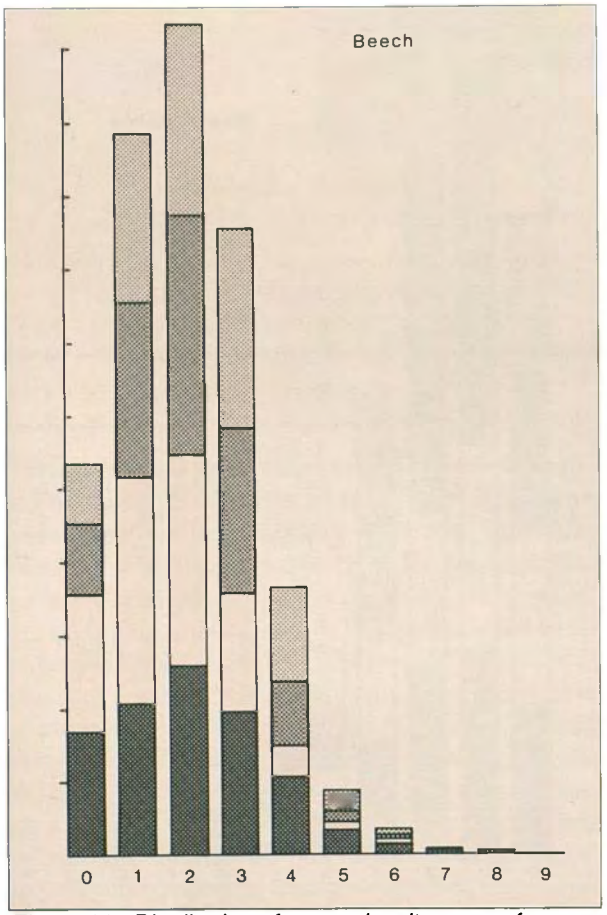


Figure 11. Distribution of crown density scores for common sample trees over the period 1987 to 1990. A score of 0 indicates a reduction in density of 0–10%, 1 represents 11–20%, 2 represents 21–30% and so on.

Tree establishment on modern domestic landfill sites

With support from Buckinghamshire County Council, an experiment has been set up at a modern domestic landfill site at Calvert. The establishment and growth of eight broadleaved tree species are being examined on two clay substrates, the engineered cap to the landfill, and the soil cover over the cap (Plate 7). The effect of tree rooting on the soil structure and hydrology will be examined as the trees become established.

A. J. MOFFAT, N. P. HAYWARD

AIR POLLUTION

Surveys of forest condition

In 1990, the condition of 7644 trees was assessed in detail. Sitka spruce, Norway spruce, Scots pine, oak and beech were included. A further survey conducted on behalf of the Commission of the European Communities examined the condition of another 1700 trees, although in much less detail. Between 1989 and 1990, the crown densities of Sitka spruce and oak improved, whereas Norway spruce and Scots pine showed little change (Figure 11). A marked deterioration in the condition of many beech was noted, the deterioration being particularly marked in the south of

Table 6. Changes in the crown density scores of Scots pine between 1987 and 1990. Classes are the same as in Figure 11. The numbers of trees in each category are given.

	Scots pine								
Crown density class in 1990	*Crown density 1987*								
0	0	1	2	3	4	5	6	7	8
n = 1348	240	311	336	257	111	43	13	17	12
0 -- 133	55	40	26	10	0	1	0	1	0
1 -- 383	84	114	111	55	14	2	2	1	0
2 -- 452	66	109	125	108	33	8	2	1	0
3 -- 232	25	35	58	64	37	13	0	0	0
4 -- 69	8	6	11	15	12	12	4	1	0
5 -- 30	2	2	3	4	10	4	2	2	1
6 -- 9	0	1	0	0	1	2	1	3	1
7 -- 18	0	2	1	0	2	1	2	5	5
8 -- 5	0	1	0	1	0	0	0	0	2
9 -- 17	0	1	1	1	0	2	0	3	3

England. This is thought to have been due to the successive droughts of 1989 and 1990. It was accompanied by an increased incidence of abnormally small leaves and abundant masting. The improvements in Sitka spruce can be attributed to the continued recovery of many trees following severe defoliation by the green spruce aphid *Elatobium abietinum* in the spring and early summer of 1989. The reason for the improvement in oak is uncertain, but may have been due to a reduced incidence in the occurence of defoliation by the oak leaf roller moth *Tortrix viridana*.

Detailed analysis of the results has revealed some marked trends that are not readily discernible from the overall results. For example, although the condition of Scots pine has remained stable over the last 4 years, there are numerous trees which changed condition significantly over the period (Table 6). Excluding the worst category, which had a very small sample size, the most stable category involved reductions in density of 21-30%. However, only 37% of the trees in this class in 1987 were classified the same in 1990. Similar variations were found in many of the other variables, confirming that the condition of individual trees fluctuates substantially from year to year. This will obviously complicate any recognition of long-term trends in forest condition.

Table 7. Development of leaf chlorosis (yellowing) in beech during the course of the programme. The numbers of trees in each category are given.

Beech chlorosis 1990				
Second visit	*First visit*			
	0-10%	11-25%	26-60%	>60%
0–10%	98	0	0	0
11–25%	29	8	0	0
26–60%	14	0	2	0
> 60%	0	2	0	5

A specific problem encountered in 1990 was the effect of the drought. The monitoring programme takes place over two months and, in the past, it has been assumed that trees show little change in this period. Because of the drought conditions, this assumption was checked in 1990. A number of plots visited early in the programme were revisited at the end. Considerable differences were encountered; changes in the amount of yellowing in beech are given in Table 7. These changes create difficulties for the interpretation of data which have still to be resolved.

J. L. INNES

Experimental studies

Detailed studies have continued in the long-term experiment to study the effect of air quality on tree growth using the open-top chambers established at three sites in Britain (*Report* 1986). Trees from four species – Sitka spruce, Norway spruce, Scots pine and beech – were planted directly into the soil inside the open-top chambers in the spring of 1988. At each site there are eight chambers receiving ambient air, eight receiving filtered air and eight outside plots to monitor the chamber effect.

Assessments of tree growth, phenology (Lee *et al.*, 1990 a and b) and physiological measurements including gas exchange and needle retention were made during the season. The ameliorating effect of the chambers themselves (the 'greenhouse' effect) continued to have a greater influence on the date of bud burst than any effect of air filtration. Effects of air quality on tree growth, however, are more complex and indicate different responses both between species and within species to the particular pollution climate found at each site.

At Headley, beech, Norway spruce and Scots pine showed improved height growth in the filtered air chambers as time progressed (Figure 12). Beech height was 22% greater ($P<0.01$), and Norway spruce 17% taller in filtered air, with a stem diameter increase of 20% (both $P<0.05$). Additionally, total dry weights and dry needle weights of the Norway spruce were increased by 45% and 49% respectively ($P<0.05$). While the growth of Scots pine was greater in filtered air, the results were not significant mainly due to the greater variation found within this species.

At the other two sites results were more variable. At Chatsworth Scots pine, Norway spruce and Sitka spruce showed slightly depressed stem height and diameter in filtered air, but Scots pine, Norway and Sitka spruce had greater needle dry weights. Results at Glendevon were similar to those at Chatsworth with the three conifers having depressed height growth but greater needle and stem dry weights in filtered air. However, none of the results at the latter two sites was statistically significant.

Measurements were carried out on Scots pine to assess needle quality and retention. Longer needles ($P<0.05$) and higher dry needle weight/stem ratio ($P<0.01$) were found in filtered air chambers at Glendevon (Figure 13). Such

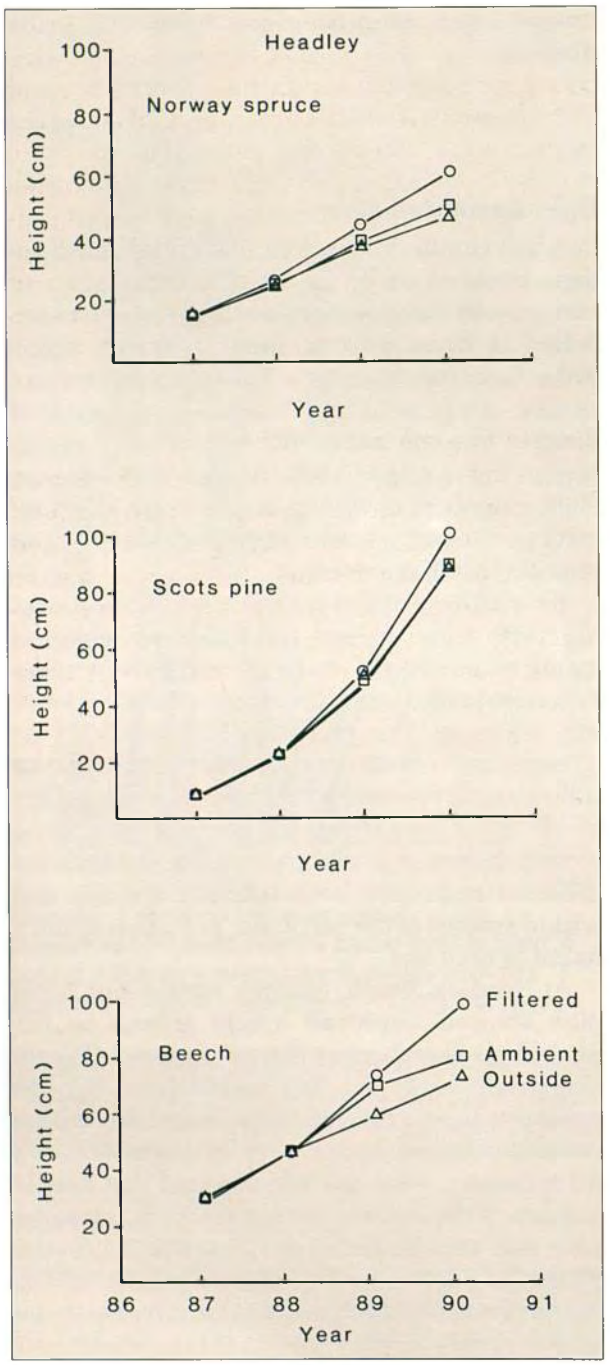


Figure 12. Effects of air quality on height of Norway spruce, Scots pine and beech grown in open-top chambers at Headley from 1987 to 1990.

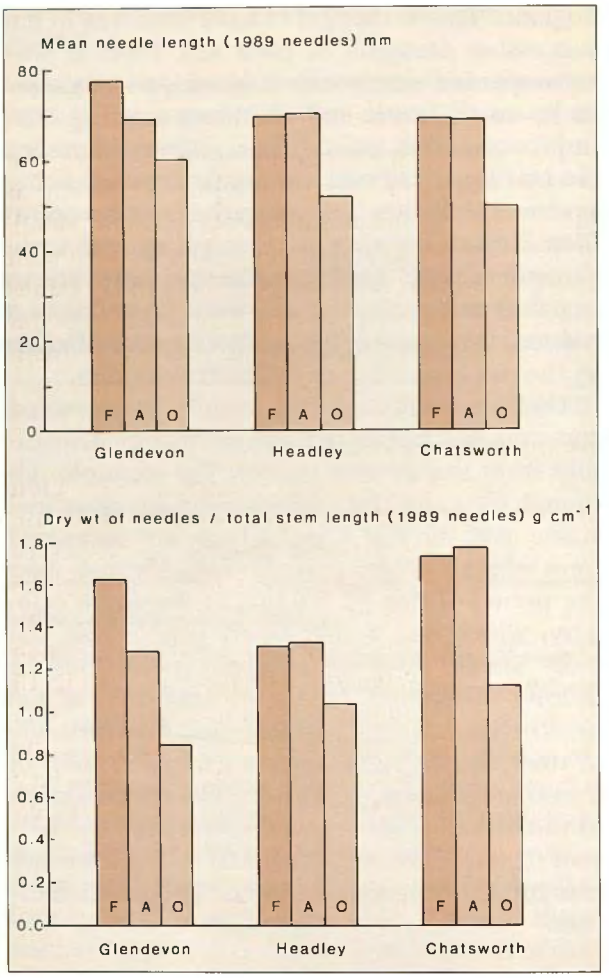


Figure 13. Effects of air quality on the needle length and retention (dry weight/total shoot length g cm^{-1}) of Scots pine grown in open-top chambers at Headley, Chatsworth and Glendevon. (F = filtered air; A= ambient air; O = air outside of open-top chamber.)

patterns of needle retention were not found at Chatsworth or at Headley.

Comparisons of pollution climates between Chatsworth and Headley confirm that Headley had the highest ozone concentrations with a peak of 104 ppb in 1990 compared with 89 ppb at Chatsworth. Ozone levels greater than 50 ppb were recorded 23 times at Headley and 18 times at Chatsworth, which had higher NO_x and SO_2 levels. NO_x reached a peak of 196 ppb and exceeded 50 ppb on 20 occasions compared with 84 ppb and 9 occasions at Headley. The maximum recorded SO_2 level was 124 ppb at Chatsworth and 85 ppb at Headley.

Investigations have continued to examine the relationship between nutrient levels in trees and air quality. Sitka spruce, Norway spruce, Scots pine and beech have been grown in pots in filtered and ambient air under a fertiliser regime designed to induce nutrient deficiencies of N, P, K, Ca and Mg. These trees have now been established in a fully replicated experiment in the open-top chambers at Headley.

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

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LEE, H. S. J., WILLSON, A., BENHAM, S. E., DURRANT, D. W. H., HOUSTON, T. and WADDELL, D. A. (1990 a). *The effect of air quality on tree growth.* Forestry Commission Research Information Note 182.

LEE, H. S. J., WILLSON, A., BENHAM, S. E., DURRANT, D. W. H., HOUSTON, T. and WADDELL, D. A. (1990 b). *The effect of air quality on the timing of tree shoot development.* Forestry Commission Research Information Note 183.

HYDROLOGY: WATER QUALITY

Thetford wet timber store

Measurements have continued to monitor the effects of the wet store of windthrown timber at Thetford on drainage water quality (*Report* 1990). Both water colour and biological oxygen demand have remained well within the guide values specified in the European Community Water Directive (75/440/EEC) for normal water treatment.

Liming in acid catchments

The pelletised limestone treatment at Llyn Brianne continues to have only a limited effect on soil and drainage water chemistry. Figure 14 presents the soil water pH data for five soil depths in the treated area (5, 15, 30, 40 and 50 cm). Amelioration of soil water acidity has been limited to the water draining through the top 15 cm of soil, although the response has only been consistent at 5 cm depth. Figure 15 presents the drainage water pH data for five forest tributary streams. Streams FS1, FS2 and FS3 drain two treated areas comprising peaty gley and peaty ironpan soils, FS4 drains a third treated area comprising *Molinia* and flushed *Juncus* bog and FS5 represents a control stream section above the treated area. The results show that only the stream (FS4) draining the 'classical' source area has responded to the treatment to date. Unfortunately, even in stream FS4 the initial improvement in pH values has not been maintained, with sharp drops down to <5.0 during winter periods of high flow. Soil and stream water monitoring is being continued.

Long-term catchment studies

Agreement has been reached with the Welsh Region of the National Rivers Authority to fund jointly 12 long-term monitoring sites in upland Wales to establish the role of forestry in surface water acidification. Sites have been chosen to cover different periods of forest growth and monthly sampling of streamwaters will commence in June 1991.

T. R. NISBET, J. E. STONARD

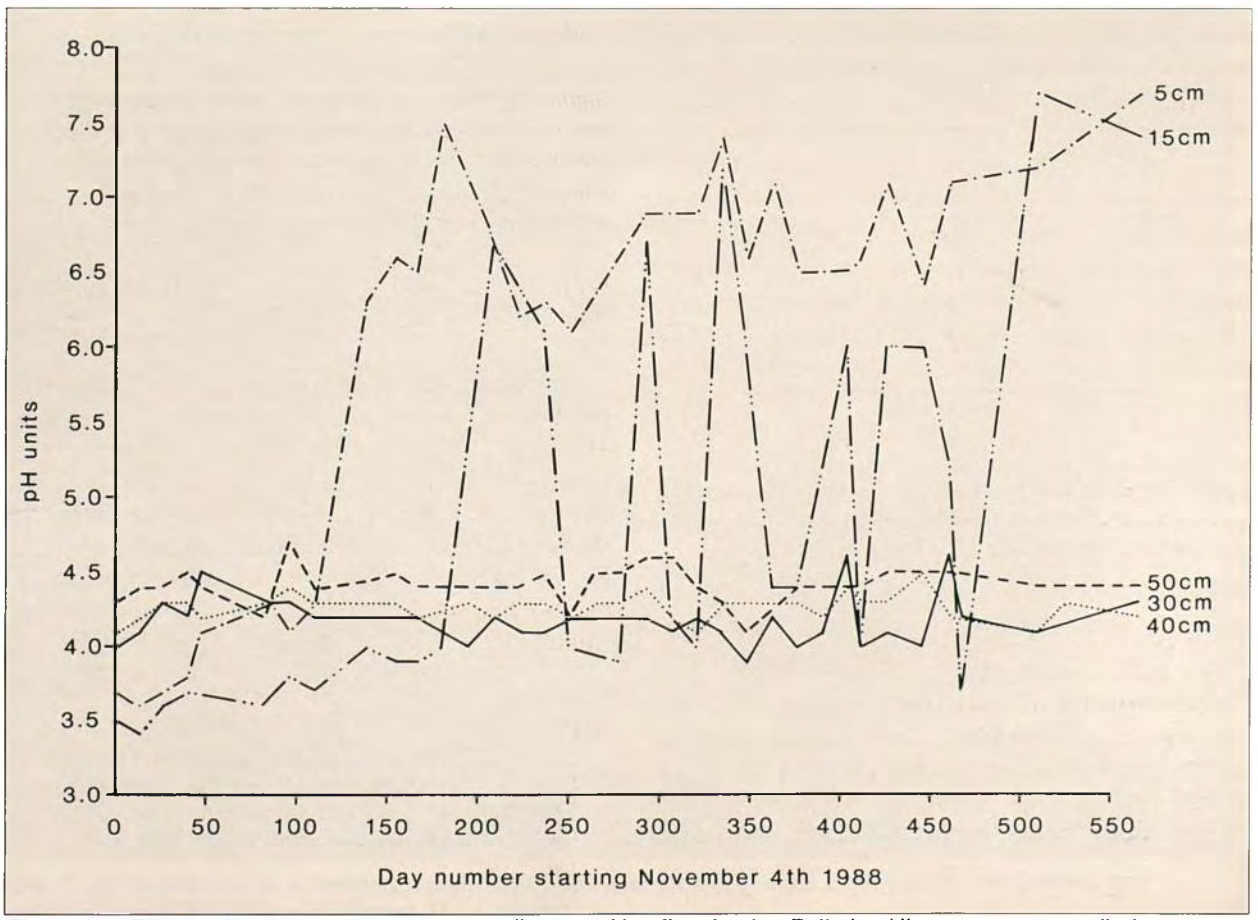

Figure 14. Effects of pelletised limestone on soil water pH at five depths. Pelletised limestone was applied to target source areas of a sub-catchment in the Llyn Brianne study area in November 1988.

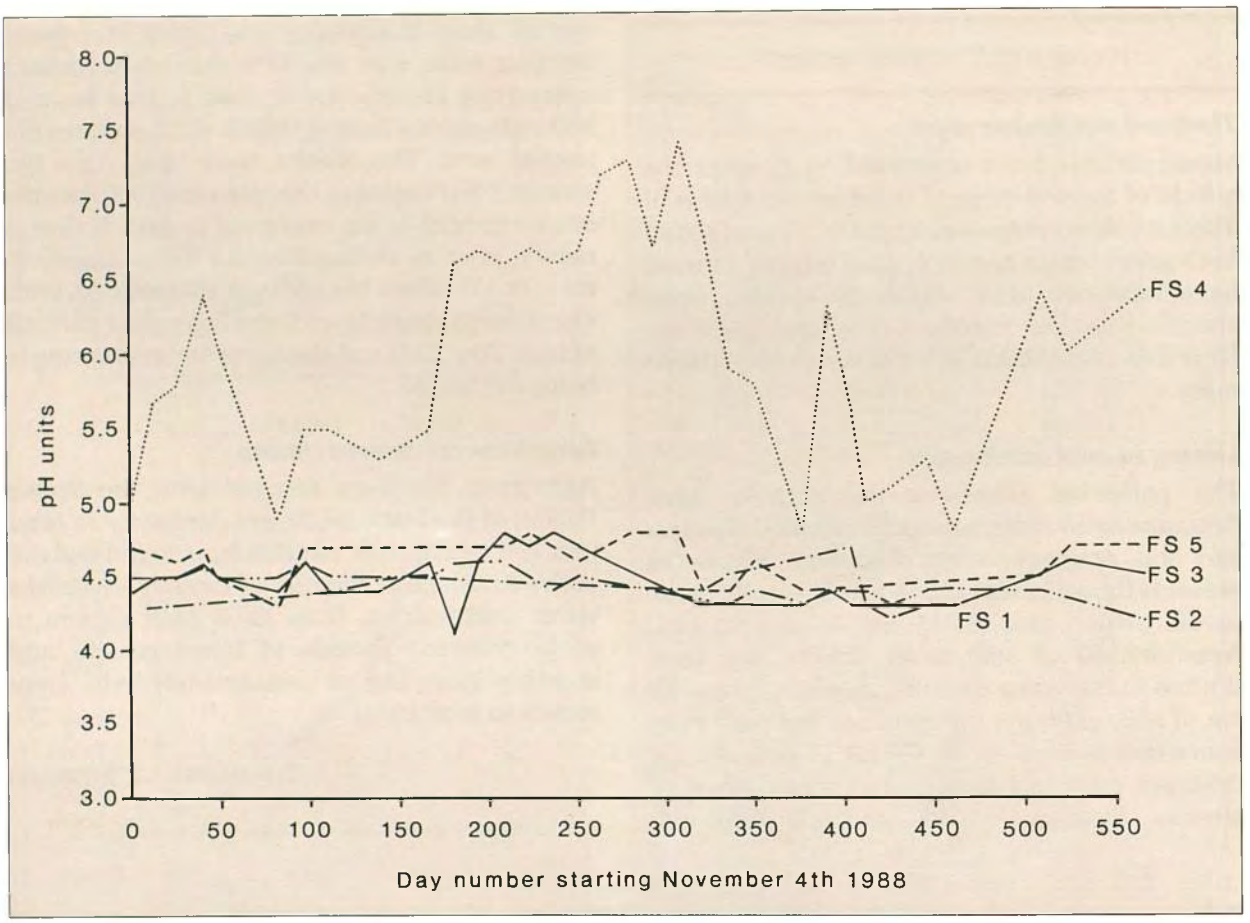

Figure 15. Effects of pelletised limestone on the pH of the four forest streams draining treated source areas (FS1 to 4) and for one stream above the limed source areas (FS5).

ADVISORY

With environmental issues receiving attention from the public and media, and with land use and pollution abatement policy under ongoing review, advice and liaison has continued to be required across the range of Site Studies (South) projects. Important forums are the Department of the Environment's Critical Loads Advisory Group and Terrestrial Effects Review Group, EC and IUFRO working groups, NERC committees and various project or programme management groups such as the research planning group on impacts of upland forestry on water quality (Forestry Commission, Scottish Office Environment Department, Water Research Centre and National Rivers Authority).

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

INSTRUMENTATION

A wide variety of jobs were completed during the year, including the design and construction of new glasshouse propagation benches, a root viewing chamber, several specialised sampling tools, an air purifier for a growth chamber gas exchange system and a photocell arrangement for counting bats. The demand for engraving work has continued, as has the requirement for installing new cables and data lines to VDUs and the electronic mail system.

T. R. NISBET

Plate 6 An experiment established at West Burton Power Station to investigate the establishment of white poplar on a gypsum mound; trees planted in M4 plots only. (I. Collier).

Plate 7 An experiment to investigate the establishment and growth of eight broadleaved tree species on a modern domestic landfill site at Calvert. (A. J. Moffat).

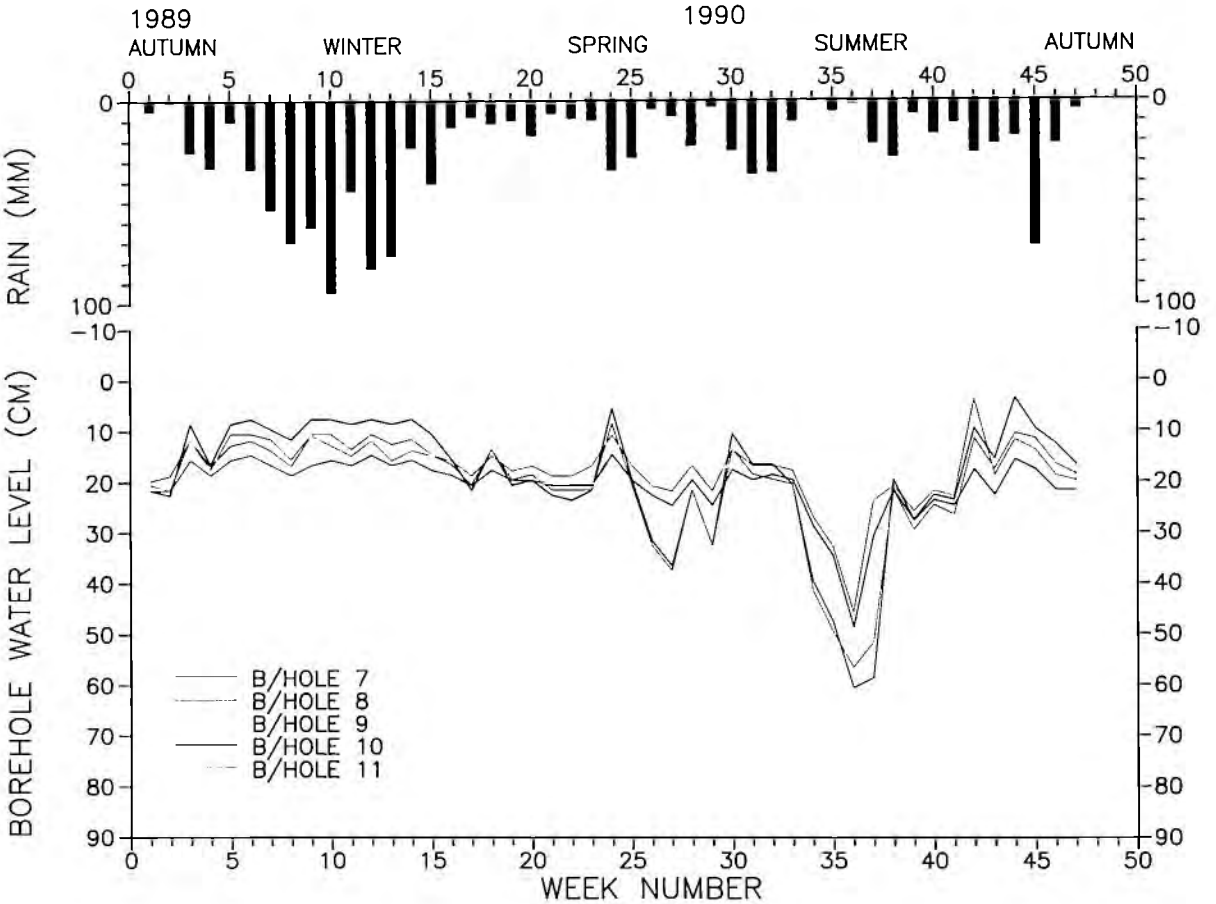

Plate 8 Kielder manual 'borehole water levels', November 1989 to October 1990. Boreholes between 20 m drain lines in upper Z; before ditching.

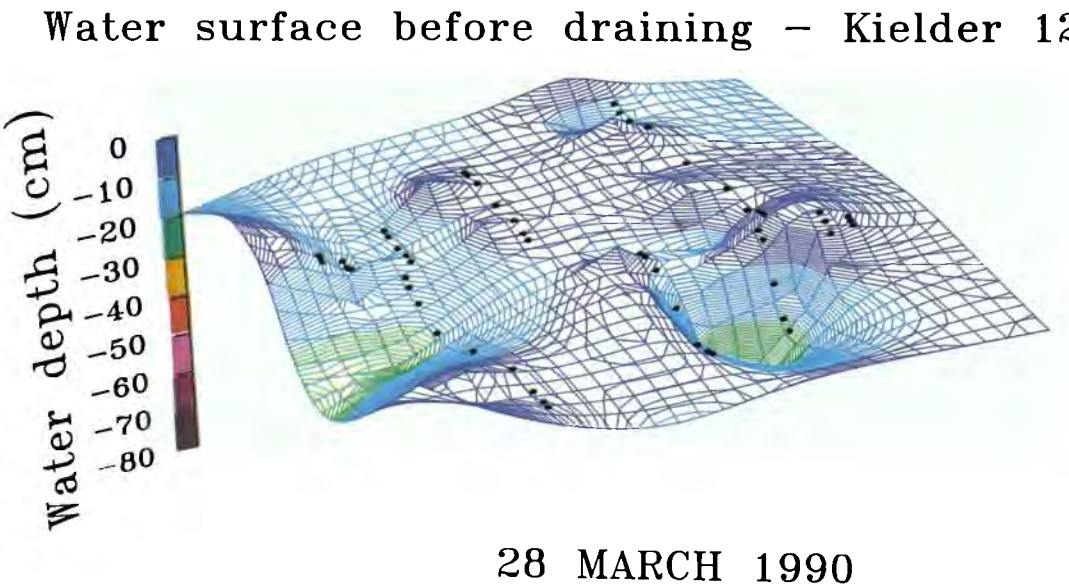

Plate 9 The 'borehole water level' surface across the 'Z' drainage demonstration during a wet period.

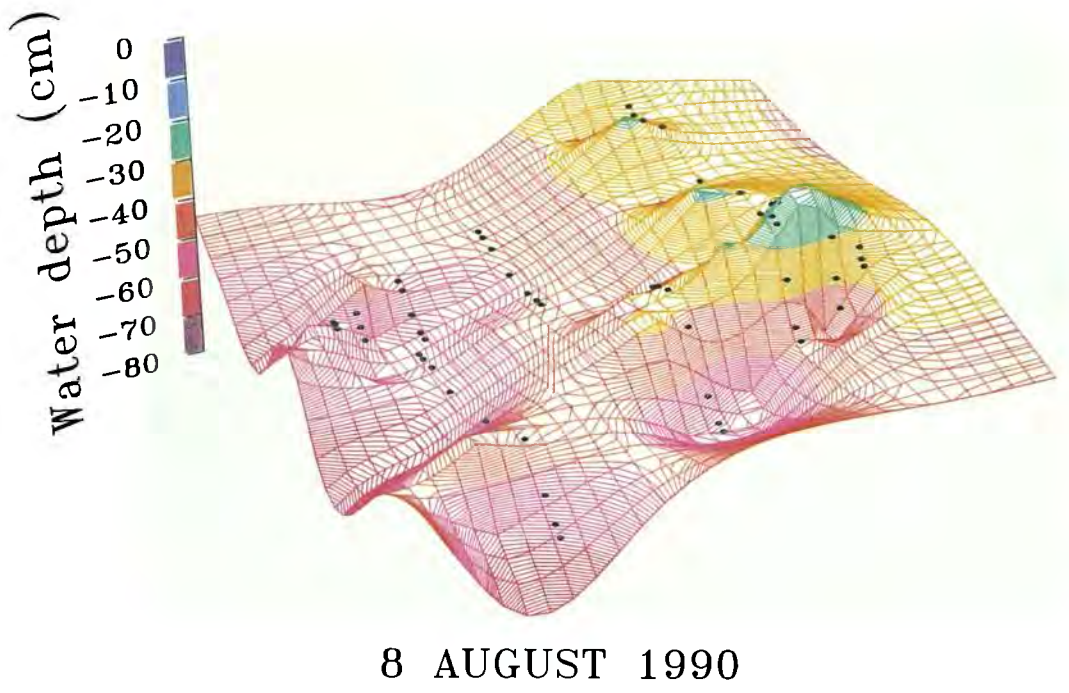

Plate 10 The 'borehole water level' surface across the 'Z' drainage demonstration during a dry period.

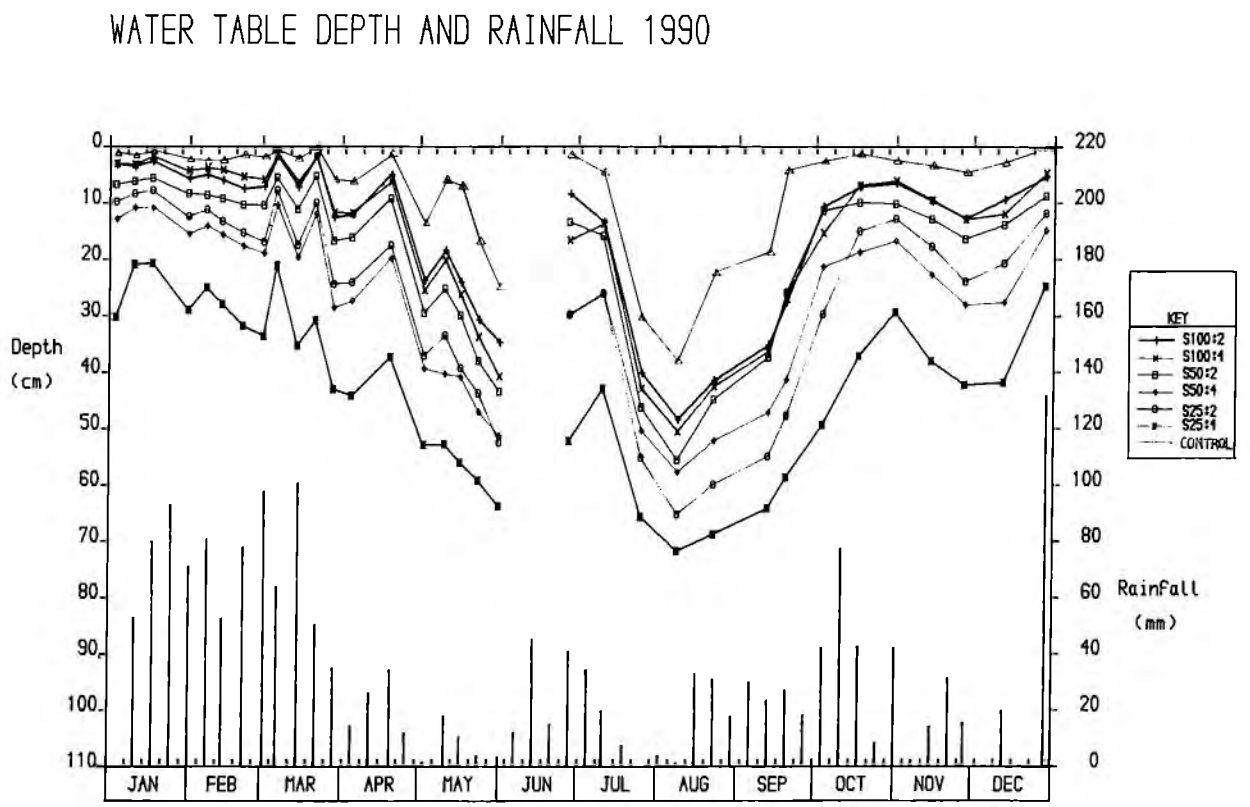

Plate 11 Weekly water table depth and rainfall for different drainage intensities at the Achray deep peat experiment.

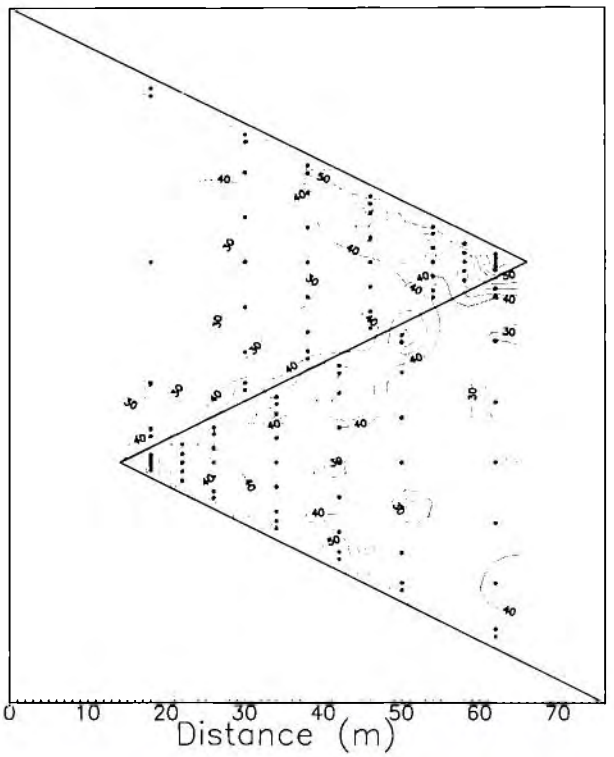

Plate 12 Water table depth (cm) in the 'Z' drainage experiment at Angus; mean of seven weekly readings. The black line represents the position of the ditch, the width of which is not shown.

Plate 13 Demonstration of a good silver birch family from Finland growing at Newton, 11 years old.

SITE STUDIES (NORTH)

CLAY SOILS

The analysis of *before drainage* weekly borehole water levels and rainfall for 50 weeks from the 'Z' drainage demonstration (see *Report* 1989, p.32 and *Report* 1990, p.32) at Kielder Forest shows a soil water regime typical of peaty gleys on the Carboniferous lithology. Plate 8 shows that water levels in the five boreholes along the 20 m long transect between drain lines in the upper part of the 'Z' were shallow, between 10–25 cm, for most of the period. The water levels deepened briefly in the spring and again during 4 weeks in mid-summer of 1990. Plates 9 and 10 show the spatial distribution of water levels as a surface plotted in perspective view for a typical week (Plate 9) and for a dry week in mid- summer (Plate 10). Note that wetter 'humps' and drier 'hollows' feature in both Plates 9 and 10 and occur in approximately the same positions.

A further 68 boreholes, to be read manually each week, were installed in December 1990, bringing the total to 61 in each half of the 'Z' and ensuring a more even coverage of the experiment.

D. RAY

DEEP PEATS

At the drainage experiment established in 1965 on the lowland raised bog at Flanders Moss, Achray Forest, Central Region water-table depth has been measured weekly for 18 months. The 35-year-old lodgepole pine crop is now about 12 m tall. The drainage treatments comprise ditch spacings of 7.5, 15 and 30 m combined factorially with depths of 0.6 and 1.2 m. There is also an undrained unplanted control. Both spacing and depth of ditches influence the depth of the water-table (Plate 11). We suspect that this responsiveness may characterise that minority of bogs which have fairly fibrous or undecomposed peat.

At the new experiment on peat in Caithness (Rumster 17, P89) (*Report* 1990, p.34) phosphorus and potassium fertilisers were applied by hand in June 1989, but no evidence of losses of these fertilisers to runoff was detected until 9 months later.

It is of concern whether plantations exert appreciable drying effects on adjoining unplanted bogs which may have high conservation value and where even a small permanent lowering of the water-table could have harmful effects on sensitive species. Measurements along a number of transects spanning the edge of plantations and extending at least 100 m into unplanted bogs in north England and at Rumster show small effects which are restricted to a few metres from the trees. Although the water content of the upper layers of the peat may be reduced, the consequent subsidence, of a few centimetres, keeps the water-table close to the surface. Such studies have been confined so far to 20-year-old plantations, but we are currently looking at the effects of 60-year-old drainage.

D. G. PYATT

LOAMY GLEYS

Further manual readings of water-table depth have been made in the Angus drainage experiment (*Report* 1988, p.32; 1989, p.33, 1990, p.35) and the results are shown in map form in Plate 12. These again give the impression that the drainage effect is restricted to the zone close to the ditch. The relationship between depth to water-table and distance to ditch indicates that ditch spacings of 33, 16 and 6.5 m would give lowerings of 5, 10 and 15 cm respectively compared with the undrained (but furrow-ploughed) condition. A second 'Z' drainage experiment is being laid down in Argyll.

A. R. ANDERSON

TREE IMPROVEMENT BRANCH

GENERAL

Over the past 2 years the research effort on tree improvement on broadleaves has increased significantly and it now constitutes more than 25% of the tree improvement programme. There is also increased pressure to work on broadleaves for upland areas; a review of tree breeding of birch in Britain is being carried out (Plate 13). Most effort is still focused on Sitka spruce and significant progress continues to be made. In October a meeting on 'Super Sitka for the 90s' held in Elgin allowed the tree breeding programme to be discussed in detail. The papers presented are being published as Forestry Commission Bulletin 103.

The importance of having methods to identify or fingerprint the origin or pedigree of material in tree improvement programmes is being increasingly recognised. Over the past 2 years biochemical equipment has been updated (gas chromatograph) and new equipment purchased (gel electrophoresis) to increase our research effort in this area.

D. A. ROOK

FOREST PROGENY TESTS

Genetic testing of Washington origin Sitka spruce candidate trees continued with a further 75 open-pollinated families planted over four sites across the western part of Britain. Improved seed of Queen Charlotte Islands (QCI) origin (and also unimproved Oregon on the two Welsh sites) will allow comparisons of survival and growth rate across different origins. Other progeny and clonal tests established this year included the testing of 56 QCI full-sib families, 55 Sitka spruce polycrossed families, 60 QCI clones and 47 hybrid larch families.

A major review of juvenile/mature correlations involving open-pollinated QCI and Scots pine clones revealed that culling of families in the bottom 25 to 33% respectively, based on 2-year nursery height, would have resulted in no decreased genetic gain for 15-year diameter at breast height. The possibility of early testing on farm field sites will now be the subject of further investigation.

Studies by the Building Research Establishment have confirmed that the strength of Sitka spruce as measured by machine stress grading is at least equally dependent on knot-size and distribution as wood density. Preliminary investigations indicate that if knot surface area is decreased by 10%, wood density can also decrease by 10% before there is an increase in machine stress grading rejection rate. This result has important implications on the Sitka spruce breeding programme where strong negative correlations between growth rate and wood density have already been established.

S. J. LEE

BROADLEAVES FOR FARM FORESTRY

As part of a joint Ministry of Agriculture/Forestry Commission contract on the genetic improvement of broadleaves for farm forestry, softwood cuttings were collected from a total of 73 selected trees of ash, sycamore and sweet chestnut. Cuttings from mature trees of ash were extremely difficult to root (mean 1%); sycamore cuttings from older trees rooted more easily (mean 20%) and showed differences in rooting ability (range 2 to 39%) between trees. Twelve ash, 39 sycamore and 15 sweet chestnut clones are now in cultivation at Alice Holt. Bud grafting of ash and sycamore in the open nursery during August 1990 gave success rates of 45% for ash and 23% for sycamore. Seed was collected from seven sycamore and seven sweet chestnut stands throughout England and Wales. Sycamore seed

was also obtained from stands in Denmark, France and Germany making a total of 11 provenances for this species. Plants will be put out into field trials in the spring of 1992.

C. M. CAHALAN, M. R. PLOWMAN

BIOCHEMICAL VARIATION

Genotype characterisation

In connection with the new native pinewood grant scheme, biochemical analyses of further populations of native Scots pine have been carried out. The results have caused modifications to some important boundaries. In association with the Nature Conservancy Council, the study of an outlying woodland in Wester Ross has led to a northward extension of the north-west Exclusion Zone. Glenorchy in the south-west consists of two major stands; the north woodland was found to belong to the south-west Exclusion Zone, while the south population was genotypically similar to populations of the Central region.

The initial stages in the identification of family and clonal markers in Sitka spruce have included an intensive study of the sources of within-tree variation of foliar and stem cortical terpenes, using several different genotypes. In all cases, the effects of aspect and sampling height were insignificant, while terpene composition was highly dependent on tissue age. This work will be extended to include isoenzyme variation.

Screening for pest resistance

Controlled defoliation of individual shoots of thicket stage lodgepole pine with *Panolis flammea* larvae has provided no evidence of induced effects on terpene composition of either needles or stem resin in the defoliated shoots over a period of a year following defoliation. This is in contrast to the induced modifications of terpene composition previously detected in very young plants.

Early results on possible resistance mechanisms to *Elatobium abietinum* in Sitka spruce (*Report* 1990, p.39) indicate that defoliation intensity is correlated with the levels of certain terpenes and also with the extent of development of the leaf resin canals, so that total resin quantity may be at least as important as resin composition.

G. I. FORREST

IMPROVEMENT OF OAK: LAMMAS FLUSHING

Most studies of lammas flushing have investigated the physiological and environmental factors that control bud activity and little attention has been given to its effects on crown growth and form. Studies have been made of the incidence of lammas shoot production in sessile oak over an 8-year period and how the pattern of branch production varied between shoots formed during spring and lammas growth.

Leading shoots produced a lammas flush more regularly than the major crown branches, but there was great variation between years; in 1987 all shoots observed produced a lammas flush whereas in 1989 < 10% of shoots flushed twice. There were significant differences between trees in the tendency to form a lammas shoot and half of the individual flushes of growth on the branches of some trees were produced as lammas shoots. Shoots produced as lammas growth were usually longer than those formed by spring growth. The number of lateral branches produced was related to shoot length and there were some differences in the branch v. length relationships for shoots produced during different flushes of growth. Lammas shoots tended to have fewer viable terminal buds than shoots formed during the spring flush. These early results suggest that lammas flushing is more likely to influence tree form by causing loss of leader than by intrinsic differences in lateral branch production on shoots formed during different flushes of growth.

R. HARMER, C. A. BAKER

FLOWERING

A study of naturally occurring gibberellins (GAs) in Sitka spruce grafts was carried out jointly with Drs Oden and Moritz of the Swedish University of Agricultural Sciences at Umea. The results indicated that there are different quantities of GAs in the differentiating shoots of heavy compared to light flowering clones and different quantities in conditions inductive compared with non-inductive for flowering. This may result from differences in GA metabolism; for example, a block in the breakdown of GA_4 to GA_1 may result in an increased availability of the physiologically active GA_4 in flowering grafts.

Cone-bud differentiation in Sitka spruce grafts treated with $GA_{4/7}$ in a polythene house has been studied in collaboration with Dr J. N. Owens,

Table 8. Flowering and seed production of 7-year-old Sitka spruce clones at the Ledmore seed orchard

Clone	*Number of ramets planted*	*Ramets/clone producing flowers*	*Total number of cones*	*Average number cones/ramet*	*Average number seed/cone**	*Total weight of seed/clone (g)*
61	20	20	1689	84	45	266
69	25	25	2234	89	41	210
94	39	39	3515	90	56	723
120	39	33	2372	61	92	855
140	30	27	2097	70	46	648
141	49	46	6153	126	104	1455
161	39	38	6651	171	143	1519
251	49	36	2786	57	41	435
320	40	35	4200	105	100	1280
323	34	32	2153	63	79	268
333	20	18	1408	70	52	194
397	20	21	1356	52	51	384
424	29	29	3269	113	65	675
425	39	37	3203	82	55	498
427	34	28	951	28	112	399
492	39	35	2621	67	76	611
493	39	36	4934	127	74	524
563	29	28	3000	103	100	644
686	29	29	2391	82	41	308
689	39	36	4194	108	142	840
690	29	28	3740	129	115	894
727	49	47	5327	109	39	448
769	49	42	4924	100	121	1080
980	34	28	1540	45	101	468
1041	39	36	3543	91	41	400
1102	49	47	6101	125	122	1680
1219	40	31	2397	60	80	435
1250	25	13	397	16	55	56
1257	39	37	4788	123	74	971
1259	40	39	6740	169	77	1425
1350	34	33	6052	178	61	965
1370	29	29	4282	148	117	1480
1492	39	35	5403	139	31	656
1500	34	34	3239	95	133	980
1551	34	32	4404	130	38	658
1583	39	35	3066	79	134	1115
1595	29	28	3195	110	85	720
1615	20	19	2560	128	107	564
1713	39	31	2038	52	115	625
1716	34	30	3672	108	61	654
2000	29	29	4848	167	81	931

*Based on a sample of 100 cones.

University of Victoria, Canada. Treatments over a 3-month period increased flowering. Treatments preceding and during the natural period of differentiation were most successful and appeared to promote more buds to develop in a uniform and vigorous manner to the stage where cone differentiation occurs. Later treatments only affected those apices which had not yet begun development.

Experiments on cone induction in container-grown European and Japanese larches indicate that $GA_{4/7}$ application may not be effective in enhancing coning in these species as they are for other members of the Pinaceae. Vegetative shoots in larch extend for 3 to 4 months. The exact timing of differentiation is not known so another alternative is that the treatments are not being applied at an appropriate physiological stage.

J. J. PHILIPSON, M. A. O'DONNELL

POLLINATIONS AND SEED PRODUCTION

Flowering in most tree species including Sitka spruce (Plate 14), European and Japanese larch and Scots pine was the heaviest for a number of years and advantage was taken to extend the pollination programmes for these species. In Sitka spruce all the remaining untested clones were pollinated with a pollen mix from selected superior trees. The trees had been injected with the gibberellins, $GA_{4/7}$, the previous year. The technique of gibberellin injection is proving very successful in increasing flower numbers in Sitka spruce and will be applied on a regular basis in seed orchards starting in June 1991.

The first good flowering occurred in the Sitka spruce seed orchard number 13 at Ledmore, Perthshire (established 1984/85) and this permitted collections to be made by individual ramets and clones. All 41 clones flowered with 93% of all the clones producing some female flowers. There was considerable variation in the number of cones produced by each clone, number of seeds per cone and total number of seed produced (Table 8). A total of 28.4 kg of seed was produced by the 5 ha orchard giving a yield of 5.68 kg ha^{-1}. This is a very high yield for such a young orchard and indicates that yields of 10 kg ha^{-1} should be achievable when the orchard is in full production between 15 and 30 years of age. At present the production per clone is unbalanced with clone 1250 contributing only 0.2% and 8 clones contributing 39% of the total.

In addition to the programme with pollen mixes, a large number of specific crosses were made to provide material in which second generation selections can be made. A number of crosses were made in seed orchard number 13 to create a new 'bulked family mixture' with a higher genetic gain than those currently available. The intention is to identify a sufficient number of outstanding crosses which could be recreated for 'bulked family mixtures' to be used in the vegetative propagation programme.

Larch flowering was also heavy in both seed orchards and clone banks and the programme of single pair matings to identify good crosses for use in the commercial vegetative propagation programme was continued. Over 30 000 female flowers were isolated but losses due to wind damage and/or low temperatures were nearly 60%. The extent of these losses which occur most years has emphasised the need to develop alternative sites for seed orchards. Trials have commenced with container-based orchards in polythene houses.

A. M. FLETCHER

BIOTECHNOLOGY

Micropropagation of Sitka spruce

Adventitious bud formation after induced vitrification has been shown to be an efficient method for multiplication *in vitro* (Plate 15). However, the micro-shoots must be reverted to normal growth before they can be removed from the culture tubes and rooted. Some micro-shoots revert to normal growth spontaneously, but attempts to induce reversion in recalcitrant micro-shoots by environmental manipulation or by the inclusion of paclobutrazol or activated charcoal in the growing medium have met with little success. Rooting in non-sterile compost in small, sealed plastic containers has proved to be the best system but the level of rooting can vary from 70% for the better clones to 25% for the poorer. Weaning of the rooted micro-shoots has also proved to be difficult.

Rejuvenation of Sitka spruce and hybrid larch

A variety of lines of research have been undertaken in an attempt to rejuvenate Sitka spruce and hybrid larch *in vitro*. Callus has been initiated from roots and needles and subjected to serial subculture on hormone containing medium. Morphogenesis is being attempted at each subculture on hormone free medium. Vegetative buds have been isolated from adolescent, field

grown Sitka spruce trees and rejuvenation is being attempted by environmental manipulation during growth and development. Adventitious buds have been induced on female floral explants of Sitka spruce and attempts are being made to elongate them after excision.

A. JOHN

PHYSIOLOGY

MYCORRHIZAS

Measurement of field plots of both Sitka spruce and Douglas fir continued. Growth responses, evident in previous years, had disappeared in the Sitka spruce plots at Shin. Fruiting body surveys showed that the *Laccaria proxima* had survived in plots in which it was used, and had spread patchily into other plots. For the first time, fruiting bodies of *Thelephora terrestris* were found in large numbers in one of the experiments (the oldest one at Shin). The evidence accumulated over the series of experiments since 1974 is that inoculation of Sitka spruce in British upland forests has not yielded significant, lasting growth improvement. Non-mycorrhizal control plants quickly become mycorrhizal after outplanting.

The results with Douglas fir mycorrhizal trials are much more promising (Figures 16 and 17). Experiments with *Rhizopogon vinicolor* had already shown that it was possible to inoculate nursery seedbeds at Wykeham, and to produce positive growth responses in the forest. A new experiment was established in Wykeham to test the repeatability of this, and to try another fungal species, *R. villosulus*. A demonstration plot was also established, in which a mixture of the two fungi was watered on to rising 2-year-old undercut seedlings. This resulted in the establishment

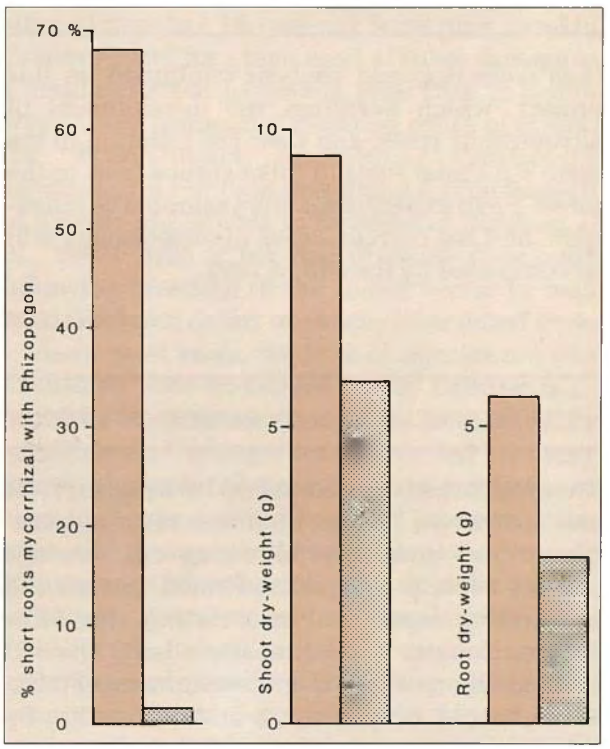

Figure 16. Rhizopogon *mycorrhizal (clear columns) v. naturally mycorrhizal (stippled columns) 1 u 1 Douglas fir seedlings. Mycorrhiza proportion and dry weights.*

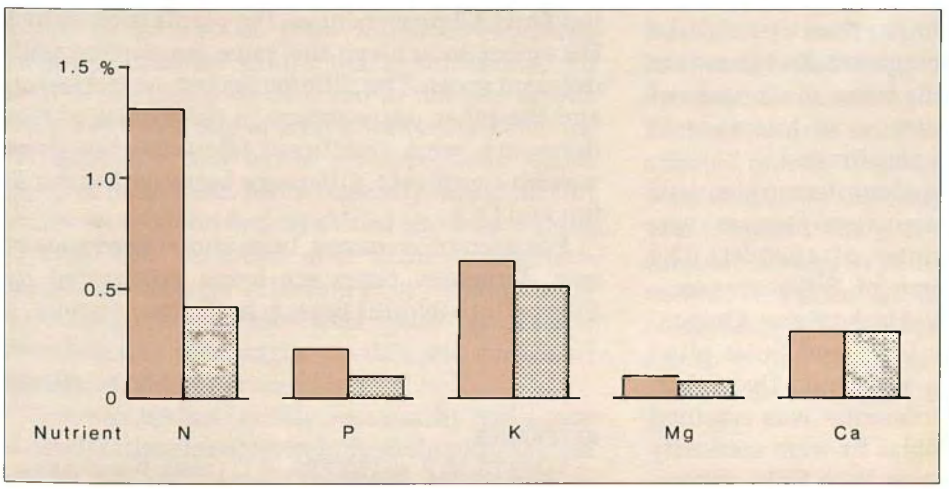

Figure 17. Rhizopogon *mycorrhizal (clear columns) v. naturally mycorrhizal (stippled columns) 1 u 1 Douglas fir seedlings. Foliar nutrient concentrations.*

of mycorrhizas and the production of fruiting bodies. Trees without the *Rhizopogon* mycorrhizas were yellowed, demonstrating nutrient deficiency, and were approximately only half the size of trees with them. Larger scale experiments will be established in Wykeham and Delamere nurseries to test the general application of *Rhizopogon* spores to Douglas fir undercuts.

C. WALKER

ADVENTITIOUS ROOT GROWTH IN SITKA SPRUCE

Data collection and analysis continued on this project, which examines the development of adventitious roots, and their contribution to the main structural roots of Sitka spruce trees in the forest. Field experiments were sampled as scheduled, and the current series of experiments will be completed by the end of 1992.

C. WALKER

PHYSIOLOGICAL QUALITY OF NURSERY STOCK

The close negative relationship between survival and electrolyte leakage from fine roots of transplants and undercuts following cold storage (*Report* 1990, p.43) was confirmed in a second outplanting experiment on a restock site. Sitka spruce, Douglas fir and Japanese larch showed marked differences in their development of tolerance to cold storage for 1 and 3 months. By mid-December, cold storage of Sitka spruce roots for 3 months caused no deterioration in the root system. This level of tolerance was maintained until April. The 'safe period' for Japanese larch, during which it could tolerate 3 months' cold storage, was earlier and shorter than that of Sitka spruce. Three months' storage resulted in severe deterioration of Douglas fir roots at all times of the winter. For this species, even tolerance to storage for a single month was limited.

The tolerance of a range of conifers to standard rough handling and desiccation stresses was followed through the winter of 1990/91. The species (three provenances of Sitka spruce – Queen Charlotte Islands, Alaskan and Oregon, and Douglas fir, Japanese larch and Scots pine) increased their tolerance until mid-December. Generally this level of tolerance was retained until March. Roots of Douglas fir were markedly more sensitive to desiccation than Sitka spruce, Japanese larch or Scots pine.

Root frost hardiness in these species was tested throughout the winter of 1990/91 by cooling roots in a programmable freezing cabinet. The species fell into two distinct groups. Douglas fir and Scots pine were tolerant to only –5°C from December until March, whereas the others could tolerate much lower temperatures. Mid-winter levels of root frost hardiness were greater the more northerly the provenance of Sitka spruce. The temperature causing 50% damage to fine roots (tested in late January) were –11°C for Japanese larch and Oregon Sitka spruce, –13°C for Queen Charlotte Islands Sitka spruce, and –15°C for Alaskan Sitka spruce.

H. M. McKAY

ROOT GROWTH AND FORM

Timing of root dormancy in Sitka spruce provenances

In a previous study of the waterlogging tolerance of three clones of Queen Charlotte Islands (QCI) Sitka spruce, differences between clones were small but it was found that roots were most tolerant to flooding when they were dormant (Coutts and Nicoll, 1990). This work has been extended to cover a larger number of genotypes, using 32 seedlings of each of three provenances (Alaska, QCI and Washington). The plants were grown as before in 2 m long perspex tubes of peat in insulated boxes out of doors, and extension of the main roots was measured periodically.

Root extension rate reached a maximum of 5–6 mm a day in all three provenances in July/August, then declined to a rate of 1–1.5 mm a day by the beginning of November. Ninety per cent of Alaskan provenance plants had dormant root systems by 17 November, while in the Washington and QCI provenances, the plants took until 1 December to achieve the same proportion with dormant roots. The differences between Alaskan and the other provenances in the timing of root dormancy were significant ($P< 0.05$) but there was no significant difference between Washington and QCI.

For each provenance, trees showing a range of root dormancy times are being propagated by Silviculture (North) Branch for further testing.

M. P. COUTTS

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PATHOLOGY

At the beginning of the year a change, outlined below, was made in the disease diagnostic service at Alice Holt. In addition, progress was made in the establishment of the new project on poplar diseases. There is an inter-branch report on page 40 dealing with the development of expert systems for fungus identification.

DIAGNOSTIC AND ADVISORY SERVICES

Scotland and northern England

The most frequently recorded diseases during the year were those caused by *Heterobasidion annosum* and *Armillaria* species. The former was primarily responsible for butt rot in older conifers whereas the latter were chiefly found as causes of root killing and tree mortality in young plantations. However, there was one case of appreciable loss due to *Armillaria* in a 40-year-old Sitka spruce crop. Two unusual outbreaks of another root pathogen, *Rhizina undulata*, were investigated in pole-stage Sitka spruce crops. It is generally accepted that this fungus requires high soil temperatures, such as occur under bonfires, to become an active pathogen (Jalaluddin, 1967). Accordingly, the sites of old fires can nearly always be found (as charcoal deposits) somewhere in groups of trees killed by *Rhizina*. However, despite protracted examination, no trace of fire could be detected in the two stands visited in 1990, one of which was remarkable for the large size (0.5 ha) of an apparently single group of dead trees. More typically, *Rhizina* fruit bodies were identified on a third site where slash burning had occurred after clear felling. Although too early for infection to be evident in the restocking, the obvious and quite remarkable abundance of the fungus on this site suggested that losses could become high.

Less serious but equally noteworthy was a case of needle discoloration in lodgepole pine caused by the fungus *Lophodermium seditiosum*, a pathogen usually associated with Scots pine. There were two unusual cases involving another common disease of pines, the canker fungus *Crumenulopsis sororia*. This normally minor pathogen was responsible for significant main stem damage to a 26-year-old Scots pine stand in Grampian and for a high level of shoot damage in a similarly sized lodgepole pine crop in Galloway. A less commonly recorded cause of injury, the fungus/insect association *Ceratocystis laricicola/Ips cembrae*, was found killing the tops of 57-year-old larches in Sutherland (Redfern *et al.*, 1987). This attack had probably developed following breeding of the insect vector (a bark beetle) in larch debris on nearby clear felled sites.

As in most years, the bulk of injuries not due to disease were accounted for by cultural malpractices or extremes of climate. Unsatisfactory handling and storage procedures led to many losses of newly planted trees and misuse of chemicals was a major cause of injury in nurseries and young plantations. In older Norway spruce crops, the physiological disorder known as 'top-dying' maintained its prevalence (*Report* 1990, p.47). Indeed, nearly all occurrences of browning and mortality of Norway spruce that were investigated during the year proved to be attributable to it.

Among the many occurrences of frost injury, three were unusual. Lesions on the lower stems of young (5-year-old) *Abies amabilis* and *A. nobilis* were found at two locations in southern Scotland. In both cases the injuries appeared to have originated early in 1989 although major symptoms, including death of tops, did not become evident until much later in most of the affected plants. The damage was thought to have been caused by the early spring frosts, noted last year (*Report* 1990, p.47) as the probable cause of cambial damage in young Sitka spruce. The third notable instance of frost injury occurred in Morayshire where severe shoot and foliage damage to young Corsican pine, noticed in spring 1990, was attributed to frost in the previous autumn.

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

REFERENCES

JALALUDDIN, M. (1967). Studies on *Rhizina undulata* I. Mycelial growth and ascospore germination. *Transactions of the British Mycological Society* **50**, 449-459.

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

Wales and southern England

This year saw a major change in the operation of the service at Alice Holt. In order to release staff time for other projects, a decision was taken to exclude all enquiries relating to privately-owned amenity trees; these amounting to around 60% of the total. Enquiries relating to publicly-owned amenity trees, as well as from forestry sources, are still dealt with, but inevitably a substantial reduction in the acquisition of information on new problems on ornamental trees will occur. The ability to monitor changes in the occurrence of recognised problems will also be reduced.

The very mild winter of 1989/90 led to the early flushing of trees and shrubs. In consequence they were all too vulnerable to the sharp frosts of April 1990. Screen temperatures below –4°C occurred quite widely with –6.4°C being recorded at Elmdon in the West Midlands on 9 April. The foliage of oak, ash and beech was conspicuously damaged at some locations, the most dramatic example reported to us involving the almost complete browning of some 20 m tall roadside beech trees at Kings Forest, Suffolk. In this area, however, the picture was somewhat complicated by additional frosts in late May: for example, –2.5°C was recorded at Santon Downham on 26 May. Refoliation occurred in all instances by mid summer. Damage associated with the hot dry summer of 1990 is covered in the next section.

Bark lesions on young (4-5 m high) ash (*Fraxinus excelsior* and *F. oxycarpa* 'Raywood') from Oxfordshire were examined and the fungus *Phomopsis scobina* was isolated from the margins. This is only our third record of this disease and the first on *F. oxycarpa* (*Report* 1987, p.44).

Cultures from an area of decay from the base of a large European larch produced the fungus *Meruliopsis taxicola*, our first record of this rare fungus which colonises dead wood and bark. In this case the tree had suffered basal damage from fire.

An area of 28-year-old noble fir in Wales showed severe shoot dieback and numerous shoot and branch cankers. The fungus *Cylindrocarpon cylindroides* was identified from samples collected from the stand. The perfect state of this fungus is now known as *Nectria neomacrospora* (= *N. macrospora*). The fungus is known to cause cankers on balsam fir (*Abies balsamea*) in Canada and on *Abies* spp. in Norway (Ouellette, 1972). Samples of the perithecia of the *Nectria* state have now been collected to confirm the identification. This may well be the first record of this fungus in the British Isles.

Numerous cases of needle browning and scattered deaths of pole-stage Norway spruce were reported, with an increase in the period November 1990 to March 1991. This has been attributed to the physiological disorder 'top-dying' and echoes the situation in Scotland and northern England.

R. G. STROUTS, D. R. ROSE, S. E. BROWN

REFERENCE

OUELLETTE, G.B. (1972). *Nectria macrospora* (Wr.) Ouellette sp. nov. (= *N. fuckeliana* var. *macrospora*): strains, physiology and pathogenicity, and comparison with *N. fuckeliana* var. *fuckeliana*. *European Journal of Forest Pathology* **2**, 172-181.

TREE DAMAGE AND THE HOT DRY SUMMER OF 1990

Not surprisingly, given the heavy winter rainfall and the cool weather of June, there was little evidence of drought-related foliage symptoms until the onset of the very hot weather in late July and early August. When symptoms did appear they were largely restricted to central and southern England. Thus, the foliage yellowing of larch that was recorded in Scotland in 1989 did not recur there in 1990.

Birch with its shallow root system showed widespread foliage symptoms: subsequent dieback and death was not uncommon. As a legacy of the 1989 summer, beech quite frequently began the season with abnormally small leaves and heavy mast (see for example Innes, 1992). Then, in August, many trees showed severe foliage browning, most notably at the periphery of the crown. These brown leaves soon fell, so that by early September the trees only had a thin sprinkling of green leaves on the older parts of the twigs. Although shoot growth in 1991 will be extremely poor (Lonsdale *et al.*, 1989), it seems unlikely that the occurrence of dieback will compare with that experienced after 1976 (Lonsdale, 1980).

Foliage symptoms were also very common on cherry, hawthorn, rowan, sweet chestnut, field

maple and sycamore. In this last species, severe local outbreaks of sooty bark disease caused by *Cryptostroma corticale* were recorded at several sites in the London area and in Bedfordshire, Berkshire and Suffolk. These records reinforce the evidence for a link between the disease and hot dry summers forged on the basis of its occurrence in the past (Young, 1978) and of experimental studies on drought-stressed saplings (Dickenson and Wheeler, 1981).

In general, oak provided a marked contrast to other species and its dark green leaves provided welcome relief in the bleached landscapes. However, at several sites south of Reading in Berkshire there were further manifestations of the dramatic branch dieback which first occurred in 1989. The trees were growing on seasonally waterlogged or ground water gley soils where the normal deep rooting system may not have been able to develop. A more complete account of the effect of the summer can be found in Gibbs (1991).

J. N. GIBBS

REFERENCES

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LONSDALE, D., HICKMAN, I.T., MOBBS, I.D. and MATTHEWS, R.W. (1989). A quantitative analysis of beech health and pollution across southern Britain. *Naturwissenschaften* **76**, 571-573.

YOUNG, C.W.T. (1978). *Sooty bark disease of sycamore.* Arboricultural Leaflet 3. HMSO, London.

PERIDERMIUM STEM RUST

In 1982, four 0.5 ha plots were set up in the main block of Thetford Forest to monitor the progress of pine stem rust, caused by *Peridermium pini*, in crops of Scots pine planted between 1922 and 1929. The plots have been assessed annually from the ground by a team of observers who examine each tree with binoculars for the presence of *P. pini*, and record the numbers falling into each of the following categories: (a) dead trees; (b) trees with a dead top; (c) trees with one or more stem lesions; (d) trees with branch lesions only. A summary of the results is shown in Table 9. During the period 1982-90, the number of trees with disease visible from the ground almost doubled from 28% to 53%. At the same time there was a six-fold increase in the number of trees killed by the disease; these accounting for 16% of the total by 1990.

From an analysis conducted in 1984/85 on the status of the disease in freshly felled 'pre-war' Scots pine in the same part of the forest, Gibbs *et al.* (1987) predicted that 9% of those that were predominantly healthy at the time of felling would have died or developed 'dead-tops' within 5 years. This is almost exactly the figure that can be derived from the data in Table 9 for the period 1985-90 and strengthens the conclusions of Gibbs *et al.* that although the disease would continue to cause losses, it would not be sufficiently serious to force a change in the policy of retaining some of the old Scots pine in Thetford beyond its normal rotation age.

B. J. W. GREIG

REFERENCE

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

Table 9. Development of Peridermium stem rust on four plots of 'pre-war' Scots pine in Thetford Forest

	Data from ground surveys in:		
	1982	*1985*	*1990*
Number of dead trees	18	49	117
Number of trees with dead tops	54	104	107
Number of trees with branch and stem lesions	144	200	166
Number of trees with no visible disease	554	413	346
Total number of trees	770	766*	736*

* Some trees lost through windthrow, etc.

ARBORICULTURE: DEPARTMENT OF THE ENVIRONMENT CONTRACT

De-icing salt damage to trees and shrubs

Rock salt used for de-icing roads, paths and driveways can cause significant damage to adja-

cent trees and shrubs. An extensive literature review has identified the range of symptoms associated with salt injury, and these include failure of buds to flush, browning of foliage, twig and limb dieback and in certain cases the death of entire trees (Dobson, 1991a). Injury is associated with elevated levels of foliar chloride and, with susceptible species, tends to occur when concentrations exceed about 0.5% of the dry weight. Analysis of information in the literature has enabled certain species to be classified as either tolerant or sensitive to salt (Table 10). It seems likely that significant reductions in salt usage (of the order of 50%) could be achieved through improved storage and spreading practices. The most promising alternative chemical to salt is calcium magnesium acetate (CMA), which is considerably less damaging to trees. Techniques which have potential for ameliorating the effects of salt on vegetation include irrigation, fertilisation (low N, high P and K) and addition of gypsum to the soil. A full report of the work described can be found in Dobson (1991b).

M. C. DOBSON, J. N. GIBBS

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POPLAR DISEASES

Disease resistance in poplars is of considerable importance because the clonal nature of a cultivar can make it uniformly susceptible to severe damage. The most serious disease of poplars in much of western Europe is bacterial canker, caused by *Xanthomonas populi*, which can render the affected timber almost valueless. Promising Belgian clones which are being widely used in UK trials have been already screened for resistance to this disease, but there is some evidence that the strains of the bacterium used in the Belgian trials may be less aggressive than those occurring in Britain and as a precaution, additional screening is being carried out. Among other diseases, Marssonina leaf-spot and Melampsora rust can cause damage to clones with particularly low resistance, and accordingly have been included in the Belgian screening trials. As with bacterial canker, there is some chance of less satisfactory performance under British conditions and so these diseases will also be subject to further UK screening. It is already known that some of the Belgian clones, although having substantial resistance to all the known races of the rust *Melampsora larici-populina*, are susceptible to *M. allii-populina*, a similar fungus which is usually prevalent only in southern Europe but which was found infecting some of these clones in southern Britain in the warm summer of 1991.

Table 10. Tolerance of selected species to de-icing salt

Tolerant	*Moderately tolerant*	*Sensitive*
Caragana arborescens	*Acer saccharum*	*Acer pseudoplatanus*
Elaeagnus angustifolia	*Fraxinus excelsior*	*Carpinus betulus*
Gleditsia triacanthos	*Pinus sylvestris*	*Fagus sylvatica*
Hippophae rhamnoides	*Salix alba* 'Vitellina'	*Picea abies*
Pinus mugo		*Pseudotsuga menziesii*
Pinus nigra var. *maritima*		*Rosa canina*
Populus alba		*Rosa multiflora*
Populus canescens		
Quercus robur		
Robinia pseudoacacia		
Salix fragilis		
Salix viminalis		
Sophora japonica		
Tamarix spp.		

Another potentially serious poplar pathogen is poplar mosaic virus (PMV). Unlike the fungal and bacterial diseases of poplar, viruses can become established in propagation stock; sometimes throughout the stock of a particular clone. All stocks of the Belgian clones held in the Forestry Commission trial grounds will be screened for the presence of PMV, using serological techniques developed by Dr J. I. Cooper at Oxford University.

D. LONSDALE

DUTCH ELM DISEASE

Aggressive subgroup of Ophiostoma ulmi *redesignated* O. novo-ulmi *sp. nov.*

The 'new' aggressive subgroup of the Dutch elm disease fungus responsible for the current pandemic of the disease in the Northern Hemisphere has been formally designated as a new species, *Ophiostoma novo-ulmi* Brasier sp. nov. The 'old' non-aggressive subgroup responsible for the first pandemic of the disease in the 1920s-40s is retained as *Ophiostoma ulmi* Buisman (Nannfeldt). The two species show a wide variety of physiological, morphological, genetical and molecular differences (Brasier, 1991). The EAN and NAN races of *O. novo-ulmi* may be designated as subspecies.

C. M. BRASIER

REFERENCE

BRASIER, C.M. (1991). *Ophiostoma novo-ulmi* sp. nov., causative agent of the current Dutch elm disease pandemics. *Mycopathologia* **115**, 151-161.

Rapid changes in O. novo-ulmi *population structure at current epidemic fronts*

Two fresh epidemic front sites in Spain each represented largely by a single vegetative compatibility type (vc) clone of *O. novo-ulmi* in 1985 (Brasier, 1988) were resampled in 1989 to see whether a predicted change from clonal to predominantly genetically heterogeneous population structure (Brasier, 1988) had occurred. Unfortunately, much of one part of the 'Guadalajara' area site, a valley farm close to Guadalajara, had been destroyed by construction. Samples from diseased suckers (Table 11a) revealed a change towards a more genetically heterogeneous population. The other part, the Casa de Campo park in

Table 11. Changes in the Avila and Guadalajara area populations of *O.novo-ulmi* between 1985 and 1989

		Clonal component			*Heterogeneous component*				
					vc group frequency				
Site	No. of *samples*	*% of sample*	*% A-type*	*% d-infected*	*% of sample*	*No. groups/ No. isolates*	*Ratio isolates/ groups*	*% A-type*	*No. of different w-factors* found*
a. Guadalajara area**									
1989 – Farm site	49	59	0	0	41	11/20	1.8	10	2
1989 – Casa de Campo	99	83	0	1	17	10/17	1.7	29	4
1985 (combined sites)	*39*	*95*	*0*	*49*	*5*	*2/2*	*(1.0)*	*(50)*	*1 (Farm) 2 (C de C)*
b. Avila area									
1989 sample	182	31	48	4.4	69	82/98†	1.2	29	14
1985 sample	*74*	*88*	*40*	*3.0*	*12*	*5/9*	*(1.8)*	*(44)*	*3*

For discussion of 1985 sample results and for methods see Brasier (1988). All samples are twig samples from individual diseased trees.

*Either unique w-alleles or unique combinations of w-alleles due to multiple w-loci.

**Guadalajara farm site now mainly comprises small patches of relict sucker growth, whereas the Casa de Campo site still comprises abundant mature elms sustained by aerial insecticide treatment.

†Based on an estimate from all x all pairings among 23 isolates in three separate sets.

Madrid, had been subject to heavy annual insecticide spraying and vector beetle populations were extremely low. Only a limited genetic change had occurred (Table 11a). The latter may reflect the suppression of the saprotrophic phase of the fungus associated with beetle breeding in diseased elm bark, and a predominance of root graft spread of the disease rather than of transmission by beetle feeding. At both locations d-factor mycovirus levels were low compared with 1985.

The Avila population (La Granja to Penaranda) showed a considerable change in genetic structure (Table 11b). Some 30% of the population comprised a residual vc clone, many isolates of which were morphologically uniform in culture. The other *c.*70% was now genetically highly heterogeneous, most isolates being of a unique vc type and of diverse colony types. Moreover, there were now a minimum of 14 different w-factors present at the site compared with only 3 w-factors found in 1985. The Avila area population has therefore shown the rapid change from a near clonal to a highly heterogeneous population structure predicted from other European epidemic front sites (Brasier, 1988). The underlying cause of this change is unknown. The possibility that it might involve rare introgression of nuclear DNA from *O. ulmi*, or novel genetic mechanisms such as transposons or hypervariability of vc genes, is under investigation. The change may also be driven by the spread of mycoviruses (d-factors) in the frontal vc clones (Brasier, 1988, 1990a).

C. M. BRASIER, S. A. KIRK

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BRASIER, C.M. (1990a). The unexpected element: mycovirus involvement in the outcome of two recent pandemic events, Dutch elm disease and chestnut blight. In *Pests, pathogens and plant communities*, eds Burdon, J.J. and Leather, S.R., 239-308. Blackwell Scientific Publications, Oxford.

In vitro *micropropagation of English elm*

Elms have highly desirable amenity and timber properties, but the public's perception of their value has inevitably been altered by their susceptibility to Dutch elm disease. Studies on *in vitro* micropropagation of English elm, *Ulmus procera*, have been initiated with a view to its possible genetic manipulation to disease resistance via transformation with *Agrobacterium*.

Proliferating shoot cultures of *U. procera* Forestry Commission clone SR4 have been readily established from softwood shoot tips on DKW-Juglans medium, with 3–4 shoots usually produced per 3-week culture period, and >20 more from the stem base callus. Such shoot cultures failed to establish on Murashige and Skoog based media, or woody plant medium. Regeneration from excised leaves of clone SR4 was obtained after 19 days on DKW-J medium after pre-treatment with DKW salts and 4 mg l^{-1} BAP for 1 week. Up to 70% of leaves showed regenerant shoots (Plates 16 & 17). These developed into apparently normal shoots suitable for micropropagation and rooting after further elongation on DKW salts medium with 0.4 mg l^{-1} BAP.

Experiments are in progress on transformation of *U. procera* SR4 by wild type and engineered *Agrobacterium* strains. Studies on micropropagation of *U. glabra, U. carpinifolia, U. laevis, U. americana* and *U. villosa* are also in progress.

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OAK DECLINE

Diagnostic test to distinguish species in 'Ophiostoma piceae'

Ophiostoma piceae is under investigation because of its involvement in the current European oak decline, and because of its possible relationship to *O. ulmi* and *O. novo-ulmi* (Brasier, 1990b). It is also a major bluestain fungus and a common bark beetle associate. European isolates of *O. piceae* fall into two reproductively isolated but morphologically similar sibling species (*Report* 1989, 1990). One, the OPH form, occurs mainly on hardwoods and the other, the OPC form, mainly on conifers. Further studies show that the OPC and OPH forms have different temperature-growth curves on malt extract agar (MEA), and that the two groups can be separated on their upper limit for growth. Twenty-two European OPC isolates failed to grow after 8 days incubation at 32°C or above. In contrast 16 OPH isolates showed between *c.*0.3–1.2 mm day^{-1} growth at 32°C in the same period, and most OPH isolates still showed slight growth (*c.* 1mm) after 4 days at 35°C although none grew at 36°C. It is proposed that a growth test over 8 days at 32°C can be used to distinguish the two species on MEA, provided appropriate OPC and OPH control isolates are used.

Thirteen *O. piceae* isolates recently obtained from Canada have also fallen into reproductively isolated hardwood (seven oak isolates) and conifer (six fir, pine and hemlock isolates) groups. Moreover, on MEA the hardwood isolates again grew at 32°C while the conifer isolates did not. Thus the OPH and OPC groups of '*O. piceae*' appear to be present in North America in addition to Europe.

C. M. BRASIER, T. M. STEPHENS

REFERENCE

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PHYTOPHTHORA CINNAMOMI INVOLVED IN MEDITERRANEAN OAK DECLINE

In southern and western Spain some 10% of the 3.5 million hectares of oak forest and oak savannah/pasture of predominantly *Quercus ilex* and *Q. suber* has been affected by a rapid decline disease. Similar oak decline is occurring in these species and in *Q. cerris* in Portugal, France, Italy and Morocco. At the request of the Instituto Nacional para la Conservacion de la Naturaleza (ICONA), Madrid, the disease was examined between 13–17 May 1991 with special regard to the possible presence of North American oak wilt (*Ceratocystis fagacearum*), or of *Scolytus/Ophiostoma* complexes similar to those described for some other European oak declines.

At the first sites examined in Toledo and Extremadura Provinces, several factors suggested instead the possibility of a *Phytophthora* root disease, and in particular an invasion by the aggressive exotic pathogen *P. cinnamomi*. These included (i) evidence that affected oaks died suddenly in only one or two seasons; (ii) the presence of stem fluxes suggestive of root damage; (iii) a tendency for diseased trees to occur in groups or foci; (iv) association of disease outbreaks with topographical depressions, occurrence along streamsides, and association with soil disturbances such as recently ploughed areas, tracks, firestrips, roadsides and sites trampled by animals; (v) associated patch dieback of maquis shrubs such as *Cistus* and *Lavendula*, the occurrence of collar and root rot of the *Cistus* and other species; and root death of seedling *Quercus*.

At some sites the root systems of partially affected large oaks were therefore examined. Usually most fine feeder roots were found to be dead, though in deeper moist soils some death of structural roots up to 20 cm diameter was observed. At Las Canas/Las Labrados near Badajoz, Extremadura, and at La Almoraina in the Parque Natural des Alcornacales, Andalucia, isolation of *P. cinnamomi* was attempted. This fungus was readily obtained from dying roots of a *Q. ilex* (at Badajoz), and from roots of three *Q. suber* (Parque Natural, Andalucia). *P. cinnamomi* was also present in the soil at both sites.

From the etiology and topographical distribution of the disease, the successful isolation of *P. cinnamomi* from roots of both *Q. ilex* and *Q. suber*, and the associated patch dieback of maquis vegetation it is proposed that soil invasion by *P. cinnamomi* may be the major causal factor in the rapid oak decline in Spain. By analogy it may also be the main causal factor elsewhere in the Mediterranean. Loss of fine roots to *P. cinnamomi* may interact with other site factors, and also lead to stress attacks by fungi such as *Diplodia* and *Hypoxylon* and by insects. The possibility that *P. cinnamomi* is associated with the recent decline of *Q. robur* and *Q. petraea* across northern Europe (from Germany to the Caucasus) requires investigation. A preliminary report was submitted to the Director General, ICONA, in May 1991 (Brasier, 1991).

C. M. BRASIER

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BRASIER, C.M. (1991). Survey of widespread oak mortality in Spain, 13–17 May 1991, conducted on behalf of ICONA and the Direccion General de la Sanidad de la Produccion Agraria (Ministerio de Agricultura, Pesce y Alimentacion), Madrid: Report on isolation of *Phytophthora cinnamomi*, 30 May 1991. 5pp. Copies available from ICONA and Forestry Commission.

INTER-BRANCH REPORT PATHOLOGY AND STATISTICS AND COMPUTING (SOUTH)

EXPERT SYSTEMS

Work has been completed on a program for the identification of wood-rotting fungi in culture (*Report* 1988, pp.63–64). The program, an 'expert key' rather than an expert system, was written in LPA PROLOG and based on published keys (Nobles, 1948; Stalpers, 1978) together with additional material collected by Pathology Branch. The program provides a means of identifying a fungus in culture using a range of features which can be entered in any order, using as many as can be determined from the sample. A feature of the program is its ability to add new identifications or unknown species to its database as part of the normal operating procedures.

The final version was demonstrated at the 4th International Mycological Congress, Regensburg, Germany in September 1990. It is currently undergoing evaluation by mycologists before wider distribution is considered.

D. R. ROSE, A. R. LUDLOW

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STALPERS, J.A. (1978). *Identification of wood-inhabiting fungi in pure culture.* Studies in Mycology No. 16. Centrallbureau voor Schimmelcultures, Baarn, The Netherlands.

Plate 14 (top) *Collection of pollen from male flowers of a progeny-tested Sitka spruce growing in a clone bank.*

Plate 15 (above) *Adventitious buds and shoots induced* in vitro *on a female flower segment of Sitka spruce.* (A. John).

Plate 16 (right) In vitro *callus development from excised leaves of English elm clone SR4.*

Plate 17 Shoots of English elm SR4 regenerating from excised leaves.

Plate 18 The effect of the root aphid, Pachypappa vesicalis, *feeding on a Sitka spruce root. The aphid, surrounded by wax, can be seen on the inner side of the root. This feeding appears to cause a change in the direction of root growth.* (E. J. Major).

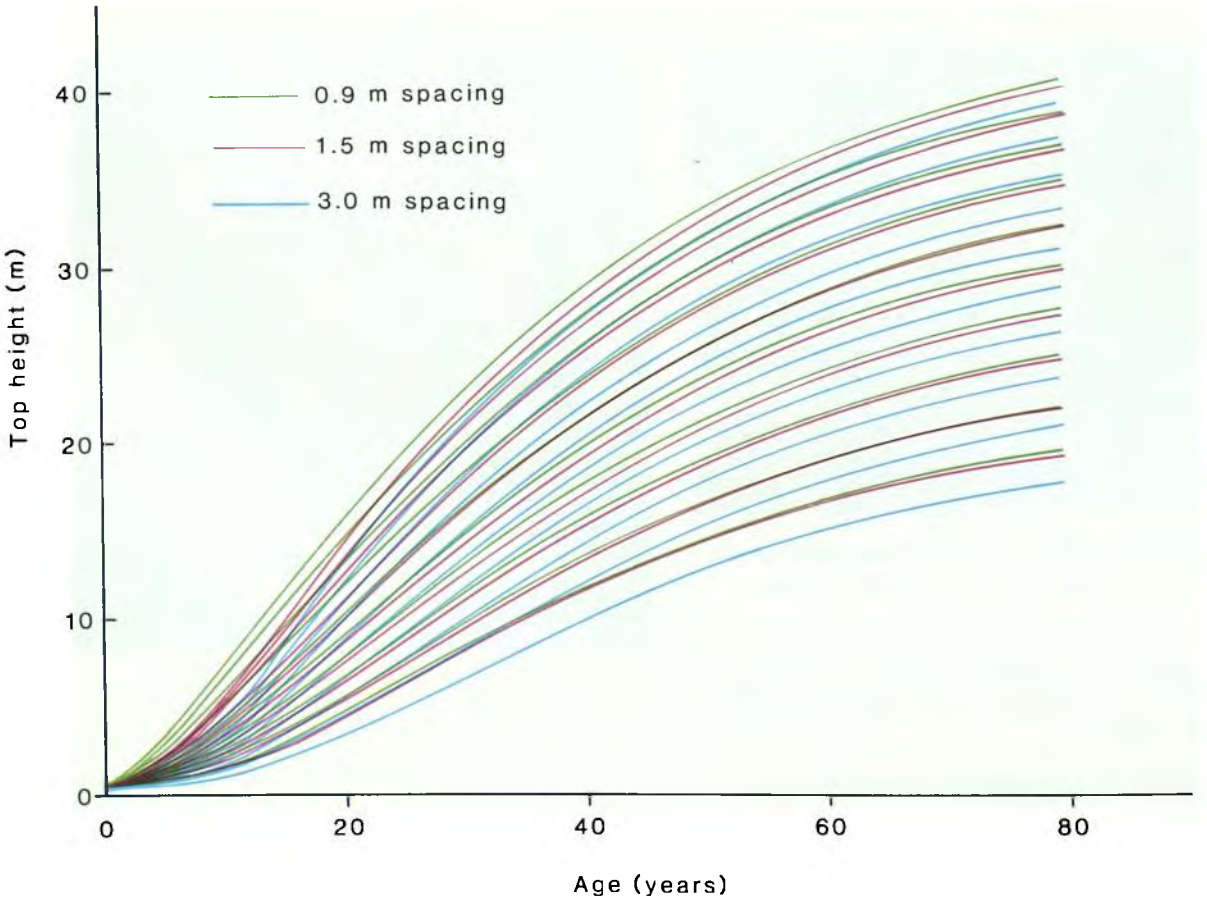

Plate 19 General Yield Class curves for unthinned Sitka spruce at 0.9, 1.5 and 3.0 m spacing. Development of top height with age.

ENTOMOLOGY

OVERVIEW

Further changes have been made to the research programme of the Branch. The effect of *Elatobium abietinum* on the growth of spruce is now being studied as part of the 'Impact' project. A new project on 'stress' as a factor determining insect dynamics is also underway, building on the information already gathered on the interactions between *Dendroctonus micans* and spruce. Pine wood nematode research was prominent, being studied in Canada and as part of a European Commission project to determine heat treatment schedules to kill the nematode in imported wood from North America. Problems from restocking pests continue to dominate work at the Northern Research Station; research has been further strengthened by the addition of a new project on the population dynamics of *Hylobius abietis.*

H. F. EVANS

GREAT SPRUCE BARK BEETLE, *DENDROCTONUS MICANS*

Biological control of Dendroctonus micans

Research surveys to assess the year-on-year changes in *Dendroctonus micans* infested trees indicated that population growth had increased slightly (from 18.6% to 22.9%) between 1989 and 1990. Populations continue to spread at a rate of approximately 5 km y^{-1}. The predatory beetle, *Rhizophagus grandis,* is now found frequently at new locations where it has not been deliberately released, confirming that it has a strong capacity to disperse and colonise new infestations of *D. micans.*

H. F. EVANS, N. J. FIELDING, P. HIGHAM, A. WATERS

Interactions of Dendroctonus micans *and spruce*

The lignification of spruce bark is an important physical defence mechanism against *Dendroctonus micans.* In both Norway and Sitka spruce stands, however, there is often considerable between-tree variability in the extent to which bark is lignified. Surveys of a number of spruce provenance trials have revealed that, for Sitka spruce at least, part of this variability can be attributed to the geographical origin of the trees. We found a linear relationship between the latitude of origin of Sitka spruce provenances and degree of lignification of bark on the lower trunk. Alaskan provenances tended to be highly lignified, while those from Oregon were relatively unlignified.

D. WAINHOUSE

THE PINE BEAUTY MOTH, *PANOLIS FLAMMEA*

Monitoring and control

Pupal surveys have indicated a general rise at several forests and it seems likely that, in 1991, it will be necessary to control the moth on up to 100 ha of lodgepole pine in Truderscaig Forest, Sutherland.

S. G. HERITAGE, H. F. EVANS

Population ecology

Panolis flammea populations on lodgepole pine in the Elchies block of Moray Forest (Grampian) showed a further increase, with 0.34 pupae m^{-2} being found overall, more than double the number found in 1989. Late larval populations were almost twice those in 1989; 3.08 m^{-2} compared with 1.67 m^{-2}.

The investigation of the influence of lodgepole pine seed origin on *P. flammea* population dynamics in replicated study plots at Elchies has continued. Numbers are low and no significant differences have yet been observed, but pupal, adult and larval counts were higher in south

coastal lodgepole pine plots than in any of the other seed origins.

S. R. LEATHER

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

Potential candidate trees expected to develop the bent-top syndrome at Afan Forest in South Wales, have been sampled over the past 4 years spanning a recent attack of *Elatobium abietinum.* Twenty-three apparently resistant or heavily defoliated trees were chosen in order to make a detailed biochemical analysis of the foliage before and after attack. The changes in amino-acid composition have now been analysed by HPLC. In addition, Tree Improvement Branch have analysed terpene components. From this we are investigating whether the chemical resistance features identified under experimental conditions (Nichols, 1988) are associated with bent-top and *E. abietinum* attack.

A detailed survey of Sitka spruce clones in a seed orchard at Slebech (Dyfed) was made following a heavy aphid attack. Certain clones, previously thought to show some resistance to aphids at other, more favourable sites, were attacked. The trees that were less severely attacked at Slebech were found to occur along the sheltered edge-rows where stresses are likely to be less.

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

REFERENCE

NICHOLS, J.F.A. (1988). Host plant chemistry and resistance to *Elatobium abietinum*. In *Aphids and conifers*, ed. C.I. Carter, 4–5. Summary of a workshop meeting. Forestry Commission, Edinburgh.

SPRUCE ROOT APHIDS, *PACHYPAPPA VESICALIS* AND *PACHYPAPPELLA LACTEA*

These aphid species have now been found to occur widely in Britain (Carter and Danielsson, 1991) and are particularly frequent on Sitka spruce roots growing on peaty gley soils. Their seasonal abundance and the appearance of winged migratory forms appear to be linked to periods of active root growth. Migration of wingless forms within a forest stand appears to occur readily. Feeding activities have a marked impact on root morphology (Plate 18); physiological changes are also being studied (this *Report,* p.70 Part II). Of the two species, only the gall forming generation of *P. vesicalis* on *Populus canescens* has, so far, been found and this appears to be a rare event. Nevertheless, the reproductive potential of the migrants leaving the galls is very high.

C.I. CARTER

REFERENCE

CARTER, C.I. and DANIELSSON, R. (1991). Two spruce root aphids, *Pachypappa vesicalis* and *Pachypappella lactea* new to Britain with illustrated keys to the morphs from *Picea* roots. *The Entomologist* **110**, 66–74.

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

Chemical protection

Experiments were set up in 1990 to study the efficacy of Gori 920, a Danish resin based formulation of permethrin. Treated plants have less odour than those treated with Permit or Permasect and may be more acceptable to planters. Gori 920, when applied at 0.8% (a.i.), provided a good level of protection combined with a low level of phytotoxicity. Experiments compared the efficacy of a number of Electrodyn Sprayer Conveyor (ESC) treatments including higher concentrations, higher flow rates and an additional spray head (bozzle). There was no evidence that any of the treatments improved the level of protection provided by the standard ESC.

Phytotoxicity

The phytotoxic effect of a range of dipping treatments was investigated for a number of broadleaved and conifer species. Beech, ash, rowan, birch, *Nothofagus, Salix,* oak, Douglas fir, Norway spruce, Japanese larch, Corsican pine and Scots pine were tested and none exhibited significant phytotoxic effects from dipping in 0.8% permethrin.

Cold storage

Various formulations of permethrin insecticide, Coopex (a wettable powder formulation), Gori 920 and Permasect (an emulsifiable concentrate) were tested for efficacy and phytotoxicity at various concentrations. It was thought that they might offer prospects for cold storage of treated plants. It was shown that the levels of protection and phytotoxicity from these formulations were

the same and that plants treated with permethrin can be safely cold stored for up to 9 weeks (below - 2°C) without any loss of efficacy.

Biological protection

Work continued on the use of entomogenous nematodes to protect plants and/or reduce the populations of developing *Hylobius*. Experiments during 1990 showed that the viability of nematodes applied to soil was not significantly affected by soil pH.

S. G. HERITAGE, S. COLLINS, T. JENNINGS, D. JOHNSON, I. WATT

THE EUROPEAN PINE SAWFLY, *NEODIPRION SERTIFER*

Long-term field experiments have been set up to evaluate the financial implications of pine sawfly attack on lodgepole pine. One of these experiments (trees are P84 KLP, average 1.3 m tall) suffered a range of levels of attack in 1990. Trees which had greater than 70% defoliation of previous year's needles, lost 7% of the height increment in the following year. However, studies of other species of defoliating insects have shown that the main effect on increment is often delayed until the second year after insect attack (see following report on 'Impact').

A. C. HENDRY

STUDIES ON THE IMPACT OF INSECTS ON TREE GROWTH

Tree ring analysis of mature Scots pine from Tentsmuir Forest, Fife, has revealed a strong, negative correlation between radial increments and population densities of pine looper moth, *Bupalus piniaria*. The Tentsmuir population of *B. piniaria* cycles in a regular manner and outbreaks occurred in 1957, 1962, 1969, 1977 and 1984. Stem growth was reduced after each of these outbreaks, the smallest increments occurring two seasons after peak moth numbers. Full stem analysis of these trees is now underway and this will provide estimates of changes in volume increment and the effect of *B. piniaria* on final timber yield. Experiments on the pine shoot moth, *Rhyacionia buoliana*, in Wareham Forest, Dorset, have provided data on the effects of different larval densities on the growth of P83 Bishop pine. Trees with 40–50% of the upper shoots infested in 1990 (n=45) showed, on average, 25% less height growth by the end of the year compared to trees with 4% shoots infested (n=45). Interestingly, trees sprayed with fenitrothion and without any shoot moth showed significantly less growth than unsprayed trees, suggesting a phytotoxic effect. On the remaining trees, larval densities have been maintained for a second year and this will allow the impact of two successive years of damage to be assessed.

N. A. STRAW

PINE LOOPER MOTH, *BUPALUS PINIARIA*

Pupal surveys were carried out in the same 38 areas surveyed in 1990. Counts were once more low, apart from highest compartment means of 12.0 m^{-2} at Hambledon, North York Moors (North Yorkshire) and 8.0 m^{-2} at Culbin (Grampian). The highest compartment at Tentsmuir (Fife) dropped from 20.8 m^{-2} in 1990 to 7.6 m^{-2} this year.

T. G. WINTER

PINE WOOD NEMATODE, *BURSAPHELENCHUS XYLOPHILUS*

Research placement in Canada, January 1990–January 1991

Experimental work on potential insect vectors of pine wood nematode, *Bursaphelenchus xylophilus*, was undertaken at Forestry Canada's Pacific Forestry Centre, Victoria, British Columbia. The only significant vectors of this potentially devastating nematode are longhorn beetles in the genus *Monochamus*. As this genus does not occur in the United Kingdom, the work focused on a range of beetle species, with similar life histories to those found in the UK, that could potentially vector the nematode should it become established here. In laboratory studies, none of the beetle species tested was capable of vectoring *B. xylophilus*.

N. J. FIELDING

ADVISORY AND TAXONOMIC SERVICES

The largest single source of enquiries related, once more, to the control of *Hylobius abietis* and *Hylastes* spp. on restock sites.

Serious defoliation of Sitka spruce by *Elatobium abietinum* was noted in Scotland but with a patchy distribution. In England and Wales, damage was noted only on Norway spruce grown for Christmas trees.

There were a few cases of *Cinara cupressi* causing dieback on Leyland and Lawson cypresses until early August, but none subsequently. This appears to have been the tail end of the outbreak that occurred in 1988 and 1989.

The eriophyid mite *Nalepella haarlovi* was found on Norway spruce foliage in Hampshire and on plants moved to Derbyshire.

Following exceptionally dry weather since 1989, there have been reports of *Pissodes castaneus* killing young pine and also older, unthrifty trees in plantations adjacent to 1987 and 1990 windthrow sites. Drought conditions have also allowed *Polygraphus poligraphus* to kill large Norway spruce growing on clay soils in eastern England. At Ifold, West Sussex, the scolytid *Crypturgus subcribrosus*, first found in Britain in 1986, was seen in association with *P. poligraphus*.

Problems concerning amenity trees included *Pulvinaria regalis* on street trees in southern England, *Euproctis chrysorrhoea* in London and Hampshire, and *Phyllobius pyri* defoliating newly planted broadleaved trees.

The only exotic bark beetle found by Forestry Commission plant health inspectors was *Ips typographus* in dunnage at Tyneside in August. One *Monochamus scutellatus* was caught in a pheromone trap at Liverpool. This species is a vector of pine wood nematode, *Bursaphelenchus xylophilus*. There were also a number of interceptions of *Monochamus* sp. larvae or galleries in timber imported from Canada.

T. G. WINTER, S. G. HERITAGE

WILDLIFE AND CONSERVATION

DEER

Roe deer management

Work has continued in analysing roe deer population data and we have confirmed that intra-uterine, and particularly peri-natal, mortality commonly occurs at a high level even in high-performance populations occupying rich habitats. It appears that mortality of around 50% of kids each year is common, and this can increase to almost 100% mortality of new born kids in very wet and cold conditions. The importance of this knowledge to management is that roe deer culls, unlike those for red deer (Ratcliffe, 1987) need to be calculated separately each year. Population simulations suggest that some upland roe populations require a cull of only 10–15% each year to achieve stability, while the most fertile populations decline with a cull in excess of 25% (Figure 18). This information contradicts current views that roe populations can seldom be controlled, and represents an important and positive advance in the management of roe deer. A Forestry Commission Bulletin containing management advice based on this work is being published.

P. R. RATCLIFFE, B. A. MAYLE

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

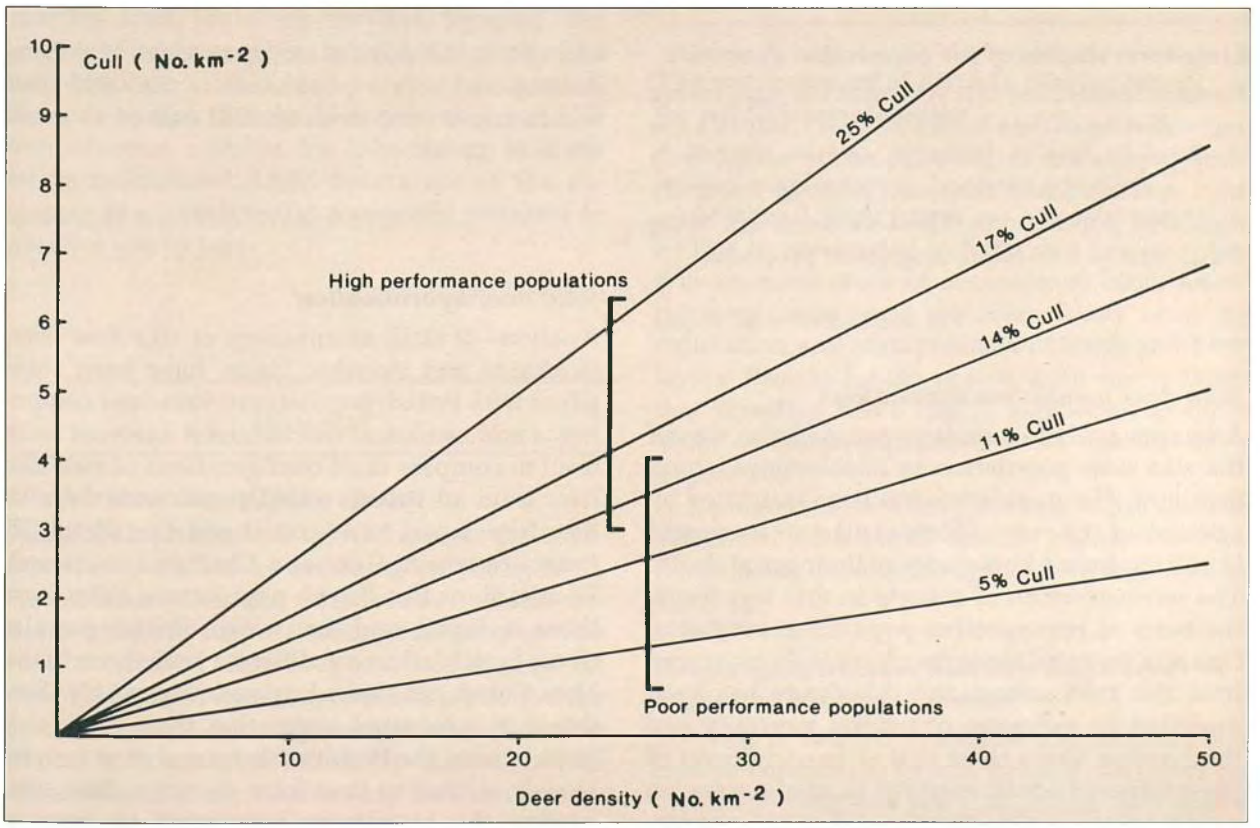

Figure 18. Cull levels required to achieve zero population growth for a range of roe deer densities.

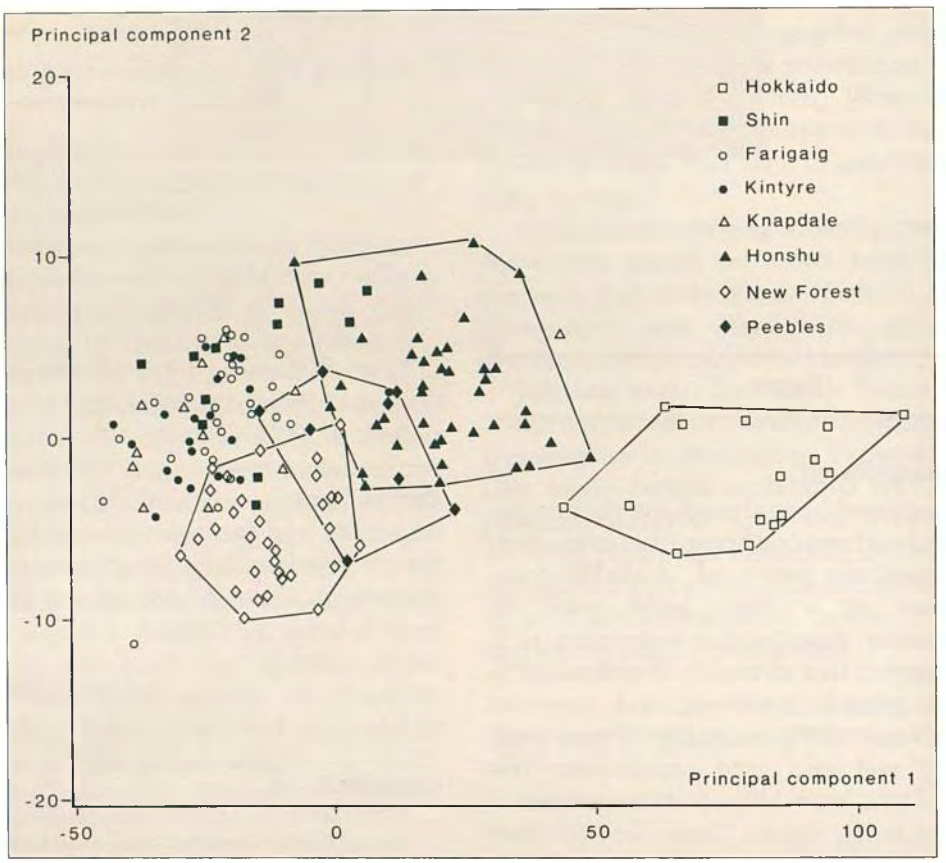

Figure 19. Principal components analysis of sika deer skulls from Japan and Great Britain.

Long-term studies of roe population dynamics

Research continued this year with the monitoring and collation of data from a 20-year study of a roe deer population in Dorset. Results reveal both high mortality and dispersal rates in naturally regulated populations. These findings are being incorporated into roe management proposals.

P. R. RATCLIFFE, R. M. A. GILL

Sika deer population simulations

Attempts are being made to estimate the size of the sika deer population in Peeblesshire, south Scotland. The population has been estimated by calculating the year of birth of all deer recovered in culling from a knowledge of their age at death. The reconstruction of cohorts in this way forms the basis of retrospective population estimates. One hundred and three deer have been recovered from the 1985 cohort and this figure has been modified by estimates of natural mortality and the number likely to be still alive. Additions of the number of adults required to produce such a cohort complete the estimate of the 1985 population. The 1985 population probably contained about 500 deer (±5%). A computer simulation of changes to the population up to 1990, including culling, suggests a population of 500–600 deer which could sustain an annual cull of 130–150 animals (26%).

P. R. RATCLIFFE, A. H. CHADWICK

Sika deer hybridisation

Analyses of skull morphology of sika deer from Hokkaido and Honshu, Japan, have been compared with British populations. Principal components and canonical discriminant analyses were used to compare skull configurations of sika-like deer from all British populations, with the sika deer from Japan, and Scottish red deer (Ratcliffe, Peace, Hewison, Hunt and Chadwick, in press). Results show that British populations differ from those in Japan, and that within British populations, Scottish deer are different from those in the New Forest, southern England (Figure 19). Evidence is presented suggesting that, of British populations, the Peeblesshire population is most closely related to deer from Honshu, thus supporting the hypothesis suggesting its relative purity compared with other British populations, and supporting the hypothesis that it originated

in Honshu. The New Forest population may also be a 'pure' population differing from Peebles by 'founder-effect'. Hybrids have been recovered from a number of Scottish populations and the evidence presented here demonstrating high variability among Scottish sika populations may be due to a high degree of hybridisation. The taxonomic position of *Cervus nippon yesoensis* as a separate sub-species is supported.

P. R. RATCLIFFE, A. J. PEACE*, A. H. CHADWICK
*Statistics and Computing Branch (South)

REFERENCE

RATCLIFFE, P.R., PEACE, A.J., HEWISON, M., HUNT, E. and CHADWICK, A.H. (in press). The origins and characterisation of Japanese sika deer populations in Great Britain. In *Proceedings of the International Symposium of Wildlife Management*, Tsukuba, Japan.

AUTECOLOGICAL STUDIES OF SENSITIVE SPECIES

Bats

Six wartime explosives storage bunds at Pembrey Forest, South Wales, have been converted to bat hibernacula (completed February 1991) by partially blocking the entrances. A range of potential roosting sites, including crevices, hanging tiles and rubble, have been provided inside. The micro-climate within each bund is being monitored to ensure that the high humidity and low temperatures suitable for hibernating bats are being maintained. Light beams across the entrances are connected to automatic counters to monitor use by bats.

B. A. MAYLE

DAMAGE

Leader browsing of Sitka spruce

A research project was carried out on the causative factors of leader browsing on young Sitka spruce trees on upland restock sites in collaboration with H. Hirakawa, a scientist from Japan. The results revealed that there was less damage on sites with more vegetation cover, in particular the presence of fine-leaved grasses or other palatable plants. It is hoped to follow up this work with other studies of the relationship between browsing and vegetation characteristics.

R. M. A. GILL

Electric fences

Electric fences against deer, and roe deer in particular, are not as effective a barrier as a line wire and wire mesh fence. Roe deer are deterred to some extent, but browsing damage and deer activity within fenced trial areas were unacceptably high.

A representative range of battery operated electric fence energisers was evaluated and none was found to comply with BS 6167 and some were considered unsafe. Each performed differently when connected to fences of different load conditions.

The electrical impedance of the body of deer appears to differ considerably between species and therefore each species will experience different sensations of shock from the same fence. Red deer appear to be most sensitive and roe deer the least.

The trials are continuing but more work needs to be done to improve the design and performance of electric fences and electric fence equipment. The technique is unlikely to have widespread application.

H. W. PEPPER, A.H. CHADWICK, R. BUTT

VEGETATION MANAGEMENT (UPLANDS)

The management of birch in conifer forests for wildlife conservation

A review of the potential values of birch in upland conifer forests has been completed.

A second experiment on a peaty gley site, adding to one started in 1989 on a brown earth, will examine ways of encouraging birch establishment from seed on clear felled areas by cultivation and manipulation of brash and litter layers. Results for the brown earth site indicate that screefing has a highly significant positive effect on initial germination and establishment (Figure 20).

A project to assess the plants and other wildlife associated with birch: spruce mixtures is currently being planned and should commence in 1991/92.

Encouraging heather (Calluna vulgaris) *on edges and unplanted areas*

The loss of heather moorland communities is a current concern. In forests, heather can thrive on disturbed roadsides and clear felled sites where dormant seed is exposed and germinates. It also benefits from the removal of stock grazing after

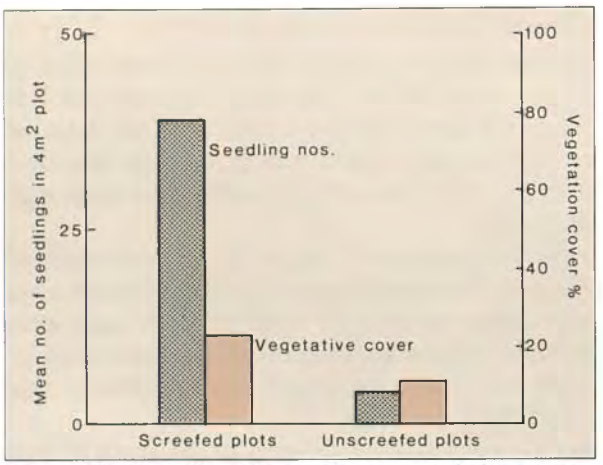

Figure 20. The effect of screefing on vegetation cover and numbers of silver birch seedlings present in October 1990, after sowing the previous autumn. Initial seedling density is significantly ($P<0.01$) higher in screefed plots but the more rapid growth of field layer vegetation may cause competitive losses in the second growing season.

initial afforestation. In many areas, however, heather was eliminated prior to initial afforestation and may not reappear. The diversity of wildlife of open and edge habitats of the forest is likely to benefit if heather is encouraged on suitable sites to form a patchy mosaic with grassland and mire communities.

Experiment and management trials are in progress at the Forest of Ae to test methods of stimulating heather to grow from sown and buried seed in *Molinia* dominated grassland areas, and also on a clear felled roadside.

Juniper as a shrub species in upland forests

Juniper has a potentially valuable role in upland forests. It is a dense native shrub which is adapted to infertile and fertile soils, and forms scrub on exposed sites. It has recently declined in range and abundance and many stands are not regenerating.

Early growth is often slow and deer browsing is a potential constraint upon its use in upland plantings. On the other hand, mature bushes form a stable vegetation which would need negligible control on roads or rides in contrast to fast-growing deciduous species or invasive conifers.

Several experiments are underway in collaboration with Silviculture (North) Branch and Plant Production Branch to test methods of enhancing early growth of planted stock (treeshelters, fertiliser) and to compare seed pretreatment methods designed to facilitate germination. Initial results from the earliest of these experiments testing the effects of treeshelters and phosphate fertiliser on growth of juniper cuttings on a podzolic soil at Glenlivet (Banff) show a significant ($P<0.001$) effect of shelters on height after 2 years. However, shoot growth of the 'no shelter' treatment caught up with that of the shelter treatments in the second year, so that the benefits may be short-lived. Juniper has also been planted under thinned Scots pine to test its tolerance to light and suitability for introducing as an understorey in mature pine stands.

G. S. PATTERSON

VEGETATION MANAGEMENT (LOWLANDS)

Ride management machinery demonstration, Micheldever Forest

A survey of ride management practices by Forest Districts in England and Wales indicated that the conservation objectives of cutting regimes were not being met in many cases. A number of respondents identified the non-removal of cut material as a possible cause.

Forage harvesters have been used for many years in agriculture, and a number of non-government organisations concerned with the management of nature reserves have begun to find a use for these machines for the management of both heathland and grassland. However, there has been little or no experience of their use in woodland conditions, where narrow working area, varying ground conditions, stumps, woody growth and log debris are problems.

A number of machines designed to cut and remove material in a single operation were demonstrated, as well as tractor-mounted long-reach flail cutters for coping with coppiced woody material across ride or road ditches. Small, robust flail/hopper mowing machines performed impressively, producing a good quality cut and collection. In addition to straightforward cutting, these machines may be fitted with scarifying tines to remove dense matted vegetation, with the added benefit of providing regeneration niches for desirable herbaceous species.

The use of herbicides and growth retardants to manage ride vegetation in lowland forests

A series of experiments was set up during 1990 to examine the role that selective chemicals might play in the conservation management of ride vegetation (Alice Holt Forest and Micheldever Forest, Hampshire). The control of dominant grass species was thought likely to provide opportunities for the regeneration of a

range of broadleaved herbs such as violets, *Viola* spp.

At Alice Holt, broad spectrum herbicides were compared with specific graminicides and growth retardants, applied to an area of tussock-forming grasses and rushes, *Juncus* spp. In addition to monitoring species composition and abundance, measurements were made of the soil and air temperature at ground level, as well as the light levels of the sward. Vegetation changes in the first season after treatment were small, and it is intended to carry out further monitoring for a second season in order to observe any longer term changes.

At Micheldever, in addition to examining chemical treatments, the feasibility was investigated of establishing a grass sward from seed into a species-poor community dominated by creeping thistle, *Cirsium arvense*. High levels of grazing pressure from rabbits and roe deer demanded that fenced plots should be added to the treatments. No significant effect of the herbicides and growth retardant on the overall number of species recorded was observed. Growth retardant effects were transient, and no clear height differences could be detected between the plots towards the end of the 1990 growing season. Clear differences in the establishment of the grass seed mix were recorded between plots that were fenced compared with those which were open; grazing leading to a patchy, open sward. The establishment of a grass sward did appear to reduce the dominance of *C. arvense*, particularly in the fenced plots. Treatment differences were, however, largely masked by phenological changes over the growing season, and effects were difficult to separate from the effects of drought during 1990.

The management of ride vegetation by cutting and grazing

Little monitoring of changes in ride vegetation in response to management has been undertaken in any detail, and a study to examine a range of different forms of management and their effects on vegetation composition was set up in Pembrey Forest, Dyfed, in early 1991. Treatments to be evaluated include flail mowing with no removal of cuttings, cutting and removal of cut material using a forage harvester, hand-cutting and pulling of invasive woody growth, and the use of goats to graze the plots. The vegetation composition is being assessed prior to and after treatment, and this is being complemented with biomass assessments. The condition and weights of the goats are being monitored.

Monitoring of vegetation succession following windthrow, with minimal intervention

Forests in east England were extensively windthrown during the severe storm of October 1987, and the creation of open space on some heathland sites has brought potential conservation benefits. There is an opportunity to plan restocking programmes to realise this potential. Consequently, areas of windthrow are to remain unplanted for various lengths of time.

In 1990, at Rendlesham Forest, Suffolk, plots were marked out in a windthrown sub-compartment, to monitor the changes in the vegetation over a number of subsequent years. Two forms of intervention were permitted on the site: fenced exclosures were set up, to examine the impact that grazing might have on the regeneration of broadleaved shrubs and trees and half of each of the fenced and unfenced plots was sprayed with Asulox. A first season of vegetation assessments is due to commence in 1991.

R. FERRIS-KAAN

MENSURATION

SAMPLE PLOTS

The sample plot estate is currently undergoing a major review, with the primary objective of assessing whether adequate coverage of species, sites and forestry practices is being achieved. Figure 21 illustrates the sample plot holding for a range of species. The demand for data from current and future growth and yield monitoring and modelling programmes is being assessed to see whether additional or alternative variables need to be measured in permanent sample plots. The potential for using temporary sample plots to complement the permanent sample plot network is also being examined.

A total of 256 sample plots were due for measurement in the 1990/91 programme. This included a carry-over of 54 plots from 1989/90 due to the January 1990 windthrow; 178 were measured by end of March 1991. Ten of a series of 28 Sitka spruce:lodgepole pine mixture temporary plots in Dornoch Forest District have been converted to permanent sample plots.

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

YIELD MODELLING

Validation

The Branch is engaged on a project to validate the published yield models. As part of this project, methods for producing flexible computerised functions to describe the master table relationships in the yield models have been developed. A mathematical function has been derived which describes the General Yield Class curves for Sitka spruce, originally produced only in the form of hand-drawn curves. The function reproduces the expected height growth of Sitka spruce stands for a range of planting spacings and yield classes. By interpolation between the published models, it is

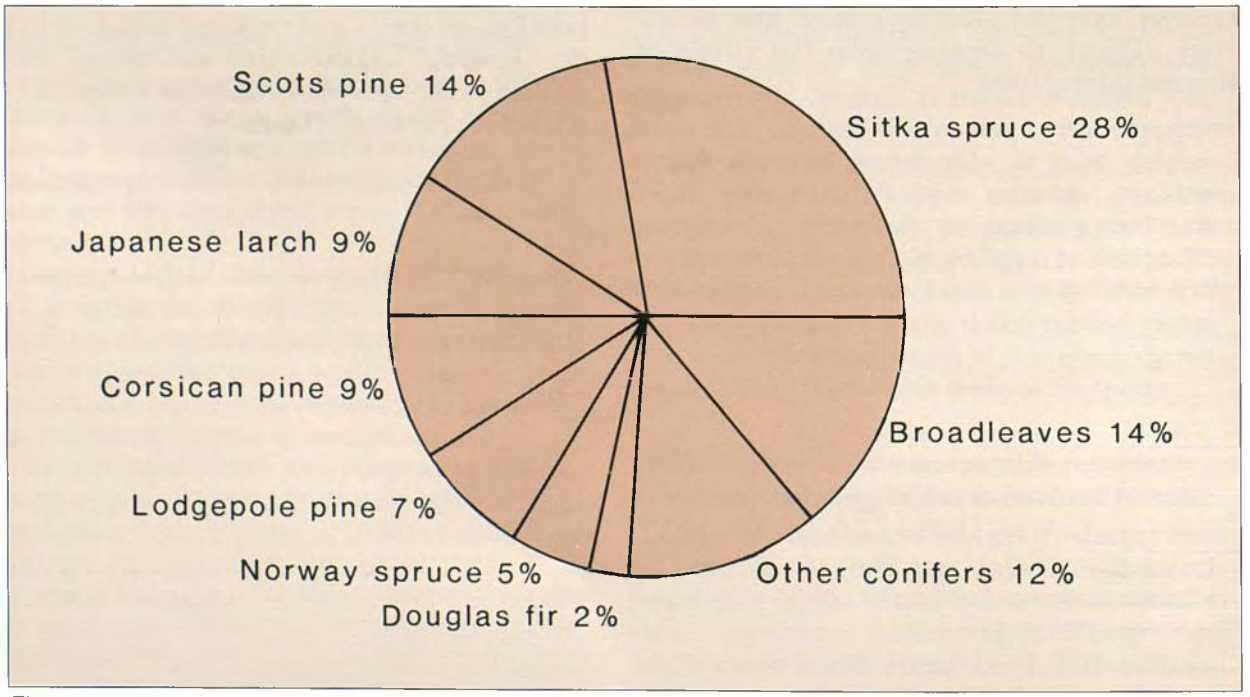

Figure 21. Distribution of viable sample plots by species, 1991.

possible to arrive at predictions of top height development in stands for which models are not currently available. Plate 19, for example, shows the set of General Yield Class curves produced by the new function for initial spacings of 0.9, 1.5 and 3 metres. Functions have also been derived for predicting cumulative volume production and surviving numbers of trees in unthinned Sitka spruce stands.

Carbon storage

A method for constructing biomass yield tables has been developed. The models predict the accumulation of woody growth above and below ground in oven dry tonnes. A review of the wood chemistry literature has revealed that the carbon content of oven dry wood is very close to 50%, thus multiplying the predicted woody biomass in the new yield tables by 0.5 gives an estimate of the tonnage of carbon locked up in the woody parts of the tree. Figure 22 illustrates the development of woody biomass in an average stand of Sitka spruce. The models have confirmed that forests in Britain store carbon at an average rate of 2 to 3 tonnes per hectare per year during their full-vigour phase of growth.

Site/yield relationships

A joint Forestry Commission and Ministry of Agriculture project to predict yield from site factors commenced on 1 October 1990. The aim is to develop a site classification system for lowland England and Wales by which growers may predict the yield of the following species: Corsican pine, Norway spruce, Douglas fir, hybrid larch, oak, beech, sycamore, ash and poplars. This involves utilisation of Mensuration Branch permanent and temporary sample plot data and establishment of further temporary plots for some species. To date, all early temporary plot data have been input into the computer. A temporary sample plot code for establishment and measurement of new plots has been written. A review of literature and Geographical Information Systems has been completed. (The project will proceed using data from the LANDIS system based at the Soil Survey and Land Research Centre, Silsoe.) A method for estimating standing volume in temporary sample plots has been devised using results of analysis of volume sample tree data from permanent sample plots.

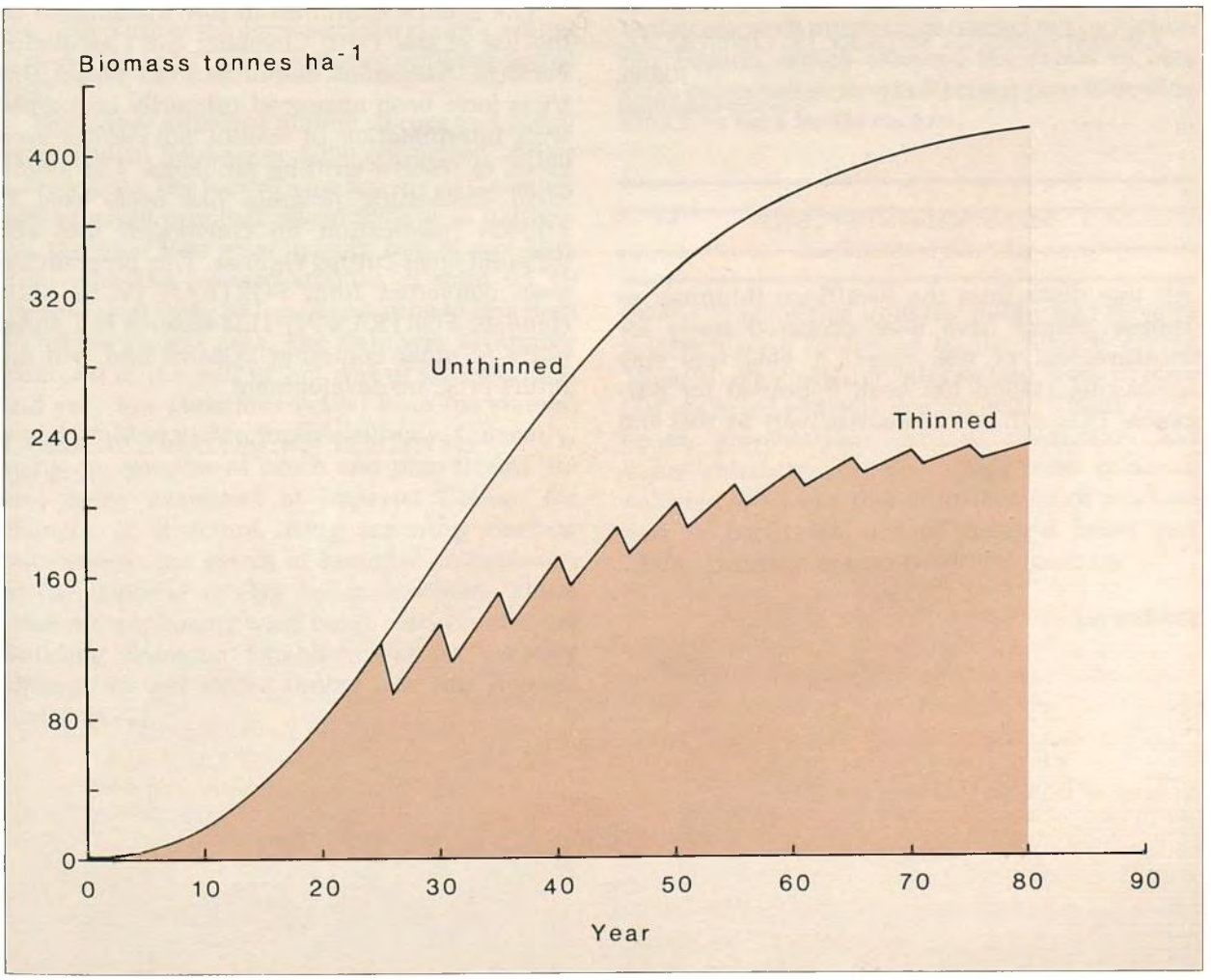

Figure 22. The development of woody biomass in an average stand of Sitka spruce.

Poplar yield models

Yield models of poplar clonal groups for the poplar study team, using existing British, French and Belgian data are being developed. There are insufficient data in the permanent sample plot databank, so data from the early Silviculture poplar trials are being utilised. All the Silviculture datasets have been keyed to computer, sorted, validated, metricated and output to sample plot format. Initially the data are being examined graphically for differences between clonal groups and for comparison with the major crop variables in the existing poplar yield tables. Yield models for 3, 4 and 8 metre spacing are being constructed.

Elatobium models

Models for simulating patterns of *Elatobium* attack have been constructed using results of entomological experiments and sample plot data. These show that if attacks occur on a random basis, as suggested by the data, then there is a likely 5–10% loss of total volume production at final felling age. This volume loss is dependent on frequency and severity of attacks.

R.W. MATTHEWS, J.M. METHLEY, J.M. CHRISTIE*, P.C. JOKIEL

*Forestry Consultant

MEASUREMENT STUDIES

All tree discs from the Swaffham thinning response project have been prepared ready for measurement of tree rings. A new tree ring measuring system has been approved for purchase. This will be used extensively by this and other research Branches, particularly those concerned with climate change research.

Two new instruments have been identified to replace the dendrometer currently used for assessing individual tree standing volume. Both will undergo field trials to determine their suitability for use in permanent sample plots.

J.M. METHLEY, N. FEARIS

MANAGEMENT SERVICES

A system for monitoring mensuration enquiries was introduced in October. Since that time over 150 enquiries have been recorded and answered. They cover a wide range of problems on yield and measurement and come from Forestry Commission staff, the private sector, other researchers and the general public. Examples are: estimation of top height in mixed stands of two or more species, estimation of yield class of stands of Bishop pine, and guidance on application of tariff procedures.

The Branch continues to provide support on the use of the Tariff Checking and Calculation Package. Numerous enquiries from Forest Districts have been answered primarily concerned with interpretation of results, advice has been given to resolve tariffing problems. The assortment forecasting program has been used to provide information on conversion loss and different cross cutting regimes. This program has been converted from FORTRAN IV to ANSI standard FORTRAN 77. This ensures full portability to other computer systems and will aid future program development.

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

FOREST PRODUCTS

WATER STORAGE OF TIMBER

Following the establishment of a water store at Thetford Forest in 1988 for the long-term preservation of windthrown pine logs, a major experiment was undertaken to assess the effectiveness of water storage for a variety of hardwood and conifer species (*Report 1989*, pp.59–60). Originally, the process of water storage was to be assessed over 2 years, but the storage period has been increased to 3 years for samples of Corsican pine, Sitka spruce and European beech with the experiment to be finally completed in July 1991. This extended period of research reflects the prolonged use of the commercial wet store, which is projected to be in use probably until the end of 1992.

The 2-year sampling of pine, spruce and beech examined in September 1990 confirmed earlier assessments, the logs sawing readily and cleanly and showing minimal discoloration. In particular, the pine logs were usually free of any blue stain with the average amount of stain on 40 boards taken from 20 logs amounting to less than 3% of the surface area. The stain was invariably localised at the butt or top end of affected logs, and very few isolations (<1%) from the stained wood yielded viable fungal cultures. Currently, wet store samples of beech and pine timber are also being examined at Imperial College for changes in structure using scanning electron microscopy; the extent of bacterial colonisation of the material is also being surveyed. These studies complement work being carried out at the Building Research Establishment on porosity changes in wet stored timber (see this *Report*, Part II, p.72).

BLUE STAIN IN PINE TIMBER

A project has recently been established in collaboration with Portsmouth Polytechnic to study the dissemination of blue stain fungi colonising recently felled trees and sawn pine timber. The project is to extend over 3 years and will explore various ecological aspects of blue stain fungi including changes in patterns of colonisation over time, the processes of dissemination in the absence of insect vectors, the population structure of the more common blue stain fungi and the likelihood of latent colonisation by such fungi in unstained timber. This study complements an earlier research programme carried out by Pathology Branch, which assessed the extent of blue stain colonisation in windthrown pine following attack by bark beetle vectors.

ADVISORY SERVICE

Over 120 enquiries from the public and forestry industry were processed by the Branch during 1990/91. Requests for information were diverse but included subjects dealing with timber properties, presentation, charcoal production and value enhancement. The single most common subject (30%) was that of utilisation of residues and in particular, use of chipped forest and timber residues as a horticultural medium.

J.F. WEBBER

STATISTICS AND COMPUTING

STATISTICS: ALICE HOLT

Work study

Investigations into the possibility of using a machine-skills rating-index in time studies of harvesting machines have given promising results. Although time is 'machine controlled' in some operations, a skilled operator is often able to co-ordinate machine movements to achieve better output. The skills index can be applied in the same way as the traditional rating of a skilled worker, but it represents a different concept. A method of converting from observed time to basic time still needs to be tested.

Silviculture (South) Branch

The analysis of 'standard' experiments has been made easier by the development of SILVAN, a Fortran interface to the Genstat code. Interacting with the system, a user can find out which experiments can be analysed, what data sets are available and can select output options. From the user's reply a Genstat program is created and run as a batch job. The interface expands codes used in file names to provide a well annotated printout; warnings are given where too many trees or plots are missing. Over 50 experiments can now have standard assessments analysed using SILVAN. A major task has been the collation, analyses and presentation of data from the open-top chamber experiments (pp.21-22). This year assessments have included harvest data, needle retention properties, and phenology, as well as heights and diameters. Multivariate techniques are used in the analyses.

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

Plant Production Branch

Analyses using the hypergeometric and binomial distributions show that the current ISTA rules for heterogeneity testing of seed lots will need to be revised.

Wildlife Branch

In an analysis of tawny owl breeding success at Kielder Forest, contouring techniques were used to link winter, spring and summer vole numbers to the start of incubation, the number of chicks hatched and the subsequent number of fledgelings.

Several research projects aim at understanding the relationships between vegetation and management techniques. Multivariate statistical techniques, including correspondence and principal component analysis, have been used to investigate both the short and long-term effects of herbicides on ride vegetation.

A.J. PEACE

Genstat procedure

A Genstat procedure, YBYX, was written which summarises the first of a pair of corresponding variates, y and x, with respect to the second; y is assumed to be subject to some random variation and both variates are long, or y is replicated (with error) within values of x. YBYX then gives features of y not otherwise available in Genstat5. The main objects in writing YBYX were:

to provide information on the irreducible random variation of one variate with respect to another, to give a better standard of success in fitting a regression equation than any derived from their simple correlation;

to expedite iterative fitting of non-linear regression models for long variates, where using y and x directly would be unnecessarily expensive in terms of computing time.

The results given by YBYX are easily plotted so that there is scope for further testing of the relationship between the two variates.

Tree Improvement Branch

Results of experiments carried out by Tree Improvement Branch were analysed showing that the sizes of the leaves and buds of oak depend smoothly and strongly on their position along the

shoot, and that of leaves also on the orientation of the point of attachment round the shoot. The form of the variation along the shoot is similar in both organs, i.e. an additive mixture of a straight line and a beta curve, for example:

$$y = ax^p(1 - x)^q d f^{(\theta)} + (b + gf(\theta)x + c$$

where, if N is the number of organs of the given type on the parent shoot, n is the serial number of the organ counting from the base to the tip, and $x = \frac{n}{N}$, is the index number of the organ, and

$$f(\theta) = w\sin\theta + (1 - w)\sin^2\theta,$$

where θ is the orientation downward from the horizontal. For buds $d = w = 1.0$, near enough. If the random variation is large enough on a shoot this can degenerate into a quadratic model. Sizes of leaves are greater on the lower side of the parent shoot than on the upper side.

The lengths of shoots arising from oak buds normally increase geometrically from base to tip of the parent shoot, but vary with orientation round the parent shoot so that the larger shoots are on the lower side, like leaves. If the leaves on the parent shoot are completely amputated, the derived shoots the following year get smaller from base to tip of the parent shoot.

Forest Products Branch

As part of research on the influence of initial tree spacing on timber strength in unthinned Sitka spruce, a study was made of stem shape to estimate the yield of standard battens from trees of different diameters. It was found that good estimates could be made by assuming that a stem profile was an additive mixture of a power curve, a hyperbola and a beta curve, but the way in which the proportions of these components varied with spacing and diameter at breast height has been difficult to determine consistently. A good fit for mean batten strength in terms of tree spacing and log size has been obtained and this relationship is being used to calculate the proportion and the quantity of battens expected to meet different strength criteria.

R.S. HOWELL

Statistical training

Courses were given on the use of Statgraphics and Genstat. A 3-day Genstat course introduced the most commonly used directives and provided hands-on experience in writing and running programs on the Prime.

A 4-day course on statistical aspects of planning and designing experiments was attended by staff from both Alice Holt and outstations. It emphasised common problems in setting up and assessing experiments. Lectures, practical exercises and field visits were backed up by re-written course notes produced using T_EX software.

R.C. BOSWELL, T.J. HOUSTON

STATISTICS: NORTHERN RESEARCH STATION

A significance test for root symmetry

All roots in an excavated system were measured. The direction from north and the root diameter at a fixed radius from the centre of the tree were recorded. Angles weighted proportionately on diameters were tested for uniformity, using a Rayleigh test (Mardia, 1972) which was modified to provide an F-ratio.

Root anchorage model

Blackwell *et al.* (1990) developed a root anchorage model for shallowly rooted Sitka spruce. Their computer program calculated turning moment of a tree, which is represented as a simple mechanical system responding to an applied force. This was rewritten in Microsoft Fortran and additional programs now assist project leaders to create input and output files and display graphics to aid interpretation of results.

Ordinal regression

A standard silvicultural assessment assigns ordinal scores to the root systems of young trees. The usual analysis is calculation of plot means followed by ANOVA, relying on the central limit theorem to justify the assumption of normality. An alternative approach is to transform raw data to multinomial frequencies and fit a regression model suitable for ordinal data. For root scores, the two analyses produce similar results. The regression analysis provides more information but reporting the results is more difficult.

Restricted maximum likelihood (REML)

Generalised lattice designs (often used for progeny trials), were conveniently analysed by REML with recovery of inter-block information. However, the method demanded considerably more central-processor time than a simple algorithm based on iterative refitting of block and treatment effects.

Modelling borehole water levels

A useful time-series model for borehole water measurements takes the form

$$observation = \text{'true' } value + error,$$

Where the 'true' value is generated by a first-order autoregressive process – without error. Modifying the model by transferring the error term from the observation equation to the autoregression has resulted in noticeable improvement in fit for some data sets.

Multivariate methods

Terpene-component data of pine resin are routinely analysed by extracting principal components or canonical variates. The 'biplot' is found to be a simple and informative way to present results, with individual terpene components represented by vectors and trees by points. Distances between points approximate dissimilarities between trees, and angles between vectors represent correlations between amounts of different terpenes.

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

COMPUTING: ALICE HOLT

The Visiting Group to Statistics and Computing Branches in 1990 recommended that computing facilities move to a distributed and local computing environment with a fast, local area network capable of connecting several UNIX-based service computers along with PCs and peripheral servers.

Planning for the new system at Alice Holt is under way with the setting up of a local area network in the Statistics and Computing Branch, linking the PRIME 9655, the PRIME EXL MBX and all the existing micros. The experience was useful when work was begun on an operational requirement for the new distributed system.

The Prime 160Mb and 315Mb disk drives were part exchanged for an 817Mb disk drive. A 'fast' cartridge tape streamer, to allow a complete system back-up every night, has reduced the disruption experienced by computer users.

I.D. MOBBS, B.J. SMYTH

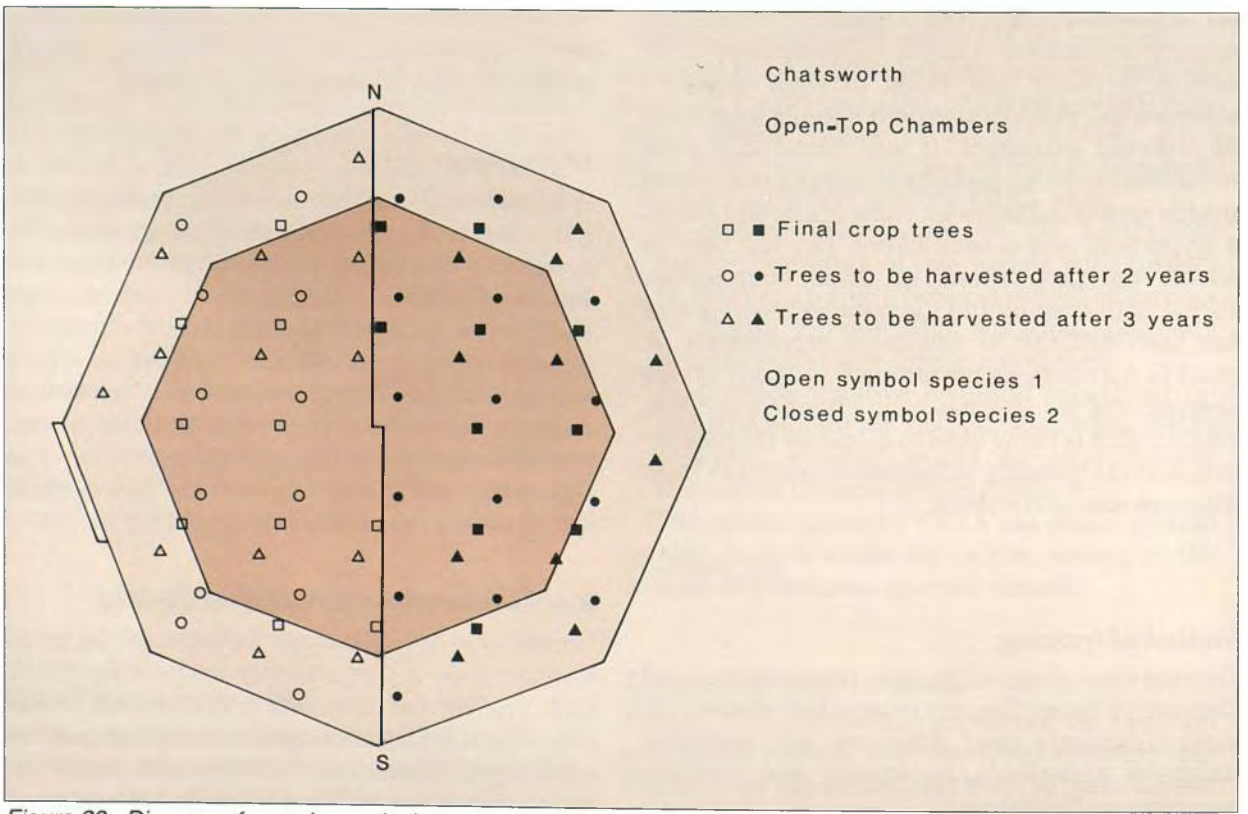

Figure 23. Diagram of experiment design in an open-top chamber.

Programming

Site Studies (South) Branch

The open-top chamber data-validation and processing system was completely revised and many new facilities added in the light of developments since the original system was written. Extracts of the data, graphical output and tabulations of an array of climate/environment indices underpin statistical analysis of the associated experiments (Figure 23).

Forest Surveys

The date of survey of each compartment was added to the database and formed the basis of many enhancements to the system, for example forecasting sub-systems were provided for disposal data and private woodland data.

Work Study

The suite of programs comprising the Microfin data checking system has been enhanced to allow the investigation of rating machine-controlled elements.

G.J. HALL, L.M. HALSALL

Plant Production Branch

The seed-testing database of the Plant Production Branch was transferred to a PC running the micro-ORACLE dbms and has proved highly successful. A demonstration was given at a statistical seminar, organised by the International Seed Testing Association (ISTA) in Budapest, Hungary. Also at this meeting, ISTA members agreed to exchange software and the Forestry Commission is actively collaborating.

A.J. PEACE

A Prolog 'model builder'

Using LPA Prolog, A. Collins wrote a 'model building' program which accepts ordinary differential equations and checks that variables on the right hand side of the equation are defined elsewhere in the model. It also checks for the consistency of units on each side of the equals sign. Equations are sorted into the order needed for calculation so they can be entered in any order. This allows them to be grouped into modules and the model builder can save and recombine modular models in many different ways. Each model is then translated into a Fortran program using the DARE P package (Korn and Wait, 1978).

A.R. LUDLOW

Data collection and entry

Micropalm hand-held PCs were used for the first time in the collection of the forest condition survey data in 1991. They are also now used for the collection of data from Silviculture (South) experiments, producing data files immediately accessible to the SILVAN system. For the forest condition survey the Micropalms were initially programmed using a proprietary package (Quick Collect) and enhanced in-house using Quick BASIC. A full in-house program will replace this for the 1991 assessment to aid field use. It is based on TurboPower Software's Object Professional 1.1 library, written for Turbo Pascal 6.

Data entry from manuscripts is now handled on a micro-based system, RODE PC. The same micros can also be used to unload data from the Micropalm units, providing a more flexible system than that previously used.

R.C. BOSWELL, G.J. HALL, L.M. HALSALL, T.J. HOUSTON

COMPUTING: NORTHERN RESEARCH STATION

Mainframe services

Computing Notes, in A4 ring binders, were issued to 50 computer users at the station. These explain, in simple terms, how to use some of the most important machines, commands, facilities and operating systems. Several new Notes were produced, including a newcomers' guide.

Distributing updates to these notes presented problems. The FCLASER program, which lists files to a laser printer, was modified to print a short title and a page number in a standard position on each page, so that new inserts could be kept in order. Other FCLASER enhancements included an Epson FX-100 printer driver, VT100 and VT320 previewers, and Fortran, C and Imp 'pretty-printing' facilities. The program has been heavily used.

Another program, FCMULTICOPY, was developed to prepare copies of a document for internal mail, each addressed to a name drawn sequentially from a list.

The FCALPHALAYOUT program, which produces field sheets and 'design files' for incomplete block experiments, was rewritten and simplified. It now generates experiment designs, removing the need to use an external package.

Work continued on the move from the EMAS operating system to UNIX and much Imp code was converted to C/SQL/Ingres.

Micro systems

User support and program maintenance claimed an ever-increasing slice of time. Digitising facilities were improved and a service was organised to back up microcomputer hard disks on to tape cartridges.

A program used by the Tree Improvement Branch, which allows plot data to be recorded in a portable encoder in a predetermined order convenient to the assessment team, was extensively rewritten. Prior entry of the plot-assessment order is now easier and more than two assessors can work concurrently.

Local area network (LAN)

An independent Visiting Group reported on the work of the Branch during 1990 and recommended that a local area network should be installed at the station. A special capital budget was approved. Cabling was installed to Ethernet IEEE 802.3 standards. Sun computers were purchased, essential software licences were negotiated and training started. Links to the Edinburgh University Computing Service will be retained but the LAN should improve micro facilities, help to unify the Commission's computing within the UNIX operating system, simplify database co-ordination within the ORACLE package and prepare the way for closer links with the country-wide network run by Headquarters.

R.W. BLACKBURN, K.P. DONNELLY

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COMMUNICATIONS

The accent continues to be on information technology (IT) development in managing ever increasing amounts of information and coping with demand.

During the year the Branch concentrated on improvements in promoting, publishing and marketing research results. Considerable effort was also devoted to publishing Forest Authority information for other Divisions, notably publication in the 'Guidelines' series and Occasional Papers dealing with *Forest employment survey* and *Supply and demand for wood in the UK.*

Visits to the Division continued at previous high levels and included three major visits by Timber Growers UK to the Northern Research Station and Alice Holt.

B.G. HIBBERD

LIBRARY AND INFORMATION SERVICE

A new high quality guide to the Library and its services was issued in 1990. It has received a wide distribution and generated more demand for our services. The Current Awareness Service is circulated very widely to those concerned with forestry and woodlands and copies even go to Belgium, Ireland and New Zealand. There were over 100 visitors to the Library, including a special visit by the Ecology and Conservation Studies Society.

Further extensions to computerisation include the installation of CAIRS LMS for recording journal holdings and controlling their circulation and a subscription to 'Current Contents on diskette', as well as continued development of CAIRS IMS for Library catalogues and references.

Borrowing of books and journals has shown an increase over last year and the supply of photocopies by the Library grew by 20%. The use of online databases has also increased.

C.A. OLDHAM

PHOTOGRAPHY

During the year new computer graphics software 'Zenographics-Mirage' and PCR matrix camera system were installed. Computer graphics are important media for the presentation of research data.

A heavy fieldwork season was completed with emphasis on farm woodland work and environmental subjects.

The cataloguing of the Section's extensive photographic library continued. By the end of the year there were 4000 entries on the CAIRS system.

G.L. GATE

PUBLICATIONS

Fourteen priced and 23 unpriced publications were issued during the year. Increased use is being made of computer-generated artwork in full colour.

Handbook 5 *Urban forestry practice* (published 1989) was one of three HMSO publications which this year received recognition for excellence. It was specially selected to demonstrate exceptional standards at the British Book Design and Production Exhibition in London and at the prestigious Frankfurt Book Fair.

Towards the year end a microcomputer-based stock control and valuation system was installed to increase the efficiency of administrative work in the Section. The program was written to provide easily-retrievable management information on stock movement, sales, customer profiles, etc.

The following titles were published during the year ending 31 March 1991:

Bulletins

89 Nitrogen deficiency in Sitka spruce plantations, by C.M.A. Taylor and P.M. Tabbush (£3)

90 Barn owl conservation in forests, by G. Shaw and A. Dowell (£3)

91 The timbers of farm woodland trees, by J.D. Brazier (£3)

92 Poplars for wood production and amenity, by J. Jobling (£6)

93 Ash dieback – a survey of non-woodland trees, by S.K. Hull and J.N. Gibbs (£4.50)

94 Monitoring of forest condition in Great Britain 1989, by J.L. Innes and R.C. Boswell (£8.50)

Field Books

10 Champion trees in the British Isles, by A.F. Mitchell, V.E. Hallett and J.E.J. White (£3.80)

11 Mid diameter volume tables (£3.65)

12 Assessment of tree condition, by J.L. Innes (£15)

Guidelines

Forest nature conservation guidelines (£4.50)

Occasional Papers

25 A new series of windthrow monitoring areas in upland Britain, by C.P. Quine and B.R. Reynard (£1.50)

26 Forest bird communities, by S.J. Petty and M.I. Avery (£5)

27 Forest employment survey 1988-89, by Jean Thompson (£1.50)

28 Edge management in woodlands, edited by R. Ferris-Kaan (£2.50)

Miscellaneous

Forest research (an account of the work of the FC's Research Division) (free)

Library and information service leaflet (free)

Research Information Notes

179 The use of containers as a method of raising tree seedlings

180 Grey squirrel damage control with warfarin (colour)

181 The introduction of improved poplar clones from Belgium

182 The effect of air quality on tree growth

183 The effect of air quality on the timing of tree shoot development

184 Research experience in direct sowing for lowland plantation establishment

185 Approved methods for insecticidal protection of young trees against *Hylobius abietis* and *Hylastes* species (supersedes RIN 140)

186 *Rhododendron ponticum* control

187 Chemical control of Sitka spruce natural regeneration

188 Potassium fertiliser – effects of different rates, types and times of application on height growth of Sitka spruce on deep peat

189 Climate change: the contribution of forestry to response strategies

190 Potential gains from genetically improved Sitka spruce (colour)

191 Grey squirrels and the law

192 Price-size curves for conifers

193 Forest condition in 1990 – preliminary results of the monitoring programme

194 Woodland management for pheasants

195 The establishment of trees in hedgerows (colour)

196 Forest drainage

197 Watermark disease of cricket bat willow: guidelines for growers

198 Vegetative propagation of oak using coppice shoots

199 Conservation management of woodlands by non-government organisations

E.J. PARKER

PART II

WORK DONE FOR THE FORESTRY COMMISSION BY OTHER AGENCIES

SILVICULTURE

HERBICIDE EVALUATION FOR FORESTRY USES

by D.V. CLAY[1] and J. LAWRIE

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

[1] Present address: Avon Vegetation Research, P.O. Box 1033, Nailsea, Bristol BS19 2FH

In this project improved herbicide treatments are sought for forest nurseries, newly-planted forest trees and certain problem weeds using container-grown plants.

Mixtures of soil-acting herbicides may be a useful means of obtaining long-term weed control on seedbeds but the possibility of increased crop damage requires investigation. Experiments showed that at higher doses damage to Japanese larch and Sitka spruce from mixtures of chlorthal-dimenthyl and diphenamid was greater than that from the individual herbicides.

The tolerance of newly-planted tree species to foliar-acting herbicides applied at four dates in the growing season was assessed on four broad-leaved and two conifer species. Bentazone and phenmedipham caused leaf necrosis on all species except Sitka spruce but damage was generally rapidly outgrown. Clopyralid had little adverse effect on any species.

The persistence of phytotoxic residues from pre-planting applications of imazapyr was studied in a model system using tanks of soil. There was severe damage to ash planted 6 weeks after soil treatment with 750 g a.e. ha^{-1} imazapyr but not to Sitka spruce. When planted 3 or 6 months after this treatment ash shoot growth was not reduced but some leaf distortion occurred.

In an experiment comparing the response of two perennial grasses to a range of doses of glyphosate applied at different dates in the growing season, spraying in August was least effective on *Calamagrostis epigejos* and applications from August to October poorest on *Holcus mollis*. This indicates the large effect that growth stage and condition can have on long-term effectiveness of glyphosate on these grasses.

The possibility of enhancing the activity of translocated herbicides on *Rhododendron ponticum* by the use of sequential sprays of different herbicides was tested but failed to show any clear synergistic effects.

SITE STUDIES

SOIL EROSION ON LAND CULTIVATED AND DRAINED FOR AFFORESTATION

by P.A. CARLING

Institute of Freshwater Ecology, Windermere Laboratory, Ambleside, Cumbria

The study of soil erosion in three types of cultivation on a peaty gley soil at Glen Skible, Kintyre Forest District has been completed. Furrows yielded 1.8 to 6.2 tonnes of sediment per 200 m run-length, with no difference between tine and non-tine plough furrows. Mole channels yielded up to 7 tonnes from each 200 m length. A rational basis for predicting erosion in furrows or drains on different slopes and soil types is being developed.

THE ROLE OF THE SOIL MICROBIAL COMMUNITY IN AREAS OF SHALE OVERBURDEN RECLAIMED TO FORESTRY AFTER OPENCAST MINING IN SOUTH WALES

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

Environment and Industry Research Unit, Polytechnic of East London

A correlation has been demonstrated between increasing microbial activity in the shale and tree growth. Further to this, areas treated with sewage sludge 3 years ago, have been investigated, with early results indicating an improvement in the structure, activity and the water holding capacity of the spoil.

Greenhouse studies have investigated applications of phosphate and NPK fertilisers with regard to microbial activity of the spoil, the types of mycorrhizal infection and tree growth. The use of coniferous tree roots, peat and deciduous leaf litter mould as inocula have been investigated. Correlations have been found to exist between phosphorus levels, certain mycorrhizal types, and tree growth.

EFFECTS OF UPLAND AFFORESTATION ON WATER RESOURCES – THE BALQUHIDDER CATCHMENTS

by R.C. JOHNSON

Institute of Hydrology, Balquhidder, Tayside

Research in the Balquhidder catchments has been carried out by the Institute of Hydrology since 1981. This year has seen the production of the 10-year report which has summarised the results so far (Johnson, 1991). Catchment water balance data continue to be collected, showing no apparent changes due to the clear felling of the Kirkton catchment. A model of catchment evaporation has been developed from the process studies. This has been used to explain the probable reasons for the differences in catchment water balances. The lower water use of the forested Kirkton catchment (17% compared to 22% in the moorland Monachyle catchment) is thought to be due to the very low annual water use of the significant area of higher altitude grassland within that catchment.

Water quality sampling continues, including chemistry, biology and sediments. Suspended sediment loads in the burns have shown the greatest change since the land use changes in 1986. Increased loads due to the ploughing in the Monachyle are now declining but the loads due to the clear felling in the Kirkton remain high.

REFERENCE

JOHNSON, R.C. (1991) *Effects of upland afforestation; the Balquhidder experiment.* Report No. 116, Institute of Hydrology, Wallingford.

EFFECTS OF CLEAR FELLING ON SUSPENDED SEDIMENT YIELD AT LOCH ARD FOREST

by R.I. FERGUSON
University of Sheffield
and
I.C. GRIEVE
University of Sterling

Suspended sediment concentrations (SSC) were monitored over a 3-year period in two streams in Loch Ard Forest north of Glasgow. During the monitoring period one catchment was clear felled using minimum disturbance techniques, the other remained under forest as a control. SSC maxima in both streams were recorded during a very wet period in early 1988, shortly after the start of felling. SSC in the experimental stream was greater than would be predicted from the larger discharge at this time. A sediment loss of at least 34 t km^{-2} during the first 3 months was related to this initial bankside clearance in the experimental catchment. This loss was some 13 times that from the control catchment. Losses from the experimental catchment declined after this initial phase to between 3 and 8 t km^{-2} $month^{-1}$, about four times those from the control catchment. Following cessation of harvesting in 1990, sediment losses from the experimental catchment recovered to less than 1 t km^{-2} $month^{-1}$, which is similar to the control catchment.

PHYSIOLOGY

AN APPARATUS TO APPLY CYCLIC LOADS TO ROOTS IN THE FIELD

by R.M. RITCHIE and M.F. O'SULLIVAN

Scottish Centre of Agricultural Engineering, Bush Estate, Penicuik, Midlothian

Root anchorage is a factor which can be reduced by the effects of dynamic loads. A machine was built which could apply cyclic loads to roots *in situ*, measuring both force applied and corresponding displacement of the root.

The apparatus (Figure 24) consists of a 240 V electric motor and 40:1 reduction gearbox, which rotate a disc at about 0.5 Hz. In turn, a connecting rod produces horizontal movement back and forth. In use, severed roots are gripped with a modified drill chuck.

Preliminary results suggest that the force needed to displace a root decreased with repeated load cycles as the root stretched and withdrew from the surrounding soil.

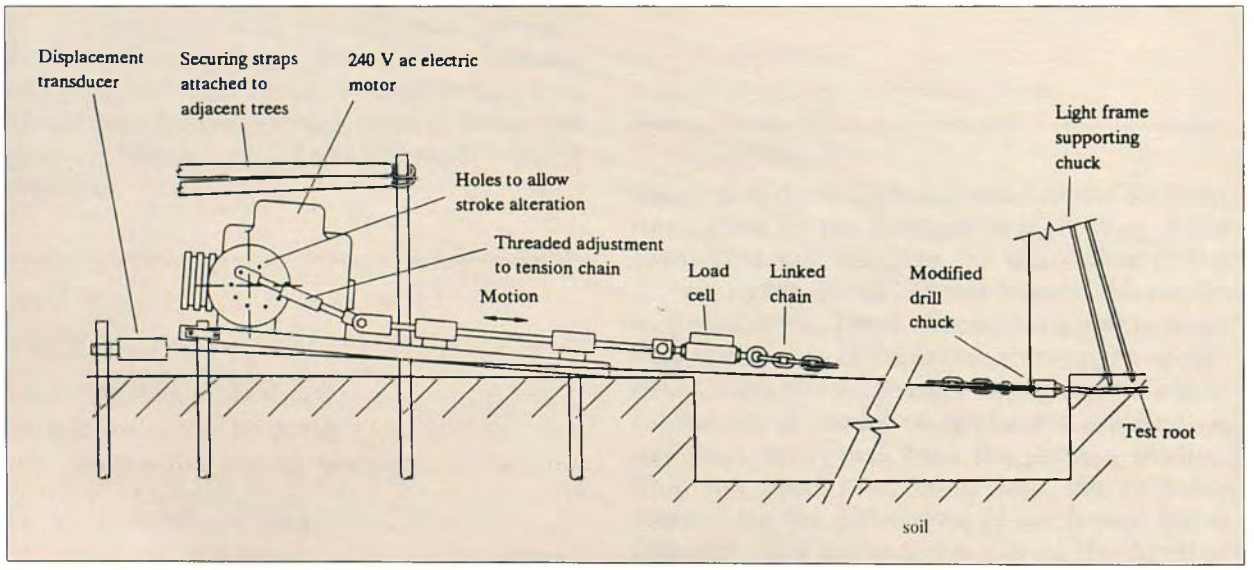


Figure 24. Schematic diagram of apparatus to apply cyclic loading to tree roots.

PATHOLOGY

VIRUSES IN BEECH

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

To evaluate claims that cherry leaf roll virus (CLRV) is associated with 'unhealthiness' in beech, a birch isolate of the virus (from UK) was inoculated into, but failed systemically to invade, 142 beech seedlings. Two methods of inoculation were used: insertion of virus-containing sap into slashed bark and, the more traditional, rubbing of carborundum-coated foliage. Analagous tests using a beech isolate of CLRV from Germany were initiated in the spring of 1990. So far, only 46 of 147 of these seedlings have been tested – none was invaded systemically as judged by serological tests (ELISA). Because CLRV is characteristically seed-transmitted, beech seedlings from seed collected in Germany (Saarbrucken) were tested for the virus: none of 159 such seedlings was infected.

The beech isolate of CLRV has many properties in common with the birch isolates that occur widely throughout Europe but may nevertheless have a distinct host range. Thus, an isolate of CLRV obtained from the pollen of a symptomless tree of *Populus nigra* growing in Oxfordshire, systemically invaded *P.* x *euramericana* cv. 'Boelare' whereas isolates of the virus from birch or rhubarb have not yet done so.

BEECH HEALTH AND AIR POLLUTION

by S.A. POWER and M.R. ASHMORE
Centre for Environmental Technology, Imperial College, London

The health of beech in southern Britain has now been surveyed at 16 sites for 4 successive years. Crown condition has deteriorated markedly in the past 2 years. 31.5% and 44.4% of the trees surveyed are currently in the worst two categories for crown thinness and crown architecture respectively, compared with values of 19.2% and 29.8% in 1987.

Overall there is an indication that below-ground factors may have a greater influence on tree health than above-ground factors. This is suggested by the fact that healthy and unhealthy trees differ in their soil chemistry, and especially their root systems, but are similar with respect to the measured leaf parameters. However, this study cannot show whether differences in above-ground tree health are a result of, or a cause of below-ground, root system differences. Climatic conditions (notably drought) are also clearly indicated as important factors influencing tree health. A clear link between pollutants and tree health has not been established but cannot be ruled out without more detailed studies.

ENTOMOLOGY

THE INFLUENCE OF ROOT APHIDS ON THE GROWTH AND PHYSIOLOGY OF SITKA SPRUCE

by E.J. MAJOR
University of Lancaster

Root aphids appear to be widespread on Sitka spruce of all ages. One of these *Pachypappa vesicalis*, is found throughout the year on the fine root system. Aphid colonies are conspicuous in leaf litter as a result of the secretion of white flocculent wax.

The objective of this project is to investigate whether the feeding activity of *P. vesicalis* restricts the uptake of water and nutrients to the roots and ultimately the rest of the tree. The majority of aphids colonise an area within 1 cm of the root tips in regions of cellular differentiation. Studies so far have shown that feeding on the roots appears to change the direction and rate of root growth and eventually leads to cessation of growth (Plate 18).

WILDLIFE AND CONSERVATION

NATURE CONSERVATION IN UPLAND CONIFER FORESTS

by J. GOOD
Institute of Terrestrial Ecology, Bangor, Gwynedd

This study examined the effects of design and management practices on flora and fauna in a large upland forest at Kielder, Northumberland.

Forest restructuring will have little effect on the conservation of semi-natural upland plant communities, but much effect on animals. Sedentary animals with poor dispersal ability are likely to benefit most.

Increased planting of native broadleaved woodland, which is generally scarce in the uplands, will greatly benefit the many plants and animals using this habitat.

Unplanted areas within forests provide many habitats which are scarce in the uplands in the absence of forestry. Their management should be integrated with that of the plantations to develop forests with maximum nature conservation values.

High altitude bog habitats were shown to be more sensitive to afforestation than drier, low altitude habitats. Bogs are also more difficult to restore and rarer in international terms.

CAPERCAILLIE ECOLOGY

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

A dichotomous key which classifies forest stands numerically according to their structure has been developed to aid understanding of capercaillie ecology in woodland. It is based on principal component analysis of structural features such as tree height and diameter, spacing, canopy closure and ground vegetation. Each stand has two scores, equivalent to the first and second principal components. The first ('old forest') score is high in the open forest resembling semi-natural Caledonian pine and the second score is greatest in tall, close-spaced stands with little ground vegetation.

The number of capercaillie cocks displaying at 18 leks was positively correlated with the average old forest score of stands within 1 km of the lek. Two important exceptions were fairly big leks in plantations – one of spruce, one of pine – where there were more cocks than expected from the score. This is encouraging because it indicates that capercaillie may survive in some managed forests. It is essential to find out why such forests support many birds, so that guidelines for management sympathetic to capercaillie can be developed.

MERLIN ECOLOGY

by S. PARR
Royal Society for the Protection of Birds, Sandy, Bedfordshire

Four study areas in Wales were surveyed for breeding merlins; two were predominantly heather moorland and two grassland sheepwalk. A total of 40 breeding pairs were located. Twenty five of these were in conifer plantation edges of which 76% were on sheepwalk. Twenty five nests were found and breeding success monitored. Breeding parameters, including egg size and nestling growth rates, were measured at a sample of plantation nests. A mean of 3.4 young fledged/successful nest (n=20 pairs). Two ground nests in heather failed during the incubation period; two broods were lost due to chilling in heavy rainfall and one to predators. The breeding data require analysis of survival using the Mayfield method because of the difficulty of location of pairs and the higher probability of locating successful nests. A total of 320 prey items were collected and identified. The data suggest that merlins preyed on conifer-edge species prior to laying and on open-country species during the incubation and nestling peri-

ods. Preliminary trials with radio-telemetry were successful and will be expanded next year to attempt to assess foraging habitats and area sizes.

The results support the hypothesis that sheep-walk populations have not declined significantly due to habitat changes, including afforestation, over the past 20 years, but that merlins now breed in conifer plantation edges, when they are available, in preference to other nest-site types. A re-analysis of a model of nest-site occupancy in relation to surrounding vegetation is being undertaken to quantify the habitat requirements.

THE ECOLOGY OF NIGHTJARS IN PINE PLANTATIONS

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

The 3-year project has now been completed. In the course of the study 29 nightjars were marked with radio-tags and tracked to obtain information on their habitat selection and ranging behaviour. During periods of activity nightjars showed a preference for grassy heaths and young pine plantations. Most foraging took place within 1 km of the nest site or home range centre. Analysis of the distribution of singing male nightjars showed that they were more likely to occur where there was a substantial area of young plantation (<6 years old) within 1 km. The nightjar population of Thetford Forest was estimated at about 300 singing males.

GROUND FLORA DYNAMICS OF SITKA SPRUCE PLANTATIONS

by E. ABDY
School of Agricultural and Forest Sciences, University of Wales, Bangor, Gwynedd

The object of this studentship project is to investigate the changes in ground vegetation under mature Sitka spruce and on newly regenerated clear fell sites. Plots on 12 sites at Clocaenog Forest are being monitored over a 3-year period (1989–1992). Twenty sites at two other north and mid Wales forests have also been assessed. The buried seed bank and seed rain are being studied. The biomass of *Calluna vulgaris* and *Vaccinium myrtillus* is being examined on conifer sites clear felled between 1 and 7 years previously.

MODELLING BIRD/HABITAT RELATIONSHIPS IN NORTHERN UPLAND SPRUCE FOREST

by I.J. PATTERSON and J.G. OLLASON
Aberdeen University Zoology Department, Culterty Field Station, Newburgh, Grampian

As large blocks of even-aged conifers approach felling age, the opportunity is being taken to restructure forests to provide mosaics of smaller blocks of different ages in subsequent rotations. It is predicted that this change will increase the density and diversity of bird populations through the creation of a more diverse habitat.

Bird population density and species diversity in upland spruce forests at Cowal and Kielder are being surveyed in relation to block size, tree age, altitude, amount of edge and other factors which can be manipulated during forest management. Surveys were started in winter 1990/91 and the data are currently being analysed; surveys of breeding species were carried out from mid-March to mid-June 1991.

The aim of this $2^1/_2$ year study is to provide a model to predict the effects of different management regimes on the density and diversity of bird population in northern upland spruce forest.

CONIFER SEED AS A FOOD SUPPLY FOR VERTEBRATES

by P.N. FERNS and R.J. COWIE
School of Pure and Applied Biology, University of Wales, Cardiff

Work has begun to determine the use made of conifer seeds by vertebrates. Field work is being done at Crychan Forest, Dyfed, which has good populations of crossbills and siskins following last year's bumper seed crop. Red squirrel densities are low. Wood mice eat seed and are common in mature Norway and Sitka spruce stands, but since rather little seed was shed during the course of the winter, they appear to have depended on the activities of birds and squirrels in making whole cones available on the ground.

Cone collections are being made at ground level and the birds and mammals which have been feeding on them are identified by the characteristic feeding signs made by each. Cone production by spruce trees is being estimated and is rather uneven throughout each block with some of the edge trees having particularly large crops.

REVIEW OF THE POTENTIAL FOR DOMESTIC STOCK GRAZING FOR WILDLIFE CONSERVATION IN FORESTS

by I. GORDON and J. FRASER

Macaulay Land Use Research Institute, Pentlandfield, Roslin, Midlothian

Macaulay Land Use Research Institute was contracted to assess the ecological case for domestic stock grazing as a method of managing forest habitats for wildlife conservation, and to design experimental tests of grazing regimes to assess their conservation, economic, agricultural and practical implications.

A literature review concluded that little information exists on the subject, despite the evidence for a historical influence of stock grazing shaping the vegetation mosaic of the UK. A more general review of literature on plant/animal interactions allowed conclusions to be drawn on grazing regimes which might achieve conservation goals. It was suggested that models of vegetation growth and animal offtake would allow an objective approach to managing stock grazing for enhancing the conservation value of forests.

THE EFFECTS OF CONIFEROUS AFFORESTATION ON THE GROUND FLORA AND CONSERVATION POTENTIAL OF THETFORD FOREST

by D. PRIGMORE

School of Environmental Sciences, University of East Anglia, Norwich

This research investigates the impacts of coniferous afforestation and commercial forestry management techniques, particularly the use of atrazine and glyphosate, on the ground flora of Thetford Forest. The conservation value of Breckland, the area of East Anglia in which the forest is located, lies in its open ground communities of heath and calcareous grassland. These have been affected by the afforestation with the result that the compartments support a very different flora and even the clear fells, at the end of the first rotation, support less valuable vegetation communities for conservation than the Breck grasslands and heaths which they have replaced. The search suggests some possible techniques to increase the floristic interest of the forest as it enters the second rotation, in the light of vegetation and seedbank trials, within the constraints of current forestry management practices.

FOREST PRODUCTS

RESEARCH ON BRITISH-GROWN TIMBER

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

Water-stored timber

To assess the effect of water storage on timber porosity, planks of softwood and hardwood cut from 18 and 24-month stored logs have now been kiln dried and re-sawn to 50 x 100 mm battens. The porosity 'air-leakage' technique developed by the Building Research Establishment for this work has been applied to all softwood and hardwood boards water stored for 6, 12, 18 and 24-month periods. Including controls, a total of 2100 boards have been processed and measured, the data input to the computer and analysis completed.

Results confirm expectations that porosity increases with water storage time. This was especially marked with Corsican pine although with Sitka spruce, increases in porosity could not be detected after 12 months although they were very apparent during the initial period of storage. Unfortunately, there have been problems with the beech material and the data are inconclusive; increases in porosity between 12 and 18 months were noted but the lack of sample material for 6 months storage and no reliable controls makes interpretation of the results difficult. All softwood timber samples were also stress graded and the results for the minimum E values indicated no significant deterioration in strength with increasing storage time up to 24 months; although some changes were noted in the structural classification yields they were inconsistent and small.

Properties of poplar timber

Progress in the work to determine strength properties of *P. robusta* from three different geographical areas in England has progressed. Small clear sections of timber to assess the properties of defect-free poplar timber have all been kiln dried and are conditioning before testing commences. In addition, conversion from poplar saw logs has yielded 450 battens for structural assessment and these were air-dried prior to testing. Observations on planed outer boards have also revealed compression creases, presumably resulting from wind damage in the growing tree.

Work on structural assessment of poplar timber has proceeded ahead of that on small clears; 260 battens selected at random to represent the three geographical sources have been kiln dried, regularised and machine stress graded using settings for structural classifications normally assigned to the SC3/SC1 and SC4/SC2 criteria applied to Sitka spruce. High yields for SC3 have been obtained similar to expectations for spruce; the lowest yield was 73% from the Wynyard Hill site. In general yields for SC4 are higher than expected for spruce. Most rejects at SC3 and SC4 occurred because of excessive spring and bow, and although much distorted material was passed by the stress grader, the visual appearance of the material was generally poor. Additional static bending work to assess the MOE/MOR relationship of 50 battens is complete and results plotted for each source. More static tests are needed to verify the quality of the results. These will be completed in the first quarter of 1991/92.

Grading rules for softwoods

Eurocode 5 issued by CEN (European Committee for Standardisation) for sawn and processed timber will eventually supersede the British Standard for structural use of timber. Currently, additional data are required for the five common British-grown timbers (Sitka spruce, Scots pine, Corsican pine, larch and Douglas fir) if they are to fully comply with the requirements of the Eurocode. To ensure this, a programme of testing is already underway. At the present, Sitka spruce and Scots pine material have been received, sampled and kiln dried (half of the pine remains to be kilned). Testing and analysis of data are complete for Sitka spruce. By agreement with the Forestry Commission, approximately five times the normal amount of data will be recorded in the grading machine. This will refine the precision of

the data and enable British-grown Sitka spruce to take advantage of possible future improvements in machine grading without the costs and time delays of acquiring additional test evidence later.

TIMBER RESEARCH

by A.R. ABBOTT

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

Strength assessment of windthrown pine

Visual inspection of sections cut from logs revealed that a small proportion of windthrown trees had observable compression creases particularly on the impact side of the stem. In an effort to find a method of detecting such internal damage using non-destructive means logs and battens cut from the same logs were assessed. Static bending tests were carried out on logs to establish the modulus of elasticity (MoE) in a number of directions, and the battens were subjected to machine stress grading. The resulting evidence suggested that measurement of MoE could be a means of detecting serious compression crease damage in logs but the sample tested contained too few logs with compression creases for the results to be statistically significant. Compression crease damage in the battens was not detectable by machine grading. Additional problems were created by testing the logs to failure after the measurement of MoE. This procedure induced further creases in the timber and, upon examination of the battens, it was not possible to determine whether the creases found had been present prior to the testing. For any further investigation into the practicalities of using MoE to detect compression creases, it would be necessary to obtain logs with a high frequency of compression creases and to cut battens from some of these for further tests after the non-destructive measurement of MoE in each individual pole. Under these circumstances it should be possible to assess critically the effectiveness of this technique in detecting compression damage due to windthrow or felling impact.

Laminated veneer from European-grown species

This European Community project involves three partners, TRADA as co-ordinators, the Danish Technical University and the French CTBA. The Forestry Commission is also acting as an industrial sponsor which includes selecting and providing the necessary material for this project. The objectives of the programme of work are to demonstrate both the technical and economic benefits and viability of manufacturing laminated veneer lumber (LVL) using timber grown within the Community. Species under test will include Sitka spruce from various sources including Britain, poplar and possibly maritime pine. Spruce material has already been selected from Britain and will be manufactured into LVL on a commercial scale and then subjected to a range of physical and mechanical tests to compare properties with sawn timber of the same species. There are also plans to include British-grown poplar material in a laboratory scale manufacture of LVL and subject it to a similar test regime.

PREVENTION OF DECAY IN AIR SEASONING UTILITY POLES

by D.J. DICKINSON

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

In the first phase of this project (*Report* 1990, p.99) it was shown that air seasoned British-grown Scots pine and Corsican pine are subject to colonisation by wood rotting basidiomycetes during the necessary pre-treatment drying period. Encouraging initial field trials suggested borates and possibly the biological control agent *Trichoderma* could be effective in deterring colonisation by these decay causing fungi.

Major trials have now established that borate can give excellent control of decay fungi for up to 18 months. The trials have also demonstrated the minimum levels of borate required and established recommended handling procedures. Environmental impact studies indicate that runoff during borate treatment is minimal and the procedure is being adopted by the preservation industry.

However, the treatment is dependent on the provision of infection free, fresh logs from the forest. Little is known about how effective the treatment is for logs already infected through delays in delivery. Also, the potential for biological control by *Trichoderma* species has not been fully investigated. In order to answer these and other questions, a SERC CASE award leading to a Ph.D. over the next 3 years has been established for studies in this research area. The project will be jointly supervised by Imperial College and the Forestry Commission.

TIMBER PRESERVATION

by R.J. MURPHY

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

Research on the preservative treatment and durability of UK-grown timber and timber products has continued through the sponsored lectureship in Forest Products at Imperial College, London. The areas covered in the review period include greenwood treatments for Sitka spruce, gas phase treatments of softwood timbers and panel products, co-operative research with the Building Research Establishment (BRE) on treatment methods and treatment and durability studies on poplars.

Research on accelerated boron diffusion treatments for sawn Sitka spruce has led to considerable shortening of diffusion storage times which, in the past, limited the practical application of the method. It is now clear that Sitka spruce construction timbers can be given a very high quality of preservative treatment such as boron diffusion treatments. Further work, supported by the CEC, will begin shortly to develop a database of scientific information on the permanence of the treatment under various service conditions. This will complete a full technical case for the use of boron diffusion treatments for home-grown spruce. Additional studies with Sitka spruce have evaluated the use of steam-Bethel treatment of roundwood with CCA preservatives. Considerable improvements in penetration were noted over conventional methods but further work is required to fully evaluate this approach. The above studies have been supported by the CEC and members of the UK preservation industry.

Scale-up trials on the gas phase treatment of panel products have been successfully completed. Commercial application of the method (protected by international patents) for treatment of oriented strand board (OSB) and other panel products against fungal and insect attack is expected in the near future. Additional studies have shown that flame retardant loadings can be delivered to OSB (Class 1, surface spread of flame) and further work on this is in progress. The treatment of solid timber is also under investigation using gas phase techniques.

Co-operative research with BRE aims to determine the effect of different timber treatment processes on the efficacy of CCA type preservatives in UK-grown softwoods. Initial studies have been commenced with Corsican pine and further work will include Sitka spruce. The work has been initiated to provide scientific data on which to base choice of treatment method as a result of the proposed changes in wood preservation standards after 1992.

Studies on poplar have been concerned with basic evaluations of treatment properties with CCA preservatives. Some problems with refractory sapwood and a refractory zone at the sapwood/heartwood boundary have been noted and anatomical work conducted to indicate the causes. Further work is planned on a wider range of poplars.

EFFECT OF FERTILISER APPLICATION ON SITKA SPRUCE WOOD

by J.A. PETTY and E.C. MACDONALD

Department of Forestry, University of Aberdeen

The aim of this project was to determine how applications of N, P and K fertiliser to Sitka spruce affect the anatomy and hence quality of the wood formed, in ways independent to those associated with vigour. The sample trees used were taken from three existing Forestry Commission nutrition experiments, where a significant growth response to fertiliser application (either N, P or K) had been reported. At each of the three sites, 16 control (not fertilised) and 16 fertilised trees were sampled. A system of stratified random sampling was used, with the strata being four diameter classes.

Ring width, basic density, tracheid diameter, tracheid wall thickness and tracheid length were examined on nodal discs cut at breast height, looking at the wood formed 1–5 years before fertiliser application, 1–5 years after fertilisation and 6–10 years after fertilisation. Knot diameter was studied on nodal discs cut from the crown, at pre-fertilisation and 7 years post-fertilisation points. Analysis of variance was used to compare the control trees with the fertilised trees, looking at the relative change (following fertiliser application) in each of the parameters being investigated.

The data indicated there were no significant differences in relative change in ring width between the control and the fertilised trees at any of the sites. Thus in terms of vigour there was no significant difference between the two groups of sample trees used. Any differences in other properties studied could not therefore be attributed to differences in vigour, and could be

assumed to be due to the effect of fertiliser application.

There was no evidence that any of the properties studied on the breast height internodal discs (basic density, tracheid diameter, tracheid wall thickness and tracheid length) were significantly affected by application of N, P or K. In contrast, knot diameter did appear to be affected by fertiliser application and this was independent of increased vigour. Application of nitrogen brought about a greater increase in knot diameter than was found in the control trees. Following the application of phosphorus however, the fertilised trees had a smaller increase in mean knot diameter than that of the control trees. The application of potassium did not have a significant effect on knot diameter overall, although in certain diameter classes the fertilised trees showed greater increases than the control.

APPENDIX I

PUBLICATIONS BY RESEARCH DIVISION STAFF

ANON. (1990). *Mid diameter volume tables.* 3rd edtn. Forestry Commission Field Book 11. HMSO, London
Tables used in the traditional method for estimating the volume of logs.

[ARNOT, J.M.,] McNEILL, J.D. [& WALLIS, B.F.J.] (1991). Operational experiences of sludge application to forest sites in southern Scotland. In, *Alternative uses for sewage sludge.* Proceedings of a conference organised by WRc Medmenham and held at the University of York on 5–7 September 1989. Ed. Hall, J.E.; 139–153.

Sewage sludge application to trial sites on mineral, heathland and opencast reclamation in south Scotland has provided rapidly increased tree growth where crops are suffering from nitrogen and phosphorus deficiency.

[BARTOS, L., McCULLOUGH, D.R.,] RATCLIFFE, P.R., [REGELIN, W.L., SERVHEEN, C. & THOMPSON, I.D.] (1990). Summary of suggestions (for wildlife management in Hokkaido). In, *Proceedings of the deer and bear forum,* Hokkaido, 1990. Eds Ohtaishi, N., Kaji, K. & Mano, T.; 112, 186–187.

Suggests the establishment of a wildlife agency to apply research data in the management of deer and bears, and a public information programme. Suggests improved habitat management and prohibition of import of exotic mammals to achieve nature conservation objectives.

[BAYES, C.D.,] TAYLOR, C.M.A. and MOFFAT, A.J. (1991). Sewage sludge utilisation in forestry: the U.K. research programme. In, *Alternative uses for sewage sludge,* ed. Hall, J.E., 115–118. Pergamon Press, Oxford.

BOOTH, T.C. (1990). Preparation of a research and extension service programme for farm forestry in the United Kingdom. In, *Marginal agricultural land and efficient afforestation.* Proceedings of a workshop in the CEC land and water use research programme, held in Gembloux, Belgium, 20–21 October 1988. Eds Bock, L. & Rondeaux, J.; 171–177.

Changes in land use within the EEC have made it essential to consider future research on the establishment and management of farm forestry. By following a methodical approach and a search for differences between the two industries it is possible to identify and place priorities on lines of research. In order to develop an effective extension service it is necessary to integrate forestry and farming research expertise to provide appropriate technical support.

BRASIER, C.M. (1990). The unexpected element: mycovirus involvement in the outcome of two recent pandemics, Dutch elm disease and chestnut blight. In, *Pests, pathogens and plant communities.* Eds Burdon, J.J. & Leather, S.R.; 289–307.

Considers the epidemic history of *Ophiostoma (Ceratocystis) ulmi* and *Cryphonectria (Endothia) parasitica* and highlights an unexpected element which may have significantly influenced epidemic outcome in both systems: the role of mycovirus infection.

[BURDON, J.J. &] LEATHER, S.R. (eds) (1990). *Pests, pathogens and plant communities.* Blackwell Scientific Publications, Oxford/British Society for Plant Pathology. 333 pp.

Arose from a meeting held at the University College of North Wales, Bangor, in April 1989. It contains 19 chapters by pathologists, entomologists and botanists. It is divided into four sections; overviews, demographic interactions between plant and parasite populations, genetic interactions between plant and parasite populations, and long-term consequences of host-parasite interactions.

[CAPE, J.N.,] FREER-SMITH, P.H., [PATERSON, I.S., PARKINSON, J.A. & WOLFENDEN, J.] (1990). The nutritional status of *Picea abies* (L.) Karst. across Europe, and implications for 'forest decline'. *Trees: structure and function* **4** (4), 211–224.

Three year-classes of foliage from 30-year-old Norway spruce were sampled from 12 sites across Europe. Where trees were showing symptoms of decline (at German sites) samples were taken

from trees with good and poor crown condition. At sites with trees of poor crown condition, even apparently healthy trees showed a lack of increase in calcium content with needle age, decreases in nitrogen content and very large decreases in magnesium content with needle age.

CARTER, C.I. (1991). Ride orientation and invertebrate activity. In, *Edge management in woodlands*. Proceedings of a symposium held at Alice Holt Lodge on 17 October 1989. Forestry Commission Occasional Paper 28. Ed. Ferris-Kaan, R.; 17–21.

Ride orientation is critically important with regard to the sunlight hours received. This influences the development of ground flora within forest plantations which in turn affects the number and diversity of invertebrates.

CARTER, C.I. [& DANIELSSON, R.] (1991). Two spruce root aphids, *Pachypappa vesicalis* and *Pachypapella lactea* new to Britain with illustrated keys to the morphs from *Picea* roots. *The Entomologist* **110** (2), 66–74.

Two species of spruce root aphids, *Pachypappa vesicalis* and *Pachypapella lactea*, hitherto unrecorded in the British Isles have been found to be widely distributed there. An account is given of their feeding site and life history together with illustrated keys to the apterous and alate morphs.

[CLARIDGE, M.F. &] EVANS, H.F. (1990). Species-area relationships: relevance to pest problems of British trees? In, *Population dynamics of forest insects*. Eds Watt, A.D., Leather, S.R. Hunter, M.D. & Kidd, N.A.C.; 59–69.

A reanalysis of data on insect diversity on British trees making use of the Forestry Commission census data to provide accurate estimates of areas occupied by various tree species. There was no correlation between area and species diversity on broadleaved trees while for conifers there was a stronger but barely significant correlation.

COUTTS, M.P. & NICOLL, B.C. (1990). Growth and survival of shoots, roots, and mycorrhizal mycelium in clonal Sitka spruce during the first growing season after planting. *Canadian Journal of Forest Research* **20** (7), 861–868.

The plants were grown out of doors in perspex tubes of peat. Two clones became mycorrhizal predominantly with *Thelephora terrestris*, but in a third clone some plants were colonised by *T. terrestris* and some by *Laccaria proxima*. The extramatrical mycelium of *T. terrestris* grew at about half the rate of the main roots during the summer and by November it had grown about 25 cm.

COUTTS, M.P. & NICOLL, B.C. (1990). Waterlogging tolerance of roots of Sitka spruce clones and of strands from *Thelephora terrestris* mycorrhizas. *Canadian Journal of Forest Research* **20** (12), 1894–1899.

The root systems of clonal plants growing in perspex tubes of peat were partially waterlogged, in either October or November, and were drained in the following spring. Clonal differences in the survival of waterlogged roots were small, but roots survived much better when waterlogging was carried out in November than when it was done in October. Extramatrical hyphae of *Thelophora terrestris* were killed by waterlogging but hyphal strands survived remarkably well.

DANBY, N.P. (1991). *Nothofagus* in wales. *Quarterly Journal of Forestry* **85** (2), 103–116.

Growth of *Nothofagus* in a series of trial plots established between 1956 and 1971 and in provenance experiments is described. Growth is rapid in Wales but trees more than 20 km from the coast can suffer badly, especially to the bole, from the effects of extreme cold. The most commercial species is *N.procera* from inland central Chile (38–40°S) and the genus has a place in broadleaved amenity planting.

DOBSON, M.C. (1990). When salt goes, trees live. British Association for the Advancement of Science Magazine, *SCOPE* 22, Winter 1990,7.

Outlines the history of de-icing salt damage to trees in Britain and possible solutions to the problem.

DOBSON, M.C. (1991). Killer condiment. *Surveyor*, 21 February 1991, 17–18.

An introduction for the highway engineer and layman to the damaging effects that de-icing salt, spread on roads and pavements in winter, can have on adjacent trees. Recommendations are given for improving salt storage and spreading practices to minimise the problem.

DOBSON, M.C., TAYLOR, G. & FREER-SMITH, P.H. (1990). The control of ozone uptake by *Picea abies* (L.) Karst. and *Picea sitchensis* (Bong.) Carr. during drought, and interacting effects on shoot water relations. *New Phytologist* **116**, 465–474.

The effects of ozone (O_3) episodes and drought on O_3 uptake, gas exchange and water relations of Norway and Sitka spruce were investigated. Flux of O_3 to watered plants was greater than to the unwatered plants at all fumigation concentrations. This was partly attributable to the greater stomatal conductances recorded for the watered plants, but was also partly due to stomatal opening caused by O_3, an effect which was diminished or reversed for unwatered plants. O_3 significantly increased solute potential in trees

subjected to 7 days of drought, an effect which was lost after 14 days of drought.

DUTCH, J.C. [& INESON, P.] (1990). Denitrification of an upland forest site. *Forestry* **63** (4), 363–377.

Rates of nitrogen loss through denitrification were monitored for standing forest and adjacent clear felled areas located on a peaty-gley soil at Kershope Forest in the north of England, in 2-year-long studies. An annual loss of 1–3 kg N ha^{-1} was estimated for the standing forest while losses from the clear felled sites were estimated at 10–40 kg N ha^{-1} during the first 2 years after felling. This loss returned to pre-felling levels 4 years after felling.

DUTCH, J.C., TAYLOR, C.M.A. [& WORRELL, R.] (1990). *Potassium fertiliser: effects of different rates, types and times of application on height growth of Sitka spruce on deep peat.* Forestry Commission Research Information Note 188.

Several experiments are described which examined the effects of different application rates and types of potassium (K) fertiliser on the growth of Sitka spruce on new planting sites. The effects of different times of year of application were also tested. Results confirm that the current prescription of 100 kg K ha^{-1} supplied as 200 kg muriate of potash ha^{-1} is correct and that the fertiliser can be applied at any time of year, provided the ground is not frozen or snow-covered.

[ENTWHISTLE, P.F.,] EVANS, H.F., [CORY, J.S. & DOYLE, C.] (1990). Questions on the aerial application of microbial pesticides to forests. In, *Fifth International Colloquium on invertebrate pathology and microbial control*, Adelaide, Australia, 20–24 August 1990, 159–163; proceedings and abstracts, organised by Society for Invertebrate Pathology.

The parameters required to utilise viral control agents effectively are described and related to examples in British forestry. In particular the efficient distribution of droplets through the forest canopy and the relationship to distribution of feeding insects is considered.

EVANS, H.F. (1990). The use of bacterial and viral control agents in British forestry. In, *The exploitation of micro-organisms in applied biology*, 195–203. Association of Applied Biologists.

A review paper summarising a range of experimental and operational uses of bacterial and viral agents against forest defoliators in Britain.

EVANS, H.F., STOAKLEY, J.T., LEATHER, S.R. [& WATT, A.D.] (1991). Development of an integrated approach to control of pine beauty moth in Scotland. *Forest Ecology and Management* **38** (1–4), 19–28.

Describes outbreak populations of *Panolis flammea* in the late 1970s and the management programmes from 1976 to 1981, then the second phase from 1982 to 1988 when methods and techniques were refined, and the research into the development of an integrated pest-management approach for this pest.

EVANS, J. (1990). Long-term productivity of forest plantations: status in 1990. In, *Proceedings of the 19th IUFRO World Congress*, Montreal, Canada, 5–11 August 1990; **1** (2), 165–180.

Growing successive forest crops on a site raises questions of sustainability, nutrient depletion and long-term productivity. A review of experience where accurate records have been maintained indicates that, at the moment, there is little evidence to suggest that intensive plantation forestry will not be sustainable on most sites.

EVANS, J. (1990). Use and abuse of tropical forests. *Science and Christian Belief* **2** (2), October, 141–144.

A review of the causes of tropical deforestation, highlighting matters of corruption, north–south trade flows and debt, as well as factors of land use, logging and other pressures on forests.

EVANS, J. & HIBBERD, B.G. (1990). Managing to diversify forests. *Arboricultural Journal* **14** (4), 373–378.

Forest managers have several means at their disposal to increase diversity in their forests including extending rotations, widening rides, re-structuring, introduction of native species, etc. These measures are discussed in the context of new woodland established on farms and as part of community forests. Originally presented at the 'Symposium on new woodlands: development for diversity', Arboricultural Association, Wolverhampton Polytechnic, March 1990.

FERRIS-KAAN, R. [& WARRENER, S.J.] (1990). *A survey of ride management practices by Forest Districts in England and Wales, 1989 to 1990.* Forestry Commission Research Division, Wildlife & Conservation Research Branch, Farnham, Surrey. 17 pp.

The results of a questionnaire survey of all Forest Districts in England and Wales in 1989/90 in relation to ride management operations are given. Particular attention is given to management with conservation objectives, and problems are highlighted. Recommendations for research and development are made in the light of these results.

FERRIS-KAAN, R. (1991). *Conservation management of woodlands by non-government or-*

ganisations. Forestry Commission Research Information Note 199.

This Note summarises the findings of a study of methods of woodland management for conservation used by non-government organisations (NGOs). The study was set up to draw upon the extensive unpublished knowledge in this subject area which exists within NGOs.

FERRIS-KAAN, R. (ed.) (1991). *Edge management in woodlands.* Proceedings of a symposium held at Alice Holt Lodge on 17 October 1989. Forestry Commission Occasional Paper 28. Forestry Commission, Edinburgh.

Brings together latest research concerned with management of woodland edges (rides, roadsides, riparian zones, external boundaries) and reviews likely impacts on various taxonomic groups.

FLETCHER, A.M. & SAMUEL, C.J.A. (1990). Early height growth in the IUFRO seed origins of noble fir in Britian. In, *Proceedings of joint meeting of IUFRO Working Parties S2. 02–05, 06, 12, 14,* Olympia, Washington, USA, August 1990. 2.98; 16 pp.

Analysis of third and sixth year height data from 8 experiments comprising 15 IUFRO collections of noble fir is presented. This species has a more restricted natural range than other *Abies* species, concentrated along the upper slopes of the Cascade Range in Washington and Oregon and in the Coast Range in Oregon. Origins from the Cascades Range were on average superior to those from the Coast Range with the best material coming from southern Washington and northern Oregon.

FLETCHER, A.M. & SAMUEL, C.J.A. (1990). Growth and branching characteristics in the IUFRO origins of Douglas fir 16 years after planting in Britain. In, *Proceedings of joint meeting of IUFRO Working Parties S2. 02–05, 06, 12, 14,* Olympia, Washington, USA, August 1990. 2.71; 11 pp.

Height, diameter and three branching characteristics were measured 16 years after planting on 38 origins of Douglas fir at two sites in south-west Britain. Basal area and volume were also calculated. Origins with the most favourable growth and branching characteristics were found to the west of the Cascade Range in Washington and parts of northern Oregon. Origins from British Columbia had below average vigour.

FLETCHER, A.M. & SAMUEL, C.J.A. (1990). Height growth of the IUFRO grand fir seed origins in Britain. In, *Proceedings of joint meeting of IUFRO Working Parties S2. 02–05, 06, 12, 14,* Olympia, Washington, USA, August 1990. 2.82; 16 pp.

Combined analysis of six and ten year data from 34 IUFRO collections growing at 11 sites is reported. Among coastal origins, which performed better than those from inland areas, those from Washington had the greatest height growth, but Vancouver Island and Oregon sources had above average height. While origin x site interaction was noted, it may be relatively unimportant if only better quality sites are used for this species in Britain.

FORREST, G.I. (1990). Fingerprints of the Caledonian pine. *Forest Life* 7, March 1990, 2–3. Forestry Commission, Edinburgh.

Resin composition has been used to study the genetic variation within and between the native Scots pine woodlands.

FREER-SMITH, P.H. (1990). *Climate change: the contribution of forestry to response strategies.* Forestry Commission Research Information Note 189.

The Intergovernmental Panel on Climate Change has included forestry among its considerations and a number of important conclusions have emerged. The total global emissions of carbon dioxide (CO_2) from the burning of fossil fuels are estimated at more than *c.*5 billion tonnes per year. The world's trees contain between 400 and 800 billion tonnes of carbon. The fluxes of greenhouse gases, particularly CO_2, between forests and the atmosphere probably have an important effect on world climate. The potential for the storage of carbon in trees in the UK and continental Europe, and on a global basis, is considered in this publication.

FREER-SMITH, P.H. (1990). Forests and climate change. *Timber Grower* 116, Autumn 1990, 17, 19.

Anthropogenic greenhouse gases may be causing a significant change to the world climate. Predictions of future UK climate remain uncertain but the possible effects on forestry are discussed.

[FRY, R.] (compiler) (1991). *Habitat conservation for insects: a neglected issue.* Eds Fry, R. & Lonsdale, D. *Amateur Entomologist* **21**.

The ecological roles and the special habitat requirements of insects are explained in support of the view that they and other invertebrates require adequate consideration in land management. These habitat requirements are described in detail together with management guidelines for: grassland; arable land; woodland; heathland and moorland; wetlands and freshwater bodies; gardens and other formally managed types of site.

GIBBS, J.N. & GREIG, B.J.W. (1990). Survey of parkland trees after the great storm of October 16, 1987. *Arboricultural Journal* **14** (4), 321–347.

A survey was conducted of 3954 parkland trees in 20 plots in southern England, approximately a quarter of which had suffered significant injury. The incidence and the nature of damage varied between species. So also did the amount of decay that was associated with the failure point. Data are also presented on the fungi causing decay, on the role of pre-existing structural weakness in the performance of the trees, and on the influence of soil type on windthrow.

GILL, R.M.A. (1991). Grazing animals: their impact and potential value in ride management. In *Edge management in woodlands*. Proceedings of a symposium held at Alice Holt Lodge on 17 October 1989. Forestry Commission Occasional Paper 28. Ed. Ferris-Kaan, R.; 49–56.

Reviews the impact of herbivores on forest vegetation and discusses the possibilities for their use in ride management.

GOSLING, P.G. (1991). Beechnut storage: a review and practical interpretation of the scientific literature. *Forestry* **64** (1), 51–59.

Beechnuts are not easy to store or long lived under any storage conditions. They exhibit storage characteristics between those of 'orthodox' and 'recalcitrant' seeds. Superimposed on this is a pronounced dormancy which is overcome by anything from 4 to 20 weeks of moist chilling, depending on the seed lot. Most evidence points to the best short-term (less than 6 months) storage/pretreatment conditions being 0–5°C at 28–32% moisture content (freshwater basis). Long-term storage (more than 6 months) requires –10°C at *c.* 10% moisture content.

GOSLING, P.G. & PEACE, A.J. (1990). The analysis and interpretation of ISTA 'double' germination tests. *Seed Science and Technology* **18**, 791–803.

The International Seed Testing Association has prescribed 'double' germination tests (one with and one without pretreatment) to assess the quality of many temperate conifer species since 1966. However, no guidance has ever been issued about how the results from these extremely labour intensive tests can be interpreted by nursery managers. This paper describes a simple arithmetic analysis of 'double' germination tests which provides an objective means for deciding whether or not pretreatment will benefit nursery emergence.

GOSLING, P.G. & RIGG, P. (1990). The effect of moisture content and prechill duration on the efficiency of dormancy breakage in Sitka spruce (*Picea sitchensis*) seed. *Seed Science and Technology* **18**, 337–343.

Using the traditional dormancy breakage prechill technique, premature germination of tree seeds is commonplace. This is a significant problem to nursery managers because sprouted seeds are easily killed during their passage through sowing machines. This paper identified the range of moisture contents over which Sitka spruce seeds respond to prechilling. It was the first report of its kind for any species. The results are not only scientifically interesting but also of considerable practical significance – some of the moisture contents enabled dormancy breakage to occur without ever permitting premature germination.

HARMER, R. (1990). Relation of shoot growth phases in seedling oak to development of tap root, lateral roots and fine root tips. *New Phytologist* **115**, 23–27.

Root and shoot growth were not closely coupled. There were about six first order laterals per cm of tap root but the relationships between length of the lateral root system, number of root tips and tap root length changed during growth. There was no evidence that rhythmic growth in oak is related to unfavourable root:shoot ratio caused by rapid growth of the shoot and leaves during a flush.

HARMER, R. (1990). The timing of canopy and epicormic shoot growth in *Quercus robur* L. *Forestry* **63** (3), 279–283.

Shoot development from buds on the branches and trunk of *Quercus robur* were observed over 2 years. Shoots on crown branches began development before those on existing epicormic branches but both stopped growing at about the same time. Epicormic buds on the trunk began expanding 3–4 weeks after crown buds, and finished growth 3 weeks later. These observations do not support previous claims that new epicormic shoots grow before development of the canopy.

HARMER, R. & BAKER, C.A. (1991). *Vegetative propagation of oak using coppice shoots.* Forestry Commission Research Information Note 198.

The origin and growth of coppice shoots is described. A method of using these shoots for the vegetative propagation of oak is explained and a practical example using shoots collected in mid-Wales is presented.

[HATCHER, P.E. &] WINTER, T.G. (1990). An annotated checklist of British conifer-feeding macro-lepidoptera and their foodplants. *Entomologist's Gazette* **41**, 177–196.

With the increase in British forestry this century there are now many more opportunities for lepidoptera that normally feed on angiosperms to come in contact with mature conifers. Some species have taken advantage of this situation and are included in the 75 species listed from the authors' own experiences and from 91 literature references.

HODGE, S.J. (1990). Hedgerow trees. *Timber Grower* 117, Winter 1990, 23.

Various establishment techniques for hedgerow planting have been undertaken by the forestry Commission with a view to halting the decline of our hedgerow trees.

HODGE, S.J. (1990). *Organic soil amendments for tree establishment.* Arboriculture Research Note 86/90/ARB. DOE Arboricultural Advisory & Information Service, Farnham, Surrey.

The addition of organic materials to amenity tree planting pits has become standard practice. However, experiments to evaluate a number of commonly used organic soil amendments have shown no consistent benefit from their use. Money spent on these materials, particularly peat, could be better spent on comprehensive site preparation and a higher level of after care. (Also published in *Urban forests*, issue 4, summer 1990, 9–10, as Technical Update Sheet No.4; *Midlands Landscape Quarterly*, Summer 1991, 17–19)

HODGE, S.J. (1990). *The establishment of trees in new hedgerows.* Arboriculture Research Note 90/90/ARB. DOE Arboricultural Advisory & Information Service, Farnham, Surrey.

Experimental results demonstrate that the use of polythene sheet mulch is the most effective method of establishing new hedgerows. Transplants, protected with 1.2 m treeshelters, should be used to establish trees within hedgerows. The cost of weed control in new hedgerows and of establishment of hedgerow trees using four stock sizes are detailed.

HODGE, S.J. (1990). *The establishment of trees in existing hedgerows.* Arboriculture Research Note 91/90/ARB. DOE Arboricultural Advisory & Information Service, Farnham, Surrey.

Planting is generally the most effective and economical means of establishing trees in hedgerows; the use of natural shoots and saplings being generally unacceptable or impracticable. Natural gaps occurring in the hedge should be utilised or notches cut to allow access for planting and weed control. Transplants should be used and protected with treeshelters. Weed control should be by a sheet mulch where possible, or by careful use of herbicides.

HODGE, S.J. (1990). *The influence of nursery spacing on outplanting performance of amenity trees.* Arboriculture Research Note 93/90/ARB. DOE Arboricultural Advisory & Information Service, Farnham, Surrey.

Close spacing of half standards and large whips in the nursery can reduce stem diameter at lifting and height and diameter growth after three growing seasons on the planting site. The whole range of nursery spacings tested, for 10 cm to 50 cm in the rows, influenced the growth of half standard sized trees, both in the nursery and after planting out. For large whips, spacings above 20 cm had little effect on tree growth in the nursery and no spacing had any effect on growth after outplanting.

HODGE, S.J. (1991). *The establishment of trees in hedgerows.* Forestry Commission Research Information Note 195.

Hedgerows and hedgerow trees are important elements of the British lowland countryside and are being lost by removal and lack of management. Research, funded by the Department of the Environment, has shown that planting using transplants in treeshelters is generally the most effective and economical means of establishing trees in hedgerows. The use of natural shoots and saplings in existing hedgerows is generally unacceptable or impracticable. Natural gaps occurring in the hedge should be utilised, or notches cut to allow access for planting and weed control. Weed control for new hedges and hedgerow trees should be by polythene sheet mulch where possible, or by careful use of herbicides.

HODGE, S.J. & WHITE, J.E.J. (1990). *The ultimate size and spread of trees commonly grown in towns.* Arboriculture Research Note 84/90/ARB. DOE Arboricultural Advisory & Information Service, Farnham, Surrey.

Published information on the ultimate sizes of the commonly planted amenity trees reflects performance in open grown positions. This Note reports sizes of trees growing in urban conditions. If the data are used when selecting trees for urban situations the need for future expensive pruning and early felling can be reduced.

HODGE, S.J. [& WALMSLEY, T.J.] (1990). *The use of water retentive materials in tree pits.* Arboriculture Research Note 92/90/ARB. DOE Arboricultural Advisory & Information Service, Farnham, Surrey.

The potential benefits of using water retentive polymers at planting has been demonstrated in

laboratory tests and container trials carried out by the Forestry Commission and Liverpool University. However, of the five products tested in field experiments, only Aquastore significantly improved the growth of newly planted trees. Water retentive polymers may be of benefit in situations where irrigation can be assured and may allow an extension of the interval between irrigation treatments. These products and unlikely to yield benefits to newly planted trees in terms of survival or sustained growth improvement during long periods of drought. (Also published in *Midlands Landscape Quarterly*, Spring 1991, 19–22.)

HULL, S.K. & GIBBS, J.N. (1991). *Ash dieback: a survey of non-woodland trees.* Forestry Commission Bulletin 93. HMSO, London.

The survey was undertaken during the summer of 1987. Two hundred 10 km squares were visited and detailed data collected on the condition of ash in a plot selected within each square. Information was obtained on 4454 ash trees, and also on 1022 oak trees which were encountered in the plots. The overall incidence of dieback was 19% in the sample of ash and 18% in the sample of oak.

[INGLES, D.W.F., CHOULARTON, T.W., HILL, M.,] GARDINER, B. [& STROMBERG, I.M.] (1990). A field and modelling study of windflow in a region of complex terrain and varying surface roughness. In, *Proceedings of 5th Conference on mountain meteorology*, Boulder, Colorado, USA. American Meteorological Society; 194–197.

This paper describes the comparisons made between the predicted winds of a computer airflow model and actual measured winds on the Kintyre peninsula, west Scotland. In general, the airflow model is good at predicting windspeeds on the windward slopes and tops of hills but tends to overestimate windspeeds in the lee of hills and in valleys.

INNES, J.L. (1990). *Assessment of tree condition.* Forestry Commision Field Book 12. HMSO, London.

Forest condition is now assessed annually in most European countries. This Field Book provides details of assessment procedures used by the Forestry Commission in their main monitoring programme. Although this programme is restricted to Sitka spruce, Norway spruce, Scots pine, oak and beech, the techniques described are applicable with little or no modification to most other tree species. Crown density indices for the main conifers and broadleaves grown in Britain's forests are illustrated in a sequence of colour photographs. While emphasis has been placed on the assessment of crown density, a variety of other indices are also used. These are described and an assessment system is provided for each parameter. The additional indices enable a full description to be made of the condition of a tree.

INNES, J.L. (1991). Forest condition and air pollution in Great Britain. *Chemistry and Industry*, 4 February 1991, 79–82.

Are British forests seriously at risk from air pollution, or is the threat much less than feared? The evidence is examined.

INNES, J.L. (1991). Measuring effects of atmospheric pollution on trees in Europe. *Geography* **76** (1), 70–71.

Establishing the effects of air pollution on trees is still a major challenge facing scientists today. Experimental studies have largely failed to take into account the substantial differences between the physiology of seedlings and small trees and mature forest trees. Surveys have helped to generate cause–effect hypotheses, but correctly formulated experimental studies are needed to test these.

INNES, J.L. (1990). Some problems with the interpretation of international assessments of forest damage. In, *Proceedings of the 19th IUFRO World Congress*, Montreal, Canada, 5–11 August 1990; Vol. **2**, 380–387.

The relationship between air pollution and forest damage was one of the most active research areas within forestry during the 1980s. The research was stimulated by reports of a widespread and severe decline in forest health. While initial reports were largely anecdotal, later assessments were based on data provided by national and international surveys of forest condition. These data have mostly been accepted without any rigorous examination of their reliability. there is now evidence that many problems exist with the collection, analysis and interpretation of such data. It is clear that the data do not provide evidence of damage to forests by air pollution. Instead, they provide rather limited evidence of the sum of all the factors that affect forest condition. The surveys have failed to identify any consistent relationship between air pollution and forest condition, throwing into question the widely held view that air pollution is the most important factor determining the health of forests.

INNES, J.L. (1990). The role of quality assurance in the assessment of forest condition in Europe. In, *Proceedings of the 3rd Annual Ecological Quality Assurance Workshop*, Burlington, Ontario, 24–26 April 1990; 99–112.

Although various protocols have been established for the investigation of forest health in Europe, numerous problems exist over the quality management, quality assurance, quality control and quality evaluation of the programme. These problems severely limit the value of the programme, to the extent that it only partly fulfils its objectives and policy requirements.

INNES, J.L. & BOSWELL, R.C.(1990). *Monitoring of forest condition in Great Britain–1989.* Forestry Commission Bulletin 94. HMSO, London.

The results of the 1989 forest condition monitoring programme are presented. Altogether, 7436 trees were assessed, with the species being restricted to Sitka spruce, Norway spruce, Scots pine, oak and beech.

INNES, J.L. & BOSWELL, R.C. (1990). *Forest condition in 1990: preliminary results of the monitoring programme.* Forestry Commission Research Information Note 193.

The preliminary results of the 1990 monitoring programme are presented. Altogether, 7644 trees were assessed in the main programme, with a further 1700 trees being examined as part of the standardised European survey. The crown densities of Sitka spruce and oak improved during the course of the year whereas Norway spruce and Scots pine showed little change. Beech deteriorated, a trend that is likely to be attributable to the droughts of 1989 and 1990. A full assessment of the 1990 programme will be published in due course.

INNES, J.L. & BOSWELL, R.C. (1990). Reliability, presentation and relationships amongst data from inventories of forest condition. *Canadian Journal of Forest Research* **20** (6), 790–799.

Variation in crown condition between stands is significantly greater than within stands. However, within-stand variation can be significant and greater account needs to be taken of this when designing surveys of crown condition. The manner in which results of such surveys are presented is important as simple histograms and bar charts may convey a very misleading picture.

JOBLING, J. (1990). *Poplars for wood production and amenity.* Forestry Commission Bulletin 92. HMSO, London.

Covers the botany, cultivation, performances and utilisation of poplars and poplar timber.

JONES, S.K. & GOSLING, P.G. (1990). The successful redrying of imbibed, or imbibed plus prechilled Sitka spruce seeds. *Seed Science and Technology* **18**, 541–547.

Sitka spruce seeds exhibit dormancy and germinate better after a moist chilling treatment at 4°C (prechill). Unfortunately, moist seeds clump together and foul mechanical sowing equipment. A particular problem of moist Sitka spruce seeds is that they are highly sensitive to drying, which either kills them or at the very least re-imposes a secondary dormancy. This paper describes a method for redrying imbibed and chilled seeds over silca gel. Redrying did not significantly reduce the beneficial effects of either treatment.

KERR, G. (1990). Evolution and current status of wide spacing and heavy thinning in Great Britain. In, *New Zealand Forest Research Institute Bulletin* 151, 21–25.

Describes the evolution and current status of wide spacing and heavy thinning in Great Britain.

[KIDD, N.A.C., SMITH, S.D.J., LEWIS, G.B. &] CARTER, C.I. (1990). Interactions between host–plant chemistry and the population dynamics of conifer aphids. In, *Population dynamics of forest insects.* Eds Watt, A.D., Leather, S.R., Hunter, M.D. & Kidd, N.A.C.; 183–193.

An account is given of the ecological relationships between the nutritional quality of conifers and the infestation patterns of three species of aphids. The work, carried out at the University College of Wales, Cardiff, and the Forestry Commission Research Station, Alice Holt, revealed biochemical and anatomical changes in the host plant that had significant effects on aphid population growth.

LEATHER, S.R. (1990). Further novel insect records for bird cherry (*Prunus padus* L.). *Entomologist's Monthly Magazine* 126, 190.

Describes the first recorded occurrence of winter moth (*Operophtera brumata* L.) and magpie moth (*Abraxas grossulariata*) feeding on bird cherry.

LEATHER, S.R. (1990). Life span and ovarian dynamics of the pine beauty moth, *Panolis flammea* (D&S): the effect of low temperatures after adult emergence on reproductive success. *Physiological Entomology* **15**, 347–353.

Adult female *Panolis flammea* were kept at 2°C either immediately after emergence from the pupae or immediately after mating, for periods ranging from 5 to 20 days and then placed at 15°C together with a male moth, food supply and suitable oviposition site (*Pinus contorta* foliage). Weight loss over the storage period was directly proportional to the time spent at 2°C irrespective of whether the moths were virgin or mated. Pre-oviposition period decreased significantly from the control after more than 5 days at 2°C, but there was no significant difference between late mated and early mated moths. The post-storage life span of late mated and early mated moths

decreased in proportion to the time spent at 2°C but late mated moths had significantly longer life spans than early mated moths. Moths mated prior to storage were significantly less fecund than moths mated after storage except those moths kept at 2°C for 20 days where the fecundities of both treatments were identical (*c.*45 eggs/female). These results are discussed in relation to the conditions likely to be experienced by *P. flammea* in the field and their bearing on the population dynamics of this insect.

LEATHER, S.R. (1990). The role of host quality, natural enemies, competition and weather in the regulation of autumn and winter populations of the bird cherry aphid. In, *Population dynamics of forest insects.* Eds Watt, A.D., Leather, S.R., Hunter, M.D. & Kidd, N.A.C.; 35–44.

Reviews the effects that host quality of bird cherry (*Prunus padus*) has on the reproductive activity of the bird cherry aphid (*Rhopalosiphum padi*). The effects of inter- and intra-specific competition are also assessed and the roles of weather and natural enemies in regulating the populations of the aphid during autumn and winter are discussed.

LEATHER, S.R. (1990). Two case studies: the pine beauty moth and the bird cherry aphid. In, *Pests, pathogens and plant communities.* Eds Burdon, J.J. & Leather, S.R.; 145–167.

The relative roles of the pine beauty moth (*Panolis flammea*) and the bird cherry aphid (*Rhopalosiphum padi*) in shaping the plant communities in which they live are discussed.

LEE, S.J. (1990). *Potential gains from genetically improved Sitka spruce.* Forestry Commission Research Information Note 190.

End of rotation genetic gains can only be measured when a stand of improved material is felled and compared with an unimproved control. In the absence of such comparative stands, potential gains must be estimated using data from the oldest progeny tests available. Such data suggest that genetic gains obtainable from planting vegetatively propagated improved bulked family mixtures or stock from approved clonal seed orchards should be a minimum of 15% for height at 10 years and also for volume at 27 years. Genetic gains for form should be around 7% at age 10. Gain estimates for timber density are not yet available.

LEE, H.S.J., WILLSON, A., BENHAM, S.E., DURRANT, D.W.H., HOUSTON, T.J. & WADDELL, D.A. (1990). *The effect of air quality on tree growth.* Forestry Commission Research Information Note 182.

Measurements of tree growth in open-top chambers at three sites were made during April 1988, November 1988 and November 1989. Height, diameter, leader extension, nutrient content and fresh and dry weights were recorded at Headley, Chatsworth and Glendevon. Significant differences between filtered and ambient air treatments were found only for Scots pine and Norway spruce at Headley. Chamber effects (mainly due to temperature differences) were found to be significant at Glendevon for Sitka spruce and at Headley for Norway spruce and beech. There were no significant air quality or chamber effects at Chatsworth.

LEE, H.S.J., WILLSON, A., BENHAM, S.E., DURRANT, D.W.H., HOUSTON, T.J. & WADDELL, D.A. (1990). *The effect of air quality on the timing of tree shoot development.* Forestry Commission Research Information Note 183.

Measurements of phenology (development of new shoots) were undertaken in the open-top chambers and outside plots in the spring of 1989 at Headley, Chatsworth and Glendevon. No significant differences were found between phenology in ambient or filtered air. Shifts in time of flushing towards earlier shoot development within the chambers were apparent between outside plots and trees in open-top chambers. These differences became more apparent with increasing latitude north.

LONSDALE, D. (1991). The kindest cut. *Landscape News* 35, February, 4.

Guidance is given on when and when not to prune trees. The 'correct' pruning postion is illustrated and the advisability of using wound dressings is discussed.

LUDLOW, A.R., RANDLE, T.J. [& GRACE, J.C.] (1990). Developing a process-based growth model for Sitka spruce. In, *Process modeling of forest growth responses to environmental stress.* Eds Dixon, R.K., Meldahl, R.S., Ruark, G.A. & Warren, W.G.; 249–262.

Describes the development and methods of testing the model. The model is to be used to predict growth and yield of Sitka spruce for management purposes, especially where it is necessary to predict responses to novel treatments. In the longer term, the model will be extended to handle the likely responses to stress.

MAJOR, E.J. (1990). Water stress in Sitka spruce and its effect on the green spruce aphid *Elatobium abietinum.* In, *Population dynamics in forest insects.* Eds Watt, A.D., Leather, S.R., Hunter, M.D. & Kidd, N.A.C.; 85–93.

Aspects of host plant physiology and chemistry

were investigated along with the performance of *Elatobium abietinum* on water-stressed and control trees.

MASON, W.L. (1990). Improving quality standards for conifer planting stock in Great Britain. *Scottish Forestry* **45** (1), 28–41.

Current standards for assessing planting stock quality are reviewed. A system that integrates morphological and physiological measures is recommended. An example of such a standard is given for Sitka spruce.

MASON, W.L. and JINKS, R.L. (1990). *The use of containers as a method for raising tree seedlings.* Forestry Commission Research Information Note 179.

MASON, W.L. & McKAY, H.M. (1990). Evaluating the quality of Sitka spruce planting stock before and after cold storage. In, *Combined Proceedings of the International Propagation Society* 39, 234–242.

Case histories show that poor cold storage practice is a major cause of post-planting failure. Experimental results indicate that Sitka spruce can be safely lifted to store after 300 chilling hours below 5°C and when Root Growth Potential (RGP) rises. Alternative tests of quality such as electrolyte leakage give faster results than RGP without any loss of accuracy.

MAYLE, B.A. (1990). A biological basis for bat conservation in British woodlands: a review. *Mammal Review* **20** (4), 159–195.

Fifteen species of insectivorous bats are resident in Britain. The numbers of most species have declined drastically in recent years and all are now fully protected under the *Countryside and Wildlife Act 1981*. Forests and woodlands offer foraging and roosting habitats for all species and it is important for forest managers to be aware of the impact which management practices may have on bat populations. Current knowledge on the importance of woodlands for roosting, feeding, water and breeding is reviewed and initial management guidelines for the enhancement of forest bats proposed. Future research needs are discussed.

MAYLE, B.A. (1990). *Bats and trees.* Arboriculture Research Note 89/90/WILD. DOE Arboricultural Advisory & Information Service, Farnham, Surrey.

Most British bats depend to some extent upon woodland habitats and trees for foraging and roosting. All species are highly sensitive to disturbance and habitat change. Bats and their roosts are protected by law. Methods of identifying and protecting natural roost sites and providing artificial sites are described. Bat habitats can be improved by increasing the structural and species diversity of woodland, by planting native broadleaved trees, by retention of old trees beyond rotation age, and by the sensitive management of waterside habitats, scrub and open grassland.

MAYLE, B.A. (1990). Meanwhile ... back at the batcave. *Forest Life* 7, March 1990, 8–9. Forestry Commission, Edinburgh.

Practical steps to ensure that our forests and woodlands are managed to create more suitable bat habitats are described.

MAYLE, B.A. [& GURNELL, J.] (1991). Edge management and small mammals. In, *Edge management in woodlands.* Proceedings of a symposium held at Alice Holt Lodge on 17 October 1989. Forestry Commission Occasional Paper 28. Ed. Ferris-Kaan, R.; 42–48.

Edge management is unlikely to affect species richness of small mammals, but distribution and relative abundance may change. Voles, shrews and bats are likely to increase, and ecotones may act as dispersal corridors. Predators of rodents may also increase.

McNEILL, J.D., HOLLINGSWORTH, M.K., MASON, W.L., MOFFAT, A.J., [SHEPPARD, L.J. & WHEELER, C.T.] (1990). *Inoculation of alder seedlings to improve seedling growth and field performance.* Arboriculture Research Note 88/90/SILN. DOE Arboricultural Advisory & Information Service, Farnham, Surrey.

Inoculation of *Alnus* seedlings with selected *Frankia* strains has been investigated. Nursery experience and subsequent field trials have given results of sufficient significance for the inoculation technique to be recommended as a standard nursery practice. Although current research has been concerned primarily with inoculation of *Alnus rubra*, work with other alder species has shown comparable results.

METHLEY, J.M. (1990). Computer recording in permanent measurements plots. *Bulletin des Recherches Agronomiques de Gembloux* **25** (1), 115–122.

The Mensuration Branch at Alice Holt currently manages a national network of some 800 viable sample plots. These plots represent a range of species, sites, rates of growth, spacings and thinning treatments. Measurements are collected from these plots usually every 5 years. All the measurements for the 800 viable plots and the data for over 800 abandoned plots are stored in computer files as a databank ready for analysis. Results of earlier analyses are the published yield

models, tariff tables, assortment tables and numerous other mensurational guides. It is essential that the data stored in the databank are accurate, consistent and up to date.

[MITCHELL, A.F., HALLETT, V.E. &] WHITE, J.E.J. (1990). *Champion trees in the British Isles.* (3rd edtn; supersedes FC Research and Development Paper 138.) Forestry Commission Field Book 10. HMSO, London.

Lists 1169 entries of 548 species (188 conifers and 360 broadleaves) with 169 cultivars and varieties. Measurements are metric. Listing is alphabetical by genus and species. The majority of species are represented by two trees. The first is the tallest and the second is the stoutest; where a species is represented by only one specimen it is both the tallest and stoutest. There are 435 changes from the previous edition as there were many losses in the 1987 storm.

MOFFAT, A.J. (1990). Reclamation to forestry. In, *Land reclamation, challenges and opportunities.* Proceedings of the Prince of Wales' Committee Environmental Study Group Seminar, University College of Wales, Cardiff, 30–31 March 1990; 26–29.

To date, most UK reclamation to woodland has taken place in Wales, mainly because forestry was the original land use before mineral extraction. The Forestry Commission has been closely involved with the reclamation of derelict and mineral sites for over 50 years, and has built up a large amount of experience in methods of landform design, ground preparation, tree species selection and establishment procedures.

MOFFAT, A.J. [& JARVIS, M.G.] (eds) (1990). *Farm forestry: implications for land and landscape.* (SEESOIL 6, 1990)

Contains papers presented at a conference on farm forestry held at the University of Reading in December 1988.

MOFFAT, A.J. & ROBERTS, C.J. (1990). Grass mixtures for afforested opencast spoils in South Wales. *Land Degradation and Rehabilitation* **2** (2), 127–134.

An experiment that investigated the establishment of seven grass and legume seed mixes on opencast and mining spoil in South Wales is described. After three years, mixtures containing *Poa pratensis* and *Festuca rubra* var. *rubra* were the most successful in covering the spoil. Tree growth was not detrimentally affected by the establishment of a grass ground cover.

MOFFAT, A.J. & HOUSTON, T.J. (1991). Tree establishment and growth at Pitsea landfill site, Essex, UK. *Waste Management and Research* **9**, 35–46.

Investigations at an 11-year-old landfill site have shown that soil physical factors are important in determining tree survival and growth at Pitsea. A 1.5 m clay cover over the landfill markedly improved tree growth, preventing landfill gas contamination and providing sufficient plant available soil moisture to negate the large soil moisture deficits experienced in summer.

[MORITZ, T.,] PHILIPSON, J.J. [& ODEN, P.C.] (1990). Quantitation of gibberellins A_1, A_3, A_4, A_9 and a putative A_9–conjugate in grafts of Sitka spruce (*Picea sitchensis*) during the period of shoot elongation. *Plant Physiology* **93**, 1476–1481.

Endogenous gibberellins (GAs) in Sitka spruce were compared in grafts grown in conditions which were inductive, hot and dry, or non-inductive, cool and wet, for flowering. The importance of the less polar GAs is again demonstrated. The results are discussed with reference to previous publications in this study and to hypotheses on the mechanism of flowering.

[MORITZ, T.,] PHILIPSON, J.J. [& ODEN, P.C.] (1990). Quantitation of gibberellins A_1, A_3, A_4, A_9 and an A9–conjugate in good- and poor-flowering clones of Sitka spruce (*Picea sitchensis*) during the period of flower-bud differentiation. *Planta* **181**, 538–542.

The levels of endogenous gibberellins (GAs) were estimated with combined gas chromatography–mass spectrometry. The results demonstrated differences in GA metabolism in good and poor flowering clones. In particular there were higher amounts of GA_9 and its conjugate in the good flowering clones, which might indicate a greater capacity for synthesis of the physiologically active GA_4 in trees which flower readily.

NELSON, D.G. (1990). *Chemical control of Sitka spruce natural regeneration.* Forestry Commission Research Information Note 187.

Dense natural regeneration of Sitka spruce can be undesirable and has proved difficult to kill with foliar application of herbicides to trees 0.3 to 1.6 m tall. This Note describes a range of treatments applied and the levels of kill achieved. Application of glyphosate to freshly-cut stumps gives good control of regrowth. Imazapyr gave good control at 6 l ha^{-1} as a foliar spray but has not yet been given approval for forest use.

NELSON, D.G. (1990). Restocking: options and positions. *Forestry and British Timber* **19** (8), August 1990, 12, 14.

The appropriate method of cultivation for the

range of site types found in upland restocking is given, plus details of the preferred planting positions, time between cultivation and planting, plant size and cultivation costs.

NELSON D.G. (1990). Restocking with Sitka spruce on uncultivated gley soils: the effects of fencing, weeding and initial plant size on survival and growth. *Scottish Forestry* **44** (4), 266–272.

The results of three experiments which investigated the relative importance of deer fencing, weeding and plant size on the survival and growth of Sitka spruce on uncultivated upland restock sites are presented and discussed.

NELSON, D.G. (1991). Seminar highlights FC nursery research. *Forestry and British Timber* **20** (1), January 1991, 46, 48.

The fourth annual Horticultural Trades' Association nursery research seminar was held in October 1990 at the Forestry Commission's Northern Research Station. Results of experiments which showed improved survival rates with undercut and regularly wrenched stock in comparison to transplants were highlighted, along with a method of assessing plant quality through measurements of root electrolyte leakage of developments in soil analysis and nutritional regimes in forest nurseries.

NELSON, D.G., WILLIAMSON, D.R., MASON, W.L. [& CLAY, D.] (1991). Herbicide update. *Forestry and British Timber* **20** (2), February 1991, 24–27.

Covers weed control experiments in both the forest and forest nursery. The potentially damaging effects of Gardoprim-A on Douglas fir are highlighted and the use of a range of adjuvants with Asulox and Roundup over bracken discussed. In the nursery, work on new seedbed herbicides to supplement the existing standards of simazine and diphenamid and on herbicides to combat triazine resistant weeds in transplant and undercut lines is presented.

NISBET, T.R. (1990). Forestry and water. In, *Forestry and environmental planning.* Proceedings of Institute of Chartered Foresters symposium. Ed. Stumbles, R.E.; 44–48.

Considers the background to the forestry–surface water acidification issue in upland Wales. It focuses on the WWA Interim Guidelines and outlines a number of concerns regarding their practical application. Recent developments are discussed and the critical load approach recommended as the best way forward to resolve the issue of the contribution of forests to the acid waters problem.

NIXON, C.J. (1990). Shelter belts. *The Sheep Farmer,* Nov.–Dec. 1990, 22–23.

Guidelines for the use of trees to provide shelter on farms.

PATCH, D. & STEVENS, F.R.W. (1991). *Control of conker formation* (revised). Arboriculture Research Note 1/91/ARB. DOE Arboricultural Advisory & Information Service, Farnham, Surrey.

The present knowledge of possible chemical treatments for reducing fruit formation in horse chestnut is reviewed and suggestions are made for alternative solutions to minimise the hazard caused by children collecting conkers in the autumn.

PATTERSON, G.S. (1991). Management of riparian edges. In, *Edge management in woodlands.* Proceedings of a symposium held at Alice Holt Lodge on 17 October 1989. Forestry Commission Occasional Paper 28. Ed. Ferris-Kaan, R.; 57–63.

Streams and riparian areas are particularly valuable habitats for wildlife. They are diverse with a large amount of edge and are important corridors for the movement of wildlife. Management practices and research priorities are outlined, aimed at improving the value of riparian habitats.

PEPPER, H.W. (1990). *Grey squirrel damage control with warfarin.* Forestry Commission Research Information Note 180.

PEPPER, H.W. (1990). *Grey squirrels and the law.* Forestry Commission Research Information Note 191.

This Note summarises the legislation relevant to the control of grey squirrels, incorporating recent changes introduced by the *Wildlife and Countryside Act 1981* and the *Control of Pesticides Regulations 1986.* Guidance is offered on interpreting the legislation.

PETTY, S.J. [& AVERY, M.I.] (1990). *Forest bird communities: a review of the ecology and management of forest bird communities in relation to silvicultural practices in the British uplands.* Forestry Commission Occasional Paper 26. Forestry Commission, Edinburgh.

Afforestation has had a dramatic effect on many upland landscapes over the past 50 years. With continued forestry expansion, concern has been expressed about the effects of afforestation on bird communities. This work objectively reviews factors which determine forest bird communities, the effects of afforestation on upland birds and ways of improving forests for birds.

PHILIPSON, J.J. & FLETCHER, A.M. (1991). Implications of cone-induction techniques for breeding strategies and the production of improved seed. In, *Forest tree improvement.* Pro-

ceedings from the Nordic Tree Breeders' Meeting, Horsholm, Denmark, September 1990; consequences of modern techniques in tree breeding for breeding strategies. No. 23, 69–80.

The paper discusses options available to tree breeders, including cone induction in field-based seed orchards and the use of container-grown grafts in polythene tunnels. Grafts can be encouraged to flower at an early age and to produce good quantities of viable seed. The clonal composition of container-based orchards can easily be varied as new clones become available.

PHILIPSON, J.J., [OWENS, J.N. &] O'DONNELL, M.A. (1990). Production and development of seed and pollen in grafts of *Picea sitchensis* (Bong.) Carr. treated with gibberellin $A_{4/7}$ to induce coning and the effect of forcing treatments. *New Phytologist* **116**, 696–705.

Good quantities of high quality pollen and seed were produced on Sitka spruce grafts in the year following cone induction, provided the grafts were placed in the polythene house for a short period only, beginning at the 2- to 3-cell pollen stage. Early forcing treatments advanced pollen shed but reduced pollen and seed yield. The cytological basis for these reductions was examined.

PHILIPSON, J.J. (1990). Prospects for enhancing flowering of conifers and broadleaves of potential silvicultural importance in Britain. *Forestry* **63** (3), 223–240.

Research on enhancing coning in commercially important conifers (gymnosperms) is reviewed. The prospects for enhancing flowering, for the purposes of breeding and seed supply appear good, particularly for members of the Pinaceae. The most successful techniques involve the application of the gibberellin A_4 and A_7 mixture combined with cultural treatments such as drought, root pruning or girdling. Less research has been published on enhancing flowering in broadleaves (angiosperms) though there has been considerable attention to factors affecting blossom and fruit development.

POTTER, C.J. (1990). *Coppiced trees as energy crops.* Final report. Department of Energy, Energy Technology Support Unit. (ETSU B 1078).

A report on a series of short rotation coppice trials funded by the Department of Energy. Poplar (RAP) proved to be the most successful species, yielding an overall average of 10.7 dry tonnes ha^{-1} $annum^{-1}$. Up to the first 4-year cut there was little difference in annual yield between the 2 and 4 year cutting cycle but a significant reduction of yield at 2 rather than 1 metre spacing. Results of nutrient removal assessment are presented, and also results from the assessment of a 'Neldar' spacing trial.

POTTER, C.J., NIXON, C.J. & GIBBS, J.N. (1990). *The introduction of improved poplar clones from Belgium.* Forestry Commission Research Information Note 181.

Six new poplar hybrids from Belgium have been added to the list of clones approved for commercial production in the UK. They are resistant to the major poplar diseases and have the potential to produce much higher yields than existing approved clones. Under certain circumstances they will qualify for grant aid but the planting of large blocks is not recommended until much more is known about their performance in the UK. (Also published in *Quarterly Journal of Forestry* **84** (4), 261–263).

PYATT, D.G. (1990). A visit to Newfoundland. *Arbor* (Journal of the Aberdeen University Forestry Society) **8** (3), 11–13.

Describes a visit in August 1989 to experimental sites on mineral soils concerned with methods to improve natural or artificial regeneration of cutover forest. The latter part of the visit concentrated on peatlands and methods of afforestation.

PYATT, D.G. (1991). *Forest drainage.* Forestry Commission Research Information Note 196.

A review of the purpose and benefits of forest drainage has indicated that drainage is unlikely to increase growth but may improve crop stability on wet sites. Drains are required to control the runoff of water from surface cultivation in order to reduce soil erosion and the movement of sediment to streams. This requires careful planning of the drainage system. On deep peat soils drain depth should be maintained but on mineral soils maintenance should be limited to the clearance of gross blockages.

QUINE, C.P. & REYNARD, B.R. (1990). *A new series of windthrow monitoring areas in upland Britain.* Forestry Commission Occasional Paper 25. Forestry Commission, Edinburgh.

A network of eight windthrow monitoring areas together with reference anemometers and wind vanes has recently been established in forests in remote upland areas of Britain. The sites chosen will allow study of the onset and progression of windthrow in productive plantations. Details of the associated wind climate will also be obtained. The data gathered will be used to validate, refine and extend the Windthrow Hazard Classification.

RATCLIFFE, P.R. (1990). A new deer management system from Scotland and its application in Hokkaido, Japan. In, *Proceedings of the deer and*

bear forum, Hokkaido, 1990. Eds Ohtaishi, N., Kaji, K. & Mano, T.; 49–54, 148–150.

Describes a deer management system based on determining densities and population dynamics which will sustain levels of culling consistent with reduced environmental impact and efficient exploitation.

RATCLIFFE, P.R. (1990). Deer management in Hokkaido: comments and suggestions. In, *Proceedings of the deer and bear forum*, Hokkaido, 1990. Eds Ohtaishi, N., Kaji, K. & Mano, T.: 94–96, 171–174.

Provides comments and suggestions on improving the management of Japanese sika deer (*Cervus nippon yezoensis*) in Hokkaido, following a tour to investigate management problems. It suggests increased culling of females, the provision of sanctuaries and improved public education.

RATCLIFFE, P.R. (1990). 'Naturalness' in woodland management. *Timber Grower*, Summer 1990, 13.

Recognises the need to conserve unique semi-natural ecosystems and emphasises the value of increasing biodiversity in artificial ecosystems through time.

RATCLIFFE, P.R. (1991). Edge habitats: an introduction. In, *Edge management in woodlands.* Proceedings of a symposium held at Alice Holt Lodge on 17 October 1989. Forestry Commission Occasional Paper 28. Ed. Ferris–Kaan, R.; 2–4.

Defines ecotones and emphasises their importance as managed habitats contributing to structural diversity in woodland ecosystems.

RATCLIFFE, P.R. (1991). Sika deer. In, *Handbook of British mammals* (3rd edtn). Eds Corbet, G.B. & Harris, S.; 504–508.

An account of the classification, description, biology and ecology of Sika deer in Great Britain.

SHARPE, A.L., MASON, W.L. & HOWES, R.E.J. (1990). Early forest performance of roughly handled Sitka spruce and Douglas fir of different plant types. *Scottish Forestry* **44** (4), 257–265.

Sitka spruce and Douglas fir of two different bare-root plant types (undercuts and transplants) were either well or roughly handled before planting out. The planting site was split for cultivation and no cultivation. Root growth potential, survival and height increment results showed the positive benefits of careful handling for both species. Douglas fir undercuts were superior to transplants and site cultivation was essential for the successful establishment of Douglas fir.

[SHERIFF, D.W. &] ROOK, D.A. (1990). Wood density and above-ground growth in high and low wood density clones of *Pinus radiata* D. Don. *Australian Journal of Plant Physiology* **17**, 615–628.

Clones previously found to produce wood of high or low density were used to study inter-relationships between above-ground partitioning coefficients, carbon gain and wood density. For all but two trees, wood densities of a stem and its branches were the same; in those two, stem density was 13% less. No simple relationship was found between wood density and either above-ground growth or photosynthesis.

[SIBBALD, A.,] NIXON, C.J., TAYLOR, C.M.A., [AGNEW, R., SENIOR, J. & SMITH, F.] (1990). The Glensaugh National Network Experiment. *Agroforestry in the UK* **1** (2), 9–10.

A summary of the third year results of tree and sward growth in this silvopastoral system experiment.

STABLES, S. & NELSON, D.G. (1990). Rhododendron ponticum *control.* Forestry Commission Research Information Note 186.

An update is given of the results from two experiments looking at the control of *Rhododendron ponticum* from either a foliar spray of ammonium sulphate or application of glyphosate to freshly cut stumps, and revised recommendations for timing of applications are made.

[STAINES, B.W. &] RATCLIFFE, P.R. (1991). Roe deer. In, *Handbook of British mammals* (3rd edtn). Eds Corbet, G.B. & Harris, S.; 518–525.

An account of the classification, description, biology and ecology of roe deer in Great Britain.

STEVENS, F.R.W., THOMPSON, D.A. & GOSLING, P.G. (1990). *Research experience in direct sowing for lowland plantation establishment.* Forestry Commission Research Information Note 184.

The FC has carried out at least 70 experiments on direct seeding since the early 1920s. Results have been extremely variable. Seed and seeding losses are difficult and expensive to control. The unpredictable results obtained lead to the conclusion that traditional establishment techniques remain preferable to direct seeding.

STOAKLEY, J.T & HERITAGE, S.G. (1990). *Approved methods for insecticidal protection of young trees against* Hylobius abietis *and* Hylastes *species.* Forestry Commission Research Information Note 185. (Supersedes Research Information Note 140.)

Damage done by *Hylobius abietis* and *Hylastes* species and methods of control are briefly described. The two types of Approval for the

general use of insecticides which may be issued by the Pesticides Safety Division of MAFF under the *Control of Pesticides Regulations 1986* and the use of 'Application Leaflets' to convey the conditions of 'off-label' Approvals and give additional information are explained. The current status, in terms of Approval, of various possible insecticide products and applications is detailed. This Note serves as an introduction to 'Application Leaflets' on pre- and post-planting treatments published as RINs and stresses that these are issued in accordance with the statutory Approvals. Copies of the Approvals relating to pre-planting treatment with two permethrin products are included as appendices.

STROUTS, R.G. (1991). *Dieback of the flowering cherry,* Prunus *'Kanzan'*. Arboriculture Research Note 94/91/PATH. DOE Arboricultural Advisory & Information Service, Farnham, Surrey.

Many *Prunus* 'Kanzan' trees died in England and Wales following the very cold 1981/82 winter and subsequent cold winters. Circumstantial evidence suggests that the bacterium *Pseudomonas syringae* pv. *syringae* may be the cause. The disease exemplifies the wisdom of using a mixture of species or varieties in ornamental planting schemes.

TABBUSH, P. (1991). Poplars' popularity set to increase? *Forestry and British Timber* **20** (3), March 1991, 26–27.

New disease resistant and high-yielding poplar clones, and the availability of land surplus to agricultural requirements set the stage for a revival in poplar planting.

TAYLOR, C.M.A. and MOFFAT, A.J. (1991). The potential for utilising sewage sludge in forestry in Great Britain. In, *Alternative uses for sewage sludge,* ed. Hall, J.E., 103–113. Pergamon Press, Oxford.

TAYLOR, C.M.A. [& WORRELL, R.] (1991). Influence of site factors on the response of Sitka spruce to fertilizer at planting in upland Britain. *Forestry* **64** (1), 13–27.

Data from Forestry Commission fertiliser experiments were analysed to determine the influence of site factors on the growth response of Sitka spruce following applications of phosphate and potassium at time of planting. Multiple regression analysis revealed that growth response was influenced by soil type and was related to the foliar nutrient levels of untreated controls. Growth response to application of phosphate was also influenced by lithology. No relationships were found between growth response and elevation or annual rainfall.

TAYLOR, G., DOBSON, M.C. & FREER-SMITH, P.H. (1989). Changes of partitioning and increased root lengths of spruce and beech exposed to ambient pollution concentration in southern England. *Annales des Sciences Forestières* **46**, Supplement 573s–576s.

Beech and spruce were grown in open-top chambers ventilated wih either charcoal filtered or unfiltered air. For both species stomatal conductance was restricted for trees grown in unfiltered (polluted) air. Ambient pollution also resulted in the production of longer, thinner roots for beech and suggests that trees grown in unfiltered air may be particularly susceptible to drought stress since thinner roots may be prone to loss of turgor and rapid dehydration.

THOMSON, A.J. & TAYLOR, C.M.A. (1990). An expert system for diagnosis and treatment of nutrient deficiencies of Sitka spruce in Great Britain. *Natural Resource Management* **4** (1), 44–52.

The production of an expert system for automatically producing a report on the diagnosis of nitrogen (N), phosphorus (P), and potassium (K) deficiency and treatment recommendation in Sitka spruce plantations is described.

WAINHOUSE, D., [CROSS, D.J. &] HOWELL, R.S. (1990). The role of lignin as a defence against the spruce bark beetle *Dendroctonus micans*: effect on larvae and adults. *Oecologia* **85**, 257–265.

The role of lignin as a physical defence against *Dendroctonus micans* was investigated in laboratory feeding experiments. The effect of lignin is dose-dependent, reducing larval survival, growth rate, and weight, as well as affecting gallery construction. Adults lay fewer eggs in lignified bark and also tend to construct abnormal galleries. The distribution of lignin in trees suggests a role in defence against bark beetles that feed in the thicker bark on the lower bole.

WALKER, C. (1991). *Scutellospora* is *Scutellospora*. *Mycotaxon* **40**, 141–143.

An erroneous change of genus name (from *Scutellospora* to *Scutellispora*) based on an incorrect interpretation of the International Code of Botanical Nomenclature is corrected, and the reasons for the correction are explained.

WALKER, C. [& HALL, I.R.] (1991). Lectotypification of *Scutellospora auriglobosa* (Glomales). *Mycological Research* **95** (4), 398–400.

The type material of *Scutellospora auriglobosa* Hall has been found to contain more than one species of *Scutellospora*. A lectotype is selected and the fungus re-described.

[WATT, A.D.,] LEATHER, S.R., [HUNTER, M.D. & KIDD, N.A.C.] (eds) (1990). *Population dynamics of forest insects.* Intercept, Andover, Hants.

The proceedings of an international conference held at Heriot-Watt University, Edinburgh in 1989. The book contains 34 papers concerned with foliage feeding forest insects. It is divided into four sections: general population studies, insect–plant interactions, insect–natural enemy interactions, and population models and pest management.

WEBBER, J.F. (1990). Relative effectiveness of *Scolytus scolytus, S.multistriatus* and *S.kirschi* as vectors of Dutch elm disease. *European Journal of Forest Pathology* **20** (3), 184–192.

Three scolytid species consistently associated with Dutch elm disease were assessed and compared for their effectiveness as vectors of *Ophiostoma ulmi.* Assessments were based on the number of beetles within a sample carrying any detectable *O.ulmi,* the number of *O.ulmi* spores carried by individual beetles and the number of discrete gallery systems colonised by *O.ulmi.*

WEBBER, J.F. [& HANSEN, E.M.] (1990). Susceptibility of European and north-west American conifers to the North American vascular pathogen *Leptographium wageneri. European Journal of Forest Pathology* **20**, 347–354.

Black stain root disease, caused by the fungus *Leptographium wageneri,* is a native disease of western North America. It primarily attacks several pine species and Douglas fir. Currently absent from Europe, any accidental introduction of the pathogen could pose a threat to the commercially grown conifers in Europe. To assess the extent of this threat, the susceptibility of nine European and North American conifer species to this disease was examined.

WHITE, J.E.J. & PATCH, D. (1990). *Ivy: boon or bane?* (revised). Arboriculture Research Note 81/90/ARB. DOE Arboricultural Advisory & Information Service, Farnham, Surrey.

Ivy, which is the only native British evergreen climbing shrub, may be unsightly and it can create problems for tree managers. These adverse effects of ivy should be compared with its conservation benefits before destroying the climber. This Note reviews both the benefits and problems of ivy growth.

WHITE, J.E.J. & PATCH, D. (1990). *Propagation of lowland willows by winter cuttings.* Arboriculture Research Note 85/90/SILS. DOE Arboricultural Advisory & Information Service, Farnham, Surrey.

Plants of native willows (*Salix* spp.) are not generally available from the nursery trade. Use of cuttings to propagate willows both in the nursery and *in situ* in the landscape are described.

WILLIAMSON, D.R. (1990). Poised for change: from food to woods is Open Day theme. *Forestry and British Timber* **19** (6), 26.

Summary of farm woodland work and promotion of Open Day 'Profitable farming and practical conservation'.

WILLIAMSON, D.R. (1990). *The use of herbicides in UK forestry.* Document prepared for the Seminar on the use of pesticides in forestry, Sparsholt, Hampshire, 10–14 September 1990. ECE, Geneva. Economic Commission for Europe; Food and Agriculture Organization & International Labour Organisation; Joint Committee on Forest Technology, Management and Training. (TIM-EFC-WP.1-SEM.33-R.9)

Summary of the use of herbicides in UK forestry.

WILLIAMSON, D.R. (1991). Help at hand for creating woodlands. *Farmers Weekly* **114** (12), 22 March 1991, 79.

Outlines methods of establishing farm woodlands.

WILLIAMSON, D.R. (1991). Weed control: be safe, be successful. *Timber Grower* 118, Spring, 13.

Describes the safe use of herbicides.

[WILSON, B.R.], MOFFAT, A.J. [& NORTCLIFF, S.] (1990). The nature and pattern of ancient woodland soils in southern England. *Quarterly Journal of Forestry* **84** (3), 173–180.

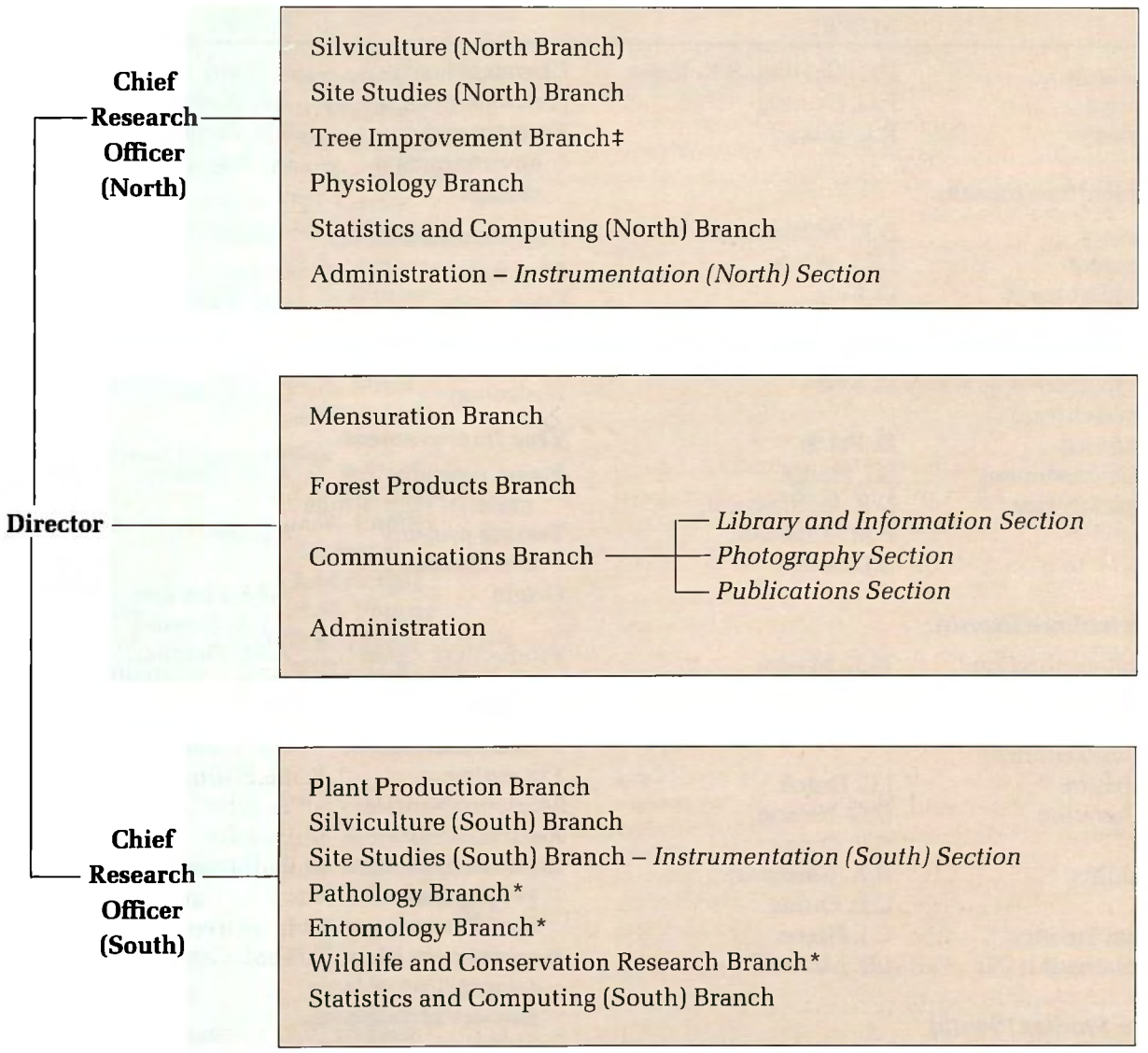
The distribution of ancient woodland sites in Berkshire and Hampshire was studied with respect to the Major Soil Group on which they stand. A general correlation between ancient woodland sites and heavy textured, gley soils is identified. Patterns in the distribution of ancient woodland on particular soils are considered in relation to local factors.

WINTER, T.G. (1990). *Crypturgus subcribrosus* Eggers (Col.; Scolytidae): a bark beetle new to Britain. Entomologist's Monthly Magazine 126, 209–211.

Crypturgus subcribrosus was found in the New Forest in 1986 in Norway spruce bark and associating with *Orthotomicus laricis* and *Pityogenes bidentatus.* The beetle is described and compared with similar *Crypturgus* species from Europe.

APPENDIX II

RESEARCH DIVISION ORGANISATION



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

APPENDIX III

RESEARCH DIVISION BRANCHES AND THEIR PROJECT GROUPS‡

	Project leader(s) at 31/3/91
Research	P.G. Gosling, S.K. Jones
Service	P.G. Gosling
Nursery	R.L. Jinks
Silviculture (South)	
Nursery	D.R. Williamson
Arboreta	J.E.J. White
Establishment	G. Kerr, D.R. Williamson, S.J. Hodge
Silviculture operations	G. Kerr
Arboriculture	
Advice	D. Patch
Establishment	S.J. Hodge
Farm forestry	D.R. Williamson, P.M. Tabbush, S.J. Hodge
Silviculture (North)	
Plant production	W.L. Mason
Species	C.J. Nixon
Planting (including weed control)	D.G. Nelson
Nutrition	J.C. Dutch
Cultivation	D.G. Nelson, C.P. Quine
Stability	B.A. Gardiner, C.P. Quine
Farm forestry	C.J. Nixon
Reclamation (N)	J.D. McNeill
Site Studies (South)	
Effects of trees on sites	A.J. Moffat, T.R. Nisbet
Lowland production forestry	A.J. Moffat
Reclamation	A.J. Moffat
Hydrology: water quality	T.R. Nisbet
Air pollution	P.H. Freer-Smith, J.L. Innes, D.W.H. Durrant
Chemical analysis	E. Ward
Instrumentation	T.R. Nisbet
Forestry and environmental change	P.H. Freer-Smith, J.L. Innes
Site Studies (North)	
Clay soils	D. Ray
Deep peats	D.G. Pyatt
Ironpan soils	A.R. Anderson
Loamy gleys	A.R. Anderson, D. Ray
Hydrology	D.G. Pyatt
Tree Improvement	
Forest reproductive material regulations	A.M. Fletcher
Testing progeny and clones	S.J. Lee
Origin	A.M. Fletcher, C.J.A. Samuel
Production: clone banks and orchards	A.M. Fletcher, W. Brown
Biochemical variation	G.I. Forrest
Biometrical studies	C.J.A. Samuel
Flowering	J.J. Philipson
Micropropagation	A. John
Rejuvenation	A. John
Improvement and propagation of broadleaves	R. Harmer
Improvement and propagation of farm forestry broadleaves	C.M. Cahalan
Physiology	
Root growth and form	M.P. Coutts
Bent top	M.P. Coutts
Planting stock quality	H.M. McKay
Mycorrhizas	C. Walker
Development of rooting patterns	C. Walker

Pathology

Disease diagnosis, damage monitoring and risk assessment	D.B. Redfern S.C. Gregory, R.G. Strouts, J.N. Gibbs
Dutch elm disease	C.M. Brasier, B.J.W. Greig
Fomes root rot	D.B. Redfern, B.J.W. Greig
Stem decays	D. Lonsdale
Poplar diseases	D. Lonsdale
Special investigations	J.N. Gibbs, B.J.W. Greig, D.R. Rose

Entomology

Dendroctonus micans	H.F. Evans, D. Wainhouse
Panolis flammea	S.R. Leather
Beech bark disease	D. Wainhouse
Elatobium abietinum	C.I. Carter
Hylastes and *Hylobius*	S.G. Heritage, S.R. Leather
Advisory and taxonomic	T.G. Winter
Genetic variations	M.R. Jukes
Impact stress	N.A. Straw, D. Wainhouse

Wildlife and Conservation

Deer	P.R. Ratcliffe
Squirrels	H.W. Pepper
Birds	S.J. Petty
Damage	R.M.A. Gill
Repellents	H.W. Pepper
Bats	B.A. Mayle
Vegetation management	R. Ferris-Kaan, G.S. Patterson
Streams and riparian vegetation	G.S. Patterson

Mensuration

Sample plots	J.M. Methley
Measurement studies	J.M. Methley
Yield modelling	R.W. Matthews
Management services	J.M. Methley
Site yield	P.C. Jokiel

Forest Products

Quality and value enhancement	J.F. Webber
Preservation	J.F. Webber
Wood and timber properties	J.F. Webber

Statistics and Computing (South)

Forest growth modelling	A. R. Ludlow

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

APPENDIX IV

NET EXPENDITURE OF RESEARCH DIVISION 1990/91

£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*
Plant Production	135	30		165
Silviculture (South)	919	2	73	994
Arboreta	507			507
Silviculture (North)[e]	1904	–85	27	1846
Site Studies (South)[f]	726	43	33	802
Site Studies (North)	160	52	1	213
Tree Improvement	1056	240		1296
Physiology	242	73	28	343
Pathology	548	82	29	659
Entomology	756	99	29	884
Wildlife and Conservation	425	99	67	591
Mensuration	304	23		327
Forest Products	58	45	155	258
Statistics and Computing (South)	460	–278		182
Statistics and Computing (North)	307	–296		11
Communications	423	–129		294
Total	**8930**	**0**	**442**	**9372**

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 £1772(000) plus Forestry Commission headquarters overheads for common services of £618(000) net of income of £492(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. Including Experimental Workshop (North) £73(000).

f. Including Experimental Workshop (South) £82(000).

APPENDIX V

CONTRACTS FOR WORK UNDERTAKEN BY RESEARCH DIVISION

Department of the Environment	Arboriculture Pathology Arboriculture Advisory and Information Service De-icing salt and tree damage Establishment on landfill sites
Energy Technology Support Unit	Biomass energy
British Coal	Opencast coal spoil
Department of Engineering, Oxford University	Aerolastic modelling
Central Electricity Generating Board	Trees on gypsum soil
Department of Transport	Alternatives to peat
Research Institute for Forestry and Landscape Planning, 'De-Dorschkamp', The Netherlands	Dutch elm disease
Ministry of Agriculture, Fisheries and Food	Vegetative propagation Progeny testing Yield assessments
BP Chemicals	De-icing salt and tree damage
Pilkington Trust	Dutch elm disease
Incitec International	*Hylobius*
EEC/EOLAS (Irish Science and Technology Agency)	Pinewood nematodes
EEC/Oxford University	Transgenetic poplar
Interox	Calcium peroxide controlled release in waterlogged soil Restocking with calcium peroxide

APPENDIX VI

STAFF ENGAGED IN RESEARCH AS AT 31 MARCH 1991

RESEARCH DIVISION

Director	D.A. Burdekin, B.A., Dip.Ag.Sci., M.I.C.For. (*Alice Holt*)
Administration and Finance Officer	J. Lumley (*Alice Holt*)
Chief Research Officer (South)	J. Evans, B.Sc., Ph.D., D.Sc., F.I.C.For. (*Alice Holt*)

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

Chief Research Officer (North)	T.C. Booth, B.Sc., M.I.C.For. (*Northern Research Station*)

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

STAFF AT ALICE HOLT LODGE

Plant Production

P.G. Gosling, B.Sc., Ph.D., Head of Branch
R.L. Jinks, B.Sc., Ph.D.
S.K. Jones, C.Biol., M.I.Biol., M.I.Hort.
Mrs Y.K. Samuel, B.A.
A.S. Gardiner

Silviculture Branch (South)

P.M. Tabbush, B.Sc., M.I.C.For., Head of Branch
A. Beaton, B.Sc., M.I.C.For.
D. Elgy
S. Hodge, B.Sc., M.Sc., M.I.C.For.
G. Kerr, B.Sc., M.I.C. For.
J.E.J. White (*Westonbirt*)
D.R. Williamson, B.Sc., M.I.C.For.

Outstation staff	*Centre*
J.L.Budd	Alice Holt
S.M. Colderick, M.I.C.For.	
A.R. Hall	
K.R. Knott	
R.A. Nickerson	
C. Morgan	Bedgebury
R.B. Collins	
D.A. Hendrie	Thetford
D.G. Rogers	
N.A. Smith	Exeter
M.W. Allen	
I. Collier	Midlands

Arboricultural Advisory and Information Service (Department of the Environment)

D.Patch, B.Sc., M.Sc., M.I.C.For., N.D.Arb.(RFS), F.Arbor.A.
F.R.W. Stevens

Site Studies Branch (South)

P.H. Freer-Smith, B.Sc., Ph.D., Head of Branch
N.A.D. Bending, B.Sc., M.Sc.
Mrs S.E. Benham
P.G. Crow
D.W.H. Durrant, B.A.
N.P. Hayward, B.Sc., M.Sc.
J.L. Innes, M.A., Ph.D.
A.J. Moffat, B.Sc., Ph.D.
T.R. Nisbet, B.Sc., Ph.D.
Mrs J.E. Stonard
Mrs D.A. Waddell
E. Ward, B.Sc., M.Sc., C.Chem., M.R.S.C.,

Instrumentation Section (South)

T.R. Nisbet, B.Sc., Ph.D., Head of Section

Tree Improvement Section (of Branch at Northern Research Station)

R. Harmer, B.Sc., Ph.D., Head of Section
Mrs C.A. Baker
C.M. Cahalan, B.Sc., M.Sc., Ph.D.

M.R. Plowman, B.Sc., M.Sc.

Pathology Branch (with Section at Northern Research Station)

J.N. Gibbs. M.A., Ph.D., Sc.D., Head of Branch
C.M. Brasier, B.Sc., Ph.D., D.Sc.
Mrs S. E. Brown, B.Sc.
M.C. Dobson, B.Sc., Ph.D.
B.J.W. Greig, M.I.C.For.
Mrs S.A. Kirk
D.Lonsdale, B.Sc., Ph.D.
C.A. Palmer
D.R. Rose, B.A.
Mrs J. Rose
R.G. Strouts

Entomology Branch (with Section at Northern Research Station)

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

Wildlife and Conservation Research Branch

P.R. Ratcliffe, B.Sc., Ph.D., C.Biol., M.I.Biol., F.I.C.For., Head of Branch
A. Chadwick (*Cowal, Strathclyde*)
R. Ferris-Kaan, B.Sc., Ph.D.
R.M.A. Gill, B.Sc.
Mrs B.A. Mayle, M.Sc.
H.W. Pepper
S.J. Petty (*Cowal, Strathclyde*)
G.S. Patterson, B.Sc., M.I.C.For. (*Northern Research Station*).

Mensuration Branch

Mrs J.M. Methley, B.Sc., Head of Branch
S.R. Abbott
N. Fearis, B.Sc.
P.C. Jokiel, B.Sc.
R.W. Matthews, B.Sc., M.Sc

Forest Products

J.F. Webber, B.Sc., Ph.D., Head of Branch

Statistics and Computing Branch (South)

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

Communications Branch

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

Library and Information Section

Miss C.A. Oldham, B.A., M.A., Dip.Lib., A.L.A., Head of Section and Librarian
Mrs E.M. Harland, M.A., Dip.Lib. (Assistant Librarian)

Photography Section

G.L. Gate, Head of Section
Miss M. Trusler

Publications Section

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

Administration

HEOs: Mrs B.K. Bartlett (*Accounts*)
R. Murray (*Personnel*)
EOs: Mrs J.C. Gates (*Office Services*)
Miss J.R. Lacey (*Personnel*)
Mrs S.J. Osborne (*Accounts*)

STAFF AT NORTHERN RESEARCH STATION

Silviculture Branch (North)

D.B. Paterson, B.Sc., M.I.C.For., Head of Branch
J.C. Dutch, B.Sc., Ph.D.
B.A. Gardiner, B.Sc., Ph.D., F.R.Met.S.
W.L. Mason, B.A., B.Sc., M.I.C.For.
J.L. Morgan, B.Sc., Ph.D.
D.G. Nelson, B.Sc., M.I.C.For.
C.J. Nixon, B.Sc., M.I.C.For.
C.P. Quine, M.A., M.Sc., M.I.C.For.

Outstation staff:	*Centre*
Stability Project	
A.L. Mackie	Northern Research Station
North and Mid Scotland Region	
A.L. Sharpe	Newton, Grampian
North Scotland Area	
W.G. Paterson	
J.Boluski	Lairg, Highland
North-east Scotland Area	
(including Central Highlands and Islands)	
J.Davidson, B.A., M.I.C.For.	
C. Edwards	

A.W. Macleod — Newton, Grampian
West Scotland Area (including Mull)
P. Cairns
D.R. Tracy — Cairnbaan, by Lochgilphead Strathclyde

East Scotland Area
F.S. Smith
D. Anderson — Perth, Tayside

South Scotland and North England Region
J.D. McNeill — Northern Research Station
South-east Scotland Area
M.K. Hollingsworth
A.J. Harrison, B.Sc. — Northern Research Station
South-west Scotland Area (including Arran)
M. Riley
D.M. Watterson — Mabie, Dumfries
Borders Area
P.W. Gough — Kielder, by Hexham, Northumberland
North-east England Area
R.E.J. Howes
A.D. Edwards — Wykeham, Scarborough, North Yorkshire

Wales Region
N.P. Danby — Talybont-on-Usk
Wales Area
C.D. Jones, B.Sc.
S.A. Mead, B.Sc. — Talybont-on-Usk

Site Studies Branch (North)
D.G. Pyatt, B.A., B.Sc., Ph.D., Head of Branch
A.R. Anderson
D. Ray, B.Sc.

Tree Improvement Branch (with Section at Alice Holt)
D.A. Rook, B.Sc., M.Sc., Ph.D., Head of Branch
Miss C.M.M. Baldwin
A.M. Fletcher, B.Sc., Ph.D., A.I.W.Sc., M.I.C.For.
G.I. Forrest, B.Sc., M.Sc., Ph.D.
S.J. Lee, B.Sc., M.I.C.For.
A. John, B.Sc., Ph.D.
Mrs M.O'Donnell
J.J. Philipson, B.A., Ph.D.
C.J.A. Samuel, B.Sc., Ph.D.

Outstation staff: — *Centre*
Northern Scotland
C.E.S. Fleming
R.J. Sykes — Newton, Grampian
Mid Scotland to northern England
W. Brown
J.S. McIntyre — Northern Research Station
Wales and southern England
G.C. Webb
A.S. Medhurst, M.I.C.For. — Shobdon, Hereford

Physiology Branch
M.P. Coutts, B.Sc., PhD., D.Sc., M.I.C. For., Head of Branch
C. Walker, B.A., Ph.D., Assistant Head of Branch
D.C. Clark
K.A. Clifford, B.A.
Mrs J. Harrower
C. McEvoy
H.M. McKay, B.Sc., Ph.D.
B.C. Nicoll, B.Sc.

Pathology Section (of Branch at Alice Holt)
D.B. Redfern, B.Sc., Ph.D., M.I.C.For., Head of Section
S.C. Gregory, M.A., Ph.D.
Miss G.A. MacAskill
J.E. Pratt

Entomology Section (of Branch at Alice Holt)
S.G. Heritage, C.Biol., M.I.Biol., Head of Section
A.C. Hendry, B.Sc.
T. Jennings
D. Johnson, B.Sc.
S.R. Leather, B.Sc., Ph.D., C.Biol., M.I.Biol., F.R.E.S.

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

Administration
HEO: C.K. Smith
EO: Mrs M. Farm

Instrumentation Section (North)
B.A. Gardiner, B.Sc., Ph.D., F.R. Met. S., Head of Section

INDUSTRIAL STAFF

The total number of industrial employees in Research Division at 31 March 1991 was 124.5.

STAFF CHANGES

Transfers in:

J.L. Budd (Forest Officer IV) from East England Conservancy to Silviculture South, Alice Holt.

P. Cairns (Forest Officer IV) from North Scotland Conservancy to Silviculture North, Cairnbaan.

C. Edwards (Forest Officer IV) from Mid Scotland Conservancy to Silviculture North, Newton.

N. Fearis (Forest Officer IV) from West England Conservancy to Mensuration, Alice Holt.

D.N. Johnson (Forest Officer IV) from Silviculture Division (outstationed Newton Nursery) to Silviculture North, Mabie.

C.D. Jones (Forest Officer IV) from Wales Conservancy to Silviculture North, Talybont.

J. Morgan (Forest Officer II) from East England Conservancy to Silviculture North, Northern Research Station.

P.M. Tabbush (Grade 7) from Wales Conservancy to Silviculture South, Alice Holt.

New appointments:

A.S. Gardiner (Assistant Scientific Officer) Plant Production, Alice Holt.

N.P. Hayward (Forest Officer IV) Site Studies South, Alice Holt.

S.D. Hibbs (Scientific Officer) Statistics and Computing South, Alice Holt.

Mrs C.A. Holmes (Personal Secretary) Administration, Alice Holt.

K.R. Knott (Forest Officer IV) Silviculture South, Alice Holt.

R.A. Nickerson (Forest Officer III) Silviculture South, Alice Holt.

Mrs J. Rose (Assistant Scientific Officer) Pathology, Alice Holt.

Mrs J.E. Stonard (Assistant Scientific Officer) Site Studies South, Alice Holt.

Mrs C.A. Tilbury (Assistant Scientific Officer) Entomology, Alice Holt.

Transfers out:

S.M. Colderick (Forest Officer III) from Silviculture South, Alice Holt to West England Conservancy.

T.D. Cooper (Forest Officer III) from Silviculture South, Thetford to East England Conservancy.

S.J. Corcoran (Forest Officer III) from Silviculture North, Talybont to South Scotland Conservancy.

D. Kerr (Forest Officer III) from Silviculture North, Kielder to North England Conservancy.

Miss A.D. Kitching (Assistant Scientific Officer) from Plant Production, Alice Holt to MAFF.

N.A.D. Muir (Forest Officer IV) from Tree Improvement, Northern Research Station to Wales Conservancy.

S. Stables (Forest Officer III) from Silviculture North, Cairnbaan to North England Conservancy.

D.A. Thompson (Grade 7) from Silviculture South, Alice Holt to Harvesting and Marketing Division, HQ, Edinburgh (on promotion to Grade 6).

Promotions

A.R. Anderson (Site Studies North, Northern Research Station) to Higher Scientific Officer.

R.W. Blackburn (Statistics and Computing North, Northern Research Station) to Senior Scientific Officer.

A.H. Chadwick (Wildlife and Conservation, Ardentinny) to Forest Officer III.

D.W.H. Durrant (Site Studies South, Alice Holt) to Forest Officer II.

P.G. Gosling (Plant Production, Alice Holt) to Grade 7.

M.K. Hollingsworth (Silviculture North, Northern Research Station) to Forest Oficer II.

W.L. Mason (Silviculture North, Northern Research Station) to Grade 7.

R.W. Matthews (Mensuration, Alice Holt) to Senior Scientific Officer.

Mrs B.A. Mayle (Wildlife and Conservation, Alice Holt) to Higher Scientific Officer.

B.C. Nicoll (Physiology, Northern Research Station) to Scientific Officer.

T.R. Nisbet (Site Studies South, Alice Holt) to Senior Scientific Officer.

C.A. Palmer (Pathology, Alice Holt) to Forest Officer III.

J.E. Pratt (Pathology, Northern Research Station) to Forest Officer I.

D. Ray (Site Studies North, Northern Research Station) to Higher Scientific Officer.

Mrs D.A. Waddell (Site Studies South, Alice Holt) to Higher Scientific Officer.

I.M.S. White (Statistics and Computing North, Northern Research Station) to Grade 7.

Resignations:

Miss K. Johnson (Personal Secretary) Administration, Alice Holt.

P.C. Jokiel (Assistant Scientific Officer) Site Studies South, Alice Holt (to undertake 3 year contract with Mensuration, Alice Holt).

M.A. Mellergaard (Scientific Officer) Statistics and Computing South, Alice Holt.

Mrs C.J. Potter (Forest Officer I) Silviculture South, Alice Holt (career break).

Mrs K. Potter (Executive Officer) Administration, Alice Holt (career break).

Mrs P.J. Rigg (Assistant Scientific Officer) Plant Production, Alice Holt (career break).

A. Willson (Senior Scientific Officer) Site Studies South, Alice Holt.

Retirements:

A.A. Green (Forest Officer III) Silviculture North, Newton.

P.H. Priestley (Forest Officer III) Silviculture North, Kielder.

C.J. Roberts (Forest Officer III) Site Studies South, Alice Holt.

J.T. Stoakley (Grade 7) Entomology, Northern Research Station.

APPENDIX VII

ADDRESSES OF RESEARCH LOCATIONS

Main Centres

Forestry Commission
Forest Research Station
Alice Holt Lodge
Wrecclesham
Farnham, Surrey
GU10 4LH
Tel: 0420 22255
Fax: 0420 23653

Forestry Commission
Northern Research Station
Roslin
Midlothian
EH25 9SY
Tel: 031 445 2176
Fax: 031 445 5124

Some staff engaged in research are also stationed at:
Forestry Commission
Headquarters
231 Corstorphine Road
Edinburgh EH12 7AT
Tel: 031 334 0303
Fax: 031 334 3047

Research Outstations

Ardentinny Wildlife
Forestry Commission
Wildlife & Conservation
Research Branch
Ardentinny
Dunoon
Argyll
PA23 8TS
Tel: 036 981 253

Bush Silv(N)
Forestry Commission
Northern Research Station
Roslin
Midlothian
EH25 9SY
Tel: 031 445 2176

Cairnbaan Silv(N)
Forestry Commission
Research Office
Cairnbaan
Lochgilphead
Argyll
PA31 8SQ
Tel: 0546 2304

Exeter Silv(S)
Forestry Commission
Research Office
Bullers Hill
Kennford
Exeter
Devon EX6 7XR
Tel: 0392 832262

Headley Silv(S)
Forestry Commission
Headley Research Nursery
Headley Park
Bordon
Hampshire
All mail via Alice Holt Lodge
Tel: 0420 473466

Kielder Silv(N) & Entomology
Forestry Commission
Research Office
Kielder
by Hexham
Northumberland
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Tel: 0434 250235

Lairg Silv(N)
Forestry Commission
Research Office
Ord Croft
Lairg
Sutherland
IV27 4AZ
Tel: 0549 2150

Ludlow Entomology
Forestry Commission
Entomology Office
Whitcliffe
Ludlow
Shropshire
SY8 2HD
Tel: 0584 878322

Mabie Silv(N) & Entomology
Forestry Commission
Research Office
Mabie
Troqueer
Dumfries
DG2 8HB
Tel: 0387 52267

Midlands Silv(S)
Forestry Commission
Research Office
Woodside
Arley
Coventry
Warwickshire
CV7 8GH
Tel: 0676 41668

Newton Silv(N) &
Tree Improvement
Forestry Commission
Research Office
Newton Nursery
Elgin
Morayshire
IV30 3XR
Tel: 0343 543165

Perth Silv(N)
Forestry Commission
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10 York Place
Perth PH2 8EJ
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Shobdon Tree Improvement
Forestry Commission
Research Division
Uphampton
Shobdon, Leominster
Hereford HR6 9PB
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Talybont-on-Usk Silv(N)
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Research Office
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Talybont-on-Usk
Brecon
Powys LD3 7YN
Tel: 0874 87444

Thetford Silv(S)
Forestry Commission
Research Office
Santon Downham
Brandon
Suffolk IP27 0TJ
Tel: 0842 810271

Westonbirt Silv(S)
Forestry Commission
Westonbirt Arboretum
Tetbury
Gloucestershire GL8 8QS
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Wykeham Silv(N)
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Research Office
Wykeham, Scarborough
N. Yorks YO13 9HQ
Tel: 0723 862031

INDEX

Acknowledgement This index was prepared by Dr John Chandler.

GLOSSARY

Latin names of trees cited by common name in this Report

BROADLEAVES	
acacia, false	*Robina pseudoacacia*
alder, common	*Alnus glutinosa*
red	*A. rubra*
ash	*Fraxinus excelsior*
beech (European)	*Fagus sylvatica*
birch, downy	*Betula pubescens*
silver	*B. pendula*
cherry, flowering	*Prunus* 'Kazan'
wild (gean)	*P. avium*
chestnut, sweet	*Castanea sativa*
elm	*Ulmus procera*
hawthorn	*Crataegus monogyna*
lime, small-leaved	*Tilia cordata*
maple, field	*Acer campestre*
oak, pedunculate	*Quercus robur*
red	*Q. rubra*
sessile	*Q. petraea*
plane, London	*Platanus* x *hispanica*
poplar, Lombardy	*Populus nigra* 'Italica'
white	*P. alba*
rowan	*Sorbus aucuparia*
sallow, grey	*Salix cinerea*
sycamore	*Acer pseudoplatanus*
willow	*Salix* spp.

CONIFERS	
cypress, Lawson	*Chamaecyparis lawsoniana*
Leyland	x *Cupressocyparis leylandii*
Monterey	*Cupressus macrocarpa*
fir, Douglas	*Pseudotsuga menziesii*
noble	*Abies procera*
larch, European	*Larix decidua*
hybrid	*L.* x *eurolepis*
Japanese	*L. kaempferi*
pine, Bishop	*Pinus muricata*
Corsican	*P. nigra* var. *maritima*
lodgepole	*P. contorta*
Scots	*P. sylvestris*
spruce, Norway	*Picea abies*
Sitka	*P. sitchensis*

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