The Forestry Authority

Forestry Commission

# REPORT ON FOREST RESEARCH

# 1993

HMSO

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for the year ended March 1993

LONDON: HMSO

ISBN 0 11 710324 1
FDC 945.4: (410)
*The abbreviated title of this Report is Rep. Forest Res., Edin. 1993*

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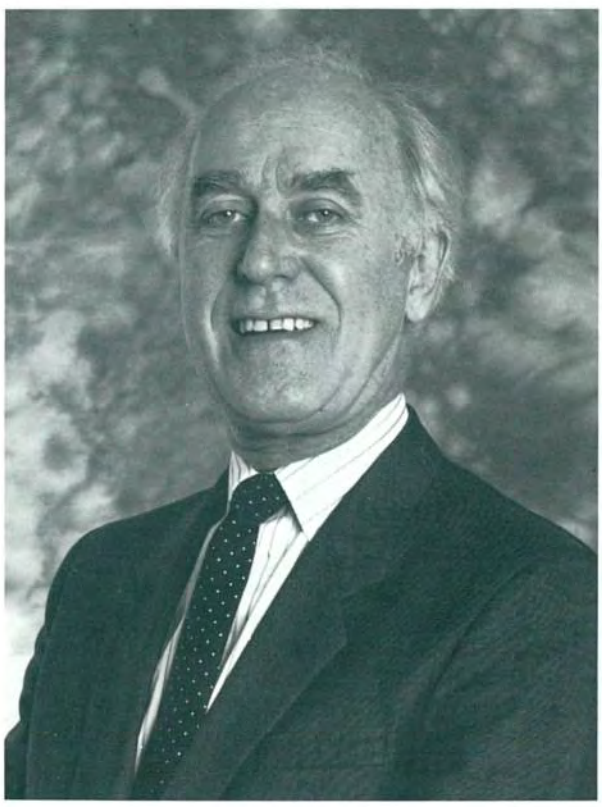
# INTRODUCTION

*by David Burdekin,*
*Director Research*



This research year was identified by two events, both of which had a dramatic effect on the work of the Research Division. One of these, our first series of open days for eight years, was an outstanding success. The other was an arson attack on the laboratories at Alice Holt Lodge; fortunately this attack had much less effect than intended, but it was nevertheless a traumatic experience.

The open days were held on June 18, 19 and 21, the last being a Family Day on the Sunday. Lord Howe, Minister of State for Agriculture, opened the event and he visited most of the displays in a tour of the site. A particularly impressive tree top walk caught the attention of many visitors, as did a display by sniffer dogs who were able to identify rotten pieces of wood. These exhibits were eye catching and were backed up by explanations of the scientific research in these areas of work. All branches provided a high standard of exhibit and a full commentary was given by the researchers directly involved.

The Family Day on the Sunday was a particular feature. The scientific exhibits from the previous days were maintained but there were, in addition, a series of activities ranging from a bouncy castle to a woodland walk and a children's drawing competition.

Special thanks to Janet Methley and her team, who made the arrangements for the Family Day.

## Advisory Committee on Forest Research

Two Visiting Groups were established by the Advisory Committee on Forest Research during the year, one on Physiology and the other on southern Silviculture.

The Visiting Group to the Physiology Branch consisted of Professor D. Read (University of Sheffield) and Professor H.G. Jones (Horticulture Research International). The Group made special mention of the high calibre of research undertaken in the Branch. The Group also drew attention to the serious loss of expertise which will occur when the present Head of Branch retires in 1993.

The Visiting Group to the Silviculture (South) Branch consisted of Professor H.G. Miller (University of Aberdeen), Mr J. MacLeod (National Institute of Agricultural Botany, Cambridge) and Dr P. Savill (Oxford Forestry Institute). The Group complimented the Branch on its income-earning capacity but recognised the considerable pressure which this placed on the available resources. Careful attention will need to be paid to the proportion of effort devoted to technology transfer so that effective use is made of limited staff resource.

For the third year in succession the Committee held a field meeting, this time in the Marches and mid Wales. The opportunity was taken to see some of the work of the Plant Production and Entomology Branches which are due for Visiting Groups in 1993.

## RESEARCH HIGHLIGHTS

The following selection of research highlights has been chosen from many possible candidates. One or two examples illustrate the involvement of the Research Division in giving advice on legislation. Other research projects have reached a stage where interesting results are forthcoming.

### *Pine wood nematode*

The pine wood nematode, *Bursaphelenchus xylophilus*, is a devastating pest of pine in Japan and perhaps other parts of Asia. It is also present in North America, though it does not appear to cause serious damage to pines there. This small, almost microscopic, eelworm lives in the wood of conifers, especially pines, and is transmitted from dying trees to new hosts by cerambycid beetles. Neither the eelworm nor the vector beetle have been found in Britain, and the eelworm is absent from the rest of Europe.

The Research Division has provided scientific advice on the potential for the pest in Europe, which in turn has been used to frame European Community legislation on plant health. This has necessarily been a particularly objective exercise with the timber trade naturally concerned about any interference in legitimate trade.

### *Water quality*

The effect of afforestation on water quality has long been a contentious issue and although legislation is not directly involved, the Forestry Commission has issued guidelines on forests and water. The Research Division has provided scientific expertise in the preparation of the guidelines. A key factor in the latest edition of the guidelines has been the use of the critical load concept. This is defined as the maximum input of air pollution which causes damage to the environment. The measurement of the air pollution input is complex and has involved scientists both inside and outwith the Forestry Commission. The co-operation between those involved in dry deposition, wet deposition, scavenging and the impact on various aspects of water quality has been greatly welcomed.

### *Natural regeneration*

Natural regeneration has become a feature of research in both lowland and upland silviculture. In the lowlands, attention is focused on broadleaves, in particular on the powerful competition which young seedlings and coppice stumps have to overcome for natural regeneration to be successful. In the uplands, research on contract to Scottish Natural Heritage has formed part of a larger study looking at the state of native pinewoods on the widely publicised Mar Lodge Estate in Deeside. Very little natural regeneration has occurred over the last hundred years due to the heavy browsing pressure from deer and sheep. The average age of trees in these woodlands has therefore increased and there was concern that these more mature trees may be losing their ability to produce viable seed. Preliminary results indicate no significant loss in viability. However, there is a tendency towards a reduction in the number of cones and seeds per unit area.

### *Treeshelter survey*

Treeshelters have become incorporated in routine planting of broadleaves, especially in southern Britain. A survey covering a random selection of 193 sites in England has shown a high rate of survival (in 89 per cent) but poor application of weed control (in 63 per cent) (see Plate 1). It was also observed that smaller stakes than those recommended were used on half the sites surveyed and a quarter were planted with the lip of the tree shelter below the tip of the stake. Recommendations are being published to emphasise weaknesses which have come to light from this survey.

### *Energy coppice*

The drive for renewable sources of energy (such as wind) now firmly includes short rotation coppice. The Research Division is undertaking research on contract for the Energy Technology Support Unit of the Department of Trade and Industry. Yields of 10–12 dry tonnes per hectare have been obtained over a series of years and at a range of sites. This yield is three or four times that achieved in traditional forestry. With such high yields it is clearly important to ensure that the optimum spacing is used and that the nutrient bank on the site is not unduly depleted. Trials are in progress to investigate these issues.

### *Biodiversity*

Biodiversity is a term which has become somewhat hackneyed after the Rio Conference. However it does have a very deep-seated significance in relation both to ancient and semi-natural woodlands on the one hand and to plantation forests on the other. There are a number of projects now being brought together under a project team which is directed at enhancing biodiversity. In broadleaved woodlands emphasis

is being placed on promoting greater illumination by the creation of gaps and wider rides (see Plate 2). Investigations into the introduction of more native species and the retention of ancient trees and snags are also being made.

Allied to the biodiversity studies, a new site classification is being developed which will be invaluable in this context and, for other reasons, in multi-purpose forestry. This classification is based on a combination of climatic, soil and ecological zones and is known as the biogeoclimatic ecosystem classification (BEC). BEC is based on a system widely used in western Canada and we have had extremely useful contacts with Canadian scientists on this topic.

## Forestry Research Coordination Committee

The Forestry Research Coordination Committee (FRCC) met on three occasions during the year. The work of the Committee was examined in the light of an increasingly diverse interest in forestry research both from those funding and from those benefiting from forestry research. To assist this, the Committee has broadened its membership, as reported last year, and has established a Research Users' Forum. The Forum represents timber industry, farming, land use, environmental and conservation interests, and met on two occasions. It will help to set priorities for forestry research through careful definition of research topics identified.

The FRCC, in its response to the Review Group on Climate Change, chaired by Dr D.C.Malcolm of Edinburgh University, suggests research emphasis should be placed in four areas:

- improving climatological models;
- elucidating the part played by trees, forests and forest soils in carbon sequestration, and their consequent role in ameliorating climate change;
- assessing the direct effects of elevated carbon dioxide on tree growth; and
- evaluating the impact of climatic change on tree health, and the wider consequences for forest ecosystems as a whole.

During the year, two five-year progress reviews were completed and published; they were the Forestry and the Environment (1985) and Biotic Damage (1986) review group reports.

A total of £19.7 million was spent on forestry and related tree research in Britain in 1992. This is a small reduction on 1991. The shift of emphasis towards environmental and conservation issues continues and now attracts one-fifth of all funds, with climate change featuring prominently. In general, there is an increased level of research on native broadleaved species and proportionally less on conifers – with the exception of the native Scots pine. Research linked to new woodland initiatives, notably farmland planting and community forests, remains at a high level.

## Thanks

There is no doubt that the output from the Research Division has reached new heights during 1992/93. A high standard of research has been achieved, a very fine set of open days presented results to our peers, and a disruptive arson attack was overcome. My heartfelt thanks are given to all the staff in the Division.

# PART 1

# THE WORK OF THE FORESTRY COMMISSION RESEARCH DIVISION

# ENTOMOLOGY

The projects on Impact and Stress (see below) are now yielding significant results that not only provide direct information on the main themes of the projects but also address the underlying ecological principles that determine the dynamics of interactions between insects and trees. The long-term experiment on the effects of green spruce aphid, *Elatobium abietinum*, and root aphids in the genus *Pachypappa* on the growth of Sitka spruce is now firmly established with sampling protocols in place for both aphid species. Detailed measurements of total aphid loads and of a range of tree growth parameters are being taken monthly in order to quantify precisely the interactions between the two variables.

The Biodiversity project has focused attention on enhancing insect diversity in productive woodland. This study has been enlarged to include three principal aspects, all of which are structural components that can be accommodated in managed forests. The first of these is a study of illumination through canopy gaps of various dimensions and of associated insect colonisation in response to light and heat. The second is to measure the benefits for insect diversity of encouraging or re-introducing native tree and shrub species in plantation woodlands. The third aspect is concerned with the retention of ancient trees and snags as refuges and breeding sites for deadwood insects, many of which are rare or endangered.

International plant health problems and risk assessment continue to occupy a small, but significant, proportion of research time. A two-year European Community (EC) funded research topic into heat treatment requirements for pine wood nematode (PWN), *Bursaphelenchus xylophilus*, in sawn wood was completed during the year. Entomology Branch was instrumental in developing, with Dr Gavin Hall of TRADA, a prototype temperature indicator system responsive to both time and temperature. Field tests in Canada, in parallel with evaluation trials of heat treatment regimes carried out with the Canadian PWN task force, demonstrated that the indicator system was capable of showing whether wood had been treated to the correct temperature to kill the nematode and its vector insects. Funding for further work to develop the system for full practical use in commercial kilns was not forthcoming.

The number of enquiries handled by the Branch's advisory service was 290. This was a slight drop from the previous year. Notable among the enquiries were several on the oak pinhole borer, *Platypus cylindrus*, a beetle that is classed as rare in the insect Red Data Book. Predictions that this species could rise to nuisance levels were made following the 1987 gale in the south of England. There has now been a number of records of the beetle damaging high quality oak logs as a result of larvae boring into the heartwood. However, the beetle attacks only moribund or dead trees and there is no requirement for premature felling of healthy oaks. The advisory service, under Tim Winter, has also set up a Biological Records Centre Bark Beetle Recording Scheme. This aims to encourage awareness of bark beetles among both professional and amateur entomologists, and to provide valuable information on the distribution and abundance of this important group of insects. Response to the scheme in its first year has been encouraging with about 400 records received.

HUGH EVANS

## POPULATION ECOLOGY OF *PANOLIS FLAMMEA*

Recent work on pine beauty moth has shown that the incidence of natural enemies varies according to both soil type and host tree species. For example, the diversity and abundance of predatory beetles is much lower in pure lodgepole pine stands growing on deep, unflushed peat sites, than in mixed lodgepole pine and Scots pine sites or in pure lodgepole pine sites growing on mineral ironpan soils.

The abundance of larval predators and larval predation rates are also markedly affected by soil type and stand composition. Larval predation is much higher on Scots pine trees than on

lodgepole pine trees, and larval mortality due to predation is higher on trees from Alaskan lodgepole pine seed than on trees from south coastal lodgepole pine seed.

In addition, rates of parasitoid attack on both the larval and pupal stages vary according to the soil type and the host plant provenance and species. Parasitism levels are three to four times higher in mixed pine stands than in pure lodgepole pine stands, and are also higher in stands grown on mineral soils than on those grown on unflushed peat soils.

These results indicate that outbreaks are very unlikely to occur on provenances such as Alaskan lodgepole pine, even in areas where natural enemies are low. On south coastal and other suitable provenances, e.g. southern interior, outbreaks will occur at frequent intervals during the course of the crop rotation in areas where natural enemies are low. Outbreaks are unlikely in areas where natural enemies are high.

These results highlight the importance of natural enemies in keeping pine beauty moth populations at levels below the economic threshold. Improvements in forest structure which encourage natural enemy numbers are likely to be beneficial and could form part of an integrated pest management scheme using selective planting and ride management. This remains to be tested in the field.

SIMON LEATHER, MAUREEN DOCHERTY,
PATRICK WALSH, JAMES AEGERTER

## GENETIC AND ENVIRONMENTAL FACTORS IN THE RESISTANCE OF TREES TO INSECT AND FUNGAL ATTACK

The term 'stress' is widely used to describe the many influences of the environment on the resistance of plants to herbivores. The link between host tree stress, site factors and forest insect outbreaks was first made in central Europe in the C.18th, particularly in relation to the ecology of bark beetles. Since then, host stress as a factor in insect population dynamics has been applied much more generally but often with no clear idea of the mode of action.

The primary aim of this project is to measure the influence of stress and site factors on the expression of generalised defences in trees, and to determine the consequences for insect and fungal attack. The ultimate aim is to provide forest managers with guidelines for maximising the resistance to damaging biotic agents of trees on a range of sites subject to different degrees of environmental stress.

Two approaches have been adopted:

- surveys and experiments in Sitka spruce provenance trials replicated at a number of sites in the west of Britain; and
- manipulation of light and nutrient regimes in potted Sitka spruce.

Only the first part of the study is reported here.

Four contrasting sites in the west of Britain, each containing a range of provenances planted in 1961 on a randomised block design, were selected for the surveys. Measurements have been made of the levels of generalised/quantitative defences in bark (terpenes, phenols and lignin) in a number of clearly defined provenances. The results have demonstrated a strong clinal variation in lignin (Figure 1), and other defences, in relation to latitude of origin of provenance. Preliminary results suggest the influence of site factors on this relationship.

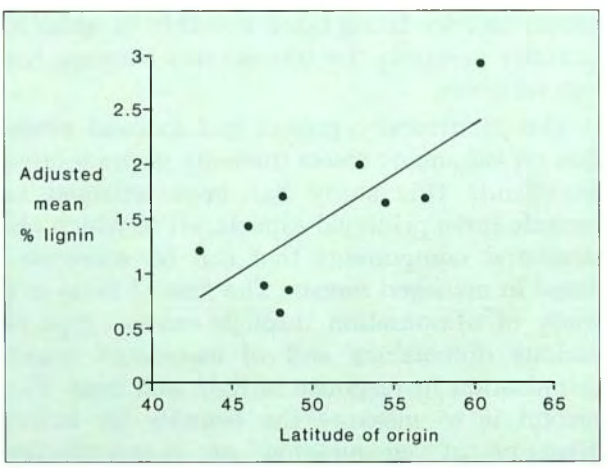



*Figure 1. Variation in lignification of Sitka spruce bark in relation to latitudinal origin of provenance. Percent lignin was adjusted for the covariate dbh.*

At two additional sites, in joint work with Pathology Branch staff, three provenances were challenged with two facultatively parasitic fungi. The smallest lesions developed on the most northerly provenances, i.e. the ones with the greatest concentration of defensive chemicals. There was also evidence of site differences in the induced response to fungal attack.

DAVID WAINHOUSE, ROBERT ASHBURNER,
DAVID ROSE, ROBERT BROOKER*

* Pathology Branch

## CONTROL OF RESTOCKING PESTS: BIOLOGICAL PROTECTION AGAINST *HYLOBIUS ABIETIS*

One of the main strategies to underpin an integrated pest management (IPM) system is the use of biological control agents. These could reduce *H. abietis* feeding damage in three ways:

1. by directly protecting the plants;
2. by reducing the population of *H. abietis* within the restock area; or
3. by suppressing the *H. abietis* population in a forest unit by its gradual reduction over a number of seasons.

Work in the Biological Control project includes both monitoring/behavioural studies and evaluation and use of biological agents. Research has concentrated on the use of entomopathogenic nematodes because they are available from a number of companies in commercial quantities. Although fungal and bacterial agents are being evaluated, these would have to be approved for use by the same registration procedures as chemicals. However, many of the techniques and principles are the same for all biological agents.

The biological control studies have demonstrated the following points.

- Several strains and species of entomopathogenic nematodes are able to kill both adults and larvae of *H. abietis* as well as inducing behavioural changes (immobility) in the adults.
- Nematodes survive for many months in a variety of soil types and pH ranges and they do not move significantly from the point of application.
- The characteristics of entomopathogenic nematodes would make them suitable for use in the long-term management of *H. abietis* populations by suppression of larval stages.
- None of the biological agents currently available commercially has the characteristics necessary for successful use in the direct protection of newly planted trees or in rapid population reduction of breeding populations in stumps. However, used in combination with other management options within an IPM system, they offer potential for long-term regulation of *H. abietis* populations below the economic threshold.

Studies of the population dynamics, particularly the resource requirements, of *H. abietis* have begun under a new project. Information from this study will underpin the IPM strategy now being developed for future management of restocking pests.

STUART HERITAGE, SARA COLLINS, JULIA BRIXEY, SIMON LEATHER, IAIN WATT

# FOREST PRODUCTS

Work of Forest Products Branch was featured at the Research Station open days from 18 to 21 June. Exhibits focused on composite wood products with their improved strength properties, and emphasised the diversity of wood when transformed into fuel, paper or packaging, and used in construction, joinery and horticulture. Research on the long-term water storage of timber was also highlighted as the last of the 75 000 $m^3$ of timber was sold from Thetford Forest logstore, originally set up to preserve windthrown timber after the severe gales of 1987.

Currently, much of the Branch's resources are directed towards commissioned research on timber properties, predicting and enhancing quality, the effect of provenance and silvicultural management on timber, and the processes causing deterioration of wood and its prevention (see Part 2 report). Timber testing continues on the five major British grown softwood species for the European Timber Standards, which are due to be implemented in 1993/94. The testing of hardwood timbers is also well under way with the eventual aim of providing grading rules to facilitate the regular use of oak and other hardwoods in construction.

In-house research commitments are mainly concentrated on the prevention of fungal deterioration in home grown pine and composting of wood residues and other forest products for horticultural use. A joint research programme with Pathology Branch has also recently been initiated to evaluate the extent to which mechanised harvesting can predispose pine to blue stain attack.

## Preservation of utility poles

Decay can occur in pine utility poles during the necessary seasoning period prior to chemical treatment, but this is obviously unacceptable because of the strength losses involved. However, previous studies have indicated that preseasoning decay can be effectively controlled using mild chemical treatments and, possibly, biological agents. The current project, as part of a Science and Engineering Research Council CASE studentship, is therefore investigating the potential of biological treatments to prevent decay of utility poles, with an emphasis on developing an on-site control method.

Four potential biocontrol fungi – *Trichoderma harzianum, Ascocoryne sarcoides, Phacidium coniferarum and Cryptosporiopsis tarraconensis* – were assessed for their ability to control decay in a large-scale field experiment. Only *T. harzianum* provided acceptable levels of protection to the freshly felled pine and the experiment highlighted the need for adopting thorough screening procedures for selecting suitable biological control agents. Subsequent work has been directed at developing reliable methods to screen large numbers of potential biocontrol fungi.

The field study also indicated that biological treatments might be more effective if used with compatible chemicals, in an integrated approach to decay control. A second series of field experiments is now looking at the use of borate-tolerant isolates of *Trichoderma* alongside mild, boron-based chemical treatments. Molecular techniques, which essentially allow individual fungal genotypes to be characterised, are proving to be of potential use in following the progress of test isolates in the field.

Magnus Schoeman, Joan Webber and Dave Dickinson*

* Department of Biology, Imperial College, London

## Advisory Service

As part of Research Division's newly organised Advisory Service, the Branch responded to more than 170 enquiries from the forestry industry, the public and educational establishments. Well over a third of the enquirers wanted information about timber quality and utilisation. Other popular subject areas included residues (23% of queries), preservation (16%) and charcoal production (10%).

Joan Webber and Carole Lishman

# MENSURATION

In collaboration with Forest Enterprise districts, sample plots were established this year to monitor contemporary and evolving forestry practices. Six plots were established in Corsican pine in Wensum Forest (Thetford Forest District) to assess the effect of modern harvesting techniques on volume production. Further sample plots were established in an existing Silviculture (South) Branch spacing trial of 24 plots of bishop pine, *Pinus muricata*, and Monterey pine, *Pinus radiata*, in Ringwood Forest, (Dorset Forest District). Data from these sample plots will help the economic evaluation of more widespread planting of these species in the extreme south of England.

Following a review of tariff data from South Scotland Region, a major study of growth characteristics in unthinned Sitka spruce has been initiated. This study is a collaborative project with Forest Enterprise using data from a combination of permanent and temporary sample plots.

The Ae Sitka spruce replicated thinning experiment was established in 1964 to compare the effect on growth of three thinning intensities and three thinning types. The experiment was felled this year and a full final measure carried out. In addition to the normal final volume assessment the opportunity was taken to collect data on assortments, conversion loss and log quality.

The data collection program on the Micropalm portable computer, used in sample plot measurement, was amended and further enhanced following rigorous field testing during the 1991/92 measurement season. Relatively few errors were found but a number of improvements were suggested by the field teams, to give greater flexibility when working. Major amendments and enhancements were written for three important computer programs used by the branch. The sample plot processing program (SPLOT) and the assortment forecasting program (ASORT), needed urgent attention following installation of the new computer network. In addition, the sample plot database was converted from RAPPORT to the ORACLE database system. The ASORT program predicts volumes of product types that can be cut from a stand. The program has been upgraded to allow theoretical cutting of unlimited combinations of product types. ASORT was used in the construction of a family of curves for predicting the distribution of maximum log lengths through the diameter range of a stand. The curves were requested, following a move to log pole conversion in the Borders, to maximise green log volume.

There was major involvement in the Forest Condition Monitoring Survey which included surveyor training and connectivity assessments. The Branch continues to represent the United Kingdom on the European Standards Committee CEN TC 175 Working Group 1: Methods of Measurement of Round Timber.

JANET METHLEY AND JOHN PROUDFOOT

## PROGRESS ON CARBON STORAGE RESEARCH

Suites of mathematical functions have been derived for predicting the total above-ground and below-ground biomass of individual trees from total height and diameter at breast height. The predictions also give a breakdown of total biomass into the main tree components with estimates of confidence. Figure 2 illustrates a mathematical function which predicts the total above-ground biomass, including foliage, of Sitka spruce trees. The relationship between biomass and diameter at breast height is shown for a range of height classes. Functions such as this example are available for all major plantation tree species.

A valuable bi-product of this research will be models for predicting the quantity of conversion-loss and lop and top left in the forest by conventional harvesting operations. There is growing interest in this previously unharvested material as a potential source of biomass fuel.

ROBERT MATTHEWS AND ROBERT ROBINSON

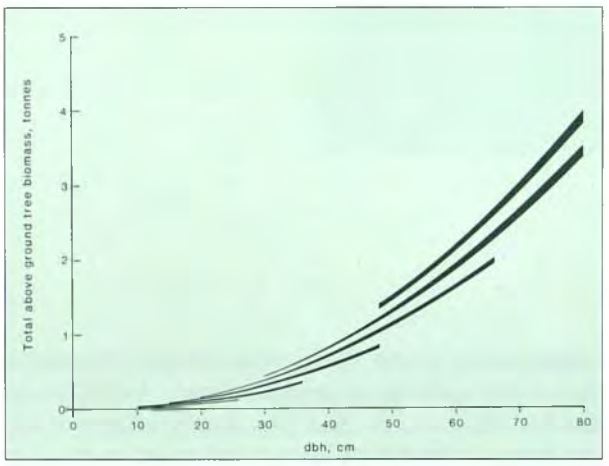



*Figure 2. Illustration of mathematical function for predicting total above-ground biomass of Sitka spruce trees from total height and diameter at breast height (dbh). The black bands indicate the 95% confidence interval for the estimate of biomass. The error in prediction of biomass for a particular tree could be larger than suggested by this interval, which is strictly applicable to groups of trees at the stand level.*

## Tree age assessment

No standard technique exists for estimating the age of standing trees without resorting to destructive methods. Under contract to the Department of the Environment, measurements of 305 open-grown trees from 19 tree species were collected from 31 sites in southern England for the development of a model for estimating tree age. The information was entered into a new database, ARBAGE, which was designed and constructed to ensure a consistent standard and format for recording measurements on amenity trees. Eleven provisional look-up graphs were produced for predicting the age of trees in different species groups from diameter at breast height and average height to base of crown. Figure 3 illustrates the look-up graph for predicting the age of oak, birch, and whitebeam trees with an average height of five metres to base of crown.

Stan Abbott, Nigel Fearis, Robert Matthews,
Janet Methley and Robert Robinson

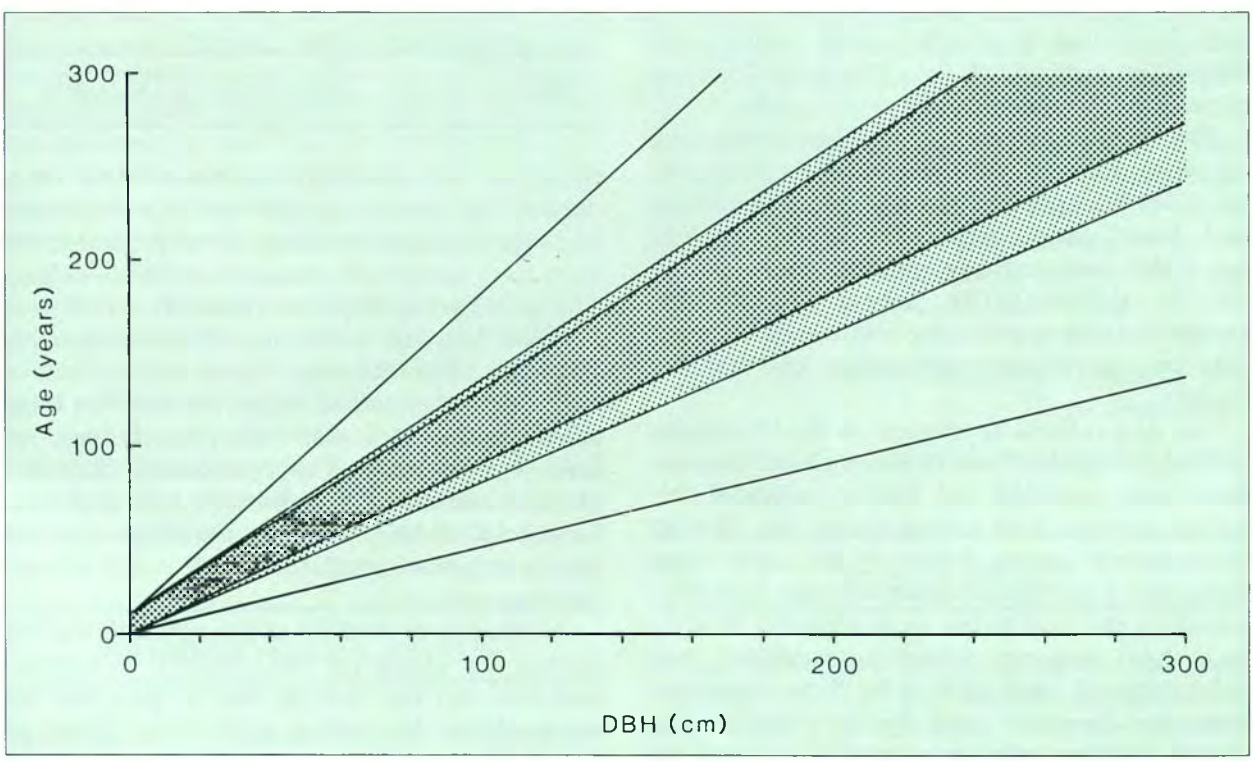



*Figure 3. Look-up graph for predicting age from diameter at breast height (dbh) of oak, birch and whitebeam trees with an average height of 5 m to base of crown. 50% of all observations of tree age, given dbh, would be expected to lie within the dark shaded region shown on the graph. 90% of all such observations would be expected to fall within the wider area covered by the light and dark shaded regions. The top and bottom lines enclose the region containing all observations of tree age given dbh.*

## SITE YIELD RESEARCH IN LOWLAND ENGLAND AND WALES

Significant progress has been made on the joint research project funded by the Forestry Commission and the Ministry of Agriculture, Fisheries and Food. Information is needed on the yield potential of common woodland species, planted on better quality lowland sites released from agriculture. Data from temporary and permanent sample plots were used to construct and calibrate models for predicting potential yield class of plantation forests by major soil group, accumulated temperature above 5.6 °C and potential soil moisture deficit. Figures 4 and 5 illustrate predictions made by two types of model of the potential yield class of Douglas fir planted on brown earths. Models developed using regression methods produce smooth response surfaces with respect to accumulated temperature and soil moisture deficit, and enable broad features such as conditions for maximum yield to be identified. For example, as shown in Figure 4, the yield of Douglas fir is predicted to be maximal for combinations of accumulated temperature and soil moisture deficit in the region of 1850 day-degrees and 100 mm respectively. Models developed using ANOVA methods are more sensitive to local conditions and do not necessarily produce a smooth response surface. Figure 5 shows a look-up table for Douglas fir produced using an ANOVA-based model. The predictions made by the two types of model do not agree for all combinations of accumulated temperature and soil moisture deficit, and research is continuing to identify the optimal model.

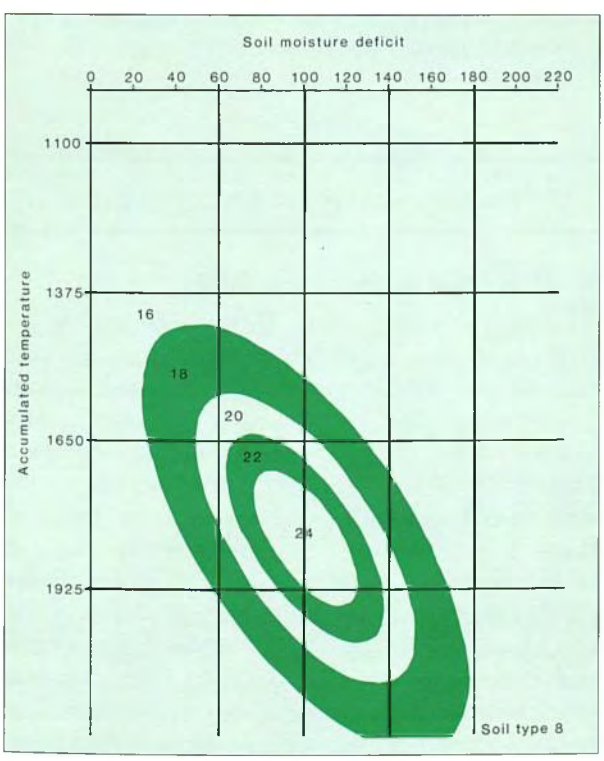
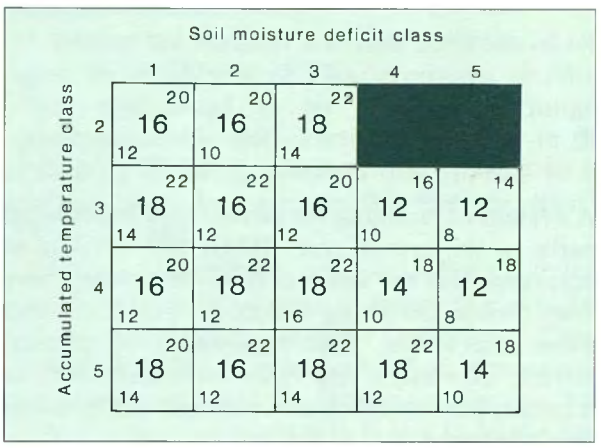



*Figure 4. Surface-type model for predicting general yield class (GYC) of Douglas fir from the site factors accumulated temperature and potential soil moisture deficit. The model is applicable to sites with a brown earth soil type. The diagram shows GYC contours with respect to the two site factors.*




*Key*

*Accumulated temperature above 5.6 °C (day-degrees C)*

| *Class* | *Range* |
|---|---|
| *2* | *1100 - 1374* |
| *3* | *1375 - 1649* |
| *4* | *1650 - 1924* |
| *5* | *1925 - 2200* |

*Potential soil moisture deficit (mm)*

| *Class* | *Range* |
|---|---|
| *1* | *0 - 60* |
| *2* | *61 - 100* |
| *3* | *101 - 140* |
| *4* | *141 - 180* |
| *5* | *>180* |

*Figure 5. Look-up table based on ANOVA-type model for predicting general yield class (GYC) of Douglas fir from the site factors accumulated temperature and potential soil moisture deficit. The model is applicable to sites with a brown earth soil type. Large numbers indicate predicted GYC for each combination of site factor classes. Smaller numbers in corners of cells indicate 75% confidence interval for observations.*

Provisional look-up tables, based on the two types of model, have been produced for oak, beech, Corsican pine and Douglas fir. Further models are being developed for ash, sycamore, poplar, hybrid larch and Norway spruce.

MELISSA ALEXANDER, PETER JOKIEL, TONY LUDLOW, ROBERT MATTHEWS, JANET METHLEY, ROBERT ROBINSON, IAN SALISBURY, SHIRLEY STEPHENS

# PATHOLOGY

A system of charging for advice was introduced early in the report year. While the number of enquiries was the same as the year before, there were fewer involving unknown problems and more concerning risk assessment or general advice. Not many site visits were made and, as a result, less scientifically valuable information was generated.

Following the resignation of John Innes of Site Studies (South) Branch in May 1992, Derek Redfern assumed overall responsibility for the Forest Condition Survey, a task for which he was well qualified by his early involvement in the work (Binns and Redfern, 1983; Binns *et al.*, 1985). The 1992 data (Redfern *et al.*, 1993) showed that a slight overall decline in crown density had occurred since 1991, principally due to changes in the condition of Scots pine and oak. There was a very satisfactory degree of consistency of scoring by the 12 survey teams involved.

The Department of the Environment Arboriculture V contract was completed during the year. As part of the Pathology Branch involvement, Bob Strouts, together with Tim Winter of Entomology Branch, completed the text of the diagnostic guide to ill health in amenity trees. In addition, John Gibbs conducted an evaluation of the attitude of highway authorities to the problem of damage to trees and shrubs caused by de-icing salt. The results of this study were generally encouraging.

Together with Forest Products Branch, a project was started on the ability of various blue stain fungi to colonize fresh pine logs at different times of the year and in relation to different harvesting methods. The research is being undertaken for a M.Phil. at Imperial College, London by Adnan Uzunovic from Bosnia.

Finally, mention must be made of the fact that Pathology Branch bore the brunt of the arson attack on Alice Holt, which took place in the early hours of December 14th 1992. Brian Greig's office was completely burnt out and several others were seriously damaged. While every effort was made to ensure that certain work programmes could continue, much research was seriously disrupted and some unique data were destroyed. Tribute is due both to members of the Branch and to all those, both within and without the Forestry Commission, who worked so hard to restore effective research in the new year.

JOHN GIBBS

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## DIAGNOSTIC AND ADVISORY SERVICES

### *Scotland and northern England*

Among the wide variety of diseases and disorders encountered, *Heterobasidion annosum* was the single most frequently recorded agent. There were also, as in previous years, many cases of damage by inappropriate use of toxic chemicals. Misuse of herbicides in nurseries and young plantations accounted for most of these but there was one noteworthy case in which materials used to clean out water mains caused significant injury to amenity trees at the discharge point. Unusually, few instances of climatic damage were brought to our attention though, towards the end of the report period, it became apparent that serious damage had been sustained during winter 1992/93 by Sitka spruce and Douglas fir nursery stock at some locations. The symptoms – browning of foliage and dieback of leading shoots – suggest a form of winter desiccation injury; the occurrence is still under investigation.

Other notable cases have involved the pathogens *Coleosporium tussilaginis, Armillaria, Pseudomonas syringae* and *Pseudonectria rousseliana*. The first of these, normally a common but quite insignificant needle rust, was responsible for severe foliage damage in a Scottish Christmas-tree plantation. *Armillaria,* a common and important pathogen of tree roots, was found to be associated with the death of 57-year-old oaks in a wood in southern Scotland. Oaks of this age are normally extremely resistant to *Armillaria* and it is possible that drought was a major predisposing factor. The species of *Armillaria* involved is still under investigation. The bacterial pathogen *Pseudomonas syringae,* which is also common, was responsible for severe dieback of *Prunus avium* in a large scale amenity planting. The unusual severity and prevalence of damage may have been attributable to pre-planting pruning. By contrast to the three previous pathogens, the fungus *Pseudonectria rousseliana* is a quite unfamiliar one in Forestry Commission records. It was found associated with extensive dieback of a large box hedge in Perthshire.

The year was remarkable for the number of enquiries in which investigation revealed that features of quite alarming appearance were in fact quite normal or, at worst, reflected negligible damage. In addition to the natural shedding of senescent foliage by pines, which is a frequent cause of concern to enquirers, there were some more unusual cases. In one, the slight over-development of pith in Sitka spruce logs gave the appearance of a central decay column. In another, heavy fungal growth on the ends of Sitka spruce logs suggested the presence of serious degrade; the fungus (*Nectria fuckeliana*) proved to be confined to the surface and was unlikely to cause penetrating stain.

STEVE GREGORY, DEREK REDFERN,
GRACE MACASKILL, JIM PRATT

### *Wales and southern England*

During the year there were a number of cases of fireblight caused by the bacterium *Erwinia amylovera* on whitebeam; in one such case in Dorset some 20 roadside trees were severely damaged.

A powdery mildew causing leaf necrosis and leaf loss on cherry laurel was identified as *Sphaerotheca pannosa*. This case is notable on two counts. Firstly, *S. pannosa* has rarely been recorded on any *Prunus;* it is the common powdery mildew of roses. Secondly, the damage (killing of discrete patches of leaf tissue and defoliation) is uncharacteristic of powdery mildews. There is an old record of what appears to be this damage on cherry laurel in Kew Garden (Salmon, 1906).

During the summer a severe outbreak of leaf spot on stool-beds of *Ulmus procera* at Alice Holt was found to be due to the fungus *Mycosphaerella ulmi.* Though described in the literature as being common this appears to be the first case dealt with by this Service since it began in 1962.

In late September a number of *Prunus avium* were found to have large numbers of shrivelled leaves scattered throughout the crown. These leaves remained firmly attached throughout the winter and into the following summer. The cause of the leaf death was found to be the fungus *Apiognomonia erythrostoma*. The fungus is well known from the literature on cherry diseases but such conspicuous and widespread damage has not been previously recorded by us. It was also unusually conspicuous in northern France (P. Chandelier, pers. com.).

The most notable abiotic damage investigated during the year involved injury to street trees caused by the herbicide imazapyr. When examined in May the trees showed a range of symptoms including failure of buds to flush, abortive flushing and the formation of multiple stunted shoots from lower sections of branches. The affected growth was tinged red or pink, a known symptom of damage from this chemical (Derr and Appleton, 1988). Enquiry revealed that, during the previous summer, the herbicide had been applied to pavements around the trees, a procedure that is contrary to the manufacturers' recommendations. This case is one of a number of instances of injury involving imazapyr that we have examined during the last few years (*Report,* 1992). This time the imazapyr had been applied alone, and not in mixture with atrazine as has often occurred in the past. Also, the 1991/92 winter was mild, so there was no likelihood that the severity of the symptoms had been exacerbated by the toxic effect of de-icing salt.

DAVID ROSE

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## ASH DIEBACK

In the early summer of 1992 a dramatic occurrence of ash dieback was reported from Cambridgeshire by staff of the County Council's Rural Group. Damage was thought to be most severe in trees on the clay soils to the south west of the county. The principal symptom was the lack of foliage on major branches, often over large parts of the crown. Trees in this condition could be found on all types of site – in woodland, on permanent pasture, and adjacent to arable land.

Examination of affected branches indicated that they had lost vitality in late summer or autumn 1991. Evidence for this came from the condition of the tissues and their state of colonisation by various fungi, most common of which were *Diplodia inquinans, Fusarium lateritium* and *Alternaria* spp. All available evidence indicates that these are not pathogens of healthy ash and that they are only able to develop in host tissue when it is weakened in some way (e.g. Griffith and Boddy, 1988). *D. inquinans* is almost certainly the 'Species 12' that was frequently isolated from dead ash twigs by Griffith and Boddy. The bark beetle *Hylesinus oleiperda* was also present in some dead branches. During the summer of 1992, epicormic shoots arose from dormant buds on some of the affected branches but the visual impact of these was still negligible by the end of the 1992 growing season.

Advice was given to Cambridgeshire County Council on the design of a survey to obtain quantitative data on the current state of non-woodland ash and to provide a basis for monitoring future change. In addition, the decision was taken to reassess some of the transects from the 1987 survey of dieback in non-woodland ash (Hull and Gibbs, 1991) to get data on the geographical distribution of the damage. The selected plots fell within a band of country across the Midlands from Worcestershire to Cambridgeshire. These were assessed between early August and mid-September and much of the work was conducted by Mr S.K. Hull of Tree Data Services. The results, in Table 1, indicate that the serious deterioration that has occurred in Cambridgeshire has not occurred further west.

It is hoped that the County Council survey will provide useful information on the relationship between the severity of dieback and factors such as soil type. The synchronous appearance of the damage over quite a large area suggests an abiotic rather than a biotic cause of the problem, and this view is reinforced by the nature of the fungi and insects that have been found in the damaged tissue. Drought is suspected as a major factor; severe drought conditions persisted in East Anglia throughout 1991 whereas in many other parts of lowland England the drought years of 1989 and 1990 were succeeded by a relatively wet 1991.

The East Anglian Conservancy of the Forestry Authority funded the first year of the Cambridgeshire County Council survey as an indication of interest in the health of trees in their area.

JOHN GIBBS

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**Table 1.** Dieback of non-woodland ash in trees observed from minor roads transecting 10 km grid squares.*

| Regional grouping of counties | No. of 10 km squares traversed | 1987 Av. no. trees assessed per plot | 1987 Percentage of trees with at least 10% dieback | 1992 Av. no. trees assessed per plot | 1992 Percentage of trees with at least 10% dieback |
|---|---|---|---|---|---|
| Cambridgeshire and north-west Essex | 7 | 136 | 17 | 154 | 48 |
| Bedfordshire, Buckinghamshire and Northamptonshire | 9 | 207 | 21 | 192 | 26 |
| Oxfordshire, Warwickshire, Worcestershire and Gloucestershire | 11 | 158 | 18 | 174 | 20 |

*The technique was developed by Pawsey and then adapted by Hull and Gibbs (1991).

## DUTCH ELM DISEASE

### *Rare hybrids may be a genetic bridge between Ophiostoma ulmi and O. novo-ulmi*

Two pandemics of Dutch elm disease have occurred in the Northern Hemisphere this century. Each was sudden and unexpected. The current, second pandemic caused by the highly pathogenic fungus *Ophiostoma novo-ulmi* involves an array of unusual biological phenomena which need to be explained if we are to understand how and why such pandemics occur. One phenomenon is the means by which, at current epidemic fronts in Europe, *O. novo-ulmi* initially spreads as a single clone, then, within a few years, diversifies into a very large number of different genotypes, including many so called 'vc-types', equivalent to animal tissue compatibility types (Brasier, 1988; *Reports*, 1990, 1991).

Possible explanations of this explosion in variability include hypervariability of certain genetic loci such as the vc-loci, transposable element mutagenesis, and rare gene flow between *Ophiostoma ulmi* and *O. novo-ulmi* (*Report*, 1991). *O. ulmi* is the fungus responsible for the first pandemic of Dutch elm disease in the 1920s to 1940s. The two species are strongly but not totally reproductively isolated. The progeny are in general unlikely to survive in nature, and indeed are often female sterile (Kile and Brasier, 1990). No definite hybrids between *O. ulmi* and *O. novo-ulmi* have been recorded, although more than 4000 fungal isolates have been sampled by the author from diseased elms across the Northern Hemisphere.

Now, however, five isolates have been identified which do not conform to the typical range of variation in either *O. ulmi* or *O. novo-ulmi*. They were all of an unusual, fast growing, appressed colony type and were dubbed 'fast-waxys'. Isolate P129 was one of 150 diseased twig samples collected in Poland in 1980. Isolate PG470 was one of more than 200 diseased twig samples, and isolates Maf f8, Tom II d10 and Tom II e27 were among more than 250 elm bark samples from epidemic front sites in Portugal in 1985–86 (Brasier, 1988). When the isolates were examined for a wide range of fitness characters in *O. ulmi* and *O. novo-ulmi* (Kile and Brasier, 1990), or used in crosses with these species, PG470 and Maf f8 were identified as probable colony morphology variants of *O. novo-ulmi*. The other three isolates, however, showed different combinations of *O. ulmi* and *O. novo-ulmi* characteristics which suggest that they are recombinants. Their faster *O. novo-ulmi*-like growth rates may partly account for their survival.

This evidence indicates that there is some hybridisation between *O. ulmi* and *O. novo-ulmi* in nature. This is most likely to occur at current epidemic fronts when *O. novo-ulmi* invades territory previously occupied by *O. ulmi* and displaces it (Brasier 1986; Mitchell, 1988), a situation which represents a potential, if temporary, hybrid zone. The putative hybrids are important because, though present only at very low frequencies, and though possibly only of transient existence, they may act as a genetic bridge between *O. ulmi* and *O. novo-ulmi*. This could allow some loci, such as vc-loci and mating type loci, to be transferred from *O. ulmi* to the *O. novo-ulmi* clones at epidemic fronts. It could therefore, at least partially, account for the sudden variability that appears in the latter. Since *O. novo-ulmi* apparently maintains its basic nuclear DNA molecular architecture during its replacement of *O. ulmi* (e.g. Bates *et al.*, 1993), only certain *O. ulmi* genes may be successfully incorporated into the *O. novo-ulmi* nuclear genome. These could well be genes such as vc genes which would contribute directly to the fungus' survival fitness, for example by enabling it to resist the spread of d-factor 'viruses' in the frontal vc clones (Brasier, 1988; *Report*, 1991).

The status of the 'fast-waxy' isolates will be further examined by molecular finger printing techniques.

CLIVE BRASIER AND SUSAN KIRK

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### *D-infection affects cerato-ulmin toxin production by the Dutch elm disease fungus*

D-factors are virus-like cytoplasmically transmitted diseases of the Dutch elm disease fungus,

*Ophiostoma novo-ulmi,* which can severely debilitate the growth and development of the fungus (Brasier, 1983) causing reduced growth rate, colony instability, premature senescence and low spore viability. They can also prevent the fungus infecting healthy elms via beetle feeding wounds, and so have the potential to break the cycle of Dutch elm disease (Webber, 1987). The molecular basis of d-factors is being studied with a view to their genetic manipulation and release as biological control agents of *O. novo-ulmi* (*Report,* 1992). In addition, the biological effects of a range of different d-factors are being investigated to compare their potential as biocontrol agents and to understand d-factor behaviour in nature.

This study has shown that some d-factors can reduce toxin production by the Dutch elm disease fungus. Cerato-ulmin is a low molecular weight (*c.* 7627), proteineacous toxin, produced in considerable quantity by *O. novo-ulmi,* which induces wilting and other symptoms of Dutch elm disease when injected into healthy elms (Takai, 1974). The toxin is thought to be an important factor in disease development.

When cerato-ulmin production in unshaken liquid cultures of isolates infected with d-factors $d^1$–$d^4$* was compared with that of their healthy counterparts, it was found to be reduced by between *c.* 50 and 90%. To examine the effects of the $d^2$-factor in more detail, this factor was transferred to eight previously healthy EAN and NAN race isolates of *O. novo-ulmi* via d-reactions (Brasier, 1983). Eight of the $d^2$-infected isolates produced significantly less cerato-ulmin than their healthy counterparts, the reduction in cerato-ulmin production (per gram biomass) ranging from 42–99% ($\bar{x}$ 78%). The other isolate (H106 $d^2$) showed slightly reduced cerato-ulmin production (8%) (see Figure 6).

This reduction in cerato-ulmin production may well contribute to the inability of d-infected forms of the fungus to infect healthy elms via beetle feeding wounds. At present the causes of toxin reduction, and the reason for the variation in reduction levels between different genotypes infected with the same d-factor, are unknown. The effect may be directly on the cerato-ulmin controlling genes. Such a phenomenon occurs in the chestnut blight pathogen *Cryphonectria parasitica* where the production

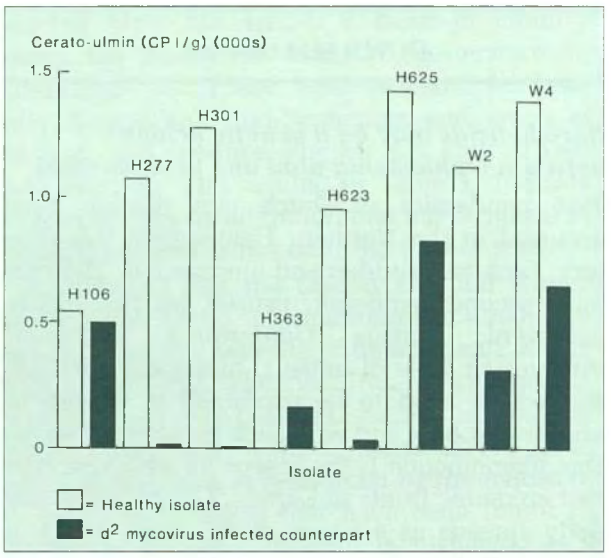


*Figure 6. Comparison of cerato-ulmin wilt toxin production by healthy isolates and their $d^2$-infected counterparts of O. novo-ulmi.*

of the cell surface protein cryparin, which shows some similarities to cerato-ulmin, is directly affected by a mycovirus (Villalon *et al.,* 1991). However, since d-factors severely debilitate the growth of *O. novo-ulmi* and induce premature hyphal senescence, the phenomenon seems more likely to be an indirect effect of d-infection on hyphal development and the cerato-ulmin excretion processes.

LOUISE SUTHERLAND AND CLIVE BRASIER

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* Different d-factors in *O. novo-ulmi* are numbered $d^1$–$d^n$.

# PHYSIOLOGY

The Branch has been successful in obtaining a number of research contracts during the year. The Department of the Environment is funding projects on the quality of broadleaved planting stock and on damage to pavements by the roots of street trees. Forest Enterprise has awarded a contract for studying changes in plant quality as the plant progresses from nursery to planting site. Physiological differences between native Scots pine populations will be investigated for the Scottish Forestry Trust. A contract on the development of tree root systems, in collaboration with Ireland, Denmark and Germany, has been awarded by the European Community (EC). Contracts have also been gained from various countries to work on mycorrhizas and for teaching endomycorrhizal taxonomy. Past work of the Branch has largely been on conifers but current contracts include broadleaved species to an increasing extent.

A plant testing service for planting-stock quality has been started in conjunction with Silviculture (North) Branch. Some 50 samples from private nurseries and Forest Enterprise have been tested. The first year's experience has been valuable in helping to modify and improve the service.

CHRIS WALKER

## QUALITY OF NURSERY STOCK

The respiration rate of fine roots on a range of conifer nursery stock was measured at intervals between October and March. There were large and consistent species differences; Douglas fir had the lowest rates of $CO_2$ evolution, Corsican pine had the highest rates with Queen Charlotte Islands Sitka spruce, Japanese larch and hybrid larch intermediate. The root respiration rate of plants whose shoots had been dipped in permethrin was slightly reduced. Of the species tested, Corsican pine was most sensitive to permethrin application.

Four years' experiments on quality of planting stock of larch (Japanese and hybrid) have been collated. The survival of undercut and wrenched stock was markedly greater than that of transplants. Larch can be successfully cold-stored (+1°C) from mid-November to mid-March for planting in early April; a survival rate of 80% and height increment of >80 cm were achieved after two years. Hybrid larch is slightly more tolerant of cold storage than Japanese larch. Survival of freshly lifted Japanese larch was best in late October with a second peak in mid–late March. Comparisons of identical stock which was either planted immediately or cold-stored until March indicate that larch lifted in the last two weeks of October and March should be planted directly whereas larch lifted between mid-November and early March should be cold-stored (+1°C).

Root frost hardiness, assessed by exposing roots to a set minimum temperature for three hours, is a good index of the ability of conifers to tolerate long-term cold storage during the hardening phase (October to January). After the time of maximum frost hardiness, the roots deharden at a steady rate, even though their tolerance to cold storage for three months may be maintained at its maximum for a further six to eight weeks. Therefore, root frost hardiness has potential as an indicator of the beginning, but not the end, of the safe lifting period.

HELEN MCKAY

## CLONAL VARIATION IN ROOT–SHOOT RATIO AND ROOT FORM OF SITKA SPRUCE

An EC-supported investigation has been undertaken of the effect of tree improvement programmes on factors likely to affect the wind stability of trees. Measurements were made on five half-sib clones from the Forestry Commission tree improvement programme (see Plate 3), and on two types of control – a batch of cuttings of unimproved trees, each of a different genotype, and normal 1+1 transplants. The trees were from a Queen Charlotte Islands replicated

demonstration set up by Silviculture (North) Branch in 1981 at Teindland on a gently sloping site which had been used as a nursery. Nine replicates of each plant type were used. Measurements included: the allocation of biomass amongst leaves, branches, stem, stump and woody roots; and the cross-sectional area (CSA) of the woody roots on a radius 45 cm from the centre of the stump.

Preliminary results show that the mean root–shoot ratio of the improved clones was significantly greater than that of the controls, but differences between clones were considerable; for example, mean root–shoot ratio varied from 0.275 to 0.395. When the weight of the stump, which does not actively contribute to stability in Sitka spruce, was omitted from the root–shoot ratio, the ranking of clones changed because of large variation amongst them in the amount of biomass allocated between stump and woody roots.

The array of lateral roots in plan view was tested for symmetry and no clustering was found: the positions at which roots had been initiated around the tree appear to be random. However, calculation of the centre of CSA, analogous to centre of mass, showed that the allocation of material within the root systems of two of the clones (77 and 83) was asymmetric (see Figure 7). The direction of displacement of the centre of CSA from the centre of the stump varied to some extent with clone; overall, it was least common in a southerly direction.

When the roots on a root system were ranked in order of CSA, significant differences were found between clones in the mean CSA allocated to the ranks (see Figure 8). For example, 87% of the root system was present in the six largest roots in clone 77, but in only the three largest in clone 74.

In conclusion, the limited amount of material investigated provided no evidence that the tree improvement programme had reduced root–shoot ratio. The work indicates that the use of conventional root–shoot ratio, in which root weight includes stump, could give misleading results so far as tree stability is concerned. Clones vary in the amount of biomass allocated

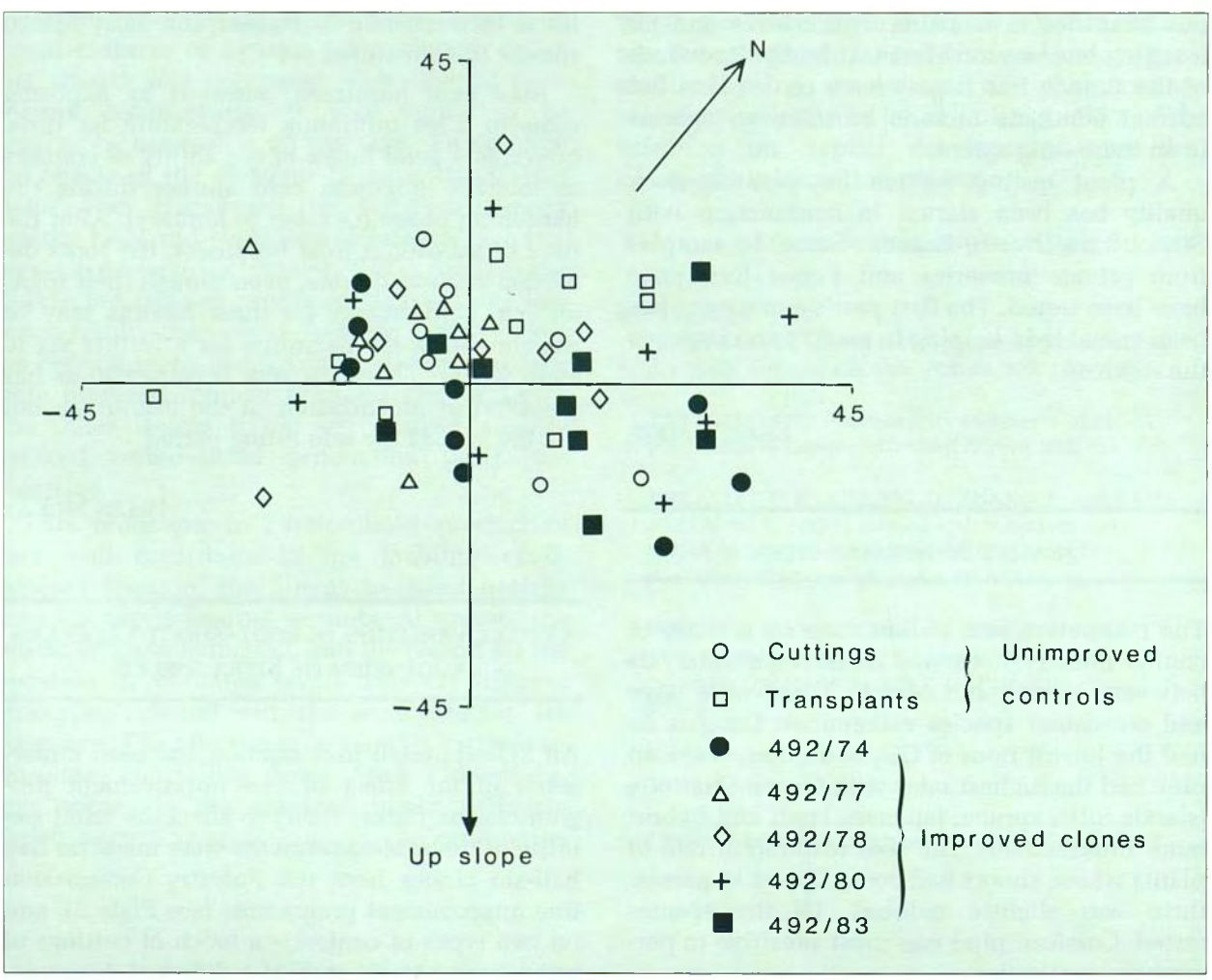


*Figure 7. Centre of cross-sectional area for cuttings and transplants of mixed genetic origin, and for five clones of Sitka spruce. The further the point lies from the centre, the greater the asymmetry of the tree's root system.*

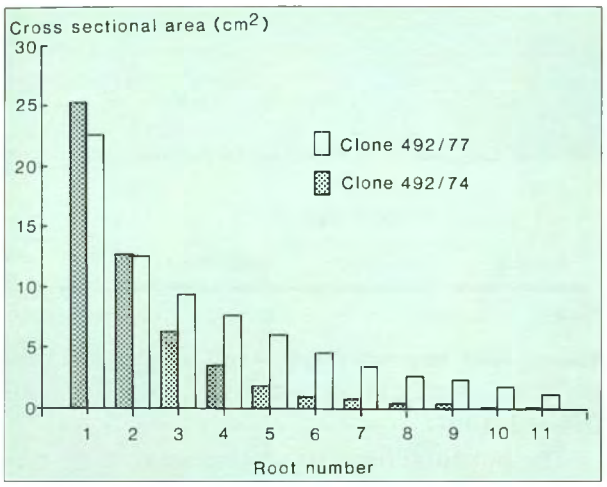


*Figure 8. The distribution of mean cross-sectional area between the 11 largest roots on the root system ranked by size, for two clones of Sitka spruce.*

between the stump and the anchoring roots. No significant clustering of lateral roots occurred but significant clonal variation was found in root architecture, even among only five half-sib clones. There are prospects for improving tree stability on windy sites by selecting for appropriate characteristics.

MIKE COUTTS, BRUCE NICOLL, ERIC EASTON, ALVIN MILNER AND CHRIS WALKER

## PHYSIOLOGY JOINT WITH SILVICULTURE (NORTH) BRANCH

A series of experiments was carried out to measure the forces generated when bags of seedlings were dropped, and to study their effect on the physiology and growth of Sitka spruce. Bags containing 200 plants generated forces of 11 g (g = 9.81 m $s^2$) when dropped from 10 cm, whereas one and three metre drops generated forces of 70 and 140 g respectively. When plants were dormant, dropping up to 15 times from three metres did not affect survival, but similar treatment of plants lifted in August reduced survival. Even though survival of dormant plants was not affected, height increment was significantly reduced by one and three metre drops. In some experiments, root growth potential and root electrolyte leakage were significantly adversely affected by the height and, to a lesser extent, the frequency of dropping. Small drops (10 cm) had no significant effect even though they were repeated up to 135 times. Damage was more closely correlated to the maximum force the plants experienced than to the mean or total force.

HELEN MCKAY, BARRY GARDINER, BILL MASON, DEREK NELSON, MIKE HOLLINGSWORTH

# PLANT PRODUCTION

Plant Production Branch is a small team of five scientists with responsibilities divided almost equally between seed testing and statutory matters related to the Forest Reproductive Material (FRM) regulations, and plant production research. There is an increasing call on staff for advisory work and consultancies.

Amongst the Branch's activities, the following are of particular note: staff have overcome the damage and disruption caused by animal liberationist firebombers; we have made major contributions to the International Seed Testing Association's (ISTA) triennial congress in Argentina, which are elaborated later; we started work on a new project concerned with improving the handling, storage, pretreatment and germination of broadleaved seed; and staff performed consultancies in Africa, Brazil and the UK. In addition, the re-analysis of physiological data in the context of natural regeneration phenomena has illustrated that some of the complexities of field observations can best be simplified and understood by laboratory experiments.

The Branch has also hosted visiting scientists from Africa, Croatia and Malaysia.

PETER GOSLING

## SEED AND NURSERY RESEARCH

The seed of many conifers, and also some broadleaved species like alders and birches, exhibit shallow or conditional dormancy. Laboratory studies show that conditionally dormant seed will only germinate over a restricted range of temperatures, often around 20°C, but moist prechilling for a relatively short period widens this range of temperatures. Moist prechilling for 3–6 weeks is recommended to nursery managers for conditionally dormant conifer seed because it is assumed that the improved germination measured in the laboratory will translate to better germination in the seed beds. Further improvement in germination may be possible with longer pretreatment, providing that measures are taken to prevent premature germination during pretreatment (*Report,* 1991).

The potential benefits of pretreatment on germination in seed beds were investigated in a nursery experiment using a conditionally dormant seedlot of Sitka spruce (83(2017)). The seed received three treatments: untreated seed sown without any moist pretreatment; pretreated seed sown after six weeks moist prechilling at 4°C; seed prechilled and then redried to storage moisture content. Seed of each treatment was sown into replicated plots at Headley nursery on four occasions from March to early June 1992 when soil temperatures were increasing. Solar irradiance, air and soil temperatures, and rainfall were recorded throughout the germination period and seedling emergence was assessed twice weekly. The seed beds were irrigated following standard nursery procedures.

Samples of seed of each treatment were germinated in the laboratory at 10 and 20°C at each sowing date to check for any variation in the effectiveness of the treatments between dates. There was no appreciable difference in percent germination of the laboratory samples between sowing dates; germination was significantly affected by pretreatment and temperature (see Table 2). At 10°C none of the untreated seed germinated, but 82% germinated at 20°C. Pretreatment with and without drying increased laboratory germination to between 28 and 44% at the cooler temperature, and to about 95% at 20°C.

In the seed beds, average soil temperatures at one cm below the soil surface reached 10°C during mid April and rose to just above 20°C by early June. At each sowing date both the prechilled and redried seed germinated significantly more than the untreated seed (see Table 2). The results for both the March and April sowings were similar with the pretreated seed achieving more than 90% of the maximum potential germination determined in the laboratory; the germination efficiency of the untreated seed was lower at about 70% of the maximum obtained from pretreated seed in the laboratory.

**Table 2.** The effects of seed pretreatment on final percentage germination, in the laboratory and in the nursery, of seed sown on four occasions in 1992

| | *Per cent germination* | | |
|---|---|---|---|
| | *Untreated* | *Prechilled* | *Redried* |
| *Laboratory 10°C | 0 | 44 | 28 |
| *Laboratory 20°C | 82 | 94 | 95 |
| Nursery 11 March | 68 | 89 | 85 |
| Nursery 8 April | 61 | 84 | 87 |
| Nursery 6 May | 28 | 50 | 56 |
| Nursery 3 June | 23 | 17 | 36 |

*Mean germination across four sowing dates.

It was also found that the rate of germination of the prechilled seed took about 15 days to complete, whereas germination of the untreated seed continued well into June until it was inhibited by high soil temperatures during hot weather. Germination of seed of all three treatments sown after the beginning of May was affected by hot weather during June and July resulting in much lower final germination percentages.

These results show that pretreatment of conditionally dormant Sitka spruce can improve germination in seed beds. Pretreatment allowed rapid, even germination at the cool soil temperatures which occurred during March and April, but sowing untreated seed at this time resulted in slow germination which continued on into periods of damaging high soil temperatures. Pretreatment does not appear to improve germination during hot weather. Further work is being carried out examining the effects of soil temperature on the germination of a range of species and on developing models for predicting emergence in seed beds.

RICHARD JINKS AND STEVE JONES

## OFFICIAL SEED TESTING STATION

Official Seed Testing Stations throughout the world employ the methods laid down by the International Seed Testing Association (ISTA). Every three years, the ISTA holds a congress to consider the adoption of improvements to seed testing methods. Dr Peter Gosling attended this congress in Argentina, and in his capacity as chairperson of the Forest Tree and Shrub Seed Committee steered the introduction of three new chapters on X-ray, weighed replicate and excised embryo testing of tree seeds into the ISTA rules.

In 1992/93, 258 Forestry Commission seedlots were tested, 66 lots from seed merchants and nursery-managers, and 102 lots from the Oxford Forestry Institute. Although the overall number of seed tests performed has not changed significantly from last year, more broadleaved tests were carried out.

PETER GOSLING AND YVONNE SAMUEL

# SILVICULTURE (NORTH)

## Overview

Following the reorganisation of the silvicultural research project groups and the Branch restructuring (*Report*, 1992), research effort was concentrated on the new areas recommended by the 1990 Visiting Group. We welcomed James Simpson as the new project leader on Farm and Community Woodlands after Derek Nelson left on secondment to Scottish Business in the Community. Satisfactory developments were seen in all subjects and it was particularly pleasing to see the increasing number of international contacts that have been made by members of the Branch. For instance: Barry Gardiner and Chris Quine travelled to New Zealand at the invitation of Forest Research Institute, Rotorua to initiate a link between researchers working on wind effects on forest stability in New Zealand and Great Britain; John Morgan was an invited speaker at the biennial meeting of the British Columbia Forestry Nurseries Association; and at the year end, Neville Danby went to Chile at the invitation of their Forest Research Institute to advise on *Nothofagus* forestry based on experience with that genus in Wales.

Following the decision to increase the amount of outside funding for our research programme, we were successful in obtaining contracts with a range of organisations and companies such as British Rail, Scottish Natural Heritage and MacFarlane Smith Limited. Support was also obtained for four collaborative research projects part-funded by the Third Framework Programme of the Commission of the European Communities. Our collaborators included other branches within the Research Division, research institutes in Britain, and research organisations in Germany, Italy, Greece, France, Holland and Denmark. We were also awarded a fellowship under the European Community scheme for Cooperation in Science and Technology with Central and Eastern European Countries. This was for a member of the Faculty of Forestry in the University of Brasov, Romania who will be working with John Morgan during 1993.

Bill Mason

## Site yield studies in Scotland

Present government incentives are encouraging diversification of uses of agricultural land. These initiatives, and the demand for rigorous financial analysis and accountability, have given rise to the need for predictive models for tree species that are important for commercial, aesthetic or conservation purposes. Models have been developed for the prediction of general yield class for Sitka spruce from site factors on both upland and lowland sites in Scotland (Worrell, 1987; Macmillan, 1991). Work on a joint project with the Macaulay Land Use Research Institute (MLURI) and funded by the Scottish Forestry Trust began in May 1992. The effect of site factors on the productivity of Scots pine, Japanese larch, Douglas fir, oak and birch is being investigated with the aim of developing site specific models for predicting general yield class. These would enable assessment of the costs and benefits associated with planting species other than Sitka spruce.

Factors known to influence tree growth in Scotland have been identified in previous studies. For the first field season suitable forest sites on Forest Enterprise land were identified and then stratified by region and elevation to concentrate sampling on better quality land.

The following site and soil factors and yield data were collected:

1. Site factors
   Altitude, aspect, slope, topex, topography and site drainage.
2. Soil factors
   Macaulay soil type, Forestry Commission soil type, soil drainage and rooting depth.
3. Yield variables
   Top height, general yield class and basal area (unthinned stands).

4. Vegetation data
   The vegetation species in a subset of plots have been recorded. These data will provide an indication of the diversity and conservation value of each species when grown under plantation conditions.

Data were collected during the summer and autumn of 1992 from over 200 sites throughout Scotland (see Table 3). Plot data have been coded and entered on a database. Site-specific estimates of mean monthly rainfall and temperature were extracted from the MLURI Climate Change Group database. Estimates of windiness from tatter flags were supplied by the Stability Project Group of Silviculture (North) Branch.

Data were examined graphically for the presence of trends. Model development is proceeding using multiple linear regression and principal component analysis. Models for Japanese larch and Scots pine provide satisfactory predictions, but the model for Douglas fir appears confounded by factors not taken into account. A potential source of variation is difference in seed origin. The models will be reviewed when data from the 1993 field season have been incorporated, and then validated. Temperature is consistently significant in influencing productivity. Exposure is also important for Japanese larch and Douglas fir, and soil drainage for Scots pine. Planting year for Japanese larch and Scots pine is a significant factor in predicting productivity. This effect has also been noted for Sitka spruce (Worrell, 1987; Macmillan, 1991).

Few suitable broadleaved stands have been found to date. Greater emphasis will be placed on these species in the 1993 season. The diversity of ground flora under the stands of the respective species was recorded and the data will be summarised in 1993. The project is due for completion in November 1993.

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**Table 3.** Distribution of site yield sample sites

| | *Conifer species* | | | *Broadleaved species* | |
|---|---|---|---|---|---|
| *Location* | *Scots pine* | *Douglas fir* | *Japanese larch* | *Oak* | *Birch* |
| North | 22 | 14 | 12 | 1 | 1 |
| North east | 25 | 14 | 16 | 2 | 1 |
| Central | 12 | 11 | 14 | 3 | 1 |
| South-east | 5 | 9 | 7 | 1 | 0 |
| West | 5 | 1 | 5 | 0 | 0 |
| South-west | 10 | 17 | 18 | 2 | 0 |
| Total | 79 | 66 | 72 | 9 | 3 |

## APPLICATION OF WIND MODELLING TECHNIQUES IN COMPLEX TERRAIN

Wind is an important factor in British forestry, influencing growth rates and causing damage during severe storms. The importance of research in this area was recognised by the National Audit Office (NAO) report on the Forestry Commission's harvesting operations (NAO, 1993). Prediction of near-surface windspeeds is therefore a key element in forestry planning for both site yield models and windthrow hazard assessments. Windspeed at a site varies substantially over time, and also varies between sites due to location and topography. This variability prevents short-term measurements adequately describing the windiness of a site, and makes simple extrapolation of measured windspeeds from one site to another unreliable.

On-site measurement is the most accurate method of assessing windspeed, but such recording is sparse in upland Britain.

Numerical models have been developed to extend point measurements into predictions of windspeeds for wider areas. Two models were tested in the Kintyre and Cowal windthrow monitoring areas (Quine and Reynard, 1990); Cowal contains particularly complex terrain. The model predictions were tested against field measurements and compared with results from simple regressions between pairs of measurement sites; the regression methods were found to produce more accurate predictions than the numerical models in most cases (Hannah *et al.*, 1991). Successful regressions were also formed between interpolated upper air windspeeds and measurements from surface sites (Hannah *et al.*, 1992).

The poor performance of numerical models meant that reliable predictions for sites without measurements were not feasible. Relationships between the annual mean windspeed and the topographic characteristics of the site were therefore explored. Good predictions were obtained using a number of site characteristics (including elevation, topex and distance to the sea). Limiting topex to distances of 1–3 km and permitting negative values proved more successful than standard topex calculations. Topex to distance is readily calculated from digital terrain models and its potential will be investigated further. The occurrence of extreme winds will also be examined by linking short-term forest measurements to the longer time-series of Meteorological Office sites.

This research was jointly funded as a CASE studentship by the Forestry Commission and the Science and Engineering Research Council.

PAUL HANNAH* AND CHRIS QUINE

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## AIRFLOW IN COMPLEX FORESTED TERRAIN

The ability to predict windspeeds in complex terrain is essential if one wishes to design more stable forests or estimate the likelihood of damage. At present the windthrow hazard classification (Miller, 1985) makes use of an empirical score involving elevation and a measure of the local shelter (Topex). Estimates of the exposure of sites to determine planting limits have used tatter flags run over a three year period (Reynard and Low, 1984), whilst early attempts to model airflow in complex terrain used scaled polystyrene models in a wind-tunnel (Booth, 1974). Both methods suffer from a number of deficiencies, in particular the time involved in obtaining an answer and the difficulty of applying them over extensive areas. Computer airflow models offer the possibility of being able to determine windspeed over extended areas more rapidly. They can also be run repeatedly in response to changes in forest structure.

Two tests of the ability of airflow models to predict windspeeds in complex forested terrain were conducted in February/March 1989 and 1990 on the South Kintyre peninsula, Argyll. The peninsula consists of two parallel ridges which are forested on their lower slopes. Windspeed and wind direction were measured at 14 locations across the peninsula, and measurements of windspeed, wind direction and atmospheric structure were made by an instrumented light aircraft from the University of Manchester.

During the experiment, ten periods of particular interest have been identified for analysis as case studies. The aircraft data were used to initialise FLOWSTAR, an analytic airflow model developed at Cambridge University (Carruthers and Hunt, 1990), and the model was run for each of the case studies. The model output has been compared with the windspeeds and turbulence measured at the ground as well as the flow structure above the peninsula measured by the aircraft. In Figure 9 the predictions of the airflow model on 12 March 1990 are compared against measured ground level windspeeds across the peninsula.

Although the general trend of the model prediction follows the measured values, the model tends to be conservative, underestimating windspeeds on the tops of hills, and overestimating windspeeds in valleys and the lee of hills. The tendency to overpredict windspeeds in the lee of hills is particularly pronounced. This is a result of the airflow at the back of the hill separating from the surface, a phenomenon that is

not easily reproduced in computer airflow models. Wind tunnel studies by Ruck and Adams (1991) indicate that the presence of trees, which aerodynamically roughen the surface, tends to encourage the separation of the airflow. Above the surface, the airflow streamlines can be visualised by plotting contours of potential temperature, as obtained by the aircraft, and compared with the model prediction (see Figure 10). The most striking feature of the airflow is the presence of standing waves, which have similar physical dimensions to the peninsula. Although the model predicts the presence of the waves, it underestimates their strength.

The Kintyre airflow study has identified the limitations of current airflow models in predicting windspeeds in even moderately sloped complex terrain. However, they still provide the best option for rapidly predicting windspeeds over large areas. A more complete description of the project and the comparison between modelled and measured winds can be obtained in Inglis (1993).

BARRY GARDINER

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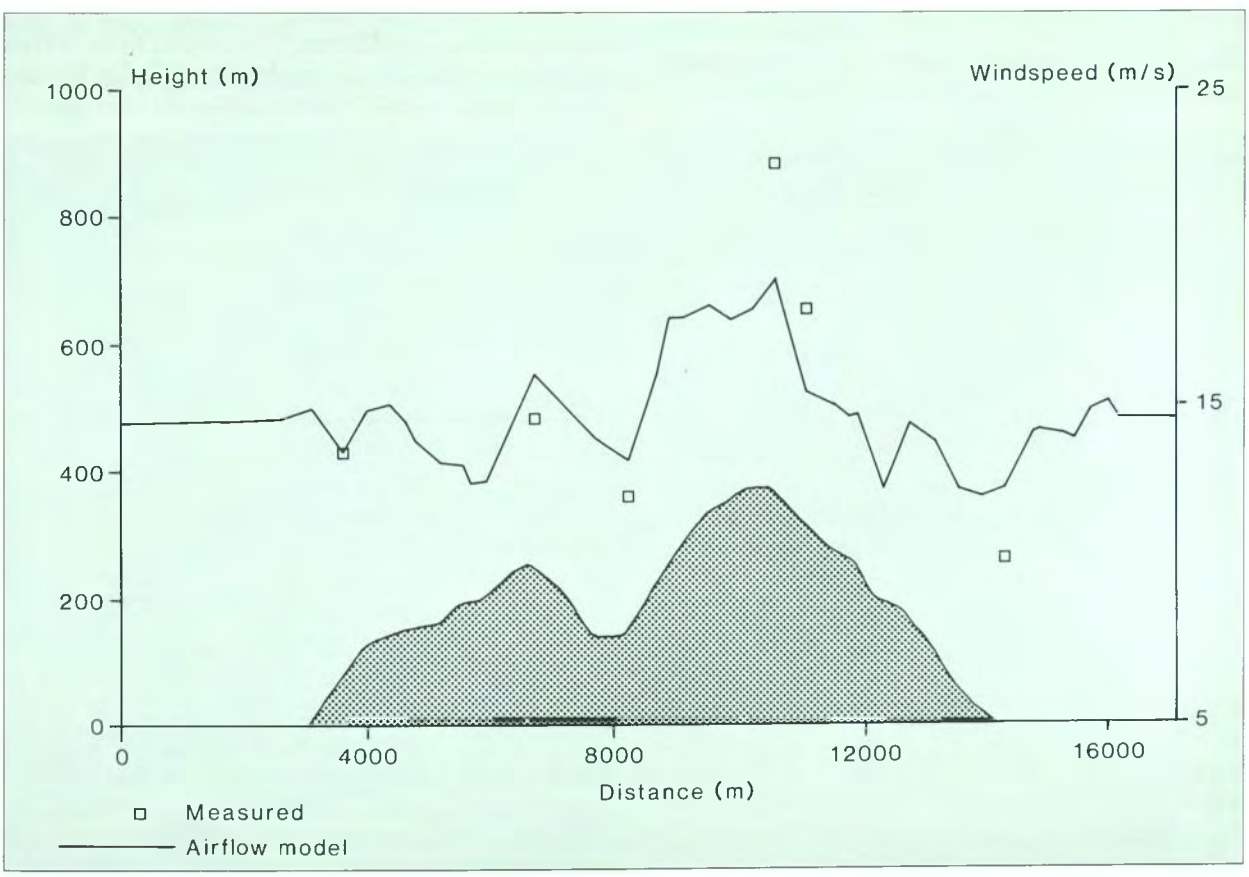


*Figure 9. Predicted windspeed at 10 m above the ground on the Kintyre peninsula (solid line) compared to measured values (squares).*

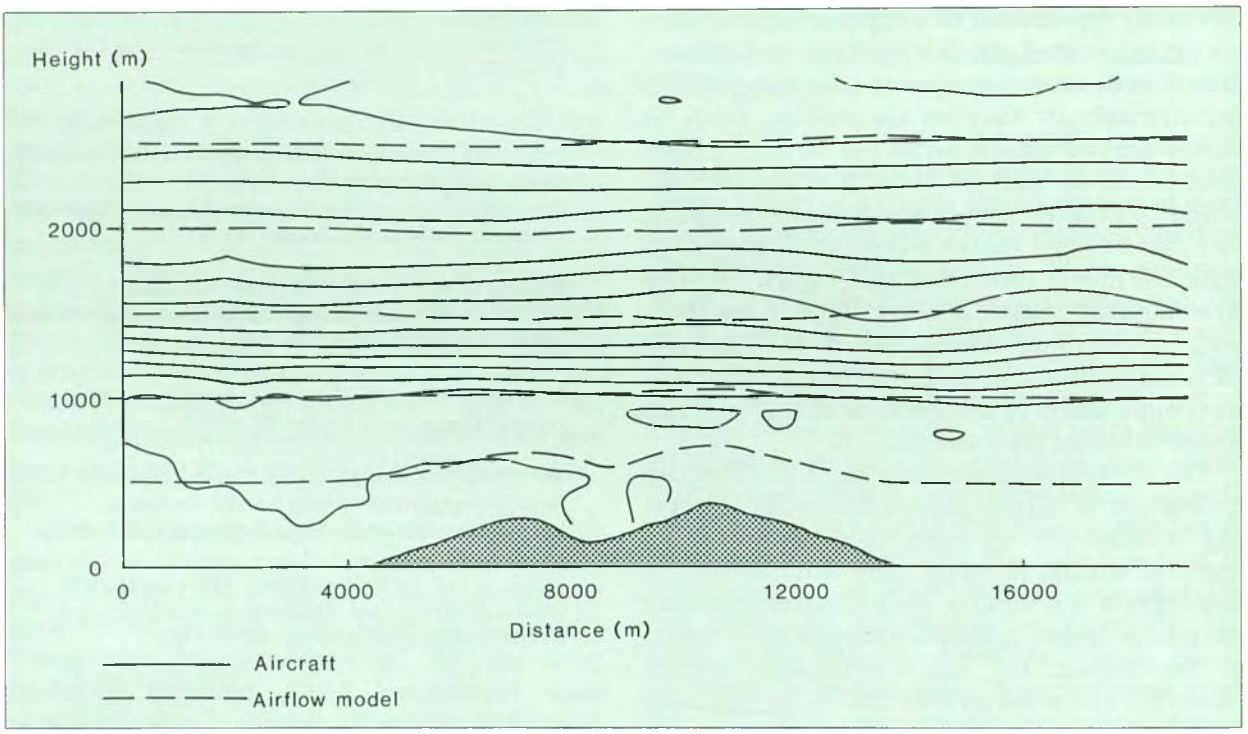


*Figure 10. Measured (solid) and modelled (dash) streamlines for air flow across the Kintyre peninsula.*

## CROFTER FORESTRY

The Crofter Forestry (Scotland) Act (1991) allows crofters to plant trees on common grazings and benefit from the resulting woodlands. In support of this initiative, we have reviewed all existing experiments within the main crofting areas. These experiments were originally planted to test tree growth and survival in areas of extreme exposure and are now providing valuable information. Results at 20 years indicate that, in more sheltered areas, Sitka spruce can be grown with commercial potential (*c.* yield class 12) and in the more exposed areas trees can be grown with considerable shelter and amenity value.

One experiment on North Uist has been converted to a demonstration, including a woodland walk and areas planted with introduced native broadleaves. The broadleaves have been planted in a replicated design to provide information on conversion of conifer plantations to a mixed woodland. Experiments on Orkney and Shetland have also been appraised for their demonstration value. New species experiments have been established on Shetland and Berneray (Harris) in collaboration with local crofters and conservation groups.

A new tatter flag network (Reynard and Low, 1984) has been established in the Western Isles. The results will help to refine existing knowledge of windiness and demonstrate the benefits to tree growth of using existing shelter and topographical landforms. It is hoped to establish a similar network in the Northern Isles by the end of 1994.

TONY SHARPE

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## NATURAL REGENERATION

### *Native pinewoods*

A project was carried out over the winter of 1992/93 under contract to Scottish Natural Heritage with the aim of establishing the age structure and regenerative capacity of the native pinewoods on the Mar Lodge Estate in Deeside.

Very little natural regeneration has occurred in the Mar Lodge pinewoods over the last 100 years (see Plate 4). This is largely due to heavy browsing pressure from deer and sheep which has prevented young trees from becoming established. However, as the trees age, there is increasing concern that they may be reaching the end of

*Plate 1a. Two-year-old oak grown in treeshelter combined with effective weed control using herbicides on a 1.0 m diameter spot (treeshelter temporarily removed).*

*Plate 1b. Two-year-old oak grown in treeshelter combined with mowing the grass sward: an ineffective method of weed control (treeshelter temporarily removed).*

*Plate 2. A sunny, species-rich forest ride, providing valuable habitat for invertebrates, showing the influence of browsing on edge shrub vegetation (Micheldever Forest, Hants.).*


*Plate 3. A skilled operator using a forwarder makes extraction of roots for research easy and efficient.*

*Plate 4. The Mar Lodge pinewoods showing absence of young natural regeneration.*

their reproductive lifespan and that this may reduce the ability of the woodlands to regenerate naturally. The purpose of this study was to estimate the period over which the existing native pine trees can be expected to produce sufficient viable seed for natural regeneration to occur.

Within each of the four pinewood areas (Glen Derry, Glen Luibeg, Dubh Ghleann and Glen Quoich), 50 trees were selected by laying out transects and locating sample trees at predetermined intervals. Increment cores were taken from each of the sample trees which were clearly marked to allow future identification (see Plate 5).

The age structure of the pinewoods was found to show a symmetrical distribution around a mean of 226 years with a range from 132 to 352 years (see Figure 11).

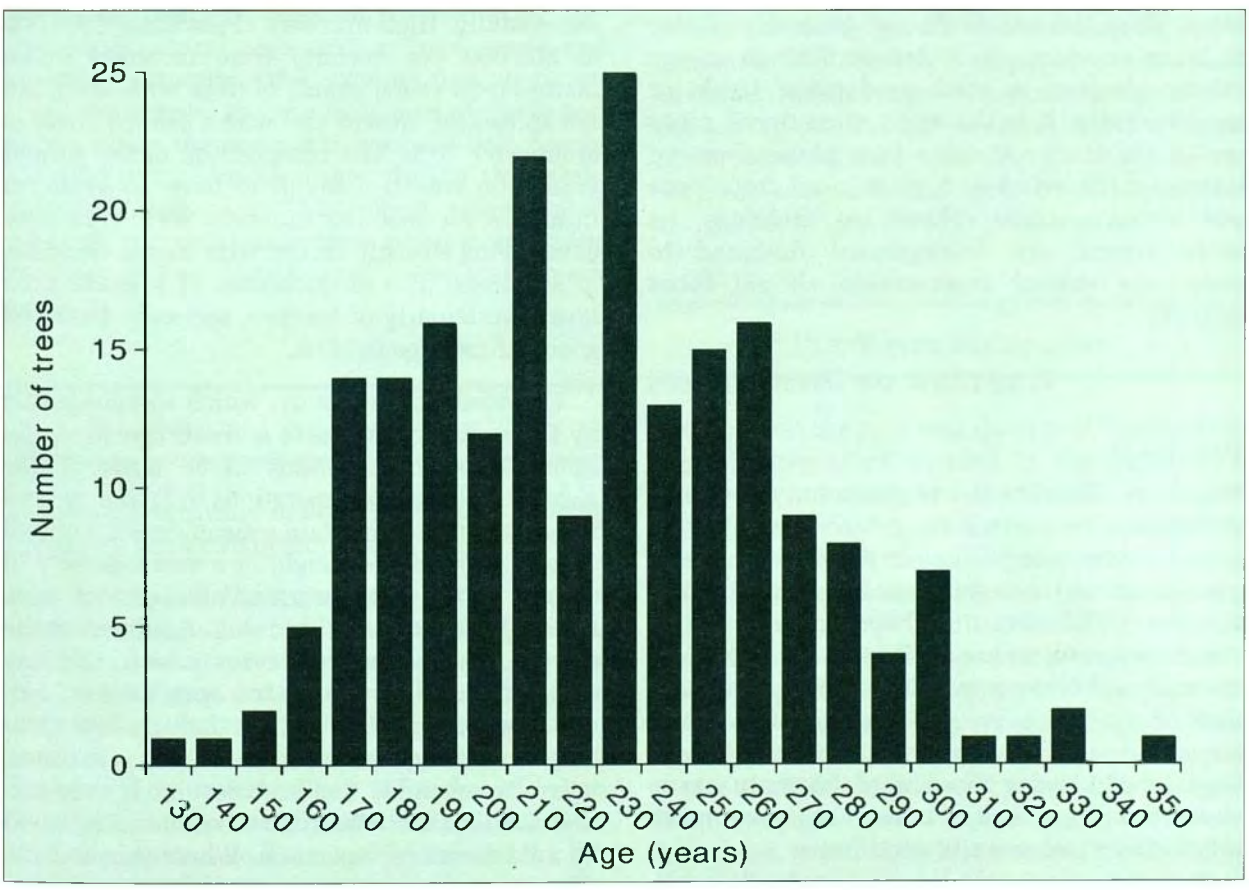



*Figure 11. Age distribution of all sample trees at Mar Lodge Estate.*

An assessment of coning levels was made on a total of 67 trees from which a sample of cones was also collected. Seed was then extracted from these cone samples and subjected to standardised germination tests. Values for the cone and seed producing trees are given in Table 4.

The results showed no clear relationship between coning and seed production in relation to tree age. A slight, but non-significant, decline was observed in the number of cones produced per unit area of crown and also in the numbers of seeds per cone on older trees. There was no reduction in the germination percentage of seed from older trees. Even trees above 300 years of age were found to be producing good quantities of viable seed.

Over the range of elevations studied (410–570 m above sea level) there was no clear effect of elevation on seed production levels or seed quality. A more significant change was seen in the proportion of empty seed produced by trees in stands of differing density. Where trees were scattered or isolated the proportion of empty seed was found to be as high as 50% compared with nearer 30% for densely stocked stands.

The age structure of the Mar Lodge pinewoods clearly reflects the historical pattern of grazing and exploitation which has resulted in an absence of any natural regeneration over the last 100 years or so. The oldest trees appear as individuals or small groups throughout the woods and are most probably survivors of earlier regeneration. The oldest trees still appear

**Table 4.** Summary of data for cone and seed producing trees

| *Pinewood area* | *Number of trees* | *Mean age in years* | *Mean dbh in cm* | *Mean crown area in $m^2$* | *Mean number of cones per tree* | *Mean number of seeds per cone* | *Seed germination* | *Percentage full seed* | *Percentage empty seed* |
|---|---|---|---|---|---|---|---|---|---|
| Glen Derry | 15 | 216 | 61 | 248 | 294 | 11.4 | 18.1 | 41 | 41 |
| Glen Luibeg | 8 | 266 | 59 | 333 | 208 | 8.2 | 20.5 | 53 | 26 |
| Dubh Ghleann | 23 | 187 | 53 | 324 | 211 | 8.9 | 24.8 | 25 | 50 |
| Glen Quoich | 21 | 285 | 82 | 583 | 203 | 10.9 | 25.7 | 35 | 39 |

healthy and have been shown to be producing similar quantities of viable seed to younger trees. Thus the woods do not generally appear to be in any immediate danger through an age related decline in seed production levels or seed viability. It is the areas of scattered pines which are doubly at risk – from physical crown damage from wind and snow, and from poor pollination success. These are therefore the areas where any management designed to encourage natural regeneration should focus initially.

CHRIS NIXON AND DAVID ANDERSON

### *Douglas fir*

Work on Douglas fir regeneration has been undertaken as part of the research programme aimed at improving our ability to encourage and predict natural regeneration. This could facilitate the use of silvicultural systems which vary stand structure, enhance habitat diversity and diversify species composition. During the summer of 1992 a survey of Douglas fir natural regeneration was carried out in south-west England and Wales. The aim of the study was to assess the occurrence of natural regeneration in relation to stand and site conditions.

Twenty two stands were surveyed with existing regeneration aged between one and ten years. At each stand features of the overstorey, vegetation and site characteristics were assessed and related to the occurrence and density of regeneration.

Analysis of the results highlighted several features common to sites which were regenerating successfully. High numbers of seedlings (100 000 to 500 000 per hectare) were recorded under mature (>50 years) stands of trees with deep, but not spreading, crowns and with a canopy cover of around 60–70%. The composition of the ground vegetation was also found to have a significant influence on seedling numbers with bryophyte cover being strongly linked with higher densities of seedlings. The development of a dense field layer, particularly of bracken, seriously inhibited good natural regeneration.

The results of this study, which was supported by Forest Enterprise, have allowed specific management recommendations to be made. These suggest that thinning operations to favour natural regeneration should retain a mean crown depth of at least 40% of tree height at a stand density of around 120% of the current management table levels given for crown thinning. Adoption of the current management table for crown thinning appears to result in stands too open for good natural regeneration. Due to the relatively low numbers of seedlings found on bare earth microsites, it is recommended that scarification is only carried out on sites which have become dominated by a thick mat of vegetation. Where this is done, the operation should be timed, if possible to coincide with good seed years.

CHRIS NIXON AND STUART BLACKHALL

# SILVICULTURE (SOUTH)

## Native broadleaves

A new project entitled Ecology of Native Broadleaves has started under the leadership of Dr Ralph Harmer. Work is concentrating initially on: natural regeneration from seeds and coppiced stumps; the competition between trees and weeds; and the influence of shade and browsing on the competitiveness of oak, beech, ash and sycamore seedlings during the establishment phase. This process-orientated research supports our more applied work on the management of broadleaved trees and woodlands.

## Natural colonisation

Natural colonisation of abandoned land is being surveyed, with two objectives:

1. to investigate the speed, extent and species composition of natural colonisation on abandoned land around urban areas; and
2. to relate these factors to site history, vegetation characteristics and substrate type.

The sampling system allows the information on colonisation to be related statistically to data from the sample plots and historical information for the site as a whole. The survey involves 45 sites around Bristol, the West Midlands and south Staffordshire, and will be completed in 1993.

## Cost-effectiveness of urban tree planting

A small survey was carried out in August 1992 in which specifications and costings were obtained and related to the performance and suitability of planting schemes. The objectives of the study were:

1. to determine and compare the costs and quality of public sector urban planting schemes; and
2. to develop objective methods for assessing a diverse range of tree-planting schemes.

Costs ranged from £13,600 to £298,700 a hectare, averaging £69,200 a hectare. Survival averaged 68%, and only 26% of live trees had an annual leader growth of more than 20 cm. A comparable Forestry Authority Research Division demonstration woodland in the area of the survey (Midlands) was established at a cost of £3,900 a hectare. After two growing seasons, survival was 90% and only 9% of trees had annual leader growth of less than 20 cm.

## Plant type and quality

Research on the type and quality of broadleaved tree planting stock, funded by the Department of the Environment, has examined a wide variety of methods for determining stock quality (*Report,* 1992). Of these, the electrolyte leakage test for root damage appeared to show most potential. Root growth potential (RGP), which is a good indicator of field performance in coniferous stock, was hard to interpret for broadleaves.

In a comparison between container and bare-rooted plants of similar size, container plants gave superior survival and growth. There have been many attempts to compare different stock-types, but it is better to compare whole establishment systems, and the current approach involves the development of a plant quality index for broadleaves.

## Arboreta

Following the UNCED summit in Rio de Janeiro, which placed emphasis on the conservation of genetic resources, the objectives of the Arboreta project have been re-defined:

1. to conserve the genetic diversity of trees which are hardy in Britain;
2. to provide information, based on reference

collections, on the potential, performance, and proper identity of trees.

These have been accepted by the advisory committees at Westonbirt Arboretum and Bedgebury Pinetum.

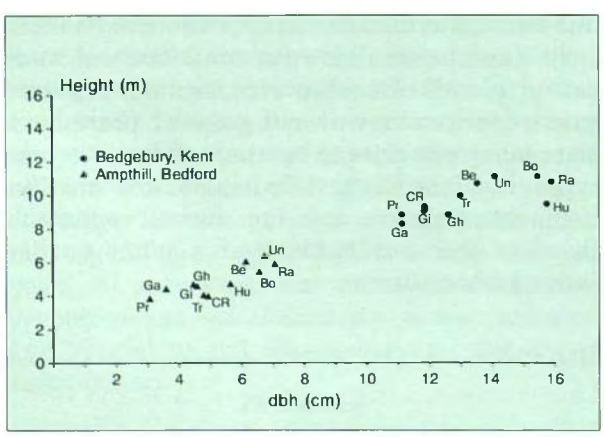
## Herbicides for farm forestry

Previous farm woodland experiments have identified a number of herbicides (mainly soil-acting) which can be used selectively to aid the establishment of broadleaved trees on arable land. These chemicals – pendimethalin, metazachlor, clopyralid, isoxaben, cyanazine and fluazifop-butyl – now have off-label approval for farm forestry, and are detailed in Research Information Note 201.

A further set of trials is now complete, attempting to identify foliar-acting treatments that can safely be applied over actively growing broadleaved trees. Unfortunately, most of the treatments proved to be damaging to some degree, but cyanazine, bentazone, pyridate and MCPB may be worthy of further evaluation.

## Poplars

The new hybrid poplar clones imported from Belgium are continuing to attract attention in relation to farm forestry. The experiments at Bedgebury and Ampthill (*Report,* 1991) have now received six-year height and diameter assessments (see Figure 12) and this clearly shows the superior potential of the *Populus trichocarpa* x *P. deltoides* hybrids.




1. *P. trichocarpa* x *P. deltoides*
   Bo - Boelare, Be - Beaupré, Ra - Raspalje, Un - Unal, Hu - Hunnegem
2. *P. deltoides* x *P. nigra*
   Gh - Ghoy, Ga - Gaver, Gi - Gibecq, Pr - Primo.
3. *P. trichocarpa*
   Tr - Trichobel, Cr - Columbia River.

*Figure 12. Height vs. diameter at the end of the 6th growing season for the above poplar clones.*

## Energy coppice

One of the options for arable land or pasture surplus to agricultural requirements is to produce wood-fuel on short rotation using fast-growing tree species (see Plate 6). A final report of work funded by the Energy Technology Support Unit (ETSU) of the Department of Trade and Industry was presented in January 1993. The main findings follow.

### *Yield*

In the three experiments at Alice Holt, Long Ashton and Mepal, *Populus interamericana* 'Rap' had been established in 1983, using two initial spacings (S1 – 1m x 1m; S2 – 2m x 2m) and two rotation lengths (R2 – 2 years; R4 – 4 years) in a factorial design. The fourth 2-year harvest was in winter 1991 (Table 6).

Low yields generally followed dry years, and the dry summers of the late 1980s probably account for the fact that the yields from the third and fourth harvests were, on average, slightly lower than those from the second harvest. Differences between treatments were generally non-significant, except that 2m x 2m initial spacing gave consistently lower yields than 1m x 1m spacing at Alice Holt. Overall, the trials confirm an expected yield of 10–12 dry tonnes per hectare per year.

### *Spacing*

Spacing was further examined in a Nelder plot at Alice Holt (see Figure 13). The results indicate an optimum initial spacing of 1.2m x 1.2m, although this result is only valid for the poplar clone tested, 'Rap'.

As stools at wider spacing age, they tend to occupy more ground and produce a higher number of shoots than stools with narrow initial spacing, so that differences in yield diminish with successive harvests.

### *Nutrient removal*

Nutrient removal rates, per hectare per year, were never greater than 100 kg of nitrogen, 11 kg of phosphorus, and 40 kg of potassium. On average, for the S1 spacing and R2 rotation, only 70 kg of nitrogen, 10 kg of phosphorus and

**Table 5.** Summary of yields for *Populus* 'Rap' (dry tonnes per hectare per year)

| | | Year of Assessment | | | |
|---|---|---|---|---|---|
| *Treatment* | *Site* | *85/6* | *87/8* | *89/90* | *91/92* |
| S1R2 | Alice Holt | 8.9 | 16.0 | 12.1 | 10.1 |
| | Long Ashton | 10.8 | 11.6 | 4.6 | - |
| | Mepal | 15.2 | 14.4 | 7.8 | 9.3 |
| S2R2 | Alice Holt | 2.0 | 8.8 | 9.6 | 9.7 |
| | Long Ashton | 9.4 | 9.3 | 4.2 | - |
| | Mepal | 9.3 | 10.7 | 5.4 | 4.4 |
| S1R4 | Alice Holt | - | 13.9 | - | 12.5 |
| | Long Ashton | 8.8 | - | 5.2 | - |
| | Mepal | - | 11.5 | - | 9.7 |
| S2R4 | Alice Holt | - | 9.2 | - | 10.2 |
| | Long Ashton | 6.0 | - | 6.0 | - |
| | Mepal | - | 9.3 | - | 8.0 |

Key to treatments:

S1 – 1m x 1m initial spacing
S2 – 2m x 2m initial spacing
R2 – 2 years rotation
R4 – 4 years rotation

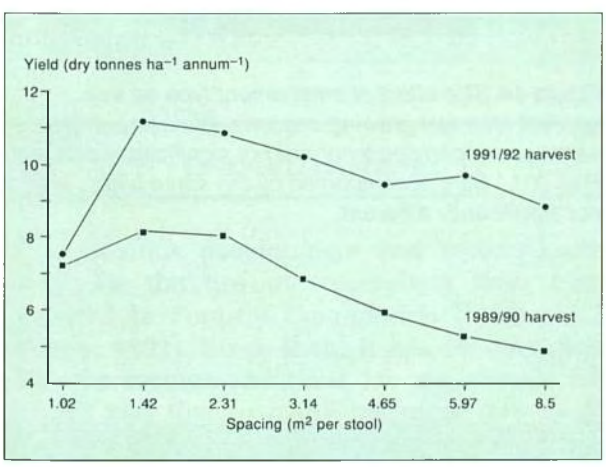



*Figure 13. Yield vs. spacing for the Neider plot at Alice Holt ('Rap').*

35 kg of potassium per year were removed. At these rates, nutrient loss is unlikely to limit growth on fertile soils, at least for the first few cutting cycles.

PAUL TABBUSH

## ORGANIC AMENDMENTS TO BACKFILL FOR PLANTING PITS ON TRUNK ROAD SITES

Trunk road verges and many amenity planting sites have soils of low fertility, high compaction, poor structure and low moisture-holding capacity. On such sites the use of organic soil amendments in conjunction with pit planting is commonplace. Past research (Hodge, 1990) has shown that these amendments often have no effect or even negative effects. Additional concern over the use of peat-based materials has arisen in the context of the exploitation of lowland peat-bogs, and has led to the evaluation of possible alternative materials. This research was funded by the Department of Transport.

### *Methods*

Three experiments were planted in March 1991. They were designed to compare the effects of eight organic soil amendments (including control-spoil replaced without amendment), in terms of the survival and growth of oak, *Quercus robur*, transplants pit-planted on three contrasting trunk road sites. The sites were:

- a gently sloping site with disturbed clay soil;
- a level site with 20–40 cm of clay loam over chalk; and

- a south-facing embankment with a silty clay loam soil.

The products used, at the manufacturers' recommended rates, were:

1. a blend of milled sedge and moss peat with added fertiliser;
2. a composted blend of coir fibre, animal manure and straw;
3. a composted blend of coir fibre, straw and vegetable wastes;
4. composted chicken manure;
5. worm digested farmyard manure, straw and sewage sludge;
6. composted fruit fibre; and
7. composted timber residues, bark and paper pulp with added fertiliser.

After two growing seasons, none of the products used on any of the three sites resulted in tree survival significantly greater than the control (see Figure 14) and none of the products resulted in superior survival. On the clay and the chalk, the use of 3 and 4 resulted in lower survival than the control. On the chalk, 7 also resulted in lower survival.

None of the products used improved total shoot extension or stem diameter increment.

Analysis of each product (see Table 6) found that they varied greatly from each other and from the manufacturers' own analysis. Tree survival and shoot extension were found to be significantly related to product conductivity. High conductivity results from high levels of nutrients inherent in, or added to, some of the products. If a product has a conductivity of more than 4000 µS per cm, it is likely to be detrimental to tree growth when applied at 30% v/v or more in the planting pit.

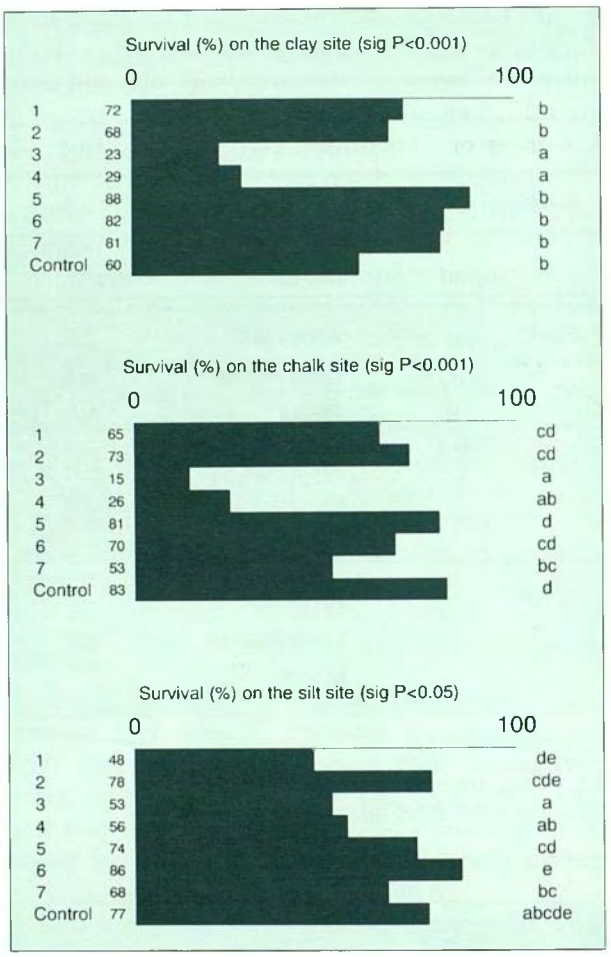



*Figure 14. The effect of amendment type on tree survival after two growing seasons. (Values with the same accompanying letter are not significantly different, P<0.001.) Bars accompanied by the same letters are not significantly different.*

**Table 6.** Results of chemical and physical analysis of the products used in the experiment

| | *1* | *2* | *3* | *4* | *5* | *6* | *7* |
|---|---|---|---|---|---|---|---|
| pH | 6.0 | 7.0 | 7.7 | 6.3 | 7.0 | 8.3 | 7.6 |
| nitrate (mg $l^{-1}$) | 182 | 2 | 1 | 4 | 121 | 1 | 6 |
| total % N | 1.7 | 2.2 | 3.4 | 5.4 | 0.5 | 1.4 | 2.3 |
| extractable P (mg $l^{-1}$) | 183 | 166 | 1740 | 2000 | 84 | 380 | 77 |
| extractable K (mg $l^{-1}$) | 795 | 4606 | 7683 | 4913 | 11 | 2838 | 791 |
| extractable Mg (mg $l^{-1}$) | 923 | 440 | 218 | 885 | 93 | 483 | 119 |
| conductivity (µS/cm) | 3540 | 4600 | 7920 | 10160 | 2370 | 3130 | 2810 |
| % loss on ignition | 83 | 73 | 70 | 78 | 12 | 83 | 85 |
| tens 50 (%)* | 156 | 352 | 195 | 169 | 34 | 256 | 197 |
| C:N ratio | 28:1 | 19:1 | 12:1 | 8:1 | 13:1 | 35:1 | 21:1 |

* tens 50 (%) is the amount of water (expressed as a percentage of the dry weight of the material) retained by a product when a pressure of 0.5 bars is applied to it.

After two growing seasons, in all three sites and with all products, roots had crossed the interface between the planting pit and surrounding substrate, reducing the dependence of the trees on the resources of the planting pit. This makes it unlikely that treatment differences will emerge. As found by Watson (1991), the planting-pit–soil interface appeared not to be an impediment to root spread, even on the clay site where smearing of the pit wall might have become a barrier.

The evidence of these experiments reinforces the previous conclusion (Hodge, 1990) that bulky organic soil amendments added to the pit at the time of planting are unlikely to benefit tree survival or growth.

SIMON HODGE

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## TREESHELTER SURVEY

The previous development and recommendations for the use of treeshelters have been reported in Forestry Commission Handbook 7 (Potter, 1991). Since then, it has become clear that the recommendations are not always followed, and that in many instances tree establishment using treeshelters is not as effective as it might be. During the summer of 1992, a treeshelter survey was carried out to determine the nature of the problem and to help to formulate further recommendations. The survey covered 193 sites in England, randomly selected from a list of schemes in which treeshelters were recorded as part of the establishment method. The sites were identified from discussion with Forest Enterprise staff, Forestry Authority woodlands officers, and private owners and agents. Of the 193 sites, 70% were privately owned.

At each site, information was collected on the type of treeshelter, its height and method of support, and the standard of weed control. In addition, 4622 treeshelters, over all sites, were sampled in more detail.

### *Results*

1. Of the individually surveyed treeshelters, 4121 (89%) contained a live tree.
2. Of the 193 sites, 121 (63%) were judged not to have good weed control.
3. Of the 193 sites, 67 (35%) were in areas of high visual amenity and of these 43 (22%) had been planted using a geometric grid pattern.
4. The most common colours of treeshelters used were brown (84%) and green (7%).
5. Of the 193 sites, 105 (54%) used stakes smaller than those recommended, and of the 4622 individual treeshelters surveyed, 1022 (22%) were installed with the lip of the treeshelter below the tip of the stake.
6. Of the 193 sites, 82 (42%) had treeshelters too short to protect the trees from the largest potentially damaging mammals recorded as being present. On most occasions this meant the use of 1.2 m shelters instead of the 1.8 m recommended to afford protection from fallow and red deer.

Following detailed analysis, the results will be published along with recommendations emphasising the benefits of good weed control and the importance of correct choice and positioning of the stake to keep the treeshelters upright without damaging the trees.

GARY KERR

**REFERENCE**

POTTER, M.J. (1991). *Treeshelters.* Forestry Commission Handbook 7. HMSO, London.

# SITE STUDIES (NORTH)

The development of a new site classification, better suited to the multi-purpose management of forests and based on the biogeoclimatic ecosystem classification (BEC) of British Columbia, has continued. Eight climatic zones based on accumulated temperature and soil-moisture deficit have been proposed, with further subdivision based on oceanicity (the annual range of temperature). The alpine and subalpine zones are defined by low accumulated temperature and lie above the limit of 'productive' forest. The six zones below the tree-line are distinguished as warm or cool, wet, moist and dry zones of woodland or other vegetation.

Within each climatic zone soil quality will be assessed using two variables, moisture regime and nutrient regime. Eight classes of moisture regime and six classes of nutrient regime have been used to form a soil quality grid within which any number of site types may be defined. Links are being established between the soil quality grid and the existing soil-type classification, with additional guidance being provided using indicator plants and a classification of humus forms. This leads naturally to a consideration of integrating BEC with the national vegetation classification (NVC). BEC and NVC seem to have a good deal in common and integration would be mutually beneficial.

During the summer, Professor Karel Klinka of the University of British Columbia, Vancouver and Mr Reid Carter, former research assistant of Professor Klinka and now with Fletcher Challenge, toured British forests at our invitation and gave much valuable advice on how BEC could be adapted to the climatic, soil and vegetation conditions peculiar to Britain. It is clear that we can learn a good deal about the growth performance and conditions required for natural regeneration of north-west American species, provided we can relate the ecological conditions in their natural forests to conditions over here. A BEC for Britain should make this much easier. A first draft has been distributed to other specialists for comment.

For three years we have supported research by the NERC Institute of Freshwater Ecology, Windermere into the factors responsible for erosion of soil in cultivation channels and drains. Further support has recently been obtained from the Scottish Forestry Trust for work on the erodibility of different soil materials. When this is completed, it should be possible to prepare comprehensive advice on how to carry out cultivation and drainage with optimal control of runoff and sediment loss.

Russell Anderson attended a workshop in Finland on carbon cycling in boreal peatlands and climate change. He presented a poster on some work at Rumster Forest, Caithness (see below). We hope to co-operate with other organisations in further research within the British Isles on carbon cycling in planted peatlands.

Three 'Z' drainage experiments are in progress (*Reports,* 1990, 1991, 1992). Fieldwork at the experiment on a clayey peaty gley at Kielder Forest, Northumberland was completed after two years and the results are being analysed. The novel experimental design seems to be producing clear evidence of drainage responses in terms of lowered water-table, albeit only close to the drains. An experiment on a loamy gley at Strathlachlan Forest, Argyll will be completed this year. At Fleet Forest, Dumfries and Galloway, an experiment has been started on a peat soil.

GRAHAM PYATT, RUSSELL ANDERSON, DUNCAN RAY

## AFFORESTATION OF BLANKET PEATLAND

Macaulay Land Use Research Institute is continuing the collaboration in the experiment at Rumster Forest, Caithness on the hydrological and soil effects of afforestation of blanket peatland. Their work consists mainly of sampling and chemical analysis of rain and runoff water.

At this same site a contract was awarded to Neil Redgate (self-employed ecologist) to undertake a vegetation survey of the experimental plots in the fourth year after planting. There are four treatments, each replicated four times:

1. ploughed, drained, PK fertiliser at planting, planted with Sitka spruce;
2. ploughed, drained, P fertiliser at planting, planted with Lodgepole pine/Sitka spruce;
3. ploughed, drained, no fertiliser at planting, P fertiliser in year 3 (one year before the vegetation survey), planted with Lodgepole pine; and
4. drained only (bog vegetation otherwise undisturbed).

Ploughing and fertilising increased the vigour of the ground vegetation (ascribed to national vegetation classification M18b *Erica tetralix–Sphagnum papillosum* mire with a tendency towards M19 *Calluna vulgaris–Eriophorum vaginatum* mire). On treatment 4 the vegetation was about 25 cm tall, whereas on treatments 1–3 it was 50 cm tall. The greater vigour of the larger plants, particularly *Eriophorum angustifolium*, reduced the diversity of species on small quadrats. However, the total number of species increased from 34 on treatment 4 to 57 on treatments 1–3, probably because of a greater variety of ecological niches.

GRAHAM PYATT

# SITE STUDIES (SOUTH)

The Branch has strengthened a number of research topics. Major new developments have been in four areas: the reclamation of landfill sites to woodland; soil sampling of the European Community (EC) Level I plots (for the annual assessment of forest condition); the establishment of Alice Holt Forest as an Environmental Change Network Site; and experimental work on the effects of elevated concentrations of carbon dioxide.

The new work on landfill follows on from the one year desk study reported last year (*Report,* 1992), and is funded by the Department of the Environment. This year, field work has begun with the setting up of woodland monitoring plots on modern landfill sites in England, a study of soil-moisture abstraction, and the establishment of an experiment on the penetration of capping systems by tree roots. Research has continued on site changes under tree crops and on lowland production forestry, and reclamation research has continued on opencast coal spoil in South Wales. A detailed account of this work is given below.

The project on interactions of $CO_2$ and other site/environmental factors has been strengthened by the winning of 50% EC funding to support the open-top experiment at Glendevon. The project, The Likely Impact of Rising $CO_2$ and Temperature on European Forests, is part of the EC Environment Programme and is coordinated by the Institute of Ecology and Resource Management at the University of Edinburgh. At Glendevon, Sitka spruce are being grown in large open-top chambers (*c.* 4.0 m) at ambient (*c.* 350 ppm) and twice ambient (*c.* 700 ppm) concentrations of $CO_2$. Fumigations were started in November 1992 after the rapid and successful installation of a large amount of new fumigation and logging equipment. Ingestad-type treatments for the control of nutrient availability have now also been installed. Joint work with Lancaster University on the interacting effects of $CO_2$ and water availability on Sitka spruce has now been completed (see Part 2 report). The air pollution experiment has continued at the other two sites (Headley and Chatsworth) and will be completed during 1993.

Forest hydrology has remained a key area of research and advisory work. A major task on this project group has been the evaluation and writing up of several years' research at Loch Dee. The investigation of the effects of a pelletised limestone treatment on soil and drainage water chemistry at Llyn Brianne was completed and will be published in the Journal of Hydrology. The analysis of water quality at the wet log store at Thetford and a urea application experiment in mid and north Scotland have also been completed. Monitoring of water quality during forest operations continues at a number of sites in Kintyre, and in forested and moorland catchments in Wales. Research grants continue to support work at Coalburn and Balquhidder, and a major catchment study has been initiated in the upper Halladale in north east Scotland. The findings of these and other studies have contributed to the revision of the *Forests and water guidelines.*

The Chemical Analysis Laboratory processed some 5700 foliar samples for macro-nutrients, 1100 for carbohydrates, 105 water samples (pH, conductivity, colour, turbidity, Al, Mn and Fe) and 75 soil samples. The continuous flow system for analysis of ammonia, nitrite, nitrate and phosphate has been updated, and the data handling system has been further developed to improve the quality and speed of analysis. Jobs completed in the Instrumentation Section include: modification of germination tanks, construction of seed test knives and seed drills; further development of a squirrel-only hopper and an anaesthetic box; repair of photocell bat counters; construction of dampers for the open-top chambers; and the building of a poplar planting tool, a clay compacting tool, an electronic notice board, a hinged sampling box, various sampling quadrats and display items for the open-day.

In addition to the funding or part-funding of research projects, income has been earned from advisory and consultancy work and from charges for foliar analysis. An EC funded consultancy to assist with the development of integrated environmental monitoring in Romania was of particular interest.

PETER FREER-SMITH

## Reclamation of mineral spoils to forestry: progress in the South Wales coalfield

The South Wales coalfield has, for many years, provided an opportunity for research to improve techniques for the reclamation of mineral workings to forestry. With support from British Coal contracts, the past five years have seen a rapid expansion in research. Three aspects are now showing much promise, and novel techniques and reclamation practices resulting from this work have considerable merit for other minespoils and in other areas of the country.

Liquid sewage sludge was first applied to South Wales minespoils planted with larch and alder in 1988. Tree response has been monitored annually. Results (Figure 15) demonstrate the effectiveness of sludge in improving larch growth, mainly by increasing the availability of nitrogen and phosphorus. Uptake of heavy metals contained in the sludge has been recorded, but the increases in foliar concentrations are small and considered harmless. An important consequence of sludge application is that the size of the alder and larch is now similar – before sludge application the alder tended to dwarf and ultimately suppress the larch. It is now evident that most tree species planted directly into minespoils require sludge applications to achieve satisfactory growth – only nitrogen-fixing species like alder grow reasonably well without the improvement of spoil nutrition.

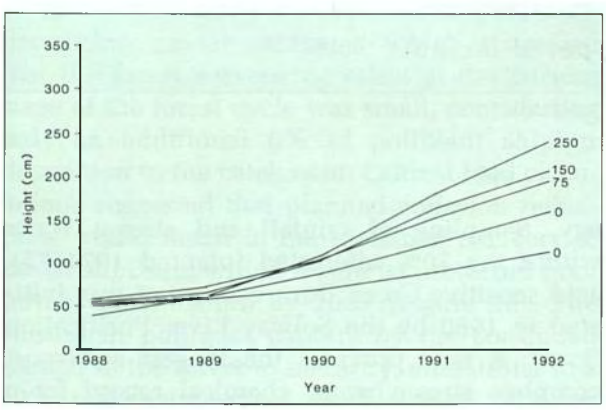


*Figure 15. Tredeg liquid sludge trial 1988–1992: larch. Numbers on the right are rates of application of sludge in $m^3$ $ha^{-1}$.*

Reclamation success is seriously hampered if soil materials are lost during mining operations. At Maesgwyn former opencast site, an experiment has been set up to examine restoration strategies using a variety of soil and soil-forming substitutes. The performance of eight tree species is being examined on raw mineral spoil, weathered shale, peat, and mixtures of these materials. After two growing seasons, tree growth is markedly larger on a substrate of weathered shale mixed with peat; raw shales provide the poorest substrate for tree growth (Table 7). The experiment has also shown that the range of tree species can be increased if better soil materials are available.

Compaction remains a major problem for tree establishment and growth on reclaimed land. Research in South Wales (*Report,* 1991) showed that conventional cultivation equipment has only limited ability to prepare a suitable medium. An experiment has been laid down to test the effectiveness of ground preparation techniques on soil physical conditions and tree growth. Three treatments are being examined: cultivation using the Neath plough; cultivation using the winged tine; and total cultivation, using an excavator to disturb the soil. After one growing season, it is too early to detect effects

**Table 7.** Soil-forming materials experiment: mean height increment March 1991–December 1992 (cm)

| *Soil/spoil* | *Japanese larch* | *Ash* | *Birch* | *Alder* | *Oak* | *Sitka spruce* | *Scots pine* | *Common osier* |
|---|---|---|---|---|---|---|---|---|
| Weathered shale | 32.9 | 6.9 | 39.1 | 56.1 | –2.9 | 22.3 | 5.4 | 88.4 |
| Soil over weathered shale | 54.5 | 8.1 | 32.4 | 50.7 | 0.1 | 25.5 | 14.0 | 107.4 |
| Weathered shale and peat mixture | 69.7 | 14.4 | 57.9 | 86.0 | 9.3 | 29.6 | 10.6 | 162.0 |
| Peat | 22.9 | 12.9 | 20.1 | 21.5 | 1.1 | 11.9 | –2.7 | 102.7 |
| Raw grey shale | 11.9 | 7.6 | 11.7 | 20.6 | –5.9 | 4.7 | –8.3 | 63.7 |

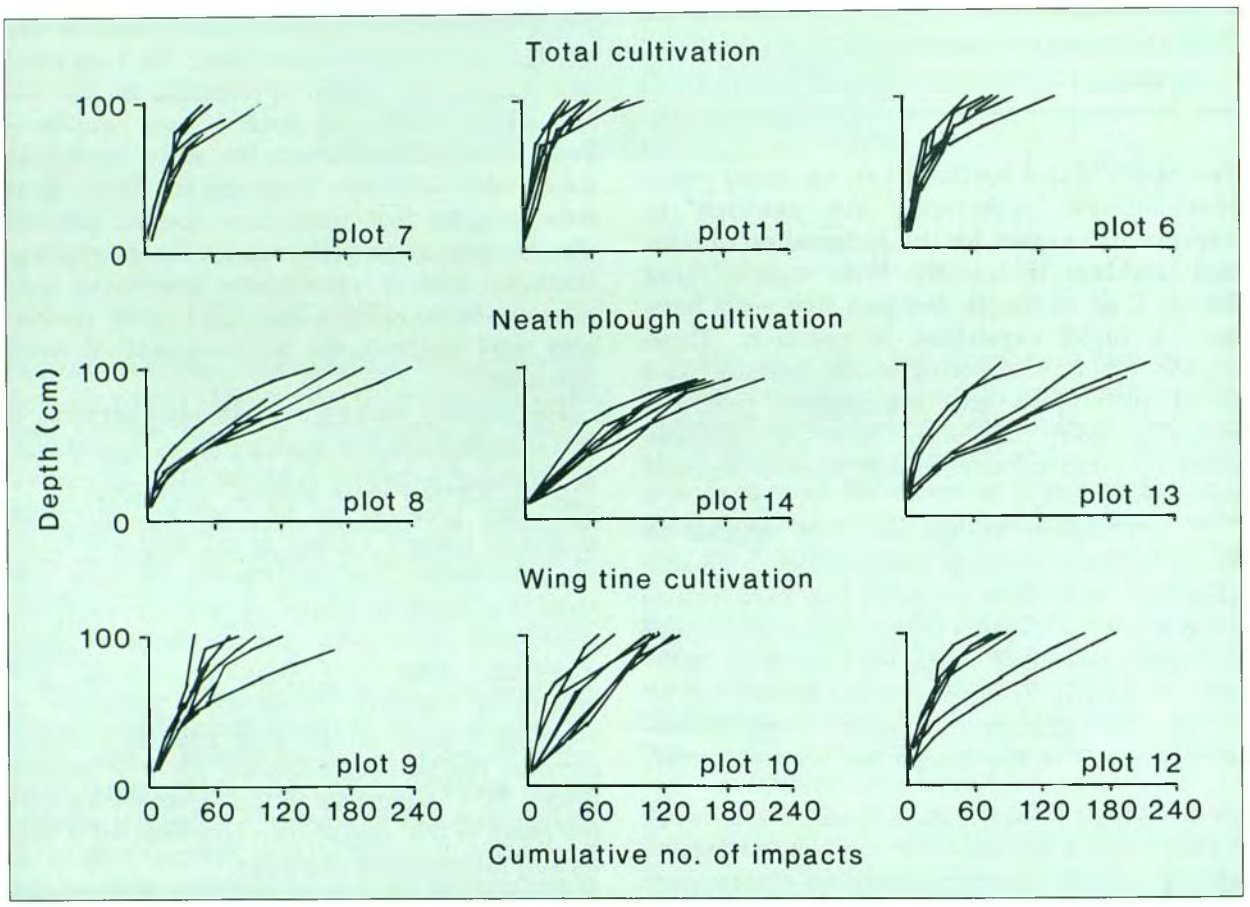


*Figure 16. Penetration resistance, Maesgwyn.*

of treatment on tree growth, but important differences in penetration resistance have been obtained (Figure 16). Total cultivation, akin to loose tipping (*Report,* 1991), is the most effective in producing a rootable substrate, but the winged tine has also performed satisfactorily. The Neath plough, in contrast, has disturbed the spoil superficially, and the results suggest that its use as a cultivation tool should be curtailed.

ANDY MOFFAT AND ALAN ARMSTRONG

## SURFACE WATER ACIDIFICATION

The role of forestry in surface water acidification continues to be a key issue. One important project was a joint assessment, with Professor D. Fowler of the Institute of Terrestrial Ecology, of the effect of conifer afforestation on stream water acidity at Loch Dee in south-west Scotland (Nisbet *et al.*, 1993). This investigation used data from the Loch Dee Project, which is a multidisciplinary study of the effects of acid deposition and forestry on surface water ecology. Sampling of rainfall and stream water within the 70% afforested (planted 1973–75), acid sensitive Green Burn catchment was initiated in 1980 by the Solway River Purification Board; it now provides the longest and most complete stream water chemical record for a forested catchment in the UK. This record covered the period of forest growth from ages 6 to 17 years, during which time a substantial part of the forest reached the stage of canopy closure, when a pollutant scavenging effect may become important.

Trends in stream water chemistry were evaluated and compared with those in an adjacent moorland catchment. Deposition models were used to estimate the scavenging effect and the results considered in the context of the catchment's freshwater critical load. Finally, the model predictions were compared with the observed stream water chemical record.

The trend analysis revealed no evidence of a forest acidification effect so far, but showed a small, but significant, decrease in stream water acidity (~0.2 pH units) within the forested Green Burn (Figure 17). Although this improvement was not mirrored in the adjacent moorland catchment, it was consistent with a similar

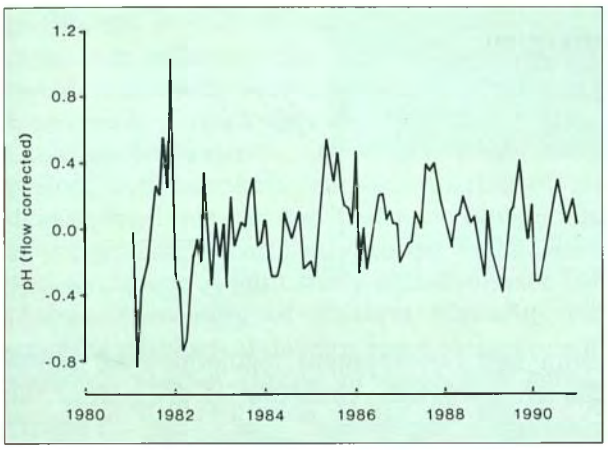


*Figure 17. Trend in mean monthly streamwater pH residuals (corrected for flow) for Green Burn, 1981–1990.*

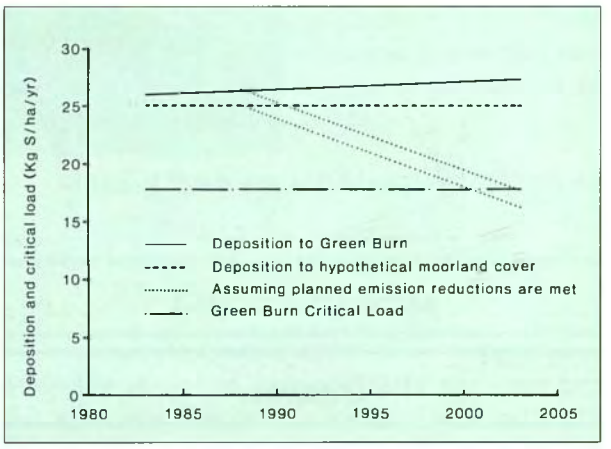


*Figure 18. Comparison of total non-marine sulphur depositions with freshwater critical load (high flow mean) for the Green Burn catchment.*

recovery in nearby moorland lochs. The decrease in stream water acidity was believed to be due to a delayed response to the marked reductions in emissions of pollutants that were achieved during the 1970s and early 1980s.

The stream water results were in line with deposition model estimates which suggested that the forest scavenging effect at the current stage of the forest cycle was small, contributing only an additional 6% of pollutant sulphur deposition to the catchment. Critical load calculations suggested that planned emission reductions would result in the sustained recovery of the Green Burn, which would be protected from further acidification by 2003 (Figure 18). The additional pollutant capture by the continued growth of the forest to maturity, amounting to a 10% scavenging effect, is calculated to delay this response by at most two years.

The absence of a forest acidification effect at Loch Dee cannot be taken as evidence that forestry will not have an impact on stream water acidity elsewhere. This is because the scavenging effect is highly catchment specific, depending on the interaction between pollutant loading, the location and extent of forest cover, and catchment buffering capacity. The usefulness of the freshwater critical loads approach in providing a context for assessing the significance of a forest effect was clearly demonstrated by this investigation. The Forestry Commission has recently adopted the critical loads approach in its *Forests and water guidelines* as a means of identifying those sites that may be at risk from the additional capture of pollutants by new forest planting.

TOM NISBET AND JANET STONARD

**REFERENCE**

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# TREE IMPROVEMENT

## Overview

This year has seen a significant increase in the time and resources of the Branch spent on contract research. In the case of one of the European Community (EC) funded projects, we are collaborating with tree breeders in several European countries to test Douglas fir half-sib progenies provided by the US Forest Service. The raising of planting stock and the siting of trials will be shared among the collaborating institutions so that we shall all benefit from sharing ideas and making more effective use of resources. In the case of Douglas fir this is particularly important; in the past we have not been able to justify the allocation of resources for an independent UK tree improvement programme because this species constitutes less than 5% of our forest estate.

Another contract, funded by the Overseas Development Agency, is on tree improvement of hybrids between Chinese and Japanese larches; it will be carried out in collaboration with scientists from the Chinese Academy of Forestry, Beijing. This contract complements current work on hybrid (European x Japanese) larches in our research programme; a report on enhancement of flowering in larch is included separately below.

We are now in the fourth year of a 50:50 Ministry of Agriculture, Fisheries and Food/Forestry Commission funded project on genetic improvement of broadleaves for farm forestry. Stands of superior phenotypes of ash and sycamore have been identified, seed collected, seedlings raised and field trials established. Some stock plants of both species are now in cultivation and planning has started on the use of the selected material in farm forestry.

A significant amount of time (equivalent to 1.5 to 2.0 staff a year) and resources of the Branch are spent on regulatory duties – such as seed stand inspections, the Native Pinewood Scheme, preparation and maintenance of National Registers – and in providing advice on EC and the Organisation for Economic Co-operation and Development regulations for reproductive materials. These duties are part of the statutory requirement of the Forestry Commission and are important for the UK forestry industry, but the input of this Branch should be recognised, because often the most experienced members of staff are involved.

Two aspects of the Sitka spruce improvement programme are reported below. The overall research programme of the Branch continues to make satisfactory progress although, inevitably, other commitments are placing our whole programme under greater pressure and priorities have had to be rigorously assigned.

David Rook

## Enhancing flowering of larch

Research is being carried out to promote early and enhanced flowering of European and Japanese larches in order to overcome delays in breeding of hybrid larch and production of seed. In the field, larch begins flowering when about 20–25 years old; for breeding programmes, grafts from mature trees are used and so far 20 hectares of mixed European and Japanese larch clonal seed orchards have been established for the production of hybrid larch seed. These orchards are now slowly coming into production, but the irregular flowering of the grafts, slightly different flowering times between the species and low numbers of viable seed produced per cone have all hindered their productivity.

Cultural and chemical treatments have been used to enhance flowering in the Pinaceae, and application of the gibberellin mixture, $GA^4/_7$, has been successful for many species, including Sitka spruce. In experiments over several years, $GA^4/_7$ applied to container-grown larch grafts by injection into the main stem gave no increase in cone production in spite of testing different quantities and times of application, and applying it both alone and in combination with heat, drought, girdling or root pruning. Inductive

treatments should be timed to coincide with cone bud differentiation and in these experiments treatments were assessed over two- and four-month periods between May and August. Long shoots extended over this four month period, and morphological examination of the developing buds showed that cone-buds could be recognised by early July, so the times tested appear correct. A joint study with Professor J.N. Owens, University of Victoria, Canada, will examine cytological development of the buds to establish precise timing of male and female cone-bud differentiation. Although the $GA^4/_7$ treatment was unsuccessful here it cannot be ruled out that it may increase flowering under different conditions, and spray application is now being assessed.

In contrast, flowering was substantially increased when grafts were placed in a polythene house from May to June or August, with mean maximum temperatures of 29–30°C. The heat treatment significantly increased both pollen and seed cone production, and a drought treatment also increased seed cone production. Treatment means of up to 143 seed cones and 250–1000 pollen cones per graft, on 1.5 m tall grafts, were observed.

An important problem in breeding programmes with *Larix* species is the high proportion of empty seed produced, sometimes with only 2–4 full seeds per cone. Reasons cited for poor seed development include lack of pollination, non-viable pollen, lack of fertilization, and poor ovule and embryo development. Larch flowers emerge early in the year and are often damaged by wind and frost. In a preliminary experiment, container-grown grafts (previously treated in an induction experiment) were placed in a frost-free polythene house in February, pollen was collected and pollination of receptive female cones was carried out. Grafts maintained indoors produced pollen of higher viability than grafts outdoors, but the differences were not statistically significant. Studies are continuing to examine seed production and viability. Field trials have been carried out with $GA^4/_7$ injections and girdling to branches and main stems of 7–8 year old grafts in an outdoor clone bank. No significant effects of $GA^4/_7$ were observed but girdling, applied as two overlapping semi-circular cuts, did promote flowering and significant increases in pollen and seed cone numbers were observed. Girdling may thus be a useful treatment for grafts outdoors though its effect has been inconsistent.

These studies have shown substantial increases in pollen and seed cone production on container-grown grafts placed in a polythene house, and the use of polythene houses has real potential for breeding and seed production of European and Japanese larches.

JULIAN PHILIPSON AND MARGARET O'DONNELL

## GENETIC GAIN TRIALS

Properly designed progeny tests are excellent for assessing the genetic quality of families in test relative to standardised check-lots, and so estimating the breeding value of the parent clones. Data collected in progeny tests are used to re-select amongst the originally selected parent clones. The best clones are then brought together to inter-mate and so produce the improved commercial planting stock for the next generation of forests.

What is actually seen in a progeny test is rarely the same as the material which will ultimately be used as improved planting stock in the next generation of forests. This is because the progeny test usually carries only half the genetic story – selection of superior mother trees. In the production population both the mother trees and the pollen input are superior.

*Prediction* of genetic gain is possible based on progeny test data, but information on actual or *realised* genetic gain can only be achieved by comparing unimproved material with commercially available genetically improved planting stock.

Comparative trials of improved with unimproved material are referred to as genetic gain trials (GGTs). They are of value because:

1. they compare *actual* improved with unimproved in an easy-to-see way, and therefore have a high demonstration value;
2. they allow the comparison of *predicted* and *realised* gains;
3. they can often include material which will be commercially available in the future but is only currently available at the research level – when such material becomes commercially available, information on *realised* gain will be to hand;
4. plot size can be large allowing the establishment of permanent sample plots, giving data on long-term gains;
5. since the trials will run to at least first thinning and hopefully final rotation, data will be collected on quality and value as well as volume improvement;
6. they are usually inexpensive to establish, with the number of treatments being small;

7. they can be established over a number of typical forest sites.

In co-operation with Forest Enterprise and the private sector, 15 Sitka spruce GGTs have been established over Britain from Caithness to Cornwall. They will yield definitive data to help forest managers to select improved material. These GGTs contain a number of different treatments including: unimproved Sitka spruce of Queen Charlotte Islands, Washington and Oregon seed origins; seed stand material; seed orchard material; improved rooted cuttings; and some of the very best seedling material currently available in research. The location of each experiment has been carefully chosen both to be easily accessible and to have a potentially high visual impact.

On advice from Mensuration Branch, plot sizes of 15 x 15 plants replicated three times were chosen. On a few occasions this was reduced to unreplicated blocks of 1000 trees per treatment.

It is envisaged that GGTs will continue to be established periodically (approximately every 3–5 years) as the genetic superiority of Sitka spruce production populations continues to increase.

STEVE LEE

## FARM FIELD SITES

Breeders try to maximise the use of genetic testing resources and the rate of realisation of genetic gain by identifying, as soon after planting as possible, those genotypes that will be superior at rotation age. Very early selection to identify superior genotypes under controlled conditions would allow significant increases in efficiency in tree breeding.

Attempts at very early selection in the past have included innovative work carried out by the (then) Genetics Branch in the 1970s which concluded that it was not possible to identify superior families in glass or polythene houses when trees were grown under extended day lengths.

The current practice for multi-trait selection within forest-based Sitka spruce progeny tests in Britain is to select for vigour based on six-year height across a minimum of three sites (Gill, 1987). Selection for form (stem straightness and branching characteristics) follows at age seven years, whilst wood density is assessed indirectly using the Pilodyn at breast height around 15 years from planting (Fletcher, 1992).

Numerous recent studies have found that both the overall accuracy of progeny testing and calculations of repeatability of family means, genetic variance and genetic gains for vigour traits, are improved by choice of good planting sites (Burdon, 1977; Carson, 1990). Others consider correlations at development stages more relevant than age (Lambeth *et al.*, 1983; Magnussen and Yeatman, 1987; and McKeand, 1988) and some authors (e.g. Magnussen, 1989) suggest that the timing of these stages can be advanced through use of closer initial spacing.

A logical extension of much of the work reported above might be to grow progeny tests at close spacing on highly homogeneous, weed-free, fertile sites. This technique is referred to as testing on farm field sites. A fertile, highly uniform ex-barley field close to our Northern Research Station will be used in early selection trials in the next five years.

Initially, two retrospective Sitka spruce progeny tests have been established under a three-year EC contract. These new farm field site tests have involved sowing surplus seed from cold stores of families already established in conventional forest progeny tests where they are now between five and seven years old. The retrospective tests will enable the correlation of 1–3 year height and diameter data (using various traits at planting as possible co-variates) from the farm field site with 8–10 year height and diameter data from the conventional forest site. Depending on the genetic correlations of family mean performance between the two sites for the various traits under selection, the possibility remains for (at worst) heavy screening of families prior to establishment in longer-term forest progeny tests, or (at best) final selection of the best clones based solely on the performance at the farm field site over a 3–5 year period.

There is tremendous potential for considerably reducing both the generation turn-over period and the expenditure per percentage increase in final rotation value in the Sitka spruce breeding programme, if the use of farm field sites proves successful.

Further retrospective progeny tests are planned with hybrid larch. Experiments with Douglas fir progeny are also planned. This will involve the concurrent planting of over 300 families at both the farm field and three conventional forest sites.

STEVE LEE

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*Plate 5. Increment core being taken from a native pine tree.*

*Plate 6. Short rotation poplar coppice at Alice Holt. The unapproved 'Rap' clones can be easily differentiated from the more recently planted 'Beaupré' and 'Boelare' clones in this picture by the leaf browning on the 'Rap' caused by an infestation of rust fungus.*

*Plate 7. Red squirrels feeding at a hopper (A. C. Baxter).*

*Plate 8. The solardomes and $CO_2$ tank at the Biology Field Station, Lancaster University.*

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# WILDLIFE AND CONSERVATION

The Branch continues to provide a consultancy and advisory service to both the Forestry Commission and other organisations. This included involvement in successful displays of practical management techniques during the open days, and support to forest health days and Forestry Authority deer management seminars.

The Head of Branch has developed a biodiversity programme both to identify methods of improving biodiversity and to develop standards of biodiversity which are applicable to managed forests. A publication outlining the programme is due later in 1993.

A major review of the damage by mammals in northern temperate forests has been published and this has led to experiments being set up to investigate the impact of roe deer browsing on the growth of different tree species.

Sites for detailed fallow deer population dynamic studies have been selected and samples collected from the 1992 doe culls.

Bats have again visited the artificial hibernation sites at Pembrey and fed on hibernating herald moths. It is hoped to install automatic monitoring equipment to monitor bat activity in relationship to temperature changes during winter 1993.

A new project examining carnivore–prey communities in upland forests is looking at interactions of mammalian predators with the field vole, an important food resource.

Progress on red squirrel conservation is being made through jointly funded projects with Scottish Natural Heritage, English Nature and the Countryside Commission for Wales. Approaches include the protection of island populations by maintaining optimum red squirrel habitat and creating buffer zones between these and invading grey squirrel populations. Supplementary feeding through the previously developed red squirrel-only hoppers (see Plate 7) and translocation to enhance low density red-squirrel populations is being investigated in combination with grey squirrel control. This important and topical area of research is described in more detail.

## THE PRODUCTION OF A WARFARIN HOPPER FOR GREY SQUIRRELS THAT PREVENTS RED SQUIRRELS GAINING ACCESS TO THE POISONED BAIT

The current legislation, the Grey Squirrel (Warfarin) Order (1973) and the Wildlife and Countryside Act (1981), prevent the control of grey squirrels with warfarin in certain specified areas and anywhere where red squirrels are present, because at the time of the legislation it was not possible to safeguard red squirrels from the poison. In recent years the design of the grey squirrel warfarin hopper, as specified in the 1973 Order, has been modified to include a flap door which excludes small mammals (mice, voles and dormice) without inhibiting use by grey squirrels (Forestry Commission Research Information Note 153). Trials in 1991 showed that the less inquisitive and more timid red squirrel is disinclined to enter a hopper with a flap door and that it may be possible to modify the door further so that red squirrels are completely excluded. Such a hopper would, with a change in the legislation, have the potential for use in two situations:

1. as a red squirrel conservation operation to control grey squirrels in areas where red squirrels are also present; and
2. for grey squirrel damage control in areas where red squirrels are present.

Four hopper types, two with flap doors and two without, were compared in a red squirrel-only area (Moray) and in a grey and red squirrel area (Clwyd) between June and September 1992. Hoppers with doors had either the current standard clear pvc door with magnet (Figure 19) or a new solid heavyweight metal door. Both are designed to prevent red squirrels, but not grey squirrels, from feeding from the hopper; experience gained in grey squirrel control operations has shown that grains of wheat in the tunnel can prevent the magnet door closing onto the tunnel floor. Hoppers without doors had either the entrance completely open to allow access to small birds and all small mam-

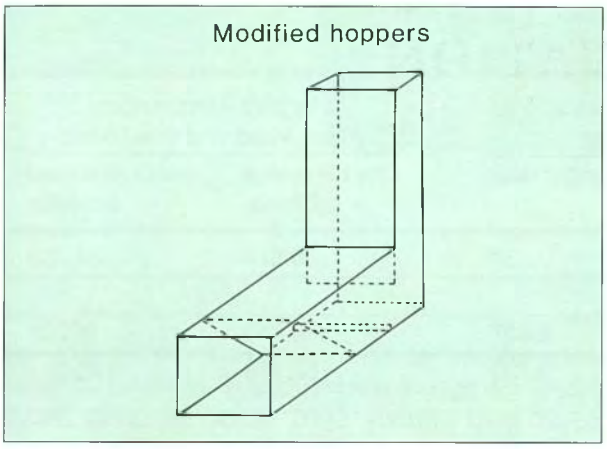


*Figure 19. Modified hopper showing position of flap door and baffle.*

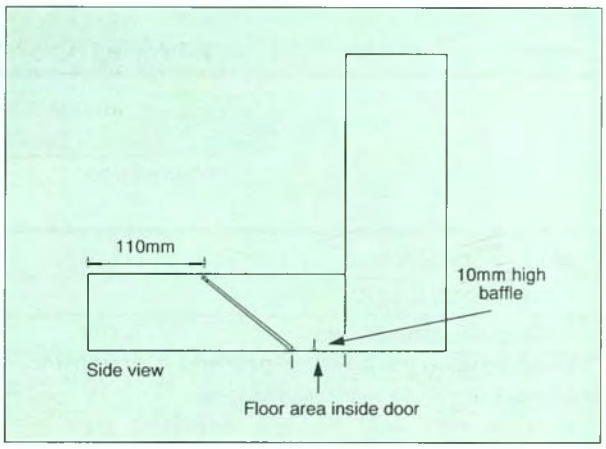


*Figure 20. Hopper showing dimensions and modifications.*

mals, including squirrels, or an entrance partially restricted with 25 mm square, welded wire mesh which allowed small mammals (mice and voles) and small birds through but not squirrels. In addition all hoppers were fitted with a baffle (Figure 20) to prevent the wheat bait spilling into the tunnel.

Unpoisoned wheat bait was coloured with a latex-plus dye solution (Killgerm Ltd) prepared as for the Grey Squirrel Concentrate, Ministry of Agriculture, Fisheries and Food (MAFF) registration number 01009, but without added warfarin. The dye and wheat were thoroughly mixed using the standard grey squirrel control procedure and rate (500 ml of solution with 12.5 kg wheat).

Two kilograms of the coloured wheat bait (4 x 500 g measures) were placed in every hopper. Forty hoppers, 10 of each type, were sited in each Forest Enterprise district at a density of approximately one hopper every five hectares.

All but 12 hoppers at Clwyd (located in or adjacent to beech belts) were sited in conifer areas with signs of squirrel feeding (presence of stripped cones), either at the base of a tree or at a tree stump and where the ground was clear of vegetation. Each hopper was firmly secured to a driven stake with wire, camouflaged with branchwood, and set with the tunnel tilted slightly down to prevent surface water flowing down the tunnel into the bait. Two handfuls of yellow maize were scattered in and around the hopper entrance to attract squirrels.

All hoppers were checked at 2–3 week intervals to ensure that the wheat was flowing freely into the hopper tunnel and that the flap door was operating correctly. The wheat bait was topped up at each visit, as necessary, with measured 500 g lots. Any wheat remaining in each hopper at the end of the trial was weighed, and the amount of wheat taken from each hopper calculated (see Table 8).

All hoppers, except those with mesh to exclude squirrels, had blocks of wood attached to the roof inside the tunnel entrance and against the bait container. Double sided sticky tape on the block surface collected hairs from squirrels entering the hopper and lifting the door (Figure 21).

There were no signs of squirrels, small mammals or birds entering the hoppers with doors at Moray. The hair collected from hoppers showed that at Clwyd only grey squirrels entered doored hoppers and that at both Moray and Clwyd red squirrels fed at hoppers without doors.

Both heavyweight metal and clear pvc magnet doors prevent red squirrels feeding from the hoppers whilst allowing access to grey squirrels. Red squirrels will feed from hoppers located on the ground if they can enter.

The data obtained from these trials will be submitted to MAFF to support an application for a licence to trial warfarin in an area with red and grey squirrel populations and ultimately for a change in the legislation.

HARRY PEPPER

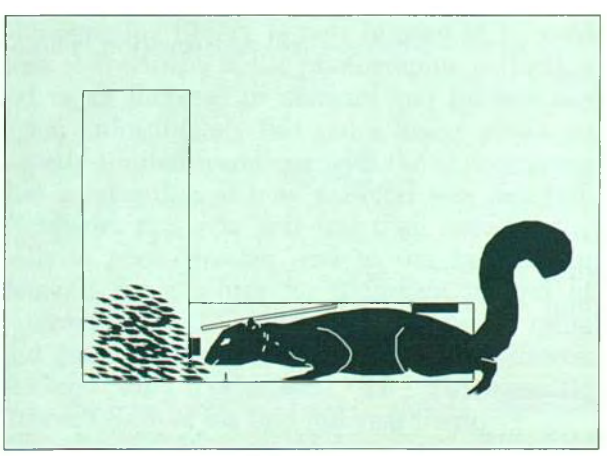

*Figure 21. Squirrel using hopper.*

**Table 8.** Total weight (kg) of wheat taken from hoppers

| | *Hoppers with doors (squirrels only)* | | *Hoppers without doors (mice, voles and small birds)* | |
|---|---|---|---|---|
| | *Magnet door* | *Weighted door* | *Open entrance (+ squirrels)* | *Mesh restricted entrance* |
| Moray Forest District | 0.123 | 0.174 | 38.076 | 31.763 |
| Clwyd Forest District | | | | |
| Grey squirrels present | 5.755 | 6.827 | 19.740 | 11.202 |
| Red squirrels present | 0.168 | 0.136 | 52.478 | 49.097 |

## Modelling songbird–habitat relationships in northern upland spruce forests

The aim of this 2½ year study was to provide a model to predict the effect of different management regimes on the density and diversity of bird populations in northern upland spruce forests.

Bird populations in upland spruce forests at Cowal and Kielder were surveyed in relation to block size, tree age, altitude, amount of edge, and other factors which can be manipulated during forest management. Surveys started in winter 1990/91 using point counts as the principal census technique.

In both years of the study, there was strong and significant variation in bird numbers and diversity with tree age, both being highest in older trees in winter and in 9–25 year old trees in spring. All of the common species showed significant variation in their abundance between tree age categories, with all except the meadow pipit occurring at their lowest density in the youngest trees.

Considerably more birds were found at the edges than in the centres of plots, but differences between edge and centre sampling meant that no conclusions could be drawn concerning the number of species in the two zones. There was little detectable effect of plot altitude, admixture of other conifer species or planting generation on either bird numbers or species diversity.

Spring numbers of common species which were resident over winter were very poorly correlated with their winter numbers.

There was a general similarity between the two years and the two areas in their overall patterns of variation of bird numbers and diversity with forest variables, but most species, especially crossbills and siskins, were very much more abundant in 1990/91 with its large cone crop, than in 1991/92, when there were few cones.

A computer model to predict changes in songbird numbers as a result of changes in forest structure has been developed from the results of the survey.

Ian J. Patterson and John G. Ollason

*Aberdeen University Zoology Department, Culterty Field Station*

# COMMUNICATIONS

Trees for Tomorrow, the first full-scale open days to be held at Alice Holt Lodge for eight years, attracted some 7000 visitors over three days in mid-June 1992. Details of a wide range of research projects were on display. Special attractions included a model forest for use in rural landscape design, trees and timber products as vehicles for carbon storage, extraction of timber by heavy horses from an environmentally sensitive site, and a tree-top walkway to view botanical features and problems of tree health in the crown canopy.

The Research Advisory Service was formed in April 1992, drawing together existing expertise within the Division and offering additional facilities such as those for plant quality testing. The Service offers enquirers specialist information and advice on forestry research and related topics. An initial brief response is free of charge; the provision of more detailed assistance, including that resulting from consultancies and contracts, will normally be chargeable. It is estimated that 20% of researchers' time is spent on giving professional information and advice to colleagues in the Forestry Authority, to managers in Forest Enterprise, to the private sector of the forest industry in Great Britain, to local authorities, and to members of the public.

Visitors to the research stations during the year included members of Timber Growers UK, Romanian foresters, two delegations from China, trustees from the Centre for International Forestry Research, and local civic leaders.

JOHN PARKER

## LIBRARY AND INFORMATION SERVICE

There has continued to be substantial use of the Library and its services. The distribution of our Current Awareness listing of recent periodical articles over the electronic mailing system of the Forestry Commission has generated a greatly increased number of requests for photocopies and loans. As in the previous year, the Library received over 200 individual visits from external users.

The use of CD-ROM technology, introduced at Alice Holt last year, was extended to the Northern Research Station this year with the purchase of another machine and another copy of TREE-CD. This provides a database of all the forestry abstract journals from 1939 to 1991, and search software which gives a quick and convenient way for researchers to find out what has been published on a particular topic or by specific authors.

The main Library catalogues, which used CAIRS IMS software on the Prime computer, have been transferred on to the new network with the software on its own CAIRS server, and there is now an opportunity to make them much more easily available to Research Division staff.

CATHERINE OLDHAM

## PHOTOGRAPHY

The year began with the transfer of the Graphics Officer, John Williams, from Publications Section to Photography. Under this new formation the mammoth task of preparing displays for open days in June 1992 was completed successfully. The section has been reorganised and the photographic library is now housed in its own area. Advertising of the photographic collection led to an increase in demand and income has risen; unfortunately this put a heavy strain on already limited resources with the consequence that cataloguing of new material was delayed. Fieldwork this year was less than normal, due both to poor weather and to the increase in demand for graphics for inclusion in end of contract reports. The demand for photographic and graphics services at the Northern Research Station fully occupied the Photographic Officer's time in his first full year there.

GEORGE GATE

## PUBLICATIONS

During the interregnum prior to the appointment of Kathy Davies as Research Publications Officer in October 1992, we were fortunate in benefiting from the experience of Jenny Claridge who provided editorial services to ensure the continued flow-through of technical forestry publications.

Co-operation with other organisations was notable, with Bulletin 106, *Woodland management for pheasants,* being written by Peter Robertson of the Game Conservancy Trust, and Bulletin 107, *A manual of good practice for the use of sewage sludge in forestry,* being co-authored by staff from the Water Research Centre, and also co-sponsored by WRc.

Publicity for the two new Handbooks was ensured by associating their release with other newsworthy forestry occasions. Handbook 8, *Establishing farm woodlands,* was published on the first of the open days at Alice Holt Research Station. Handbook 9, *Growing broadleaves for timber,* was launched in conjunction with a Centre of Excellence award presented to John Workman by the Forestry Authority for England in recognition of his fine well-managed broadleaved woodlands at Sheepscombe in Gloucestershire.

The following titles were published during the year ending 31 March 1993:

***Bulletins***

83 Seed manual for forest trees (£10.95)

103 Super Sitka for the 90s (£7.95)

105 Roe deer biology and management (£5.50)

106 Woodland management for pheasants (£3.75)

107 A manual of good practice for the use of sewage sludge in forestry (£5.30)

108 Monitoring vegetation changes in the conservation management of forests (£3.50)

***Guidelines***

Lowland landscape design guidelines (£9.95)

Forest recreation guidelines (£7.00)

***Handbooks***

8 Establishing farm woodlands (£6.75)

9 Growing broadleaves for timber (£13.50)

***Miscellaneous***

Research Advisory Service leaflet (free)
Entomology Branch leaflet (free)
Forest Products Branch leaflet (free)
Mensuration Branch leaflet (free)
Pathology Branch leaflet (free)
Plant Production Branch leaflet (free)
Tree Improvement Branch leaflet (free)
Wildlife & Conservation Branch leaflet (free)

***Research Information Notes***

218 Shake in oak.

219 The protection of trees in silvopastoral agroforestry systems.

220 Incorporating the threat of windthrow into forest design plans.

221 Air quality and tree growth: results of open-top chamber experiments 1991. (colour)

222 Inoculating Douglas fir seedlings with mycorrhizal fungi.

223 Do dominant oaks have few epicormic branches?

224 *Rhizophagus grandis* as a means of biological control against *Dendroctonus micans* in Britain.

225 Farm forestry research. (colour)

226 Price-size curve for conifers.

227 Forest performance of hybrid larch cuttings.

228 Forest performance of different birch plant types.

229 Recreational use values of woodland features.

KATHY DAVIES

# STATISTICS AND COMPUTING (NORTH AND SOUTH)

At Alice Holt, 1992 saw the installation of the local area network followed by the important stages of training users and providing support when problems occurred.

Benefits of the network were quick to show. The SILVAN data analysis system (based on Genstat) and the command-driven plotting program CDPLOT (based on Ghost) have both been enhanced as they have been converted to Sun/Unix. The ease of linking programs and the increased processing speed meant that final tabulations of the Forest Health Survey Data could be achieved in a fraction of the time previously needed. A subset of these data is used for the International Co-operative Program on Assessment and Monitoring of Air Pollution on Forests. Another analysis involved data from about 130 000 London trees, as part of a subcontract for the Department of the Environment.

At the same time, the programming section transferred the sub-compartment database and production forecasting systems to HQ, following the move of the Surveys Branch of Policy Studies Division. The database, in Oracle, was restructured to bring it into fully normalised form. The section has also implemented a system to record and analyse time-summary information to assist in project management. Work on data capture continues.

DAVID MOBBS

## COMPUTING: NORTHERN RESEARCH STATION

This year has seen the consolidation of the Sun local area network. Modifications and enhancements have included the provision of a menu-driven interface for less experienced users and training has been provided as required. Additional modifications were made to the main data summary programs to allow errors to be traced more readily.

A program was written for Silviculture (North) Branch to allow tatter flags to be measured on a digitising tablet, which will give faster and more accurate results. A modified version of the field assessment program was produced to select trees for thinning where a known basal area needs to be removed.

Progress was made in the use of the Postscript printer language and an A3 Postscript laser printer was installed. Various improvements were made in accessing printers from WordPerfect and other software packages.

In August, a temporary contract was signed with the Edinburgh University Computing Service to provide support for PC users. This will continue in the short term while uncertainty prevails. Under the terms of the contract, training in statistical and graphics packages such as SAS and Uniras has been made available.

WAYNE BLACKBURN AND IAN MARTIN

## STATISTICS: NORTHERN RESEARCH STATION

Canonical variate analysis was used to compare samples of four-component monoterpene mixtures from different geographical areas. This approach was compared with the result of displaying raw data and the simplex containing them as an isometric projection. Some differences showed up more clearly with the second approach.

Fourier analysis was used to investigate clustering of tree root systems, by regarding different types of clustering as analogous to the periodicities of time series. Similar methods can be used to analyse the two types of data, although there are problems of interpretation specific to the spatial case.

Courses were run on experiment design and on the use of the statistical package Minitab. This is an on-going activity to reinforce the trend towards researchers doing their own basic statistical analysis.

IAN WHITE

## Planting distance and wood strength of unthinned Sitka spruce

It has long been recognised that the space available for the growth of a tree affects its form and vigour which, in turn, affect the quality of the timber produced. In recent years planting distances for Sitka spruce have been increased to reduce establishment costs. At one time, tree spacing was commonly 1.4 m but has been widened to 2.4 m and occasionally 2.7 m.

Data supplied by J.D. Brazier (formerly at the Princes Risborough Laboratory) were analysed to examine the effect of initial planting distance on timber strength. The material tested came from twenty 40–50 year old unthinned sample plots which had been established at different planting distances.

Samples of trees from these plots were converted into 4 m logs, which were sent to Princes Risborough Laboratory for conversion into 5 x 10 cm battens. These were kiln dried to a consistent moisture content, then stress graded at 10 cm intervals along each batten to find the force required to cause a fixed deflection. A mean minimum force was calculated for each log and plotted against initial tree spacing.

To characterise the relationship it seemed sensible to fit models with asymptotes and both Gompertz and Logistic models were tried in a weighted analysis, using the reciprocal of the within-log-variance between battens to weight the results for individual logs. Both Gompertz and Logistic models produced similar results, with the Logistic giving the most consistent curves for different log grades. Figure 22 shows the curve fitted to the whole population of logs.

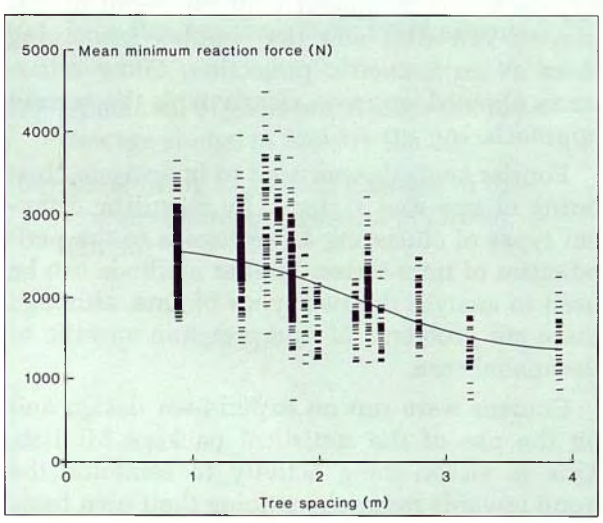


*Figure 22. The relationship between planting spacing and the mean minimum reaction force for the timber from sampled sites.*

It can be seen that an increase in initial tree spacing, from what used to be the conventional 1.4 m, affects timber strength in unthinned stands.

David Mobbs

## Modelling the processes of forest growth

The Forestry Commission model was developed to help understand the effects of competition and spacing on trees (*Report*, 1991) and simulations this year have explored the way inputs may have a different effect on growth of the whole stand or on the growth of individual trees within the stand.

In the model, for example, the crowns of Sitka spruce are conical, and we have simulated a group of trees with different crown angles (Figure 23). Those with wider crowns do better

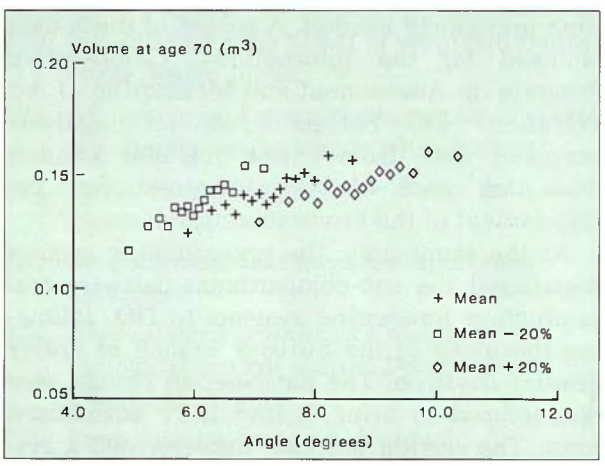


*Figure 23. Variation in volume ($m^3$ to 7 cm diameter) at age 70 years in simulated Scots pine, in Finland, when the stand mean of the crown angle was altered by ± 20% from a mean of 7.3°. The CV within each stand was 10%.*

than their neighbours because they capture more of the growing space, but increasing the mean crown angle of the whole stand has almost no effect on final stand volume. Other variables, such as light interception per unit of foliage, increase both stand growth and the growth of individual trees, and the simulations should help in planning and interpreting tree improvement studies as well as studies on spacing and thinning.

The model has also been compared with six others in a Europe-wide project supported by the European Science Foundation, under the

auspices of FERN. All of the inputs to the models were taken from the literature, so there was no 'fitting', and weather data were taken from a site in Finland. Each of the models was then run to simulate growth of the Finnish stand up to 90 years. None of the models predicted absolute growth well, but they all responded in a similar way when the inputs were changed in ways that might happen if the climate changed. That implies that we may be able to predict the percentage effects of climate change, even if we cannot yet predict the absolute growth entirely from physiological processes. A book reporting the combined study is being prepared.

TONY LUDLOW AND TIM RANDLE

# PART 2

# Work Done for the Forestry Commission by Other Agencies

# RESEARCH ON BRITISH GROWN TIMBER

*BY TONY BRAVERY*

*Building Research Establishment, Garston, Watford*

### *Water-stored timber*

The evaluation of timber sawn from wind-thrown logs and held under long-term water-storage is now complete. Material studied included: 50 x 100 mm battens cut from Sitka spruce and Corsican pine and 25 mm planks from beech logs after 6, 12, 18 and 36 months in the water store; and battens from Scots pine, Norway spruce, Japanese larch, Douglas fir, ash and sycamore logs after 18 months in store.

Results with Sitka spruce and Corsican pine showed the expected progressive increase in porosity up to 24 months and thereafter only small further increases. Whilst the increase in porosity on a percentage basis was the same for both timbers, Corsican pine was three times more porous than the Sitka spruce, both at the start and after 36 months in store. Machine stress grading of the battens from these particular Sitka spruce logs revealed a small but practically insignificant decrease in the E values after 6 months in store, but no significant further reductions for the duration of the 36 month storage period. A similar pattern occurred with Corsican pine but in this case the small initial reduction in E value was statistically significant. In the main, all logs went into the wet store within about two weeks of the windblow. However, a few logs of Sitka spruce, Corsican pine and beech were pre-stored for longer (six weeks and ten weeks) and indications from this material were that, although differences were very small, a slight increase in E values and also in yields was achieved after longer pre-storage times.

Assessment of the yields in the commercially important structural strength classes of SC3 and SC4 were high for both timbers, and there was no significant reduction in yields with increasing storage time (see Figure 24).

Although only assessed once after 18 months in storage (rather than at six monthly intervals like the Sitka spruce, Corsican pine and beech), a broadly similar pattern of increasing porosity was established for Norway spruce, Japanese larch and Douglas fir. The various timbers differed to some extent from one another, with Scots and Corsican pine being similar, as were Norway and Sitka spruce, but the pines showed higher porosity values. Japanese larch and Douglas fir were also similar to each other with porosity values between those for the pines and the spruces. In general, the E values and structural classifications for Scots pine, Norway spruce, Japanese larch and Douglas fir showed no significant reductions resulting from water storage.

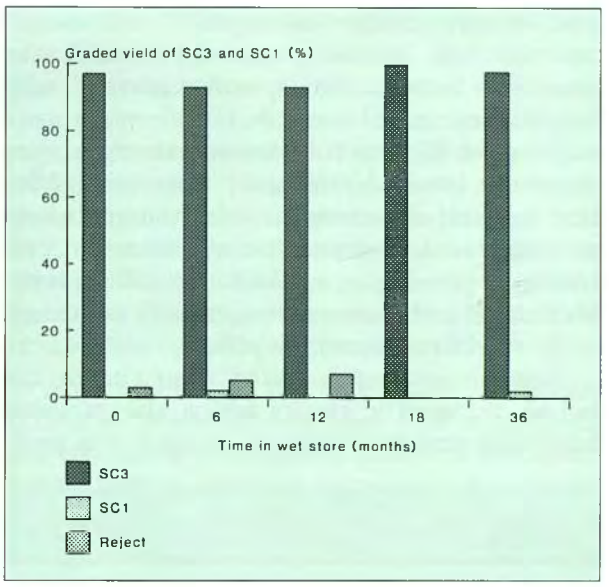


*Figure 24. Machine stress grades of sawn Sitka spruce for strength classes SC3 and SC1.*

Studies on the hardwoods gave indications that porosity increased, with beech especially markedly between 12 and 18 months storage, which may suggest water storage of this timber should not be longer than 12 months. Sycamore showed a slightly smaller increase in porosity than the beech after 18 months, and the ash showed much smaller increases.

### *Quality of British grown poplar*

Studies are almost complete to determine the basic strength properties and structural classification for battens of *Populus* x *euramericana* 'Robusta' cut from logs representing three different British sources.

Sixteen trees were supplied to the Building Research Establishment from Cannock Chase, Bliss and Wynyard Hall. From these, samples were cut for small clear tests and larger sections for structural size strength evaluations. Trees were sampled so as to correlate basic strength properties with height up the tree and distance from the pith. For strength evaluation of the structural sized battens the trees were converted using normal commercial sawing procedures for construction use.

Initial sawing resulted in stress release, inducing considerable bowing and splitting, though this varied for the different sites. In gen-

eral, strength properties increased with height up the tree, probably correlated with the observed increase in specific gravity with height. Modulus of elasticity (MoE), modulus of rupture (MoR) and compression strength were all much lower for material originating from butt logs and also more variable. Material representing the outer wood furthest from the pith tended to give higher values for specific gravity, MoE, MoR and compression strength compared with wood from nearer the pith.

Strength properties varied from site to site but so did specific gravity which always correlates with strength (Table 9). Hence it was probable that site factors were important in the extent to which they influenced specific gravity. Material from two of the sites compared favourably with published values for Sitka spruce, black poplar and grey poplar. The lowest strength material (from Cannock Chase) compared rather less favourably and did not reach the normally expected values for Sitka spruce or black or grey poplar.

**Table 9.** Summary of mean properties data for *Populus* x *euramericana* `Robusta' from three British sites

| *Site* | *Specific gravity* | *Impact resistance (m)* | *MoE (N/mm²)* | *MoR (N/mm²)* |
|---|---|---|---|---|
| Cannock | 0.37 | 0.58 | 7200 | 60 |
| | (0.02) | (0.11) | (1270) | (8.5) |
| Bliss | 0.39 | 0.59 | 8500 | 60 |
| | (0.03) | (0.03) | (900) | (8.9) |
| Wynyard | 0.41 | 0.75 | 8600 | 68 |
| | (0.04) | (0.20) | (1500) | (10.2) |
| Black poplar* | 0.38 | 0.56 | 8600 | 72 |
| | (0.02) | (0.08) | (1320) | (7.1) |
| Grey poplar* | 0.43 | 0.61 | 9500 | 76 |
| | (0.03) | (0.08) | (830) | (7.3) |
| Sitka spruce* | 0.34 | 0.51 | 8100 | 67 |
| | (0.04) | (0.16) | (1660) | (12.4) |

$N/mm^2$ = Newtons per square millimetre
* = reference values from BRE Report (1983)
() = standard deviation

### *Grading rules for softwoods*

Work to ensure British grown timber will comply with Eurocode 5 has continued, both to determine characteristic strength values according to the relevant European standard and to determine grading machine settings for European standard strength classes.

Results from Sitka spruce were completed and reported in 1992. Work has continued on Corsican and Scots pine; the initial results for Corsican pine indicated a lower than expected strength. In the case of Scots pine, a narrower than expected range of MoE was observed, giving a low correlation coefficient for bending strength (MoR) against MoE. Further Scots pine material has now been selected to increase the range of MoR and improve the correlation coefficient. Results for Corsican pine will then be integrated with those for Scots pine to provide the combined data necessary to justify marketing the two species together. Work on larch and Douglas fir has still to be initiated.

Submissions have been made to the CEN Committee responsible for assigning grades and species to strength (SS) classes. Although machine grading is more important for UK timber than visual grading, it is worth noting that the visual SS grade of Sitka spruce will meet strength class C18 rather than the lower C16 originally expected. The test data for the SS grade of Corsican and Scots pine confirm what has long been suspected, that they are not equivalent to European redwood/whitewood and fall into strength class C22 instead of C24. The mathematical model for grading machine settings suitable for CEN strength classes has been conducted in collaboration with sawmillers to establish satisfactory grades of Sitka in class C16, which contains G5 redwood/whitewood.

Work to derive visual grading rules and characteristic strength properties for oak is also continuing. All testing on the original 50 x 100 mm and 100 x 200 mm stock is complete and strength reducing characteristics have been assessed and recorded. On the basis of the results, it was concluded that the kiln dried English oak was broadly equivalent to European

redwood/whitewood, British grown Scots pine/larch and Canadian spruce/pine/fir in terms of characteristic values. Further material is under test in the green condition to establish whether these rather low values for oak were a consequence of kiln drying prior to testing. One hundred pieces each of 2" x 4" and 6" x 6" sizes have been visually graded in the green state, and they are being kiln dried to 30 per cent moisture content prior to strength testing. Derivation of draft grading rules is expected to be completed by the August 1994. Results from the assessments of structural sized battens are not yet available.

## TIMBER PRESERVATION

*BY RICHARD MURPHY*

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Several research projects on the durability and preservative-treatment of British grown timber and timber products have been advanced during the review period.

The three-year programme on the influence of treatment process on the performance of CCA wood preservatives in UK grown Corsican pine and poplar is approaching completion. It was conducted as a Ph.D. studentship with assistance from the Building Research Establishment (BRE), and has shown that manipulation of the pressure-treating process can enhance the effectiveness of CCA protection against decay by both microfungi and basidiomycetes. The project will be concluded in 1993 with the full results for poplar, and will be of use in assessing the impact of the new European standards applying to wood preservative treatments in the UK.

Research has continued on boron-based preservative treatments. These have advantageous environmental and toxicity properties whilst still being highly effective against wood degrading fungi and insects. Previous studies on water-based boron treatments on Sitka spruce with the Forestry Commission, Rentokil Ltd and Borax Consolidated Ltd have been translated recently into commercial application for home grown timber. Research on vapour-phase boron treatments of solid timber at Imperial College, in co-operation with colleagues at the New Zealand Forest Research Institute, has also progressed considerably. The process is suitable for use on joinery or general construction timber and the research is supported by a contract from the European Community. Research on the interaction of the process with the physical and mechanical properties of UK manufactured panel products was also completed during the review period and has demonstrated that vapour boron treatment has only very minor effects on most properties in both short-term and long-term tests (conducted jointly with BRE). Similar results have been found in other work at Imperial College on the vapour boron treatment of the new generation of structural composites e.g. parallel strand lumber.

Approaches to the life-cycle assessment (LCA) of preservative-treated timber products are also being investigated. LCA is a fast developing, systems analysis approach to the evaluation of environmental or other consequences arising from the use of materials or processes. Appropriate system boundaries and approaches to LCA have now been established for treated timbers and data on the model treatments are currently being incorporated into a database. The project is supported by companies from the wood preservation and electricity supply industries and is undertaken jointly with the Centre for Environmental Technology at Imperial College.

Fundamental research on the structure and degradation of woody plant cell walls using FTIR spectroscopy has continued, with concentration on the significance of lignin distribution and form. Lignin residues remaining after fungal degradation of wood or after digestion by insects have been compared with chemically extracted lignins or lignin precursors enzymatically polymerised *in vitro*. The knowledge gained is being used to refine the FTIR technique in order to follow progression of microbial decay of wood. Further studies are in progress to examine wood in various other states of degradation, including blue stain and UV and chemical degradation, and to assess the potential of the method in non-destructive evaluation of timber material and structures.

## HERBICIDE EVALUATION FOR FORESTRY USES

*BY DAVID CLAY AND FIONA DIXON*

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Further investigation of herbicides for control of problem weeds of forests and nurseries was carried out on container grown plants at Long Ashton Research Station.

### *Control of Rhododendron ponticum with imazapyr*

Imazapyr is a promising herbicide for pre-planting control of *Rhododendron ponticum*. A series of experiments on factors affecting the activity of imazapyr, started in 1990 and 1991, was completed in 1992. When imazapyr was applied to different *R. ponticum* plants at two-monthly intervals between June 1990 and January 1991 doses greater than 2.0 kg a.i. per hectare were effective at all dates. With lower doses, treatments in December and February were less effective, indicating some reduction in efficacy with winter treatments. The surfactant additive 'Mixture B' enhanced the effect of imazapyr on *R. ponticum* more than the non-ionic surfactant 'Agral' or the organosilicone surfactant 'Silwet L77'. When the same dose of imazapyr was applied to whole, half or quarter of the foliage of *R. ponticum* plants, severe effects were found in unsprayed parts, but there was some reduction in overall activity from spraying parts of plants compared to whole bushes. Application of a mixture of the contact herbicide sodium monochloracetate with imazapyr increased the rate of development of foliar damage symptoms on *R. ponticum* compared with imazapyr alone. However, at lower doses of imazapyr the mixture was much less effective than imazapyr alone.

### *Tolerance of tree seedlings to contact herbicides*

A number of contact herbicides were tested for safety to birch, Japanese larch and Sitka spruce. Fluroglycofen-methyl, metamitron + oil and pyridate showed some selectivity, particularly on the conifers, and warrant further testing. Two-way mixtures of three contact herbicides (clopyralid, cyanazine and tribenuron-methyl) generally had no more effect on birch and spruce than the individual herbicides; however with mixtures of metazachlor with each of these herbicides there was a considerable increase in damage.

Some contact herbicides also have activity via root uptake so post-spraying rainfall or irrigation may affect toxicity. In an experiment on the effect of different watering regimes on tolerance of larch to clopyralid and cyanazine, simulated rain after spraying enhanced toxicity of both herbicides. This result suggests that a post-spraying 'rain' treatment should be included to evaluate fully the safety of new contact herbicides for seedbeds.

### *Control of wavy hair-grass, Deschampsia flexuosa*

D. flexuosa was killed by low doses of cycloxidim and imazapyr; glufosinate, flyphosate, fluazifop-p-butyl, hexazinone and propyzamide were less effective. Addition of the surfactant 'Mixture B' generally gave slightly greater enhancement of herbicide activity than adding 'Agral' or another non-ionic surfactant 'Galion'.

### *Leaching of herbicide residues*

There is a need to confirm that repeated use of herbicides such as diphenamid and simazine on the same land, particularly forest nurseries, does not lead to movement into groundwater. Soil samples were taken, up to 60 cm depth, from different positions on two forest nurseries in England and tested for diphenamid and simazine residues. No detectable residues were found at any depth. This indicates there has been no herbicide build up in the soil from repeated use and, with relatively strongly adsorbed herbicides, there is little likelihood of significant downward movement.

## EFFECTS OF ELEVATED $CO_2$ ON THE GROWTH AND PHYSIOLOGY OF SITKA SPRUCE

*BY J. TOWNEND AND PROFESSOR T. MANSFIELD*
*Lancaster University*

It is predicted that the atmospheric concentration of carbon dioxide will rise from its present level of 0.035% to approximately double this concentration by the end of the next century, due to the burning of fossil fuels and clearance of much tropical forest. It has been widely publicised that $CO_2$ is an important greenhouse gas and might, therefore, contribute to global warming, but its increased presence in the air will almost certainly also have direct effects on plant growth.

For the past three years a study at Lancaster University, funded by the Forestry Commission and the Department of the Environment, has been using solardomes (Plate 8) to study the effects of increased concentrations of $CO_2$ on young seedling and clonal Sitka spruce plants. The plants have been grown in large containers within the solardomes, which are supplied with air containing either 0.035 or 0.060% $CO_2$. High and low nutrient and watering treatments have also been imposed to study interacting effects with elevated $CO_2$.

The work has shown that the plants in high $CO_2$ generally have higher rates of growth and

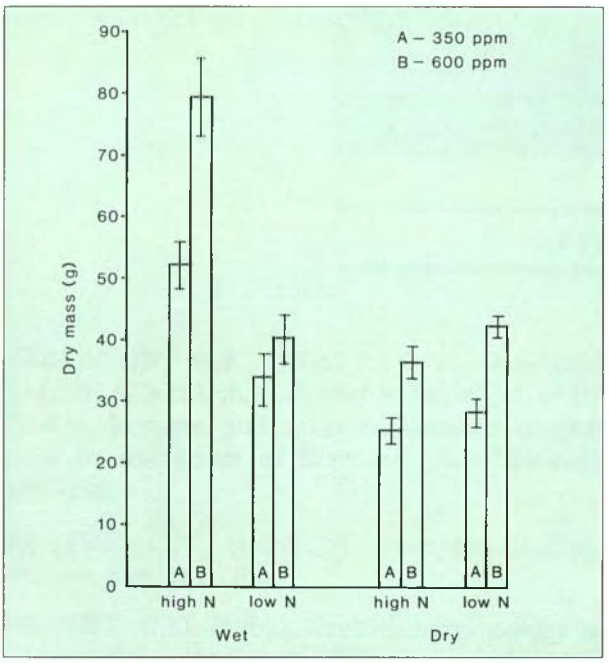


*Figure 25. The mean total dry mass of Sitka spruce after two years of exposure to 350 or 600 ppm $CO_2$. Plants were either well watered (wet) or exposed to moderate water deficit (dry) and had high or low soil supply of major nutrients.*

higher water use efficiencies, although in situations where nutrients are limited the growth response to elevated $CO_2$ can be greatly reduced (Figure 25). Differences in the response of different origins and different clones suggest that this may be an important consideration in the selection of planting stock for tree crops which are expected to stay in the ground until well into the next century.

## THE IMPACT OF STAND MANIPULATION ON THE BIODIVERSITY OF MANAGED FORESTS

*BY KIRSTI THORNBER, COLIN LEGG AND DOUGLAS MALCOLM*

*Institute of Ecology and Resource Management, Edinburgh University*

A review was carried out as part of the Forestry Authority Biodiversity Project, to examine how management intervention at a stand scale might influence structural and species diversity in commercial forests. A critical analysis of the silvicultural systems in current use was undertaken, and operational restrictions examined. Regular, even-aged systems were compared to irregular, uneven-aged systems, in terms of relative costs, ease of operation, applicability in particular forest types, and their influence on biodiversity. The impact of silvicultural operations was also assessed, and a cost–benefit analysis carried out.

The report pointed to: the need for management to diversify the age and size range of trees within stands; the use of a greater variety of species; alteration of felling coupe size; and retention of old and dead trees. Alternative silvicultural systems need to be evaluated on a sufficiently large scale, from both an economic and an ecological standpoint. In the meantime, critical thinning levels for the development of understorey vegetation in even-aged forests need to be estimated.

## THE INTRODUCTION AND ESTABLISHMENT OF UNDERSTOREY VEGETATION IN WOODLAND

*BY MARY CUNNINGHAM*

*Environmental Management Consultants, Newmarket*

This review concentrated on the objective of recreating plant communities typical of native woodland, and aimed to develop practical guidelines for the successful introduction of woodland plants. It attempted to predict what patterns of species composition and distribution might be expected from introduced propagules or plants.

Woodland plants can be introduced as seeds, nursery-grown plants, or bulbs. Decisions concerning choice of planting material need to consider rates of seed production, seed germination, and growth. Critical factors involved in the establishment of understorey vegetation include light intensity, soil conditions and biotic factors such as competition from other plants. A number of establishment techniques are considered, and the importance of design and site preparation stressed. Timing of introductions is critical in relation to canopy development, and planting patterns may have an important influence on the vegetation communities which result.

Management and monitoring following introduction is likely to be vital, including canopy manipulation to control light levels. Judicious use of herbicides to control competing weed species may be necessary, and will help to optimise the relative competitive ability of the introduced species.

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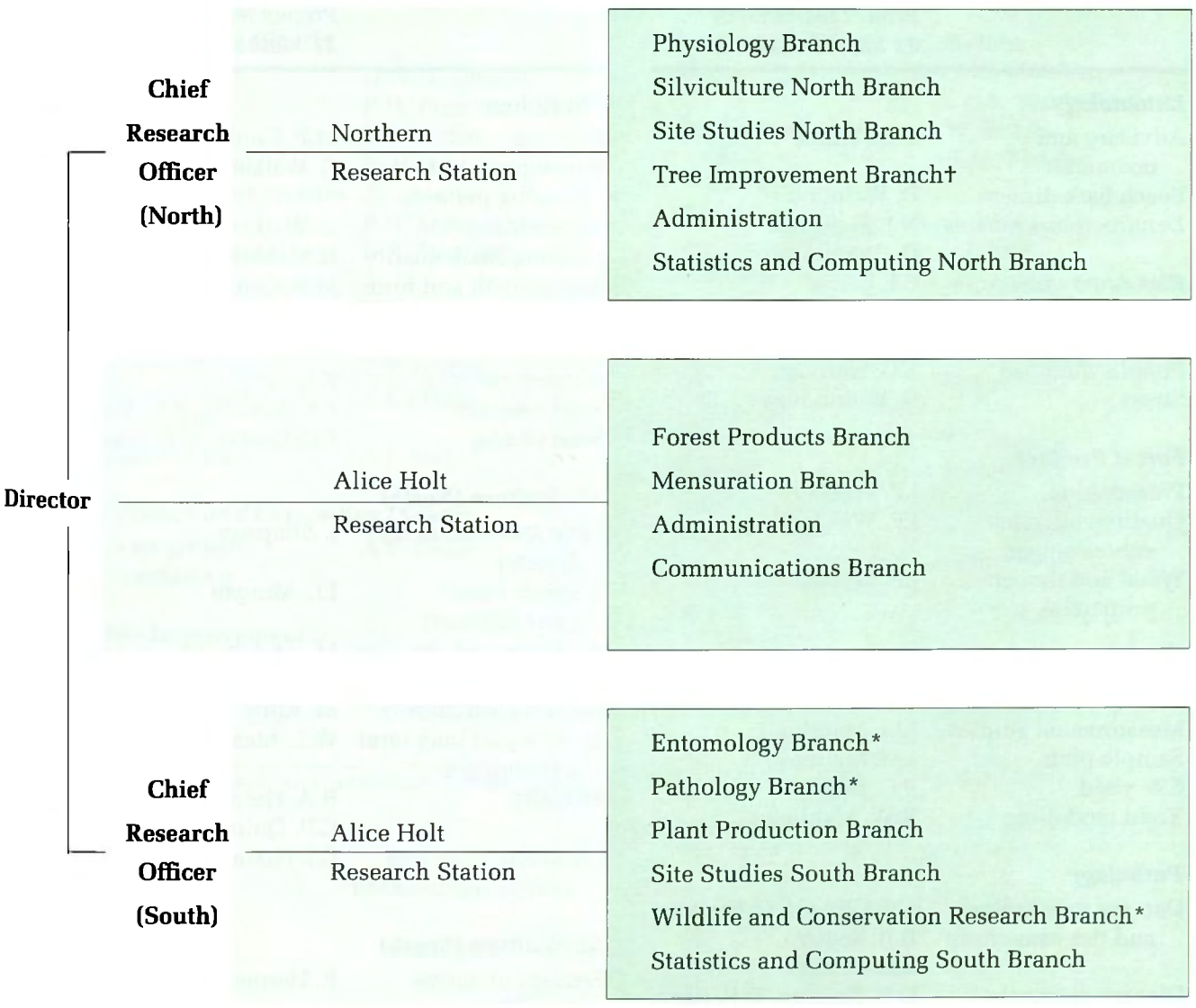
# RESEARCH DIVISION ORGANISATION

## APPENDIX 2




† – with Section at Alice Holt Research Station
* – with Section at Northern Research Station

# RESEARCH DIVISION BRANCHES AND THEIR PROJECT GROUPS[1]

## APPENDIX 3

| | *Project leader(s) at 31 March 1993* |
|---|---|
| ***Entomology*** | |
| Advisory and taxonomic | T.G.Winter |
| Beech bark disease | D. Wainhouse |
| *Dendroctonus micans* | N.J. Fielding, D. Wainhouse |
| *Elatobium abietinum* | C.I. Carter |
| *Hylastes* and *Hylobius* | S.G. Heritage |
| Impact | N.A. Straw |
| *Panolis flammea* | S.G. Heritage |
| Stress | D. Wainhouse |
| ***Forest Products*** | |
| Preservation | J.F. Webber |
| Quality and value enhancement | J.F. Webber |
| Wood and timber properties | J.F. Webber |
| ***Mensuration*** | |
| Management services | J.M. Methley |
| Measurement studies | J.M. Methley |
| Sample plots | J.M. Methley |
| Site yield | P.C. Jokiel |
| Yield modelling | R.W. Matthews |
| ***Pathology*** | |
| Damage monitoring and risk assessment | J.N. Gibbs, S.C. Gregory D.B. Redfern, R.G. Strouts |
| Disease diagnosis | D.B. Redfern, D.R. Rose, R.G. Strouts |
| Dutch elm disease | C.M. Brasier |
| *Fomes* root rot | B.J.W. Greig, J.E. Pratt, D.B. Redfern |
| Poplar diseases | D. Lonsdale |
| Special investigations | J.N. Gibbs, B.J.W. Greig, D.R. Rose |
| Stem decays | D. Lonsdale |

| | *Project leader(s) at 31 March 1993* |
|---|---|
| ***Physiology*** | |
| Bent top | M.P. Coutts |
| Development of rooting patterns | C. Walker |
| Mycorrhizas | C. Walker |
| Planting stock quality | H.M. McKay |
| Root growth and form | M.P. Coutts |
| ***Plant Production*** | |
| Nursery research | R.L. Jinks |
| Seed research | P.G. Gosling, S.K. Jones |
| Seed testing | P.G. Gosling, Y.K. Samuel |
| ***Silviculture (North)*** | |
| Farm and community forestry | J. Simpson |
| Nurseries and establishment | J.L. Morgan |
| Nutrition and site yield | J.C. Dutch |
| Reclamation (north) | M. Riley |
| Species and long-term experiments | W.L. Mason |
| Stability | B.A. Gardiner, C.P. Quine |
| Stand structure and natural regeneration | C.J. Nixon |
| ***Silviculture (South)*** | |
| Ecology of native broadleaves | R. Harmer |
| Establishment and stand silviculture | G. Kerr |
| Farm woodlands, short rotation coppice and weed control | I. Willoughby |
| Poplars | P.M. Tabbush |
| Species and arboreta | J.E.J. White |
| Urban and community forestry | S.J. Hodge |

[1] 'Advisory' is distinguished as a separate project group in certain branches, but is an activity in all of them.

| | *Project leader(s) at 31 March 1993* |
|---|---|
| ***Site Studies (North)*** | |
| Biogeoclimatic ecosystem classification | D.G. Pyatt |
| Clay soils | D. Ray |
| Deep peats | A.R. Anderson |
| Loamy gleys | A.R. Anderson |
| [2]***Site Studies (South)*** | |
| Air pollution | D.W.H. Durrant, P.H. Freer-Smith, A.J. Moffat |
| Chemical analysis | E. Ward |
| Effects of trees on sites | A.J. Moffat, T.R. Nisbet |
| Forestry and environmental change | P.H. Freer-Smith, D.A. Waddell |
| Hydrology: water quality | T.R. Nisbet |
| Instrumentation | T.R. Nisbet |
| Lowland production forestry | A.J. Moffat |
| Reclamation | A.J. Moffat |
| ***Statistics and Computing (South)*** | |
| Forest growth modelling | A.R. Ludlow |
| ***Tree Improvement*** | |
| Biochemical variation | G.I. Forrest, J. Cottrell |
| Biometrical studies | C.J.A. Samuel |
| Flowering | J.J. Philipson |
| Forest reproductive material regulations | A.M. Fletcher |
| Improvement and propagation of farm forestry broadleaves | C.M. Cahalan |
| Micropropagation | A. John |
| Origin | A.M. Fletcher, C.J.A. Samuel |
| Production: clone banks and orchards | W. Brown, A.M. Fletcher |
| Rejuvenation | A. John |
| Testing progeny and clones | S.J. Lee |
| ***Wildlife and Conservation Research*** | |
| Bats; roe and fallow deer | B.A. Mayle |
| Birds | S.J. Petty |
| Damage | R.M.A. Gill |
| Deer | P.R. Ratcliffe |
| Predators | A.H. Chadwick |
| Squirrels, rabbits and tree protection | H.W. Pepper |
| Streams and riparian vegetation | G.S. Patterson |
| Vegetation management | R. Ferris-Kaan, G.S. Patterson |

[2] From 1 April 1993, renamed Environmental Research

# NET EXPENDITURE OF RESEARCH DIVISION 1992/93

## APPENDIX 4

£000

| *Branch (a)* | *Expenditure by Branch direct (b)* | *Net value of in-house services less than those provided (c)* | *Commissioned research (d)* | *Expenditure attributable to Branch* |
|---|---|---|---|---|
| Entomology | 671 | 109 | 10 | 790 |
| Forest Products | 67 | 12 | 238 | 317 |
| Mensuration | 378 | 58 | – | 436 |
| Pathology | 567 | 102 | 52 | 721 |
| Physiology | 287 | 95 | 29 | 411 |
| Plant Production | 165 | 40 | – | 205 |
| Silviculture (North) | 1981 | –131 | 38 | 1888 |
| Silviculture (South) | 1281 | 68 | 58 | 1407 |
| Site Studies (North) | 160 | 66 | – | 226 |
| Site Studies (South) | 676 | 118 | 49 | 843 |
| Tree Improvement | 1146 | 235 | 15 | 1396 |
| Wildlife & Conservation | 449 | 118 | 130 | 697 |
| Communications | 557 | –210 | – | 347 |
| Stats & Computing (North) | 234 | –234 | – | – |
| Stats & Computing (South) | 430 | –284 | – | 146 |
| Workshops (North & South) | 162 | –162 | – | – |
| **Total** | **9211** | **–** | **619** | **9830** |

*Notes:*

(a) Ordered as in the 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 £1.553m plus Forestry Commission headquarters overheads for common services of £0.642m, net of income of £0.799m 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.

# CONTRACT WORK DONE BY RESEARCH DIVISION

## APPENDIX 5

| | |
|---|---|
| British Coal | Opencast coal spoil |
| Department of the Environment | Arboriculture |
| | London tree survey |
| | Pathology |
| | Potential for woodland establishment on landfill sites |
| Department of Trade and Industry(Energy Technology Support Unit) | Coppiced trees as energy crops |
| Department of Transport | Alternatives to peat |
| | Backfill studies |
| EC | Forest condition surveys |
| | Poplar trials |
| EC/Institute of Virology and Environmental Microbiology | Transgenic poplar |
| EC/Irish Forestry Service | Wind stability |
| EC/University of Edinburgh | The likely impact of rising $CO_2$ and temperature on European forests |
| Kemforschungszentrum (Germany) | Spruce root stock |
| London Boroughs | Survey of salt damaged trees in London |
| Lothian Regional Council | Transplant performance |
| MacFarlane Smith | Animal repellent studies |
| Ministry of Agriculture, Fisheries & Food | Provenance testing |
| | Vegetative propagation |
| | Yield assessments |
| Niko Chemical Co Ltd | Animal repellent studies |
| Northern Ireland Forestry Service | Experimental assessment |
| Pilkington Trust | Dutch elm disease |
| Scottish Forestry Trust, via TGUK | Physiology of native Scots pine |
| | Private woodlands squirrel questionnaire 1991 |
| Scottish Natural Heritage | Study of the Mar Lodge Pinewoods |
| Southern Water Services | Short rotation coppice/sewage sludge |
| Strathclyde Greenbelt Co | Mycorrhizas in spoil heaps |
| | Species choice on reclamation sites |
| | Use of sewage sludge |

# CONTRACT WORK DONE BY OTHER AGENCIES FOR RESEARCH DIVISION

## APPENDIX 6

| | |
|---|---|
| Avon Vegetation Research | Nursery herbicide evaluation |
| Building Research Establishment | Effect of provenance on timber properties |
| | Effects of water storage on strength and porosity of timber |
| | Modelling strength properties of Sitka spruce |
| | Strength testing of poplar timber |
| | Testing British grown hardwoods for British standards |
| | Testing British grown softwoods for European standards |
| Ecological Surveys, Bangor | Plant communities associated with birch in upland Sitka spruce |
| Environmental Management Consultants Ltd | Introduction and establishment of understorey vegetation in woodlands |
| Forest Insect Surveys | Invertebrate fauna of birch in spruce forests |
| Imperial College, London | Greenwood preservative treatments |
| | Potential of entomopathogenic nematodes for control of restocking pests |
| Institute of Hydrology | Effects of afforestation on water resources |
| Institute of Terrestrial Ecology | Capercaillie ecology |
| Macaulay Land Use Research Institute | Nutrition of nursery stock |
| | Nutrition of trees on restock sites |
| National Rivers Authority (Welsh Region) | Effects of forestry on surface water acidification |
| Royal Society for the Protection of Birds | Golden eagle ecology |
| Timber Research and Development Association | Feasibility of producing laminated veneer lumber from British grown species |
| Tweed Foundation | Fauna of a small burn |
| University College of North Wales, Bangor | Crown development and wood quality |
| | Effect of silviculture on wood quality |
| University College of Wales, Aberystwyth | Biology of *Ramichloridium* dieback of lodgepole pine |
| University of Aberdeen | Biocontrol of *Heterobasidion annosum* in Sitka spruce stumps |
| | Songbird ecology in spruce forests |
| University of East Anglia | Windspeed prediction in complex terrain |

| | |
|---|---|
| University of Edinburgh | The influence of stand manipulation on the biodiversity of managed forests |
| University of Lancaster | Long-term effects of elevated carbon dioxide concentrations on trees |
| University of Nottingham | Development of transformation systems for Sitka spruce |
| University of Portsmouth | Bluestain development in processed timber |
| University of Wales, Cardiff | Conifer seed as a food for vertebrates |

# STAFF ENGAGED IN RESEARCH AT 31 MARCH 1993

## APPENDIX 7

### RESEARCH DIVISION

Director — D. A. Burdekin, B.A., Dip. Ag. Sci., M.I.C. For. (*Alice Holt*)

Chief Research Officer (North) — T. C. Booth, B.Sc., F.I.C. For. (*Northern Research Station*)

Head of the Northern Research Station. General responsibility for research north of the Mersey/Humber line and in Wales, with specific responsibilities for silviculture and site studies in the uplands, and throughout Britain for research in tree physiology and tree improvement.

Chief Research Officer (South) — J. Evans, B.Sc., Ph.D., D.Sc., F.I.C. For. (*Alice Holt*)

General responsibility for research south of the Mersey/Humber line, with specific responsibility for silviculture and environmental research in the lowlands, and throughout Britain for research in pathology, entomology, wildlife and conservation, seed research, instrumentation and technical aspects of legislation relating to plant health.

### STAFF BASED AT ALICE HOLT LODGE

***Administration Branch***

J. Lumley, M.I.P.M., Personnel and Administration Officer, Head of Branch

**Finance Section**

R. Murray
Ms S. J. Worman

**Office Services Section**

Mrs C. A. Evans

**Personnel Section**

M. G. Wheeler
Miss J. R. Lacey

***[1]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., Manager
Ms D. J. Marshall, B.Sc., M.Phil.

***Communications Branch***

E. J. Parker, Ph.D., C. Biol., M.I. Biol., Head of Branch
M. R. Jukes, C.Biol., M.I.Biol.

**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
G. R. Brearley (*Northern Research Station*)
J. Williams

**Publications Section**

Ms K. A. Davies, Head of Section

***Entomology Branch*** (*with section at Northern Research Station*)

H. F. Evans, B.Sc., D.Phil., F.R.E.S., Head of Branch
R. Ashburner, B.Sc.
C. I. Carter, M.Sc., C. Biol., M.I.Biol., F.R.E.S.
N. J. Fielding (*Ludlow*)
Mrs G. Green, B.Sc.
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.

***Forest Products Branch***

J. F. Webber, B.Sc., Ph.D., Head of Branch

[1] From 1 April 1993, independent, managed by the Tree Advisory Trust

***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.
J. C. Proudfoot

***Pathology Branch*** (*with section at Northern Research Station*)
J. N. Gibbs, M.A., Ph.D., Sc. D., Head of Branch
C. M. Brasier, B.Sc., Ph.D., D.Sc.
Mrs S. E. Brown, B.Sc.
B. J. W. Greig, M.I.C. For.
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Mrs Y. K. Samuel, B.A.

***Silviculture (South) Branch***
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J. L. Budd
I. Collier (*Midlands*)
D. Elgy
A. R. Hall
R. Harmer, B.Sc., Ph.D.
D. A. Hendrie (*Thetford*)
S. J. Hodge, B.Sc., M.Sc., M.I.C. For.
G. Kerr, B.Sc., M.I.C. For.
R. A. Nickerson
D. G. Rogers (*Exeter*)
N. A. Smith (*Exeter*)
D. West (*Thetford*)
J. E. J. White (*Westonbirt*)
I. Willoughby, B.Sc.

***Site Studies (South) Branch***
P. H. Freer-Smith, B.Sc., Ph.D., Head of Branch
A. Armstrong, M.I.C. For.
Mrs S. E. Benham
P. G. Crow
M. C. Dobson, B.Sc., Ph.D.
D. W. H. Durrant, B.A.
T. R. Hutchings
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 (South) Section**
T. R. Nisbet, B.Sc., Ph.D., Head of Section

***Statistics and Computing (South) Branch***
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R. C. Boswell, B.Sc., M.I.S.
G. J. Hall, B.Sc., B.A.
Miss L. M. Halsall, B.Sc.
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A. J. Peace, B.Sc.
T. Porter, B.Sc.
T. J. Randle, B.Sc.
Miss B. J. Smyth, B.Sc.
J. Taylor, B.Sc.

***Tree Improvement Section*** (*of branch at Northern Research Station*)
C. M. Cahalan, B.Sc., M.Sc., Ph.D., Head of Section
Mrs C. A. Baker
M. R. Plowman, B.Sc., M.Sc.

***Wildlife and Conservation Research Branch***
(*with staff at Northern Research Station*)
H. W. Pepper, Alice Holt leader
A. Chadwick (*Cowal, Strathclyde*)
R. Ferris-Kaan, B.Sc., Ph.D.
R. M. A. Gill, B.Sc.
Mrs B. A. Mayle, M.Sc.
S. J. Petty, Ph.D. (*Cowal, Strathclyde*)

## STAFF BASED AT NORTHERN RESEARCH STATION

***Administration***
M. Abrahams
Mrs M. Farm

***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.

***Pathology Section*** (*of branch at Alice Holt*)
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S. C. Gregory, M.A., Ph.D.

Miss G. A. MacAskill
J. E. Pratt

***Physiology Branch***

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C. Walker, B.A., Ph.D., Assistant Head of Branch
C. McEvoy, B.A.
H. M. McKay, B.Sc., Ph.D.
B. C. Nicoll, B.Sc.

**Instrumentation (North) Section**

C. Walker, B.A., Ph.D., Head of Section
D. J. Brooks

***Silviculture (North) Branch***

W. L. Mason, B.A., B.Sc., M.I.C. For., Head of Branch
D. Anderson
J. Boluski (*Lairg, Highland*)
P. Cairns (*Cairnbaan by Lochgilphead*)
N. P. Danby (*Talybont-on-Usk*)
J. Davidson, B.A., M.I.C. For. (*Newton, Grampian*)
J. Dick (*North Yorkshire*)
J. C. Dutch, B.Sc., Ph.D.
C. Edwards
B. A. Gardiner, B.Sc., Ph.D., F.R. Met.S.
P. W. Gough (*Kielder, Northumberland*)
A. J. Harrison, B.Sc.
M. K. Hollingsworth
R. E. J. Howes (*Wykeham, Scarborough*)
C. D. Jones, B.Sc. (*Talybont-on-Usk*)
A. L. Mackie, M.I.C. For.
A. W. MacLeod (*Newton, Grampian*)
J. D. McNeill
J. L. Morgan, B.Sc., Ph.D.
C. J. Nixon, B.Sc., M.I.C. For.
C. P. Quine, M.A., M.Sc., M.I.C. For.
M. J. Ridley (*Kielder, Northumberland*)
M. Riley (*Mabie, Dumfries-shire*)
A. L. Sharpe (*Newton, Grampian*)
J. M. S. Simpson, B.Sc.
D. R. Tracy (*Cairnbaan by Lochgilphead*)
D. M. Watterson (*Mabie, Dumfries-shire*)

***Site Studies (North) Branch***

D. G. Pyatt, B.A., B.Sc., Ph.D., M.I. Soil Sci., Head of Branch
A. R. Anderson
D. Ray, B.Sc.

***Statistics and Computing (North) Branch***

I. W. Martin, B.Sc., M.Sc., Head of Branch
R. W. Blackburn, B.Sc.
A. D. Milner, B.Sc., Ph.D.
I. M. S. White, B.Sc., M.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
W. Brown
J. Cottrell, B.Sc., Ph.D.
C. E. S. Fleming (*Newton, Grampian*)
A. M. Fletcher, B.Sc., Ph.D., A.I.W. Sc., M.I.C. For.
G. I. Forrest, B.Sc., Ph.D.
A. John, B.Sc., Ph.D.
S. J. Lee, B.Sc., M.I.C. For.
J. S. McIntyre
A. S. Medhurst, M.I.C. For. (*Shobdon, Hereford*)
Mrs M. O'Donnell
S. P. Osborne, B.Sc.
J. J. Philipson, B.A., Ph.D.
C. J. A. Samuel, B.Sc., Ph.D.
R. J. Sykes (*Newton, Grampian*)
G. C. Webb (*Shobdon, Hereford*)

***Wildlife and Conservation Research Branch*** (*with staff at Alice Holt*)

P. R. Ratcliffe, B.Sc., Ph.D., C.Biol., M.I.Biol., F.I.C. For., Head of Branch
G. S. Patterson, B.Sc., M.I.C. For.

## Administrative Staff

The total number of administrative support staff in Research Division at 31 March 1993 was 45.

## Industrial Staff

The total number of industrial employees in Research Division at 31 March 1993 was 93.5.

## Staff Changes

***New appointments:***

M. C. Dobson (Higher Scientific Officer) Site Studies (South), Alice Holt (3 year period appointment; contract).
Mrs G. Green (Assistant Scientific Officer) Entomology, Alice Holt.
A. D. Milner (Higher Scientific Officer) Statistics and Computing (North), Northern Research Station.
J. M. Taylor (Scientific Officer) Statistics and Computing (South), Alice Holt.

***Transfers in:***

M. Abrahams (Higher Executive Officer) from Headquarters to Administration, Northern Research Station.

Ms K. A. Davies (Senior Executive Officer) from the Employment Department Group to Communications, Alice Holt.

S. P. Osborne (Forest Officer IV) from Forest Enterprise, Kincardine Forest District to Tree Improvement, Northern Research Station.

J. M. S. Simpson (Forest Officer I) from Lothian and Borders Conservancy to Silviculture (North), Northern Research Station.

D. West (Forest Officer III) from Forest Enterprise, Thetford Forest District to Silviculture (South), Thetford.

I. Willoughby (Forest Officer II) from Forest Enterprise, Somerset and South Devon Forest District to Silviculture (South), Alice Holt.

***Promotions:***

S. R. Abbott (Mensuration, Alice Holt) to Forest Officer III.

R. C. Boswell (Statistics and Computing (South), Alice Holt) to Grade 7.

J. L. Budd (Silviculture (South), Alice Holt) to Forest Officer III.

C. M. Cahalan (Tree Improvement, Alice Holt) to Senior Scientific Officer.

Mrs C. A. Evans (Office Services, Alice Holt) to Executive Officer.

A. J. Harrison (Silviculture (North), Northern Research Station) to Forest Officer III.

H. M. McKay (Physiology, Northern Research Station) to Senior Scientific Officer.

A. S. Medhurst (Tree Improvement, Shobdon) to Forest Officer III.

T. J. Randle (Statistics and Computing (South), Alice Holt) to Higher Scientific Officer.

M. Riley (Silviculture (North), Northern Research Station) to Forest Officer II.

Mrs Y. K. Samuel (Plant Production, Alice Holt) to Higher Scientific Officer.

N. A. Smith (Silviculture (South), Exeter) to Forest Officer III.

N. A. Straw (Entomology, Alice Holt) to Senior Scientific Officer.

R. G. Strouts (Pathology, Alice Holt) to Forest Officer I.

Ms S. J. Worman (Finance, Alice Holt) to Executive Officer.

***Transfers out:***

Mrs J. C. Gates (Executive Officer) from Office Services, Alice Holt, to Forest Enterprise, New Forest.

N. P. Hayward (Forest Officer IV) from Silviculture (North), Talybont, to Forest Enterprise, South Downs Forest District.

T. J. Jennings (Forest Officer III) from Entomology, Thetford, to Forest Enterprise, Northants Forest District.

K. R. Knott (Forest Officer IV) from Silviculture (South), Alice Holt, to Forest Enterprise, North Scotland Region.

A. S. Medhurst (Forest Officer III) from Tree Improvement, Shobdon, to Forest Enterprise, Chilterns Forest District.

D. G. Nelson (Forest Officer I) from Silviculture (North), Northern Research Station, on secondment to SCOTBIC.

G. S. Patterson (Forest Officer I) from Wildlife and Conservation Research, Northern Research Station to Headquarters.

C. K. Smith (Higher Executive Officer) from Administration, Northern Research Station to Headquarters.

D. R. Williamson (Forest Officer I) from Silviculture (South), Alice Holt, to Forest Enterprise, West Downs Forest District.

***Resignations:***

Mrs S. E. Brown (Scientific Officer) Pathology, Alice Holt.

J. L. Innes (Senior Scientific Officer) Site Studies (South), Alice Holt.

S. R. Leather (Senior Scientific Officer) Entomology, Northern Research Station.

***Retirements:***

R. B. Collins (Forest Officer III) Silviculture (South), Thetford.

W. G. Paterson (Forest Officer III) Silviculture (North), Lairg.

F. S. Smith (Forest Officer III) Silviculture (North), Perth.

# ADDRESSES OF RESEARCH LOCATIONS

## APPENDIX 8

***Main Centres***

The Forestry Authority
Research Division
Alice Holt Lodge
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Fax: 0420 23653

The Forestry Authority
Northern Research Station
Roslin
Midlothian
EH25 9SY
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Fax: 031 445 5124

Some staff engaged in research are 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
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Lochgilphead
Argyll
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Tel: 0546 2304

**Exeter** *Silv* (*S*)
Forestry Commission
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Exeter
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**Headley** *Silv* (*S*)
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Headley Park
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Hampshire
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**Kielder** *Silv* (*N*) & *Entomology*
Forestry Commission
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Tel: 0434 250235

**Lairg** *Silv* (*N*)
Forestry Commission
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Lairg
Sutherland
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Tel: 0549 2150

**Ludlow** *Entomology*
Forestry Commission
Entomology Office
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**Mabie** *Silv* (*N*) *& Entomology*
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**Midlands** *Silv* (*S*)
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**Newton** *Silv* (*N*) *&*
*Tree Improvement*
Forestry Commission
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**Shobdon** *Tree Improvement*
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**Talybont-on-Usk** *Silv* (*N*)
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**Thetford** *Silv* (*S*)
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**Westonbirt** *Silv* (*S*)
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Westonbirt Arboretum
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# INDEX

**Acknowledgement** This index was prepared by Dr John Chandler.

Printed in the United Kingdom for HMSO Dd. 0294487 6/94 C13 531/3 12521


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