

Forestry Commission

REPORT ON
FOREST RESEARCH
1983



Forestry Commission

ARCHIVE

REPORT ON
FOREST RESEARCH

for the year ended
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Front Cover: Close-up of the Great spruce bark beetle
Dendroctonus micans. 36164

Background: Defoliation of a *D. micans*-infested stand
of Sitka spruce at Gatley, Mortimer Forest (Salop.).
36165 (*M. R. Jukes*)

Back Cover: Aerial view of part of Alice Holt Forest
(Hampshire) showing tree shelters fostering the growth
of young oak trees in a replanted compartment
bordered by mature oak plantations. CN 1009
(*I. A. Anderson*)

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INTRODUCTION

By A. J. GRAYSON

Director of Research and Development

Forestry Research Co-ordination Committee

Following the report entitled "Scientific Aspects of Forestry" by a sub-committee of the House of Lords Select Committee on Science and Technology the Government decided to set up a Forestry Research Co-ordination Committee. The Committee's terms of reference are:

- to identify and define forestry research needs and opportunities,
- to advise on research requirements and priorities in relation to the needs and opportunities identified,
- to stimulate research in forestry, the exchange of information and collaboration between research organizations and individuals and the publication of research findings, and
- to encourage the financing of identified research proposals.

This Committee, under the chairmanship of the Commissioner responsible for research and development, Mr D. A. Mithen CB, met twice in the year and one of its first actions was to consider the Lords' response in a Second Report of the Select Committee to the Government reply. This report identified four points on which the Committee urged action, namely: research into end use, long-term policy for broadleaved trees, integrated land use, and international research funds.

The Committee has decided to carry out some of its work by means of review groups. The purpose of such groups is to review current research in a given field, to consider research requirements and to suggest adjustments needed. Two groups were established during the year under report, one on wood science and processing under the chairmanship of Professor J. Levy, Imperial College, the other on the integration of forestry and farming in lowland Britain under the chairmanship of Professor D. K. Britton.

Broadleaves in Britain

A conference under this title was organized jointly by the Forestry Commission and the Institute of Chartered Foresters in July 1982. The meeting, held at Loughborough, Leics., was the biggest forestry meeting ever held in Britain and brought together a wide representation of professional foresters and academics; the only group whose numbers were regrettably small being the owners. It is too easily forgotten that the great bulk of broadleaved woodlands and trees are in the hands of estate owners and farmers and it is they whose objectives have to be remembered in considering what other interest groups propose.

The Director is a member of a Forestry Commission group reviewing policy on broadleaves, a group owing its existence to the discussions at Loughborough. It was recognised at that meeting that while much research on broadleaved tree growing had been undertaken in recent years, changes in the extent of broadleaved woodland and hedgerow trees, especially elm, had significant effects on landscape, timber producing potential and nature conservation and that these were the cause of widespread concern. The House of Lords Committee also identified this subject as one of major policy interest, and while research continues on biological matters the issues of the policies to be promoted and the means of achieving them clearly fall outside the research field.

Broadleaved silviculture

Marked increases in the growth of trees in tree shelters have now been demonstrated in a range of tree species. It is estimated that half a million shelters were used in the 1982/83 planting season. Further research is in hand to clarify the reasons for enhanced growth and to determine the appropriate place and use of shelters in different woodland conditions.

Silvicultural open day

One hundred and seventy foresters and arboriculturalists attended an open day devoted to broadleaved silviculture at Alice Holt on 1 October 1982. The event was organized as a tour of four demonstrations at each of which the project leader spoke of his work and described the experiments being demonstrated. This method of communication has proved to be a most successful one.

Dendroctonus micans

This bark beetle has long been feared as a major pest of Sitka spruce and indeed a study tour to Denmark was undertaken in 1964⁽¹⁾ to review the incidence of the beetle on Sitka spruce and the damage caused. *Dendroctonus* was found for the first time in Shropshire in August 1982 and the fire brigade function of the Entomology Branch brought speedily into action. A major survey effort was mounted by field staff and a resolute programme undertaken to fell infested trees and remove their bark. The destruction of this material has inevitably created some difficulties for research into the dispersal of the beetle through time.

EEC research: CREST

The European Commission invited tenders for research in three areas of wood supply, namely growing, harvesting and processing. The total Community contribution in this sub-programme of CREST (Committee on research, science and education) was planned to be 12 million units of account over the period 1982–85. Regrettably, the Forestry Commission was unable directly to receive the benefit of EEC contributions but other UK contractors have been successful in bids for these research funds and the Commission collaborates by making sites and experimental records available to investigators.

Communication of results

First among the Division's objects is to conduct relevant research which is likely to produce a benefit in excess of its cost. The sense of this aim is self-evident but there are certain features of forestry in Britain which make its achievement difficult. Firstly there is the fact that the scale of forestry activity, even when allowance is made for its expansion through afforestation, is small relative to that in many other countries. In addition, to the extent that research findings are only applicable to certain sites, or site-species combinations, Britain's diversity of site conditions means that the potential gains from every such result are liable to be smaller than in countries blessed with less heterogeneity.

⁽¹⁾ Reported in *Forestry Commission Bulletin* 38.

To achieve benefits, research findings and recommendations have to be communicated to practitioners. Apart from talks, demonstrations and conferences, research staff are under an obligation to publish written results of their work. A Technical Publications Committee has been established under the chairmanship of the Chief Research Officer (South), Mr D. A. Burdekin, to consider needs in the field of technical, as opposed to general interest, publications, whether these are published in Forestry Commission series or in journals. The Committee also checks progress with publications under preparation by staff of the Division or other Commission officers.

Renewed efforts are being made with the help of the Commission's Education and Training Branch and with the Forestry Training Council to ensure that forest managers are up-to-date in their knowledge of recent research findings. This represents the other leg of the three modes of communication, demonstration by researchers themselves, writings by researchers, and education and familiarization by trainers, which are essential if the objectives of the Division are to be fulfilled.

Joint projects

A number of projects in the Division are joint between two or more Branches. More joint work is desirable. Two areas in which formal joint projects have been arranged are stand growth modelling and upland restocking. The first aims initially at work between mathematicians in Statistics Branch and mensurationists in Field Surveys Branch on distance-dependent functions for individual trees' growth. It is planned to extend the work to more fundamental physiological processes, such as the stand's water economy and nutrient flows, in due course. The other group is comprised of representatives from seven Branches and includes a representative of Headquarters' Forest Management Division. It has as its main task the preparation of guidance aimed at getting better value for money in the establishment of crops after clear-felling.

Census

The year saw the completion of census field work. This related to all woods and trees other than Forestry Commission woodlands and those managed by private owners under Dedication and Approved Woodlands Schemes. Computation of the results of the survey and aggregation with data from Commission and Dedication Plan records has progressed steadily. Publication will be by counties in England and Wales and by Conservancies in England, Wales and Scotland.

Arboreta

The importance of arboreta has long been recognised. Britain's equable climate makes it a particularly suitable place to cultivate plants from a very wide range of non-tropical regions and we have been fortunate in having not only the landowners and gardeners responsible for these collections but also a small yet passionately involved group of those who record trees and their growth. The records of Mr A. F. Mitchell of Silviculture (South) Branch hold a wealth of information of value not only to plant lovers but also those concerned with understanding growth in relation to site factors. A start has been made on such an analysis with the data on Douglas fir specimen trees.

The Westonbirt Arboretum Consultative Committee noted with pleasure the award in the 1983 New Year's Honours of a Knighthood to Sir Harold Hillier who has served on the Committee for 24 years.

Visitors

We were pleased as ever to welcome visitors from Britain and from overseas, although there were regrettably few from developing countries. A total of 803 visitors came to Alice Holt and 438 to the Northern Research Station during the year. Notable among these visitors were: the Earl Ferrers, Minister of State, Ministry of Agriculture, Fisheries and Food, Dr K. Dexter, Director General of the Agricultural Development and Advisory Service, MAFF, Mr E. J. G. Smith, Deputy Secretary, MAFF, Mr M. O'Neill, Director General New Zealand Forest Service, a party of members of the Norwegian Forestry Society and a party from the Commonwealth Forestry Association who attended a meeting at Westonbirt Arboretum and witnessed the planting by the Association's President, the Duke of Buccleuch, of a sycamore from his Drumlanrig estate to mark the 60th anniversary of the Association.

Conferences and tours

Divisional staff attended 58 meetings and conferences in Britain and made 26 visits, plus five regular EEC business meetings, abroad. A tour of particular interest in view of the increasing problem of forest decline in West Germany was that undertaken by Dr W. O. Binns, head of Site Studies (South) Branch, and Dr D. B. Redfern of Pathology Branch to several Länder. Their report ⁽¹⁾ was published after the end of the year under review.

Staff

Mr R. M. Brown, who has served for 9 years as Chairman of the Staff Side of the Forestry Commission's Whitley Council, was awarded an MBE. Dr J. N. Gibbs was awarded the degree of Doctor of Science by his *alma mater*, the University of Cambridge, and H. Insley was awarded his Ph.D. by Wye College for a thesis based on work funded by the Department of Environment on the establishment of amenity trees. Mr. A. W. Westall, Head Forester at Bedgebury Pinetum until his retirement in 1981, was awarded a Kew Medal in recognition of the close working relationship formed between Bedgebury Pinetum and Kew Royal Botanic Gardens during his 33 years in charge of the Pinetum.

A feature of the organization of the Commission's R&D Division is the high proportion of Forest Officers and Foresters who are engaged on a tour of duty at the end of which they return to field or Headquarters posts. Decisions resulting from an internal management structure review have meant that the normal process of interchange has slowed in the course of the year. It is hoped that the inevitable uncertainties so generated will be dispelled in the course of 1984.

At year end the Division employed 310 non-industrial staff (80 of whom are regarded as project leaders) and 154 industrial staff. Names of Forester, Forest Officer and Scientific staff are listed by branch in Appendix III.

⁽¹⁾ *Forestry Commission Research and Development Paper 131.*

The Work of the Forestry Commission

RESEARCH AND DEVELOPMENT DIVISION

SEED

Research*Laboratory experiments*

Preliminary studies have been made to discover the effect of pre-chill duration on subsequent germination of conifer seeds over a range of temperatures. Evidence suggests that as well as increasing the rate of germination at any particular temperature pre-chilling also widens the range of temperatures over which seeds are capable of germinating.

In an experiment to investigate the considerable variation in germination behaviour between individual Sessile oak acorns, methods for leaching possible chemical inhibitors were tested against other dormancy breakage treatments. None of the leaching techniques proved any more effective than imbibing seed for 48 hours in a 1:1 (v/v) ratio with water. However, a combination of imbibition followed by pre-chilling for various lengths of time promoted a more rapid, and hence synchronous, seedling emergence as well as increasing the maximum percentage germination on subsequent transfer to incubators at 20°C (Figure 1). The practical application of this technique to intensive oak seedling production in Japanese paperpots is currently under investigation in a joint project with Silviculture (South) Branch.

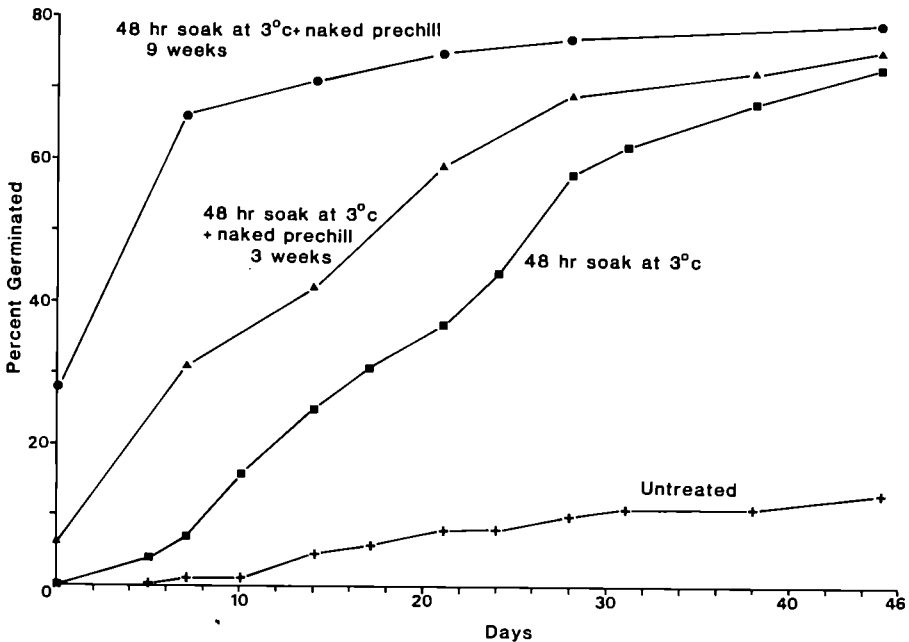


Figure 1. The course of germination of acorns at 20°C following various treatments.

Nursery experiments

Further experiments were laid down at Headley Research Nursery to study whether germination rate, maximum percentage germination, seedling survival or seedling height were affected by sowing date, covering material or shading. The following six species were sown on three dates between 31 March and 14 April 1982: Noble fir, Western Hemlock, Sitka spruce, Lodgepole pine, Common alder and Silver birch. Seeds were covered with a yellow brown grit (YBG), yellow brown sand (YBS) or white sand (WS), and protected by 30 per cent shading removed in June and August or 50 per cent shading removed in June and August. A series of control plots was left unshaded.

None of the treatments significantly affected either maximum percentage germination or survival ($P < 0.01$). The effect of the latest sowing date was to increase the rate of germination of all species regardless of other treatments but it had no long lasting effect other than to result in lower mean seedling heights for Sitka spruce and Lodgepole pine when measured at the end of the growing season. Both levels of shading, whether removed in June or August, almost invariably slowed down the germination rate and reduced height growth without improving survival. Research into the effects of shading on normal nursery sowings will therefore be discontinued.

The most significant feature emerging from the above experiment was that contrary to all previous work reported here (*Reports 1976–1980*) YBG proved better than either YBS or WS, even for the smaller seeded species. With the exception of Silver birch where covering had no effect, YBG gave the best rate of germination and final seedling height. A tentative explanation is that the grit used, despite bearing the same label as previous consignments, contained a greater proportion of smaller sized (sand) particles. The results emphasize the need to quantify particle size when working on seed covering materials.

Service*Official Seed Testing Station*

The testing of tropical seed collected by the Commonwealth Forestry Institute once again became the responsibility of this section and together with the routine testing of newly acquired and stored seed lots for sale or use by the Forestry Commission occupied the majority of staff time.

P. G. GOSLING, D. C. WAKEMAN

SILVICULTURE (SOUTH)**Plant production***Seedbed nutrition*

In a comparison of seedbed fertiliser regimes greater height and root collar diameter were obtained with slow release Osmocote than with traditional mineral fertilisers. An interesting feature was the lack of response by Sitka spruce to any of the fertiliser treatments in comparison with untreated controls.

J. S. P. SALE, P. D. HOWARD, P. W. W. DABORN

Vegetative propagation

The propagation of stocks of broadleaved trees from leafy, softwood and semi-ripe cuttings continued in greenhouses and frames equipped with automatic overhead mist irrigation. The problems of raising oak from cuttings and of producing reproductive material from grafted and budded stocks accounted for more than half the programme. Trials were carried out on the effects of cutting origin, type of cutting and substrate composition on root initiation and development.

J. JOBLING. P. MARSH

Lowland silviculture

Sweet chestnut coppice

In south-east England there are 18,000 hectares of Sweet chestnut coppice most of which is actively worked (Plate 1). Where coppicing has been practised for a long period and several crops harvested from a site there are *prima facie* reasons for expecting possible nutrient deficiencies to develop. In 1981 foliar analysis of Sweet chestnut coppice in Kent, from sites where six to nine crops had been cut, suggested that some crops were marginally phosphate deficient (proportion of P by oven dried weight = 0.12–0.14 per cent).

In 1982 two fertiliser experiments were laid down, in newly cut and in 10-year-old coppice, to test the effects of adding phosphate, potassium and lime. Liming at a rate of 2 tonnes/hectare altered soil acidity at a depth of 10 cm from pH 4.5 to 5.0 and significantly depressed coppice growth in the first year after application. It is too early to report on the effects of adding either P or K.

J. EVANS, R. E. PRESTON

Underplanting pole-stage oak

In the 1960s many pole-stage oak stands were underplanted with conifers, notably Western hemlock. A survey of several such crops suggested that the conifer understorey has led to accelerated stem diameter increment of the overstorey oak compared to that of similarly spaced oak with a natural herb/shrub understorey. This possible effect is being investigated further.

J. EVANS, S. WELLS*

Nutrition on free-drained soils

Since earlier work reported in the *Report* for 1980 (p.11), an additional experiment has confirmed the benefit of potassium fertilising of Corsican pine on shallow soils at Thetford. Both survival and height growth are improved. Large-scale field trials are being conducted.

J. EVANS, I. H. BLACKMORE

Tree shelters

Since 1979 data gathered from over 40 experiments on a wide range of species and sites confirm that broadleaved trees respond to shelters, providing the species is the right one for the site. Japanese larch behaves like the

*Commonwealth Forestry Institute, Oxford

broadleaves but other conifers are less responsive. In the oldest experiment the oak trees in Alice Holt Forest (Hampshire) (*Report 1982*, p.8) had to be supported by stakes when the shelters were removed. After a further year most of the trees do not need support because the increase in stem diameter and volume has been substantial but the increase in height growth has been small (Table 1).

TABLE 1
MEAN SIZE OF OAK AFTER THREE AND FOUR YEARS FROM PLANTING

Treatment	Height (cm)		Stem volume (cm ³)	
	End 1981	End 1982	End 1981	End 1982
Control	49	65	14	26
Treeguard	71	90	28	48
Shelter	163	170*	102	174*

*Shelter removed at the end of 1981

At the end of 1981 the differences in height increment were significant ($P < 0.01$) as were those for diameter ($P < 0.1$), but using the experiment to test taller shelters made it impossible to analyse the growth in 1982. Twenty oak trees that had been in 1.2 m shelters for three years had the shelters extended to 4 m in height. Trees in these shelters grew 1.4 m in 1982 and three of them have over 4 m of straight stem. The stem is slender and it will be several years before the trees can stand without support.

At Exeter Forest (Devon) a wide range of broadleaved species were planted in 1981 on a good forest soil. All have grown well in Treeguards but even better inside shelters (Table 2). Growth in experiments on poorer sites is slower but shelters still improve growth (Tuley, 1983a, b)

TABLE 2
HEIGHT INCREMENT OF BROADLEAVED TREES AFTER TWO YEARS IN A TREGUARD OR A SHELTER

Scientific name	Common name	Height (cm) at planting	Height increment (cm) after two years in		Significance levels
			Treeguard	Shelter	
<i>Acer platanoides</i>	Norway maple	32	49	124	**
<i>Acer pseudoplatanus</i>	Sycamore	47	27	111	***
<i>Alnus glutinosa</i>	Common alder	49	34	61	**
<i>Betula pendula</i>	Silver birch	50	49	124	***
<i>Carpinus betulus</i>	Hornbeam	54	81	103	NS
<i>Fagus sylvatica</i>	Beech	25	24	62	***
<i>Fraxinus angustifolia</i>	Narrow-leaved ash	26	55	94	*
<i>Ilex aquifolium</i>	Holly	6	33	42	NS
<i>Juglans nigra</i>	Black walnut	30	47	96	***
<i>Juglans regia</i>	Common walnut	15	31	37	NS
<i>Nothofagus dombeyi</i>	Coigüe	48	108	172	**
<i>Nothofagus procera</i>	Rauli	64	65	124	**
<i>Prunus avium</i>	Gean	67	105	138	NS
<i>Pterocarya x rehderana</i>	Hybrid wingnut	40	76	107	**
<i>Quercus petraea</i>	Sessile oak	17	11	62	***
<i>Sorbus aucuparia</i>	Rowan	55	121	140	NS
<i>Tilia platyphyllos</i>	Large-leaved lime	29	35	66	*

(*, ** and *** differences significant at $P < 0.05$, 0.01 and 0.001 levels respectively.
NS = not significantly different)

In the 1982/83 planting season some half million tree shelters were used nationally, a fivefold increase over the previous year. Clear and translucent plastics are suitable and a less conspicuous pale brown material is under test. Larger diameter shelters do not give better growth and 8 cm is adequate. Research continues into methods of fastening and supporting the plastics. More detailed study of the factors influencing tree growth in shelters is being supported at Wye College (see p. 59)

G. TULEY, P. G. RISBY

Nothofagus

One seed lot of *N. obliqua* from Neuquen Province, Argentina has grown much taller than any of the other origins of *N. obliqua* and *N. procera* in experiments planted in southern England in 1981 and 1982. This origin was not available when the provenance experiments were planted in 1979. The *N. procera* from Nuble Province, Chile is still the poorest performer.

G. TULEY

Fast growing pines

There is little difference between seed lots of the northern variety of Bishop pine (*Pinus muricata*) after three years in the forest. Home collections of Monterey pine (*P. radiata*) are growing faster than any from the native stands in California.

G. TULEY

Forest weed control

An experiment to assess the effects of repeated overall applications of glyphosate on eight conifer species generally confirmed expectations that damage increased with successive applications, was worse at higher application rates and when applied earlier in the growing season.

A trial of glyphosate on cut-over rhododendron indicated that good control can be obtained using 3.24 kg a.i. (9 litres of Roundup)/hectare for at least two years without significant regrowth. Preliminary results from a separate trial of a range of herbicides on older rhododendron indicate that surfactants increase the rapidity of foliar penetration, if not always the final effect. There has also been some response to a new soil-injection technique.

A series of experiments on grass and heather herbicides applied as special formulations through an electrostatic sprayer (ICI's Electrobyn) was carried out. Weed control was not significantly enhanced, while crop damage was sometimes more severe than with other application methods, probably because the crop plants, standing taller than the surrounding weeds, received a proportionately greater number of the electrostatically charged droplets.

J. S. P. SALE, K. F. BAKER, P. R. BARWICK, D. ELGY, C. W. SHANKS

Arboriculture – Department of Environment contracts

Tree establishment

First year results of an experiment at Milton Keynes to investigate the effect of various proportions of peat in the planting pit were inconclusive. Black

polythene mulching on a very dry motorway verge near Portsmouth (*Report 1982*, p.9) continues to yield good results. On very wet clay sites at Alice Holt and Milton Keynes various mulch materials reduced the survival rate of young trees; anaerobic soil conditions were probably the cause. The experiment established in 1980 at Alice Holt (*Report 1981*, p.15) has now been planted with cherry; first year growth was closely related to soil moisture availability; trees grown in bare soil produced nine times the height increment of trees grown in mown grass. Cutting the grass increased its soil drying ability and reduced tree growth. First year results of the series of experiments on motorway verges to examine the relationship between weed control and summer soil moisture deficit show little variation between sites; increasing the level of weed control increased the height and basal area increment of trees on each site, tree shelters increased height growth but had little effect on basal area in the first year. A nutrient response trial with an avenue of Common lime growing in a grass sward at Blickling Hall, Norfolk (*Report 1979*, p.13) did not reveal any response to the fertiliser treatments. An experiment was planted at Wormwood Scrubs with three weed control treatments, each with or without a NPK fertiliser; in the first year weed control increased leaf size, height and diameter increment of the oak and ash, whereas fertiliser has had little effect. An experiment has been established at Milton Keynes to examine the response of trees to various fertilisers, either mixed into the backfill of the planting pit or broadcast on the surface. A broad scale survey assessing the potential instability of trees planted on motorway and trunk road verges has begun.

R. J. DAVIES, J. B. H. GARDINER

Colliery spoil

Four experiments were laid down to see if the survival and vigour of newly planted trees on reclaimed spoil can be improved by protecting them with plastic tree shelters. Two experiments were started to examine the role of herbaceous legumes on colliery wastes as possible alternatives to conventional grass swards. This new work is located on reclaimed tips in Northumberland, County Durham, West Yorkshire, Greater Manchester and Nottinghamshire. At Alice Holt a preliminary pot trial was carried out to observe the behaviour of three major broadleaved species in intensely acid spoil limed to different levels.

In experiments started before 1982 (*Report 1982*, p.10) special attention was paid to tree development in compacted spoil cultivated before planting. Three-year-old specimens of Scots pine examined in Northumberland and four-year-old pine in County Durham showed much greater root extension in cultivated spoil, both laterally and downward, than in uncultivated spoil.

J. JOBLING, B. F. EDWARDS

Arboriculture Advisory and Information Service

Enquiries about trees and shrubs grown primarily for amenity were received by the Service from 1,760 professional and lay people. The problems reflected seasonal conditions especially during the spring and early summer when damage caused by the 1981/82 cold winter became apparent (see p. 35). Many requests for guidance on the management of affected trees and shrubs were

received. There was also a seasonal interest among the public, estate owners and nurserymen in Christmas tree growing. Architects, engineers and developers, as well as individuals purchasing houses, continued to be aware of the potential problems of buildings on highly shrinkable clay soils, especially near existing trees.

During the year five new Arboriculture Research Notes were published and five existing titles were revised. The new titles were:

41. Trees after winter – An interim report.
42. Shelters for improving the growth of young trees.
43. Rabbit control – Phostoxin.
44. The effects of tree species on vegetation and nutrient supply in lowland Britain.
45. Cobweb fungus – *Athelia*.

D. PATCH, F. R. W. STEVENS

Short rotation coppice – Department of Energy contract

Early results from this series of experiments are encouraging. At Long Ashton (Bristol) coppice of *Populus* 'RAP' reached 4 m height and 6 cm basal diameter on one-year-old shoots from two-year-old stools (up to 5 kg annual fresh weight production per stool). *Eucalyptus archeri* coppice shoots were killed by the 1981/82 winter temperature but regrowth from the stools occurred the following season.

M. L. PEARCE

Dendrology and arboreta

Dendrology

During the year, visits were made to 141 estates, gardens and collections, of which 61 were new and 80 were for re-measuring known trees and adding others. The total number of trees measured was 5,495 and 3,381 of these were additions to the Tree Register. A complete recount of trees in the Register shows the full total now to be 60,300 trees of 1,953 species and 905 cultivars. Conifers maintain their lead in numbers of specimens, now 35,950 to 24,350 broadleaf trees, and lag in the number of species, now 285 against 1,168 (with some losses to both from the revised counts, from a few genuine losses, and more botanical changes). A start has been made on the analysis of these records in relation to site by entering all the data for Douglas fir onto a computer file.

The two tallest known trees in Britain were carefully checked on adjacent days and both were found to be 60 m (197 feet) tall. One is a Grand fir at Strone House, Argyll and the other a Douglas fir on Forestry Commission land in Craigvinean Forest but seen best from the Hermitage belonging to the National Trust for Scotland at Inver, Dunkeld, Perthshire.

Bedgebury National Pinetum

Much progress has been made in thinning thickets of rhododendron and self-sown Scots pine which had obscured boles of good trees and vistas. The large extension to the collection of Lawson cypress cultivars and the mixed plantings continuing Cedar Bank have been brought fully into the Pinetum by the removal of fences. A new footpath has greatly improved access along Thornhill bank.

A. F. MITCHELL

Westonbirt Arboretum, Gloucestershire

This was a year of consolidation, with additions to the lime, ash, oak, *Abies* and *Eucalyptus* collections, and the establishment of a Japanese maple cultivar collection. Despite the very low January 1982 temperatures and the apparent damage to many specimens, very few were ultimately lost. A revision of the illustrated guide was published and a scale model (1 : 1,600) of the Arboretum added to the exhibits in the Visitor Centre, both of which will improve the interpretation of the Arboretum to some 160,000 visitors annually. An exhibit was mounted at the 1982 Chelsea Flower Show illustrating the scientific and recreational functions of this tree collection.

M. L. PEARCE

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SILVICULTURE (NORTH)**Species, seed origins and arboreta***Pinus peuce*

Small trials planted in 1961/62 have shown that after a slow start *Pinus peuce* Grisebach can grow well on upland sites in Britain, even at 58° N. Both form and basal area are better than adjacent Scots and Lodgepole pines. Before starting further experiments, Yugoslavia and Bulgaria were visited in order to see the species in its native range and to try to arrange seed collections from locally selected superior stands. The visit confirmed impressions of its hardiness, good form and tolerance of a wide spectrum of soil conditions. Excellent stands were seen up to elevations exceeding 2,000 m, well above the observed limit for Scots pine.

Engelmann spruce

Experiments comparing seed origins of *Picea engelmannii* (Parry) Engelm. at Shin Forest (Highland), Rheidol Forest (Dyfed) and Brendon Forest (Somerset) showed highly significant differences in height at 15, 12 and 13 years respectively. At all three sites, the northern origins from Kispiox River and Babine Lake, British Columbia were the tallest, followed by those from the southern interior of this province. Seed origins from Washington and Colorado showed by far the poorest height growth. At Shin the best Engelmann spruce was taller than adjacent Sitka spruce at 10 years, but the latter had overtaken it by 15 years. At the other sites Sitka spruce was generally taller than all Engelmann spruce origins.

Very large differences in seedling and transplant height were found in the collection of 'Interior' spruce (*P. engelmannii* and *P. glauca* (Moench) Voss) sown in 1981. The tallest were from parts of British Columbia where these species overlap, though the second tallest (Clackamas, Oregon) can only be pure *P. engelmannii* as *P. glauca* is not found in Oregon.

Sitka spruce

The unusual frost damage in April 1981 which severely damaged the IUFRO experiments at Farigaig and Ratagan Forests (Highland) before the trees flushed (*Report* 1982, p.27) has resulted in the closure of the Farigaig experiment. Both experiments were subjectively assessed by the same research foresters for the severity of damage on a scale 1 = no damage to 4 = severe damage. A very small number of trees were killed and these were given a score of 5. A separate statistical analysis for each site showed that differences in severity of damage between seed origins were highly significant and that most of this variation was due to differences between eight geographical groups. A combined analysis of the 39 seed origins common to both experimental sites showed a similar result. As Sitka spruce occupies a narrow strip roughly north to south along the coast of north-west America, latitude is an obvious dimension of variation between seed origins. Spearman's rank correlation coefficient between mean frost damage scores at the two sites and latitude of seed origin was calculated and a highly significant negative value was obtained, showing decreased frost damage for the higher latitudes.

Lodgepole pine

In the 1972 IUFRO experiment series, 10 year heights showed a similar pattern to those at 6 years (Lines, 1980). Only seven of the 25 origins had changed in relative height by more than 5 per cent. These are mainly seed origins known to be sensitive to blasting winds, such as Lund and Mesachie Lake, British Columbia and the Puget Sound, Washington seedlots John's Prairie and Vail, together with the Californian origin Samoa, which does not tolerate the 15° latitude transfer northwards. Conversely, some northern origins showed improved relative height, including those from Queen Charlotte Islands, British Columbia and the most northerly origin, Ethel Lake, Yukon, which nevertheless was only one-third the height of the tallest origin, Pacific City, Oregon. These experiments have indicated seed origins which combine resistance to basal sweep, blasting winds and snow damage with good stem form and an acceptable rate of growth.

R. LINES

Production of planting stock*Vegetative propagation of conifers*

In a field scale trial of Sitka spruce propagation at Newton Nursery (Grampian), 100,000 cuttings were inserted of which 84 per cent rooted successfully. Current techniques using low-level beds necessitate undesirable backbending; an alternative tray-based system would allow operators to sit during cutting insertion. Comparison of various tray depths (71–134 mm) showed no appreciable differences in quality of rooted cuttings.

At Bush Nursery (Lothian) dormant Hybrid larch cuttings, collected at two week intervals from mid-February until late April, were used to compare rooting success with date of collection, and also to compare immediate insertion with insertion after two weeks cold storage. Rooting success improved from 25 per cent for the earliest collection date to 60 per cent for

the latest. For all insertion dates cold storage improved rooting by an additional 4 per cent.

The effects of nutritional regimes on rooting of Sitka spruce and Hybrid larch cuttings were investigated. For Sitka spruce inserted in March, three basal fertilisers combined with five liquid top dressings were compared, with and without algicide. All fertiliser treatments encouraged algal growth, but produced only minor improvements in rooting. However, fertiliser-induced improvements in colour and needle length may lead to improved second year growth. For Hybrid larch cuttings inserted in July the effects of two basal fertilisers combined with two liquid top dressings were compared, again with and without algicide. Rooting percentage and root development were depressed by the presence of basal fertiliser. Top dressing had no effect on rooting percentage but improved root development. Algicide applications controlled algae but had no effect on rooting of either tree species.

Comparison of cuttings from Hybrid larch stock plants of different moisture status showed that apparent plagiotropism is frequently due to cuttings of poor moisture status wilting immediately after insertion, particularly under conditions of high evaporative demand.

Root development of Hybrid larch cuttings was examined in parallel experiments at Bush and Alice Holt comparing four different dates of collection and insertion from July to mid-August. At both locations early July insertion gave the best results.

Cloches for broadleaves

Pedunculate oak germinated and grew better under polythene tunnel cloches erected over seedbeds at Bush Nursery than in uncloched beds. Initial growth of birch and sycamore was also better under cloches but the improvement was not maintained after cloche removal.

Nursery handling systems

High-output transplant lifters being introduced into forest nurseries are likely to necessitate the use of rigid airtight cardboard cartons rather than polythene bags for plant storage. Comparison of the two types of container showed no appreciable difference in plant survival and subsequent growth.

P. BIGGIN, W. L. MASON

Planting and herbicides

Plant handling

An experiment at Falstone (Northumberland) (*Report* 1982, p.12) has shown that damage caused by exposure of bare-rooted Sitka spruce transplants to drying conditions can be estimated by measuring root moisture content or shoot water potential; shoot water content proved to be a less sensitive indicator. Short periods of exposure during lifting, dipping and transport did not reduce either the visible surface wetness of the root system or the internal moisture status of the plants. At the forest the plants were subjected to two exposure treatments (1¾ and 3¼ hours) during which the plants were spread individually on the forest road on a cool (7°C), still, sunny day. Despite a small reduction in water status, as measured by root moisture content and shoot water potential, no reduction in survival or growth increment after one

growing season could be detected in the 1¾ hour treatment. The 3¼ hour treatment, however, markedly reduced root moisture content, shoot water potential, survival and growth.

The proportion of dead or leader-damaged trees was significantly greater for plants dipped in gamma-HCH than for undipped plants ($P < 0.05$), but the increment of undamaged trees was unaffected by dipping. The increment of trees transported and stored in sealed polythene bags was significantly greater than that for unbagged plants ($P < 0.001$), although death of the leader was more common in bagged than in unbagged plants ($P < 0.05$).

Forest weed control

Experiments at Ae Forest (Dumfries and Galloway) and Brycheiniog Forest (Powys) showed similar responses of Sitka spruce to weed control on weedy, mineral soils. No weeding and hand weeding gave the poorest height growth and no weeding also depressed survival. Chemical weeding delayed until the second year gave little improvement, even when applied broadcast. However, chemical application prior to or shortly after planting gave a height response which increased with the intensity of weeding. A 40 cm diameter spot treatment was clearly inadequate; broadcast treatment gave the best result but was only marginally better than 80 cm spot and 80 cm strip applications.

In late August of 1980 and 1981 trial areas were treated by helicopter with low volume overall application of Roundup (glyphosate) at 5.5 l/ha to control *Calluna* and 2.0 l/ha to control grasses. Grass control was more reliable than heather control and the higher rate frequently caused severe damage to Sitka spruce leaders. Use of later application dates for heather control is being investigated.

P. TABBUSH

Nutrition

Establishment phase

Results to date from an extensive series of experiments on mineral soils with grass/herb vegetation have shown that, up to 8 years of age at least, fertiliser application even at high levels has little or no effect on the height increment of Sitka spruce stands. In contrast, intensive weed control involving annual herbicide applications has invariably resulted in significantly greater mean height at 8 years. This beneficial effect is thought to be largely due to a reduction in competition for moisture during the growing season.

The problem of severe nitrogen deficiency in Sitka spruce stands on heathland mineral soils and deep unflushed peats continues to be important. Investigations of alternatives to repeated applications of standard nitrogen fertilisers include the use of slow-release nitrogen fertilisers, the use of nitrogen-fixing shrubs such as *Lupinus nootkatensis*, and the promising role of mixtures of Sitka spruce with a larch or pine species. Mixture experiments on infertile sites continue to demonstrate a dramatic effect of the mixture on growth and nitrogen status of the Sitka spruce component. Table 3 summarizes results for a deep, unflushed peat at Inchnacardoch Forest (Highland).

TABLE 3

THE EFFECT OF ADMIXTURES OF LODGEPOLE PINE (LP) AND JAPANESE LARCH (JL) ON THE GROWTH AND NITROGEN STATUS OF SITKA SPRUCE (SS) IN INCHNACARDOCH EXPERIMENT 164/65

Treatment	Mean height at 15 years (m)	Height increment 12 to 15 years (m)	Foliar N concentration at 17 years (%)
Pure SS. No N applied	2.89	0.61	1.06
Pure SS. N applied in years 9, 12 and 15	5.12	1.88	1.40
SS in mixture with JL. No N applied	4.43	1.86	1.48
SS in mixture with Alaskan LP. No N applied	4.80	1.94	1.40
Least significant difference (P = 0.05)	1.19	0.54	0.21

Pole Stage

Results from fertiliser experiments in pole stage Sitka spruce stands suggest that, although previously unfertilised stands of low productivity on infertile sites may show a significant fertiliser response in the pole stage, stands of general yield class 12 or above are not particularly responsive. Where a response has occurred, it has not been predictable using standard foliage analysis techniques. Examination of foliar nutrient concentrations throughout the crown of the tree has revealed concentration gradients of the major nutrients with respect to needle age and crown position, and this finding may help to improve the diagnostic value of foliage analysis results.

R. McINTOSH

Use of sewage sludge

At Angus Forest (Tayside) three rates of primary sewage sludge were applied by 'rain-gun' to a 42-year-old Scots pine stand on a heathland soil. Foliage, sludge and soil samples are being analysed by the Macaulay Institute for Soil Research and run-off water quality is being monitored by the Water Research Centre. After one growing season application rates of 240 and 480 m³/ha had produced some improvement in basal area and in foliage nitrogen and phosphorus but at the 720 m³/ha rate basal area increment and foliage P were depressed.

P. TABBUSH

Cultivation, drainage and site preparation

Initial trials, on peaty gley soils, of a twin-disc plough with mole draining heads indicated that effective site preparation is possible (Plate 2). Scarification by the discs can give sufficient weed control and aeration for establishment, with less root growth restriction than with spaced furrow

ploughing. Mole drains beneath each scarified trace should give water table control and encourage deeper rooting for improved stability. The plough, based on a twin beam carriage, has two heavy serrated scarifying discs pivoted on floating arms 2 m apart and two tines (which may be fitted with moling or ripping socks) rigidly mounted 1.5 m apart and operating to a depth of 500 mm. The plough can be used on restocking sites, with removal of the tines allowing the unit to function as a trailed twin-disc scarifier. The disc assembly may also be removed from the carriage and mounted directly on the tool bar of a heavy wheeled tractor.

A new experiment at Moffat Forest (Borders) compares various configurations of ridge replacement ploughing against standard D45/T60 ploughing. It involves mainly hand simulation of ridge replacement, with various furrow depths combined with complete and partial inversion of the replaced ridge.

Growth data to 30 years are now available from an important cultivation experiment at Teindland, Speymouth Forest (Grampian). The six treatments involved spaced furrow or complete ploughing of an ironpan soil with indurated subsoil. Planting was with Scots pine and a Japanese larch/Lodgepole pine mixture. It now appears that the growth benefits attributable to complete cultivation (Thomson and Neustein, 1973) were significant only during the first 10 years. Subsequently, treatment differences have tended to diminish, possibly because of the undemanding species used.

Stability

An initial examination of wind conditions above and within the canopy of an unthinned pole-stage Sitka spruce plantation at Moffat Forest (Borders) (*Report* 1982, p.16) has been completed. Preliminary analysis of data from the unthinned stand, producing mean velocity profiles, turbulence intensity profiles and velocity power spectra, has been undertaken jointly with the Ecological Physics Research Group at Cranfield Institute of Technology.

Tree response to a range of wind conditions has been investigated using accelerometers to monitor tree oscillations, making it possible to calculate tree deflections and their frequency composition as indicators of momentum transfer from the wind. A new data logging and signal conditioning system, permitting microprocessor disc storage of data from 15 anemometers and three pairs of accelerometers, has been successfully developed. The system is capable of preliminary data analysis, and can transfer recorded data directly to mainframe computers for full analysis. The first of three thinnings to the study stand has been marked, these being aimed at changing the spacing to height ratio in line with previous wind tunnel simulations.

Tree pulling tests in a 1935 Sitka spruce spacing experiment at Brechfa Forest (Dyfed) examined the effects of stem shape and crown architecture on bending moments.

K. F. MILLER

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Chemical analysis

Service

Ten thousand six hundred samples of foliage were presented for analysis during the year. Two hundred and seventy of these were from Forestry Commission and private growers, the rest being from research projects. A Transdata Cx502S microcomputer has been fitted to the Spectraspan III spectrometer. This is used both as a data capture device and also to check the stability of the instrument during analytical runs.

Methods

A study has been made of the chloride levels in foliage where damage by salt spray from roads is suspected. The chloride is extracted with nitric acid and then estimated colorimetrically using mercuric thiocyanate in the presence of ferric ions. Damage to foliage is observed when chloride levels exceed 0.5 per cent dry matter. At concentrations above 1 per cent almost all trees suffer extensive damage to the foliage.

Studies of trees suffering from lime-induced chlorosis suggest that measurements of iron and manganese should be made in those parts which are chlorotic rather than using the whole leaf or needle.

A. WILLSON, Y. Y. CHEUNG

Soil

The quantity/intensity aspects of the interaction of phosphate with upland soils show that the measurements of phosphate adsorption and desorption are very sensitive to temperature and moisture content, any drying of the soil prior to analysis having an adverse effect on the interpretation of the results. The measurements indicate the ability of a soil to maintain the phosphate concentration in the soil solution and reflect the proportion of the added phosphate which is adsorbed by the soil. The methods are to be tested in a pot experiment, comparing conifers with a horticultural crop, where growth can be related to the measurements.

A. WILLSON, D. A. WADDELL

Effects of trees on sites

The experimental work at Beddgelert (Snowdonia) in collaboration with the Institute of Terrestrial Ecology (*Report* 1982, p.17) has been pursued vigorously. The clearfelling and whole-tree harvesting treatments on the intergrade and peaty gley soils will be applied in May 1983. Comprehensive studies of soil nutrient flux, decomposition, and anaerobic fronts in the soil prior to felling have been made. Point-to-point variation in nutrient leachate concentration has been very high. Nitrate has, rather unexpectedly, been detected in the soil solutions. The soils show a consistent band of anaerobic conditions present between 15 and 25 cm from the mineral soil surface; the top margin of this band oscillates between 5 and 10 cm from the soil surface following long periods of saturation. Some evidence from rates of loss of cellulose bait placed in the litter has shown very marked (>300 per cent)

acceleration of cellulose decomposition during the periods when the soil profile was saturated and anaerobic near the surface. Techniques for measuring cellulose decomposition and soil anoxia have been extended to two other felling experiments at Kershope and Torridge Forests. A start has been made on estimating the differences in development of soil oxygen profiles in a joint FC/ITE experiment at Gisburn, Bowland Forest (Lancs) on the comparative effects of different tree species on a gley soil.

M. A. ANDERSON

Lowland forestry

Maximum amelioration

Several of the plots in the 13-year-old trial at Wareham Forest (Dorest) have reached the height and basal area at which the first thinning normally takes place. During the winter, the Corsican pine, Sitka spruce, Douglas fir, Western hemlock and Radiata pine plots were all measured and thinned to Management Table standards. All except the Radiata pine were taken on by Field Surveys Branch as permanent sample plots (see p.44 and Table 7).

Reclamation: opencast coal

The first plantings on the Woorgreen site in the Forest of Dean were made more than three years ago and, apart from some problems with rushes in wet hollows, growth of larch and Corsican pine is good. Alder is particularly vigorous, averaging about 2 m total height, and very evenly grown. Larch on ridges with tree lupin (*Lupinus arboreus*) is growing better than where grass was sown all over to control erosion.

Reclamation: sand and gravel

In north-east Hampshire, on former heathlands worked for plateau gravel, ridges have improved drainage and the establishment and growth of trees. The accentuated slopes appear to improve nutrition as well as drainage; older trials on flatter ground are often constrained by poverty of the former heathland topsoil, especially by phosphorus deficiency.

Both Italian and Common alder are highly appreciative of improvements in aeration and drainage. On flat wet compact spoils they grow poorly, with frequent dieback, basal sprouting, and abundant early coning. Alders are labelled as trees tolerating wet sites but nevertheless grow best where improved aeration and drainage are provided.

Reclamation: nitrogen fixation studies

The simplest method of increasing nitrogen capital on reclamation sites is to include a proportion of alder with the other tree species, the main constraint being the supply of suitable planting stock. Transplants (1+1) at least 50 cm tall, with a thick collar, perform markedly better than smaller 1+0 plants; this is presumably due to better reserves, bigger root systems, and the superior inoculation in the nursery with the nitrogen-fixing organism.

Alternatively legumes can be used and a wide range of species is now on trial, which includes a legume 'garden' in a worked-out sandpit. Tap-rooting species are able to penetrate deeply into difficult spoils, while diffuse-rooting

species such as *Trifolium*, *Lotus* and *Ornithopus* are much less vigorous. The biennial *Melilotus* and the perennials *Lupinus*, *Lathyrus*, *Galega* and *Astragalus*, most of which are unpalatable, appear to offer substantial advantages in colonizing and maintaining the mechanically formed fissures resulting from the winged-tine treatments, and also prevent slaking down of the spoils.

D. F. FOUNT, N. BEST

Legume supplies

Further collections were made of Tree lupin, Everlasting pea (*Lathyrus sylvestris*) with smaller amounts of Goats rue (*Galega officinalis*) and Milk vetch (*Astragalus glycyphyllos*), for trials of unpalatable species on infertile areas.

The standard 10 minute abrasion treatment (*Report* 1981, p. 10) is used for all Tree lupin seed, while the more fragile *Lathyrus* seed only needs 5 minutes treatment. *Galega* and *Astragalus*, with fewer hard seeds, are sown as collected or after sterilization with hydrogen peroxide. The small import from Iceland of Nootka lupin seed (*Lupinus nootkatensis*), a native of Alaska, was found to benefit from 10 minutes abrasion.

N. BEST

Upland forestry

Drainage : peaty gleys

The drainage experiment at Crychan Forest (Powys) which was clearfelled in 1980–81 has had half of each plot cultivated. The experiment has been replanted, all drains reinstated to design depth and the original number of boreholes trebled to 432. Each new borehole was installed halfway between an existing mid-plot borehole and the nearest treatment drain. Daily readings of water levels will be taken from mid-March to mid-April. The data will be used to assess the effect of clearfelling and cultivation on some of the soil physical characteristics of the site.

R. CARNELL

Drainage : surface water gleys

From early December 1982 until mid-March 1983 daily measurements were made of water levels in open boreholes in the 1962 drainage experiments at Torridge Forest (Devon). The Sitka spruce crop had closed canopy in about 1975 and these measurements will be compared with those made just after planting in 1970 (*Report* 1970, p. 88). After rainfall ceases the draw down to 35–40 cm is very rapid, then slower. There still seems to be an effect of the moling treatment in the widest drain spacing of 50 m. After a slow start on these very phosphorus-deficient soils (three heavy fertiliser applications were made, the last in 1969) growth is now good, but lacks conspicuous response to the drainage treatments, the spruce growing well even at the widest spacing. Heights range from 10 – 12 m, or about GYC 18, and foliage colour and needle holding are both good.

Reclamation : opencast coal in South Wales

The main species planted on these sites has been Lodgepole pine, with smaller amounts of larch and Corsican pine, the last being confined to sites below 150 m altitude. Growth and foliar analysis (*Report* 1981, p. 25) show that larches appear better able to take up phosphorus from the shaly spoils than Lodgepole pine, although Corsican pine is also able to exploit these materials. All these species are limited by nitrogen deficiency, responses to fertiliser being very short lived. At Tumble, Coed Deufor Forest (Dyfed) the nitrogen fixed by small groups of Red alder appears to be improving colour and growth of adjacent Corsican pine. On the basis of this and other evidence future plantings should be larch or Corsican pine mixtures with alder in a proportion of 1 in 5 to 1 in 2.

Below 200 m altitude Tree lupin seems to be a possible alternative to alder but it seems insufficiently hardy on exposed sites or even in the lowlands in severe winters. The only legume so far that has been successful at these altitudes is the Everlasting pea (*Lathyrus sylvestris*) but a fully practical system for these sites has still to be worked out.

The practice of ridging is now general on all areas with slopes of less than 5 degrees; this should eliminate the problems previously experienced on former level stockpile sites. Loosening of these compacted spoils has been done with the plough (designed by South Wales staff) and also with winged tines; both pieces of equipment were mounted in pairs on a 300 hp crawler tractor. Work is continuing to decide the conditions in which each tool works the better, or where differences are unimportant.

D. F. FOURT, N. BEST

Acid rain, forestry and fish

Considerable concern has been expressed over the increasing acidity of streams and lakes in the uplands, with consequent disappearance of fish stocks; this process seems to be more rapid when the stream or lake catchments are afforested. Collaborative work with a number of organizations is in hand or proposed for the most sensitive areas, which are on acid geologies in south and west Scotland and in Wales. The relative importance of acid rain, forest cover and forest management practices has to be established so that forest managers can be advised on the best ways to prevent or reverse deterioration, where it occurs.

There has also been considerable concern in central Europe over the effects of pollution on forests. This concern has been most evident in West Germany and reports of widespread decline of Norway spruce and European Silver fir stands were sufficiently alarming to require first-hand investigation. Two members of staff from Site Studies (South) and Pathology Branches visited forests in several parts of West Germany during the year and concluded that because the species, age, climate and, in particular, altitude of stands affected were so different from those in British upland forests, the same phenomenon was unlikely to occur here (Binns and Redfern, 1983); there is so far no evidence of damage to forests or forest soils in Britain from acid rain.

W. O. BINNS

Amenity forestry and arboriculture

Work published this year on the influence of depth and type of cover material on tree establishment on a domestic refuse landfill site (Insley and Carnell, 1982) showed that trees survived better in mineral soil than in a cover of composted refuse. Some species survived better than others but overall no better results were obtained by using more than 0.5 m of cover.

Temperature profiles indicated a significant difference between the two types of cover, the composted refuse being higher but not dangerously so. These higher temperatures were at first thought to indicate a secondary fermentation; an alternative explanation however is that the heat generated in the freshly deposited refuse is less easily conducted to the surface through the composted refuse which has a lower thermal conductivity. It has also been noticed on this type of site that the fill material has a higher bulk modulus than natural soils (and is thus more resilient). This suggests that the final cover over refuse cannot be compacted to the same extent as over mineral fill and that this must be allowed for in making specifications.

R. CARNELL

Advisory

A number of samples of unthrifty Norway spruce intended for the Christmas tree market were sent in during the autumn. Symptoms of deficiency in magnesium, and occasionally potassium, were ascribed to the very wet October, while nitrogen-deficient trees were usually from sites where weed competition or waterlogging had not been controlled.

Several refuse tips were examined and the heating of several materials suggested as a possible cause of soil drying. Temperature measurements are however required to confirm this. Tree growth was examined on some heavy metal spoils in Cornwall and reclamation prescriptions were prepared for mineral workings for clays, sands and gravel, and the surrounds to industrial sites.

Enquiries on forest hydrology, in particular the water use of trees, continued throughout the year.

W. O. BINNS, D. F. FOURT

Meteorology and phenology

Participation in the International Phenology Gardens scheme has been finally discontinued.

The store of meteorological data forming the information source for the small advisory service operating from Alice Holt has been transferred from paper to disc storage. As a result more sophisticated enquiries can be pursued by customers with the aid of the Prime computer.

M. ANDERSON, D. DURRANT

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SITE STUDIES (NORTH)

Classification and improvement of upland soils*Damage to soil caused by harvesting*

The small feasibility trial at Black Isle Forest (Highland) (*Report 1976, p.25*) is now 6 years old. The soil is a gley of sandy loam texture with indurated subsoil and subject to winter waterlogging. The previous crop of pine was harvested with care during the summer so as to cause minimum disturbance to the soil. For the experiment two degrees of damage, 'moderate' involving compaction only and 'severe' involving churning to 15 cm depth followed by compaction, were produced using a tracked vehicle. These treatments were applied as uniformly as possible to plots of 0.025 ha and together with an undamaged control treatment were randomized in three blocks. Finally, half of each plot was given a 'remedial' 2 m spaced D60/T90 ploughing treatment in a non-random layout. The ploughed and non-ploughed plots were again split for planting with either Sitka spruce (SS) or Lodgepole pine (South coastal provenance) (LP). Non-ploughed plots were planted at a precise 2 m square spacing; on the ploughing a ridge-side planting position was used with a similar stocking.

Complete beating up after the first and second years has resulted in high stocking rates after 6 years. Although not statistically significant, there is poorer survival of SS with increasing soil damage without subsequent ploughing. A trend of poorer growth with increased soil damage became visually evident from the start but after 3 years differences between treatments were not significant. Mean heights after 6 years are given in Table 4.

TABLE 4
MEAN HEIGHT (m) AFTER 6 YEARS

Damage treatment	Ploughed		Not ploughed	
	SS	LP	SS	LP
Control	1.85	2.01	1.94	2.13
Moderate	1.66	2.02	1.76	1.46
Severe	1.20	1.67	1.33	1.31
Least significant difference (m) between treatments (P = 0.05)	0.38		0.62	

The non-random allocation of ploughing does not allow valid comparisons between with and without ploughing, and separate analyses of variance are required for ploughed and not ploughed plots. Within each there are large and significant differences in mean height related to degree of damage. It is surprising how the effects of soil damage have not been remedied by the ploughing. The best growth of both species is on undamaged soil without ploughing.

Growth in the plots with damaged soil is very variable and it is likely that careful choice of planting site (avoiding hollows and ruts) would lead to a better crop in most conditions where damage is patchy.

Clay soils

The experimental work at Kershope in collaboration with the Institute of Terrestrial Ecology (*Report* 1982, p.19) has continued. Clearfelling half of the experiment began in May 1982 and two-thirds of the felling has been completed. The intensively studied 'hydrology plots' are being felled last to permit collection of two years' pre-felling data. Study of the chemical composition of the water has been extended to include the rainfall outside the forest and under the canopy.

D. G. PYATT

FOREST GENETICS**Testing***Pollinations*

Flowering in clonal tree banks was especially good on larches and Sitka spruce. Seventy-four European larch clones were pollinated with a Japanese larch pollen mixture in the clone banks at Newton and Teindland (Grampian) and in addition 30 single-pair matings were made to test for outstanding combinations for future commercial vegetative propagation. During the programme the weather was poor and over 30 per cent of female flowers were damaged by frost.

Sitka spruce flowered heavily and allowed several projects to be undertaken including the creation of Sitka spruce \times White spruce hybrids using pollen from seven locations in British Columbia and Ontario, Canada. A severe frost on 8 May 1982 extensively damaged developing female flowers. The Scots pine programme was directed at further tests of all individuals, previously selected for good general-combining-ability, in a series of disconnected diallels. These should yield confirmatory evidence on high general-combining-ability and some evidence on specific combining-ability. At Neroche (Devon) the Lodgepole pine programme of wide crosses continued with 91 single-pair matings made between selected trees of Queen Charlotte Islands, B.C. and Skeena (Telkwa/Smithers) B.C. origins.

The 1982 pollination programme exceeded all previous programmes: 806 artificial crosses were made involving 12,581 isolations and 32,000 flowers; 400 separate pollen lots were extracted.

Good flowering in a five-year-old Sitka spruce clonal seed orchard at Slebech, Coed Preseli Forest (Dyfed) provided an opportunity to create genetically superior families for vegetative propagation in bulk. Twenty-one of the constituent clones, known to be good general-combiners, were hand-pollinated with a mixture of pollens from nine other clones, also known to be good general-combiners, without isolation of the female flowers. The orchard is well isolated from contaminant pollen arising from outside sources and, because of its youth, pollen production within the orchards is minimal. A severe late frost damaged many flowers but despite this over 15,000 full seeds were produced. The Branch provided on-site training in flower-bud recognition and pollination procedures for the local Conservancy staff, who then carried out almost the entire programme. Seedling families from the 15,000 seeds will be multiplied vegetatively over a period of years, using intensive rooted-cutting techniques, to provide up to 4½ million rooted cuttings for use in commercial plantations.

Forest progeny tests

Alpha designs with five replications have been used for the 1983 progeny tests; they replace previously used complete randomized block designs, also with five replications. Alpha designs, a form of resolvable incomplete block design described by Patterson, Williams and Hunter (1978), are more flexible in the number of treatments (families) which can be accommodated than the commoner incomplete block designs such as square and rectangular lattices. Generating arrays for five replications were furnished by the ARC Unit of Statistics, University of Edinburgh, and used by Statistics (North) Branch to produce forest layout plans. The use of alpha designs will improve the efficiency of progeny tests without restricting the number of families and will introduce only minor additional constraints on the forest layout.

Heights and diameters at 10 years were assessed for 43 Sitka spruce half-sib families on seven sites and high correlations were again found with height at 6 years. Sixth-year height was assessed for 170 Sitka spruce half-sib families growing on two to seven sites and 15 were found to be genetically superior (15 per cent above standard imported spruce). The parents of these families will be grafted for inclusion in the breeding population, and the better clones will be included in future seed orchards. In addition, progeny tests of 158 clones from a single Sitka spruce population have revealed 33 clones with genetic superiority on northern upland sites with a restricted growing-season. An orchard, based on these clones and specifically for such sites, will be planted in 1987-88.

Breeding programmes for species involving selection for general-combining-ability have now reached the size shown in Table 5.

TABLE 5

Selection type	Sitka spruce	Scots pine	Corsican pine
Plus/candidate trees selected	1991	1007	678
Other selections	385	0	0
F ₁ selections	0	47	0
Plus/candidate trees with half-sib families in forest progeny tests	1244	839	581
Plus/candidate trees with half-sib families in nursery-stage tests	76	80	0
Number of older families with reliable performance data	624	453	581
Number of plus/candidate trees selected for breeding population	79	62	20

Seed Production*Seed stands and seed orchards*

A National Register of Seed Sources had to be established when Britain joined the European Economic Community in 1972. A summary of the current Register is given in Table 6.

TABLE 6
NUMBERS AND AREAS OF REGISTERED SEED STANDS AND SEED ORCHARDS AS AT 31 MARCH 1983

Species/hybrid	Seed stands		Clonal orchards	Seedlings orchards
	Number	Area (ha)	Area (ha)	Area (ha)
<i>Conifers</i>				
Scots pine	22	1352*	17	—
Corsican pine	14	231	—	—
Lodgepole pine	48	497	3	22
European larch	12	87	—	—
Japanese larch	22	127	—	—
Hybrid larch	9	44	19	—
Douglas fir	16	87	2	—
Norway spruce	3	15	—	—
Sitka spruce	2	5	11	—
Miscellaneous	20	50	—	—
<i>Broadleaves</i>				
Beech	15	158	2	—
Sessile oak	14	160	—	—
Pedunculate oak	33	135	—	—
Miscellaneous	—	—	—	—

*Mainly native pinewoods

Biochemical variation

Attempts are being made (jointly with Pathology Branch) to correlate the variation between trees in the degree of resistance of Sitka spruce to the decay fungus *Heterobasidion annosum* with the biochemical characteristics of individual trees. Work has continued on the analysis by capillary gas chromatography of the terpenoid constituents of the main stem xylem and cortical oleoresin systems of trees whose stumps, after felling, have been infected with basidiospore suspensions of the fungus.

Capillary chromatography of oleoresin has provided many useful data in the genotypic analysis of Sitka spruce populations, hybrids with other spruce species, Scots pine and Lodgepole pine populations.

Databases

During the year the Codasyl-based data management system IDMS had to be abandoned in favour of the relational system Rapport, now supported by the Edinburgh Regional Computing Centre and through which the limited in-house resources available can be more effectively used. Some minor links in the original network have been sacrificed to provide two relational databases, one concerned with selected trees, families, testing and breeding, the other with orchards, seed stands and commercial seed production. Further stock records of seed, pollen and grafts will be maintained on a microcomputer.

R. FAULKNER, A. M. FLETCHER, G. I. FORREST, J. G. S. GILL, C. J. SAMUEL

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TREE PHYSIOLOGY

Root growth and form

Root anchorage

Techniques have been developed for studying components of root anchorage in relation to tree stability. Sitka spruce trees on a peaty gley soil were pulled by a cable attached to the lower part of the stem, using a winch, the upper part of the tree having been cut off. The applied force was recorded over small measured increments of root-soil displacement. The cable was then relaxed so that the tree returned to its original position, and the pulling process was repeated yielding a series of stress-strain curves. The contributions of the different components of anchorage were assessed sequentially. The roots and soil were cut around the windward perimeter of the root-soil plate, then the 'lee' side roots were cut, and finally all attachment to the roots and soil was broken so that the contribution of the weight of the root-soil system could be determined. Stress-strain relationships were measured at each step. Preliminary results indicate that the importance of the measured components of anchorage lie in the following order: roots and soil on the windward perimeter > weight of root-soil plate > roots forming lee side hinge. The large contribution of the windward perimeter to stability emphasizes the disadvantage of producing a zone of weakness on one side of the tree by making a plough furrow.

During the process of windblow, as the stem is progressively displaced from the vertical, its weight produces a turning moment at the base additional to that caused by pressure of the wind. The contribution of stem weight to the total weight changes in a complex way depending partly on the curvature of the stem, and has been calculated from measurements of the curvature of trees pulled by a rope attached in the crown region. The latter work is also giving information on amount of crown displacement associated with important phases of the uprooting process, e.g. when the soil and roots first begin to break, and at the point of maximum applied force.

M. P. COUTTS

Mycorrhizas

Cuttings

The work on Sitka spruce cuttings continued with two experiments, one to examine the effect on rooting of adding mycorrhizal inoculum at the callus stage, and one attempting to synthesize mycorrhizas on cuttings after rooting. Preliminary results from the former indicated no effect on rooting when plants were assessed on a scale of 0 to 10 for overall rooting density. However, more accurate measurements are being made, and these will be used in the final analysis. In the latter experiment two fungi, *Laccaria proxima* and *Thelephora terrestris* were each added in two different ways; in water and in peat-vermiculite. The inoculated plants formed mycorrhizas with the fungi that were applied, and some of the plots inoculated with *Laccaria* produced fruiting bodies of that fungus. However, untreated control plants also became mycorrhizal, considerably complicating the assessment, which is not yet complete. Further work is in progress with different fungal treatments.

Seedlings

In order to determine the best time for inoculation the ontogeny of mycorrhizal colonization is being studied in Sitka spruce seedlings. In a growth room experiment, no fully-formed mycorrhiza was observed until 35 days after emergence of the radicle, indicating that extremely young seedlings may not be susceptible of mycorrhization. Further detailed examinations will be made on the invasion of fungal hyphae into the plant.

Inoculum of *L. proxima* and *T. terrestris* was obtained from a joint pilot study of commercial production by the University of Surrey and Tate & Lyle p.l.c. Both fungal species induced mycorrhizas on potted Sitka spruce plants, but significant height growth increases were recorded only on sterilized soil. The growth medium for this experiment was a high nutrient nursery soil, as used for the production of seedlings and transplants.

The joint work with the Institute of Terrestrial Ecology (ITE) continued (Report 1982, p.24). Mycorrhizal plants grew significantly better in forest soils than did non-mycorrhizal controls. However, the experiment took place in a greenhouse and it will be necessary to see if similar responses can be obtained under forest conditions.

The effects of short-term inundation on mycorrhizas were examined in an experiment. The seedlings were produced with mycorrhizas of either *Laccaria proxima* or *Paxillus involutus* by staff at ITE, and grown in peat or peat and sand in long plastic tubes. When the tubes were flooded for 24 hours the mycelium of the *Laccaria* was killed, then regrew from the flood-line. In contrast the *Paxillus* hyphae stopped growing for a time but resumed growth later without hyphal dieback.

C. WALKER

Vegetative propagation

Micropropagation

Sitka spruce can be multiplied vegetatively *in vitro* by the subculture of axillary buds and shoots from established juvenile cultures. Extension and axillary bud proliferation occurred on Murashige and Skoog medium in a growth room at 21° with 18 hour days and a light intensity of 10.5 wm^{-2} . Shoot extension and bud proliferation were not promoted by high temperature and high light levels (27° and 49 wm^{-2}), by etiolation or by applied plant growth regulators. Some clones have been maintained in culture for up to two years through eight subcultures without apparent ageing, loss of vigour or a reduction in the rate of bud and shoot proliferation.

Fewer than 1 per cent of the micropropagated shoots rooted *in vitro* on the Murashige and Skoog medium and the level of rooting was not increased by continuous or transient plant growth regulator treatment. Transfer of the shoots, without environmental preconditioning, to a mist propagation unit under non-sterile conditions resulted in a rooting level of 5 per cent after 77 days. Removal of the basal callus formed *in vitro* before insertion of the shoots in the mist unit resulted in rooting levels of 17 per cent and 35 per cent in two rooting trials. Experiments are now underway to refine the micropropagation technique and to increase the levels of rooting in both *in vitro* culture and under non-sterile mist conditions.

Rejuvenation

The work on rejuvenation of Sitka spruce by sequential grafting onto juvenile rootstocks has continued. A test of the rooting potential of cuttings collected from the forest trees at the same time as the initial scions (*Report* 1981, p.29) demonstrated that those from the 45-year-old trees at Durriss had a mean rooting level of 0.9 per cent and those from the 13-year-old trees at Speymouth had 3.9 per cent. A second rooting test of first order lateral shoot cuttings taken in March 1982 from first generation grafts showed that the mean rooting level of the 45-year-old grafted trees had increased to 16.2 per cent and that of the 13-year-old grafted trees to 34.1 per cent. Three hundred and ninety three regrafts from the first generation grafts were made in March 1982 with a success rate of 47 per cent with the 45-year-old scions and 73 per cent with the 13-year-old scions. The number of successful grafts, particularly in some clones of the older trees, was too low to provide material for a rooting test. Two hundred and four regrafts of the second generation grafts were made in February 1983 with an overall success rate of 97 per cent.

A. JOHN

Flower induction

Gibberellin A4/7 applications can stimulate regular and heavy flowering in potted Sitka spruce grafts in a polythene house, provided a heat or drought stress is also applied. The response in the field is more sporadic, though heavy flowering has occurred in good flowering years. In an attempt to achieve a more regular response to GA4/7 application in the field the role of stem girdling was investigated. Sixty trees from 10 clones of mature 8 m tall Sitka spruce grafts at Wauchope (Borders) clone bank were given two overlapping half girdles in April and injected with 0, 100 or 250 mg GA4/7 dissolved in ethanol in June and July. A significant ($P < 0.001$) stimulation occurred with GA4/7, with all clones flowering and mean values of 200 male and 90 female cones per tree (Figure 2). The response to girdling, however, was barely significant, and it appears that the heavy flowering in response to GA4/7 was facilitated by favourable environmental conditions during the inductive period as there was also some flowering in the untreated control trees. Further evidence on the role of girdling comes from an experiment with potted Sitka spruce grafts out of doors; here GA4/7 treatment alone was non-inductive, presumably because the environmental conditions did not stress the plants, and additional girdling did not alter this response. Thus girdling appears not to act as a physiological stress, and does not induce flowering with GA4/7 application in otherwise unfavourable conditions, although it can increase the response once flowering has been triggered.

Two samples of current year Sitka spruce shoots were collected for analysis of endogenous hormones in relation to flower induction. In the first, shoots were collected weekly from April to September from grafts at Wauchope clone bank; shoot elongation was recorded and changes in hormone levels will be related to bud development. In the second, shoots were collected from grafts which were maintained under either non-inductive cool wet conditions or inductive hot dry conditions. Half the plants were sampled and the remainder kept for assessment of flowering. The flowering response relates well to previous experiments; none of the control grafts flowered, but over 60 per cent of the induced trees responded with mean values of 7.8 male and 1.7 female cones per tree.

J. J. PHILIPSON

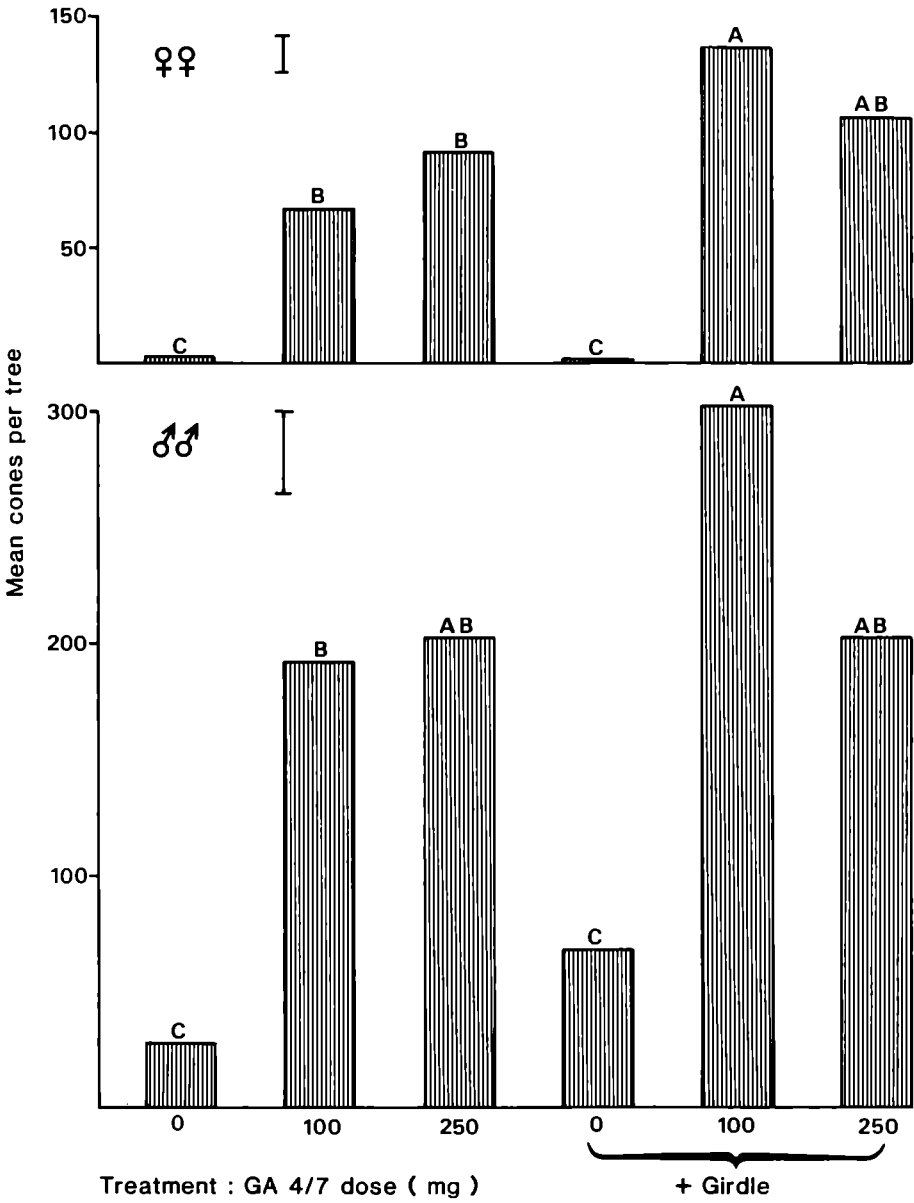


Figure 2. The effect of GA4/7 dose and girdling on male and female flowering in Sitka spruce. The vertical bars represent one standard error; columns with the same letter do not differ significantly at $P < 0.05$.

FOREST PATHOLOGY

Advisory services

The effects of the severe 1981/82 winter on various tree species are described on pp.35–36.

Southern England and Wales

London plane dieback (*Report* 1970, pp.117–8) recurred in 1982; it was concluded that road de-icing salt was the principal cause (Gibbs and Burdekin, 1983).

During summer 1982 many flowering cherries, mainly *Prunus* 'Kanzan', died in England and Wales. Bark infections occurred near the base of limbs during dormancy 1981/2 and spread to the trunk, often girdling it. Isolations made after lesion spread had ceased yielded no pathogen, but de Kam's (1982) work on the association between *Pseudomonas syringae* diseases and low temperatures, and the frequency of such diseases in 1982 following the severe winter (Anon., 1982) suggest this bacterium as a possible cause. Fireblight was very common, notably on *Sorbus aria*.

Between July 1981 and November 1982 damage to thicket and early pole stage Lodgepole pine in England, Wales and on the Isle of Man was investigated. Symptoms ranged from the death of scattered one-year-old shoots to the death of over 30 per cent of dominants and co-dominants. Developing shoots died when inoculated in June 1982 with a then unidentified fungus obtained frequently from dying shoots in the field. Concurrently this same fungus was shown to be responsible for the disease in Scotland and identified as a new species of *Ramichloridium* (Rahman, 1982).

Four whitebeam in a row of 50 planted in 1968 in Cambridgeshire were dying from *Heterobasidion annosum* (*Fomes annosus*) which had spread from infected supporting stakes. *H. annosum* was also seen fruiting on the base of a living 32-year-old *Metasequoia glyptostroboides* in Kent where another infected tree died in 1972 – the first records on *Metasequoia* in Britain.

An 8-year-old Leyland cypress in Hampshire was found dying from *Seiridium* (*Coryneum*) *cardinale*, the first recorded natural infection on this host in Britain (Strouts, 1973).

Basidiocarps of *Perenniporia* (*Fomitopsis*) *fraxineus* were noted on the base of a 30 m London plane in London – again a new record for this country.

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

Scotland and Northern England

In addition to injury attributed directly to the winter cold, a number of infections by facultative pathogens were believed to have originated in tissues injured by the low temperatures; these included *Cryptodiaporthe salicella* associated with cankers on willow and *Potebniamyces coniferarum* causing dieback of young Douglas fir and cankers on a mature *Cedrus deodara*.

The most frequently recorded pathogens were *Armillaria* species and *Heterobasidion annosum* but there was also an unusually high number of cases involving damage by *Botrytis cinerea*. In one such case, dieback of 1981 shoots on Norway spruce Christmas trees had followed infection of buds killed by a late spring frost. Several instances of group killing in large conifers were also investigated following their discovery during surveys for *Dendrocto-*

nus micans. Most of these group deaths occurred in spruce plantations and were caused by the root pathogen *Rhizina undulata*, but two more unusual cases, one in Japanese larch and the other in Sitka spruce, were attributed to lightning injury.

D. B. REDFERN, S. C. GREGORY, J. E. PRATT

Dutch elm disease

A disease of Ceratocystis ulmi

A transmissible disease has been discovered in *C. ulmi*. The factor responsible, termed the d (disease)-factor, is transmitted via hyphal fusion between mycelia. In paired d-infected and healthy cultures, a zone of sunken abnormal mycelium develops in the healthy culture (Plate 5). Sub-cultures from this diseased area are usually considerably weakened in growth and show poor spore viability. Preliminary investigations indicate that the d-factor is transmitted by the conidia (asexual spores) of the fungus but not by the ascospores (sexual spores). Transmission of the d-factor is also impeded by the vegetative incompatibility system of the fungus. The d-factor has a number of features in common with transmissible hypovirulence in *Endothia parasitica*, responsible for remission of Chestnut blight in Europe, and under investigation in North America as a biological control agent of blight. Like transmissible hypovirulence, it may be associated with a dsRNA mycovirus. Its distribution, biological properties and potential in the control of Dutch elm disease are under investigation.

The origin of Dutch elm disease

Efforts are continuing to identify the geographical source of the different strains and races of Dutch elm disease, thought to be in eastern Asia. Two isolates of *C. ulmi* from Tashkent (Uzbekistan, USSR) were found to be of the EAN race of the aggressive strain, the first record of this form of the fungus east of Iran. A single isolate of *C. ulmi* from Kashmir has proved to have unique characteristics. It is unlike either the non-aggressive strain or the EAN and NAN races of the aggressive strain in colony morphology. Its temperature relations are similar to those of the aggressive strain. When inoculated into English elm it behaves like a weakly pathogenic EAN. In fertility (mating) tests it is rejected as a mating partner by all three known strain/races of the fungus. The form of the fungus in the Himalayas, therefore, may be different from those so far identified. Sample surveys of *C. ulmi* in the Himalayas and China are planned.

Future of present epidemics

Part of present research on *C. ulmi* is aimed at assessing the likely future behaviour of the disease. Samples from Holland and Britain show that the frequency of the non-aggressive strain is declining rapidly in the epidemic outbreak areas. The present prognosis is that the non-aggressive strain may be virtually eliminated, and that the aggressive strain may survive to attack the next generation of young elms. Any reduction in disease level is likely to come about through attenuation in pathogenicity of the aggressive strain (EAN and NAN races) itself, possibly as a result of the influence of factors such as the d-factor (see above). The conclusions of this research are presented in detail elsewhere (Brasier, 1983).

C. M. BRASIER



Plate 1: Sweet chestnut coppice at Challock Forest (Kent) (p.7).

J. Evans

(a) Clearfelled area with 15-year-old coppice poles cut to length ready for cleaving into fence palings. *A10410*



(b) Foreground : one-year-old shoots
Mid-ground : freshly cut stumps
Background : 12-year-old coppice. *A10411*

J. Evans



Plate 2: Prototype scariying/ripping plough (p.16). 36166

K. Miller

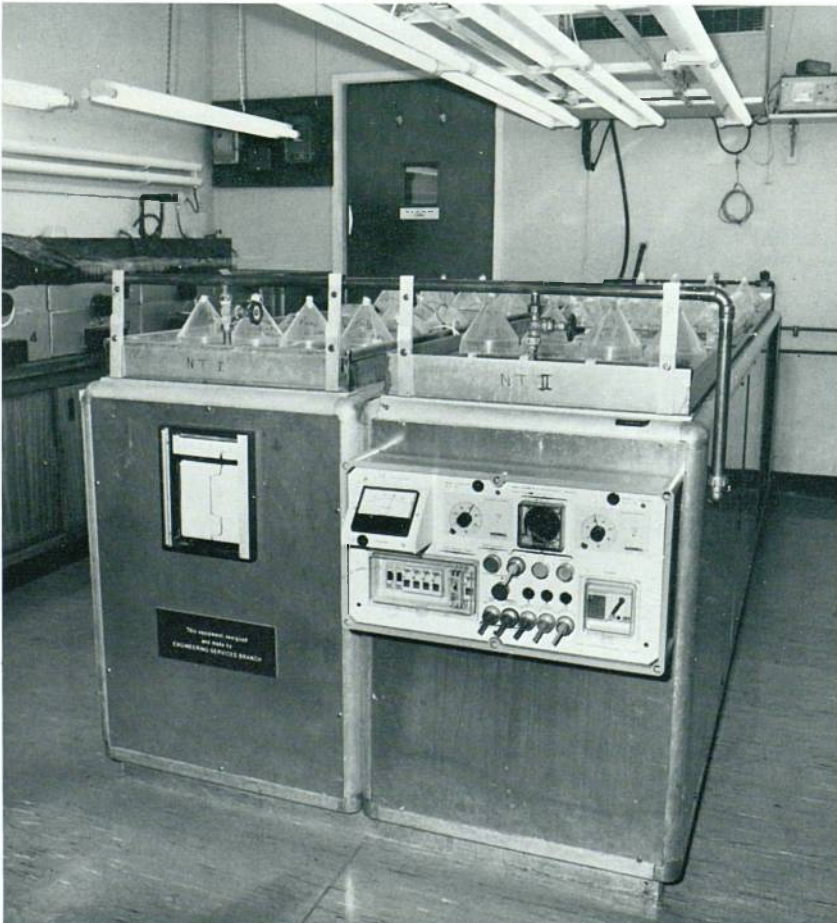


Plate 3: A pair of Jacobsen (Copenhagen) type seed testing units with recently modified control equipment (p.48). B 9113



Plate 4: Synthetic aperture radar (SAR) — X band imagery (3.2 cm wavelength) of Thetford Forest flown in June 1981 during the European SAR 580 experiment. The radar shadow to the north of the restocked areas highlights height differences (p.44).

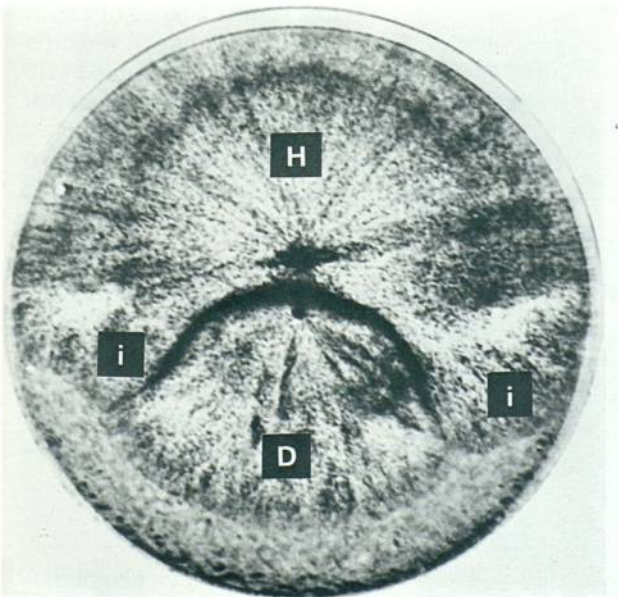


Plate 5: Developing reaction between a d-infected donor isolate (D, below) of *Ceratocystis ulmi* and a healthy recipient isolate (H, above) showing dark sectors of abnormal newly d-infected growth developing on the recipient (i). The white barrage between the two isolates is the vegetative incompatibility reaction (p.32). A10432

C. M. Brasier



Plate 6: Latest version of seat rail camera mount in Cessna FR182. The video camera and monitor are used as a drift sight. The cursor can be rotated to assess drift angle and the Hasselblad camera is then turned about the optical axis to compensate for the difference between aircraft heading and track (p.52). *B9111*

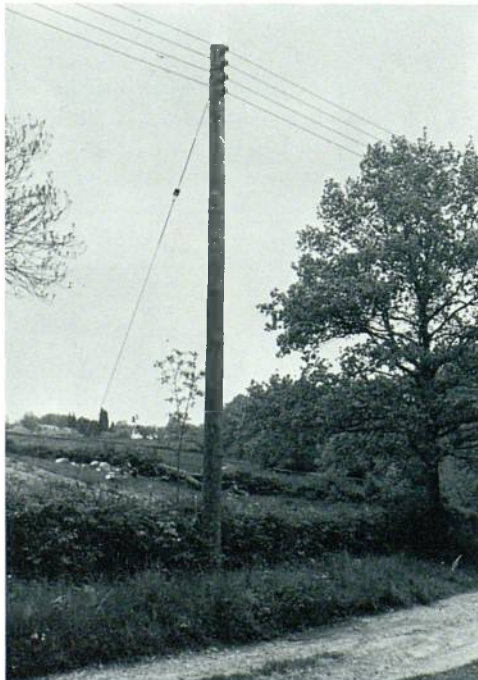


Plate 7: One of a thousand spruce power transmission poles now in service following preservative treatment with copper-chrome-arsenate by a sap displacement process (p.53).
Photograph : *SEEBOARD*

Fungicide injection

Trials with thiabendazole hypophosphite (TBZ) marketed as Ceratotec (*Reports* 1980, p.33 and 1981, p.34) were completed. High volume, low concentration injections arrested the spread of Dutch elm disease within infected trees if treatment was applied before symptoms exceeded 5 per cent of the crown (Greig and Coxwell, 1983). In four years of trials, 84 per cent of treated trees recovered while all but 9 per cent of the controls died. Over half the twig samples showed appreciable residual fungicide one year after treatment. Limited trials indicated that good results could still be achieved if the volume injected was reduced from 20 to 10 litres per 30 cm stem circumference, the concentration of active ingredient being doubled to retain the same dose.

B. J. W. GREIG

Implications of fungicide tolerance

A study of mutants of *Ceratocystis ulmi*, tolerant to the fungicides carbendazim (MBC) and thiabendazole (TBZ), has indicated that they fall into two distinct classes: those that tolerate only very low levels of fungicide (≤ 2 ppm MBC) and those that are resistant to very high levels (> 100 ppm MBC). A tolerant mutant of *C. ulmi* can be injected into a mature elm to cause disease. If such a tree is later used as breeding material by scolytid beetles, the mutant escapes from the xylem and colonizes the breeding galleries of the beetles within the overlying bark. As a result a significant proportion (20–50 per cent) of the young emergent beetles carry fungicide tolerant *C. ulmi*. However, fungicide tolerant isolates of *C. ulmi* have been found to have a slower growth rate, to be less pathogenic and also to be less efficient in saprophytic colonization than their wild type (fungicide susceptible) counterparts. It would appear, therefore, that even if fungicide tolerant isolates of the fungus are transmitted by beetles in the field they are likely to be outcompeted by wild type isolates except when infecting a tree recently treated with fungicide. Since such trees represent an extremely small proportion of the total elm population this will be a very rare event.

J. F. WEBBER

Biological control by Pseudomonas

In 1983, 24 bacteria were screened for antagonism to *C. ulmi* in culture, and nine were selected for trials. Nine 2 m English elm were given preventative injections with each bacterium and inoculated four weeks later with *C. ulmi*. No differences were obtained between disease levels in these trees and in nine control trees which did not receive bacteria.

SHI JIN LIN*, C. M. BRASIER

Armillaria

'*Armillaria mellea*' as formerly understood by forest pathologists in Europe is now known to comprise five genetically distinct species which vary in

*On study leave from the People's Republic of China

pathogenicity and ecology. Work has begun on identifying the species most commonly associated with forest sites in northern Britain and collections have been made from sites where killing has occurred. A number of experiments with isolates of four *Armillaria* species have been carried out using potato tubers as low resistance hosts in order that rapid assessments of pathogenicity might be made. Two isolates of *A. mellea* caused more infection in tubers than two isolates of *A. bulbosa*. This corresponds well with the known behaviour of these isolates towards conifers. However an isolate of *Armillaria* 'species B' caused more tuber infections than was expected from its known low pathogenicity to young conifers.

Two pathogenic isolates of *A. ostoyae* were also tested in several trials. While the overall results showed a high proportion of tubers infected by both isolates, the results of individual experiments were generally inconclusive owing to the consistently low proportion of inocula that produced rhizomorphs during the course of the experiment. Other differences in rhizomorph behaviour of potential significance to the ecology of *Armillaria* species were revealed by the tests. Most notably, the lengths of rhizomorph which became attached to the hosts differed markedly between some isolates. Pathogenic isolates of *A. mellea* and *A. ostoyae* generally achieved infection via shorter lengths of attached rhizomorph than did isolates of *A. bulbosa*.

S. C. GREGORY

Decay in amenity trees

The observation that large wounds on beech and lime trees show a faster callus growth than small wounds (Mercer, 1982) was followed by an experiment designed to test whether the effect was related to size *per se* or to the horizontal extent of the wound. This involved the creation of circular and elliptical stem wounds on young sycamores. After one season's growth, the callusing around elliptical wounds was greater than that around circular wounds to the extent that small elliptical wounds callused more quickly than larger, but less wide, circular wounds. This effect may indicate that width is the controlling factor, perhaps because of the greater diversion of nutrient flow around a wide wound.

The biological control agent *Trichoderma viride* has now persisted well for four years after application to wounds, with very little colonization by basidiomycetes. A commercial preparation of *Trichoderma* spp. (Report 1981, p. 36) gave better results when used in combination with a latex sealant than when used alone.

D. LONSDALE

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INTER-BRANCH REPORT : PATHOLOGY-SILVICULTURE

The cold winter of 1981-1982

In December 1981, temperatures in some places fell below -20°C , and on 10th January 1982 the lowest temperatures ever recorded in Britain (-27.2°C) and in England (-26.1°C) were registered at Braemar (Grampian) and at Newport (Shropshire) respectively. However, winter cold damage to trees depends on the interplay of many factors of which absolute cold is only one; others include the duration of the low temperatures, and the rate, degree and frequency of temperature fluctuations. The winter was remarkable principally for the two short periods of intense cold. However, it may be compared, insofar as damage to established trees was concerned, with rather less cold winters in which other factors were relatively more important.

Permanent effects upon established trees were generally slight, with serious damage being most conspicuous, or most often reported, on species which are well-known to be intolerant of cold. The one unexpected occurrence of any consequence was the death of large numbers of sizeable \times *Cupressocyparis leylandii* in the coldest areas. Apart from this, established evergreen trees suffered various amounts of leaf browning, defoliation and dieback. The most notable species thus affected were *Araucaria araucana*, *Cupressus macrocarpa*, *Cedrus deodara*, *Pinus radiata*, *Pinus muricata*, *Sequoia sempervirens*, *Taxus baccata*, *Eucalyptus* spp., *Ilex aquifolium* and *Quercus ilex*. Recovery has usually been good, but in the coldest districts many sizeable *C. macrocarpa* were killed.

As damage to deciduous trees was not conspicuous until the following growing season it was less obviously an effect of the winter cold and thus caused some alarm. In Shropshire, for example, some *Quercus robur* suffered considerable death of twigs. As in previous cold winters, the lower stem bark of some *Nothofagus procera* and *N. obliqua* was killed but roots usually escaped injury. Girdled trees coppiced vigorously during the 1982 growing season and partially killed stems callused rapidly (Tuley and Gordon, 1979). Many eucalypts died back but these also sprouted from the undamaged roots or from surviving stem portions (Evans, 1980).

In nurseries, little damage was reported on forest species but large numbers of pot-grown ornamentals, including Leyland cypress, were killed (Gilbert, 1982). Planted stock was less affected though *Nothofagus* spp. were often girdled near ground level or killed completely (Report 1979, p.33). In places damage was mitigated by snow cover. The effects of the cold winter on shrubs and nursery stock are described by Gilbert (1982) and Patch and Strouts (1982). Some indirect pathological consequences are mentioned on p.31 of this Report.

R. G. STROUTS, D. PATCH

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FOREST ENTOMOLOGY

Population studies

The Pine beauty moth, Panolis flammea

Population monitoring using pheromone traps continued in 1982. The trap dosage level was similar to that used in 1981, allowing a direct comparison between years for the first time. In general, results showed a significant but not yet threatening rise in the level of populations. The high trap counts prompted pupal surveys at three sites in autumn 1982. At one of these sites the population density (13 pupae m⁻²) was found to be approaching a level at which control is normally required. However, control measures appear not to be justified in 1983. The life-table study begun in 1981 was continued in the study plot at Shin Forest (Highland).

A series of laboratory experiments has indicated that exposure to temperatures below 8°C is required to break diapause. Prolonged exposure to temperatures of 0°C and below increases the time spent in diapause and prolonged exposure to temperatures below -10°C results in increased pupal mortality. *Aphanistes xanthopus*, a pupal parasite of *P. flammea*, appeared to be more resistant to sub-zero temperatures than its hosts.

The size and weight of both male and female pupae are significantly positively correlated and both parameters are significantly correlated with the weight of emerging adult moths. The larger adult females contain more well developed eggs and are more fecund than smaller individuals.

J. T. STOAKLEY, D. A. BARBOUR, S. R. LEATHER

The Pine looper moth, Bupalus piniaria

Populations of *B. piniaria* were sampled (Report 1960, p.37) at a smaller number of units than previously. All but three units showed increases in

population size compared to 1981/82. Some large increases were observed in Scottish forests with Culbin increasing from 3.2 to 14.4 pupae m^{-2} , Roseisle from 2.4 to 16.0 and Tentsmuir, with this year's highest population, increased from 3.2 to 21.2 pupae m^{-2} . In an additional compartment at Tentsmuir, outside the routine sample plots but adjacent to the compartment with the highest mean count, population density reached on average 32.4 m^{-2} with one 0.25 m^{-2} sub-unit yielding 18 pupae.

R. M. BROWN

Dendroctonus micans

The Giant spruce bark beetle *D. micans* Kug. was found for the first time in Britain in August 1982 breeding in a few trees of *Picea sitchensis* on Callow Hill, near Craven Arms (Salop.). Within a few weeks it was subsequently recorded, mainly in *P. abies*, from Lake Vyrnwy in the north to Caerphilly in the south, Dyfi in the west and Wyre and Dean to the east. All these are more or less in the rain-shadow of the Welsh Mountains and are thus subject regularly to an appreciable degree of soil moisture deficit during the growing season. This may be a factor in stand susceptibility to attack. It has proved possible to determine the probable date of initiation of outbreaks by counting the annual rings around occluded brood galleries. By this means, it was established that the epicentre of the infestation was within Mortimer Forest, near Ludlow (Salop.) and that the beetle had first arrived in about 1973, some 9 years before being discovered.

Current research in the Dean, Wyre and on a small private estate at Bwlch-y-Cibau (Powys) has concentrated on the beetle's dispersion pattern and its relative success in *P. abies* and *P. sitchensis*. This information is required both for an appraisal of its aggressiveness and the planning of future surveys. It is evident that the beetle is an ecologically highly 'plastic' species and is able to adapt to a wide range of physiological conditions of the host tree. There is a marked lack of regularity in patterns of behaviour and life cycle and there is therefore little basis for predicting the intensity or timing of future activity. It appears that drought (and thus moisture-stress in the host) is the common predisposing factor to outbreaks.

Whilst the adult beetle has a predilection for forks, stem irregularities, drought-cracks and in particular immediately below branch whorls, it will also breed in roots and stems. A high proportion of attacks are abortive. The adult beetle is able to withstand or escape the heaviest resin-flow but eggs and young larvae may often be drowned. A resident population therefore seems always to be poised to take advantage of reduced resin-flow through drought and stress in the host.

So far in Britain attack has been mostly upon *Picea abies*, and indeed the beetle appears to find this species more attractive than *P. sitchensis* when given the choice of the two together. However, deaths to *P. abies* have occurred only when individual trees have suffered repeated attacks over many years or when attack has been particularly heavy. *P. sitchensis* on the other hand seems to succumb typically within 2 or 3 years.

D. BEVAN

Population ecology of the Beech scale insect, Cryptococcus fagisuga

Within stands of beech, the distribution of *C. fagisuga*-infested trees is characteristically discontinuous, with heavily attacked trees often growing in close proximity to uninfested ones. Host resistance probably accounts for some of the differences but the insects also appear to adapt to an individual host tree and this may reduce their ability to colonize other trees (Wainhouse and Howell, 1983). This has important consequences for the dynamics of beech bark disease. Very little is known about the growth of *C. fagisuga* populations on individual trees and which factors affect establishment and subsequent survival of the dispersive first instar or crawler stage.

In this study in a beech forest in southern England, populations of *C. fagisuga* on three 30-year-old trees with different densities of attack were monitored from 1981 to 1983. Estimates were made of the proportion of crawlers dispersing in the air from host trees and the mortality resulting from larvae being washed from the bark during rainfall. Choice of settling site probably has an important influence on crawler survival and the effect of factors such as previous occupation of sites by *C. fagisuga* colonies, presence of bark flora and physical features of the bark were investigated in a series of artificial inoculation experiments.

A major factor in determining population size was the number of crawlers establishing on the tree rather than post-establishment survival. Rainwater flowing down the bole during the autumn dispersal period and the failure of remaining crawlers to establish appear to be the two major mortality factors. The results of the inoculation experiments indicate a positive relationship between density of previous infestation of sites and crawler survival. This appears to result from an influence of previous feeding on the quality of the site and it has an important influence on the within-tree distribution of *C. fagisuga* infestation.

I. M. YATES.*

Host plant susceptibility*Green spruce aphid, Elatobium abietinum*

A study of the relative resistance of a range of spruce species to *Elatobium abietinum* has continued with a comparison between the aphid's relative growth rate (weight increase in mg per mg body weight per day), and the chemical composition of the foliage of the various spruce species. From this study it seems that the aphid's relative growth rate on pot-grown plants is not limited by the nutrient quality (i.e. amino acids) of the foliage during the plant's dormant period when aphid attack occurs. Analysis of the foliage identified several non-volatile phenolic compounds, including four stilbenes, which occurred in high concentrations in the foliage of the less favoured Asiatic spruces (such as *Picea glehnii*, *P. brachytyla*, *P. smithiana*) but were undetectable in the foliage of the susceptible North American species (*P. sitchensis*, *P. engelmannii*, *P. glauca*). Investigations are continuing on the relationship between secondary compounds in spruce and the feeding preferences of *E. abietinum* (see also Inter-Branch report on pp.40-41).

J. F. A. NICHOLS

* Post graduate research student seconded from Imperial College, London.

The Beech scale insect, Cryptococcus fagisuga

Beech trees in several forests in southern England were artificially inoculated with beech scale larvae in small cages attached to the bole of trees. Five trees moderately infested with beech scale were used as hosts and as donors of larvae for inoculation. Each tree was inoculated with larvae derived from each of the the five trees. In general, results showed that survival to the fecund adult stage was greatest when larvae were reinoculated on to their original host than in cases of cross-inoculation, suggesting that some populations have become adapted to their original host tree. The presence of these reproductively isolated, adapted populations may partly explain the discontinuous distribution of infested trees within forests. This phenomenon has important consequences, both for the dynamics of beech bark disease and the management of infested stands.

D. WAINHOUSE

Tree aphids

Many of the broadleaved trees currently used in amenity plantings suffer from aphid attack and may be the overwintering hosts of pest species. The Bird cherry *Prunus padus* has been widely planted but is only weakly colonized by aphids in the south of England where it is introduced. However, host plant choice and over-wintering survival of aphids appears to vary greatly in different locations. A phenological study is being made on a new collection of British and foreign provenances and cultivars of *P. padus* at Alice Holt to compare their relative susceptibility. Egg populations of the Bird cherry-oat aphid *Rhopalosiphum padi*, the apple-grass aphid *R. insertum*, the birch aphid *Euceraaphis punctipennis*, and the sycamore aphid *Drepanosiphum platanoidis*, were monitored throughout the winter on Bird cherry, hawthorn, birch and sycamore respectively, in the Edinburgh area. All aphid species showed egg mortalities of 60–80 per cent.

C. I. CARTER, S. R. LEATHER

Biological control*The Pine beauty moth, Panolis flammea*

The major sex-attractant pheromone of *P. flammea* ((z)-9-tetradecenyl acetate) formulated as microcapsules by ICI was applied to an isolated Lodgepole pine plantation at Rumster Forest (Highland) with the object of disrupting mating. Applications by helicopter were made at the beginning of the flight period in mid-March. In the treated area pheromone traps, baited at four dosage levels, gave markedly reduced catches compared with a corresponding series of traps in an untreated control area. However, reductions in trap catches were not maintained to the end of the flight period in early May.

J. T. STOAKLEY, O. T. JONES*, J. C. LISK*

*Chemical Entomology Unit, Southampton University

Chemical control

The Pine weevil, Hylobius abietis

Experiments, to run from spring 1982 until autumn 1983, were established to test the effectiveness, phytotoxicity and persistence of some of the newer and more persistent pyrethroid insecticides as alternatives to gamma HCH for protecting young transplants against pine weevil. Treatments with Cypermethrin, Permethrin and Deltamethrin prior to planting were made on Sitka spruce in Scotland and Corsican pine in the south of England. Experiments on the phytotoxicity and persistence of the insecticides were made in the absence of weevil attack. Preliminary results show that Cypermethrin was neither more toxic to weevils nor less phytotoxic than gamma HCH but it may be the best of the three pyrethroids tested. Some further experiments are being established to compare Cypermethrin and gamma HCH in more detail.

J. T. STOKLEY. C. J. KING. S. G. HERITAGE

Advisory services

Forestry Commission staff sent 91 enquiries to Alice Holt and 67 to the Northern Research Station. The number of private enquiries received was 201 at Alice Holt and 32 at the Northern Research Station.

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

Green spruce aphid *Elatobium abietinum* and secondary chemicals in spruce foliage

Following initial work on the major nutrients likely to account for differential performance in the Green spruce aphid on Sitka spruce foliage, additional studies have begun to determine the secondary compounds within a wide range of spruce species that are related to susceptibility and attack. Those species containing a more diverse range of secondary compounds, such as *P. glehnii*, are less susceptible than *P. sitchensis* to attack, suggesting that genetic differences between species are important. As the Green spruce aphid is capable of selecting out *Picea* spp. from a mixed planting of conifers it suggests that a volatile component may, in addition, be associated as an attractant. Methods have been developed to feed this aphid on an artificial diet by which it is intended to test aphid performance against the secondary

compounds that are present in foliage. One or two volatile sesquiterpene hydrocarbons have been shown to be negatively correlated with aphid performance.

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

WILDLIFE MANAGEMENT

Management of deer, squirrels and other mammals

Information on red deer density, reproduction, mortality and movements has been used to model the dynamics of forest red deer populations. Many populations exhibit a post-winter calf recruitment rate approaching 60 calves per 100 hinds (after approximately 10 per cent calf mortality) compared with about 35 calves per 100 hinds (after 30–35 per cent calf mortality) in some open range populations. The mis-classification of calves as hinds when recording information on culled deer can produce an important source of error in the data required for population modelling. The use of such population data and a study of the dynamics of an isolated population of red deer in Galloway, south-west Scotland, suggest an increase from about 1,700 in 1965 to about 3,500 deer in 1982. This represents a density of about eight deer per 100 hectares, a low figure compared with many other forest areas. Monitoring the use by deer of re-seeded deer control glades is continuing. The collection of data on reproductive performance of roe deer populations has been extended to investigate regional differences in productivity and condition. Similar research has been initiated for woodland sika deer. The problems of managing muntjac deer, particularly females, have been reviewed as these animals are becoming increasingly important in lowland restocking areas.

One new live trap for squirrels was tested during the year; the Clap Trap. This caught more birds and did not catch as many squirrels as the Legg Single with which it was compared. It proved extremely difficult to kill squirrels in it humanely and to release other animals undamaged. A Trip Trap did not catch voles and mice as effectively as the Longworth live-catch small mammal trap with which it was compared, largely because the door release mechanism did not operate effectively in damp conditions.

B. A. MAYLE, H. W. PEPPER, P. R. RATCLIFFE, J. J. ROWE, L. A. TEE

Bird studies

Research on the ecology of the raptor community in extensive upland spruce forests has concentrated on species present in short rotation crops during the establishment of the second rotation. With goshawks, attention to nesting areas has resulted in an increase in the number of young produced which, with low adult mortality, is the main factor leading to steady population growth. The density, population dynamics and interactions of tawny owls with other forest raptors are being studied in two areas where nest-boxes have been successfully used. The main prey of tawny owls is the field vole and the relationship between this prey population and tawny owl reproduction is also being investigated.

S. J. PETTY

Damage assessment and evaluation

The fourth quinquennial mammal/bird/damage questionnaire has been issued to Forestry Commission forests for completion in 1983. This requires that the presence and absence of a variety of mammals and birds, and the occurrence of damage by any species, be noted. A survey of grey squirrel damage to broadleaved trees in privately owned woodlands in southern Britain has been initiated. This is being compared with a similar survey being carried out in state forests. The damage is being assessed using the nearest neighbour assessment method now recommended for accurate, objective assessment of vertebrate damage (Melville *et al.*, 1983). Simulated browsing of side shoots of Norway spruce for four growing seasons appears to have depressed height growth although stem diameter has not been affected. Equally heavily damaged trees in tree guards are showing the same height growth as control undamaged and unprotected trees.

H. W. PEPPER, J. J. ROWE, L. A. TEE

Chemical and mechanical repellants

Development of high tensile netting following last year's tests is now showing some promise in producing a lightweight alternative to the B-grade netting fence. Samples of a strong plastic mesh netting have shown considerable potential for deer, stock and possibly rabbit fencing. A lightweight netting developed for roe deer damage prevention in upland spruce restocking areas has successfully protected plantations for three years without evidence of deterioration from rusting. Joint work on rabbit fencing with the Ministry of Agriculture has shown that there is still no significant difference in the effectiveness of mild steel, spring steel and electric/plastic mesh netting in preventing damage to farm crops from rabbits harboured in woodland. Electrified plastic mesh netting appears to be protecting restocked areas in east England from rabbits and deer more effectively than conventional electrified strands and to require less maintenance. There is a suggestion from work in the rabbit research enclosure that 0.75 m may be as effective as the conventional 0.9 m height fencing. One rabbit repellant, Negastop, has been tested but is not as effective as Aaprotect. The Spanish Comb has been further developed using plastic mesh tubes on the leading shoots only of Norway spruce to prevent roe browsing. There are still problems in keeping the tube on the shoot.

H. W. PEPPER, L. A. TEE

General

Discussions on a number of research projects have taken place with colleagues in the Department of the Environment, Institute of Terrestrial Ecology, Ministry of Agriculture, Ministry of Defence, Red Deer Commission, Royal Society for Protection of Birds and a number of Universities. Wildlife interests are represented on the Institute of Biology Environment Division and Deer Liaison Committees and fencing interests on the British Standards Institute Committee on Wire Fences. Advisory work involved more than 600 enquiries varying from fencing out camels to using bat boxes: as usual the majority were concerned with grey squirrels, deer and rabbits.

J. J. ROWE

REFERENCE

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

FIELD SURVEYS BRANCH**CENSUS**

Field work for the Census of Woodland and Trees 1979–82 was completed by November 1982 and summarization of the results continues apace. Reports for counties in south-east England and for the South-East England Conservancy were published by the end of the year under report. Further analyses required for the proposed Great Britain report have been determined.

W. T. WATERS

FIELD SURVEYS AND APPLICATIONS

Although field teams were involved in census work in Wales and Scotland until the latter part of 1982 the main interruption to routine survey work was caused by the need to update plantation data for plantation sales. In addition, a higher than average number of sample plots remeasurements was required to compensate for a shortfall in this work during the previous year.

Routine surveys and forest inventory

Survey and inventory of some 48,000 hectares in 26 forests were completed during the year, which is well up on last year's performance. Twelve forests were completed to the provisional mapping stage.

Plantation sales

Special plantation assessments were conducted in 25 blocks (involving some 7,500 hectares) to check data. A further 12 blocks covering some 4,000 hectares in forests currently included in the routine survey programme were given special priority for sales purposes.

Growing stock database and production forecasts

The quinquennial production and valuation forecasts were completed by the end of May. Special consequential project work continued until the latter end of the year. A number of special project forecasts were carried out, mainly for Harvesting and Marketing Division, involving marketing catchment studies. The forecasting programmes were tested on private woodlands data assembled in the course of the census and this work continues.

The growing stock database is used increasingly by field staff for routine management purposes. It is under continuous development to enhance its value for this purpose in close consultation with the field and with other Divisions. Logica's Rapport database management system is used for speedy data access. Micro Rapport for use on microcomputers has been under test using plantation data from South-East England and North Wales Conservancies in order to gain experience in data handling for local managers' needs.

Remote sensing developments

Studies continue on the potential of remotely sensed data, other than aerial photography, for surveys, forest inventory and monitoring change. Satellite data using Landsat tapes are under trial in co-operation with RAE Farnborough, the Department of the Environment, the Macaulay Institute for Soil Research, Aberdeen, the National College of Agricultural Engineering, Silsoe and Grampian Regional Council. Results for lowland woodland are encouraging but there are problems in the uplands where it is apparent that details of the terrain and site characteristics held in computer form will be required for their proper solution. Work on this aspect of the subject is proceeding with RAE.

Synthetic aperture radar (SAR 580) tapes, derived from an airborne active radar system tested over sites in Britain as part of a European experiment, and carried out during 1981, were available for analysis during the year (Plate 4). A good deal of woodland and isolated tree information has been obtained from these but the uplands again produce complications due to high land relief radar shadow which requires further investigation.

The Forestry Commission co-operated with the RAE in the Agrispine project, testing fast transfers of Landsat III multispectral scanner data following a satellite pass. Although, because of cloud, only two usable scenes of Thetford were obtained, it was evident that there is some potential in the system for uses such as windthrow monitoring. Preparatory work on data that simulates the outputs from late and future generation satellites such as the Landsat Thematic Mapper and the French SPOT system, with their greatly improved resolution, shows considerable promise.

SITE SURVEYS

Work has continued with four specialist surveyors in Scotland concentrating on surveys of plantable land reserves, but some surveys designed to assist with forest landscaping and associated activities, and with further assessments of windblow risk, were carried out in established plantations. Survey teams in England and Wales collected outline site information in the course of crop assessment.

G. M. L. LOCKE, A. I. D. HORNE

MENSURATION

With the close co-operation of Statistics Branch, the growing stock (sample plot) database is now mounted in computer store and final editing, checking and summary production was in hand at the end of the year. The database will be used to create a new generation of yield models over the next few years.

Fifteen sample plots were abandoned during the year and a thinning experiment on the Island of Mull was destroyed by windthrow. Four plots were established in the maximum amelioration experiment of Site Studies (South) Branch at Wareham (Dorset) in fast growing Western hemlock, Sitka spruce, Corsican pine and Douglas Fir. A summary of the measurements collected at the time of first thinning in February 1983 is presented in Table 7.

Stem analyses from trees in a P35 spacing experiment were made during the year. These data will be used to test an individual tree competition model. Data from two thinning experiments in Sitka spruce suggest that thinning

TABLE 7

SUMMARY MEASUREMENTS OF 13-YEAR-OLD SAMPLE PLOTS IN THE MAXIMUM AMELIORATION EXPERIMENT AT WAREHAM FOREST

Species	Yield class (general) (local)		Main crop after thinning					Thinnings			
			No. of trees	Top height (m)	Mean dbh (cm)	Basal area (m ²)	Volume to 7 cm (m ³)	No. of trees	Mean dbh (cm)	Basal area (m ²)	Volume to 7 cm (m ³)
Sitka spruce	34	32	1833	11.7	14.9	32.0	153	676	13.2	9.2	40
Western hemlock	30	31	1784	12.3	15.0	31.4	146	754	12.2	8.9	40
Corsican pine	22	24	1892	8.9	13.1	25.4	91	656	13.2	8.9	32
Douglas fir	20	24	1637	9.9	13.3	22.8	87	843	11.2	8.3	28

cycles of between two and six years have little influence on volume production or on diameter size distributions. This has important management implications since extended thinning cycles imply a greater yield at each thinning and hence more economical working. Crown diameter/breast height diameter/volume relationships were studied for individual trees on behalf of the Census Section. These data were used to prepare air photo volume tables which provided a check on volume estimates derived from data collected during the ground measurements of non-woodland trees.

Tariff analyses were carried out on 220 data sets submitted by field managers. The tariff check and assortment forecasting services have been widely used by field staff and further developments to improve their value continue. A local volume table for low value Japanese larch for Wales entered by mean diameter and mean height was constructed as a service to local management. Estimates of taper rates and volumes of telegraph poles were made for east Scotland.

A number of electronic data capture devices were tested in the field and the Epson HX20 has been found very suitable for sample plot and general field survey use.

T. J. D. ROLLINSON

DRAWING OFFICE

The development of an automated mapping system based on computer digitizing from aerial photos as well as from forest maps is in preparation and was well advanced by the end of the year. This step represents a major advance in technique that will speed up map preparation and provide a valuable locational key to the growing stock database. The Air Survey Section has been the main activity point for this project.

The backlog of final stock and forest maps remains substantial but some slight progress in its reduction has been made since the census tasks were completed. Map preparation for plantation sales has absorbed some 40 per cent of the Drawing Office resources.

K. F. BALL

WORK STUDY

Forest management

Method studies have concentrated on plant production from seed collection procedures to mechanized nursery techniques. Initial evaluation of a Summit precision seed sower has been carried out in conjunction with Silviculture (North) Branch with promising results, and two Zijlstra and Bolhuis plant lifters have been installed in an operational role.

A major survey of plant handling procedures, from nursery to planting site, has identified the main problem areas and will result in a number of multidisciplinary investigations in the coming year. An investigation into the efficiency of aerial application of fertilisers has been started, initially to identify the factors affecting distribution patterns, and subsequently for the development of improved monitoring procedures. Following the successful introduction of ground based application of foam for fire fighting, work continues in the development of systems for aerial application by helicopter of both foam barriers and water bombing. This work is at an early stage, but shows potential in high risk areas where equipment can be made readily available.

The monitoring and development of new herbicide applicators is maintained as new products come on to the market. Use of the modified veterinary drench gun for medium volume application is being extended following initial trials, and the use of direct applicators, both hand-held and tractor-mounted, offers numerous advantages in that there is no spray drift, no calibration is necessary and only minimal protective clothing is required.

A new development for inter-row weeding and cleaning has been achieved following the evaluation and introduction of the small Holder C500 tractor with GMI flail scrubcutter. This combination of a narrow reverse control tractor with scrubcutter attachment will play an important part in cleaning scrub areas in southern England.

Harvesting and marketing

With the continuing move from pole length working towards shortwood harvesting, the Branch has been heavily committed in installing organized felling methods for forwarder extraction, working closely with local management and Education and Training Branch.

In steep cable crane terrain a new, safer, organized felling system has been developed in an attempt to increase output in such terrain. Significant increases both in felling and extraction have been achieved in trials. The new technique remains to be evaluated in normal field conditions. Rigging procedures in cable crane extraction are being improved by the introduction of lightweight polyester strops and other items of rigging. Safer crane operation is being achieved on the tractor mounted cranes by installing a live skyline as opposed to the fixed skyline, a shift which also allows the use of proprietary pay-off carriages.

Mechanized harvesting continues to play an important part in the evaluation programme. During the year two grapple processors, the Skogsjan and Lokomo 750, were evaluated. Both achieved the high outputs predicted, but the delimiting quality overall was inferior to that obtained using the compact type processors, and because of the high capital cost the machines

are not regarded as competitive at this stage. Evaluation of the Gremo thinnings harvester is continuing with a switch to the new SK35 harvester head. This shows more promise than the original TH25 and, subject to its reliability in regular use, the combination should significantly reduce costs of harvesting first thinnings.

Short trials of four new forwarders have been carried out during the year. Two of these are variants of existing models; the Lokomo 919T eight wheeled version of the Lokomo 919 shows enhanced performance over very soft ground, and the Bruunett 678F turbocharged forwarder with a more powerful engine gives enhanced climbing ability. The Kockums 83-35 introduced into the country showed only marginal advantage over the Bruunett as a pulpwood and small sawlog carrier. The British built BP Shuttle ST7 prototype shows promise for use in smaller scale operations, but requires further development.

The testing of chainsaws and ancillary equipment has continued with regular monitoring of new models and testing for approval of suitable saws, continuing the move towards lighter weight saws which have a good power to weight ratio. New chains and bars which are safer and give less kick-back are introduced as they become available.

Work measurement

Work measurement continues to play an important part in the work programme, monitoring and updating the data for all operations. The new electronic data collector (*Report 1982, p.38*) has now been introduced for general use allowing data to be collected in the field on the hand held microcomputer terminal, which has a full alpha-numeric keyboard plus timer. The data are transmitted by telephone direct to the Prime computer. This has allowed a considerable time saving in processing the data.

The locally developed Autoreport system of time study analysis is employed for processing the data. This allows a uniform system of data analysis and reporting, which is essential for the pooling of data collected on a national basis. The computer output is in four distinct parts, giving: (i) transcription of the electronically collected study data, (ii) collation of the study data, including a listing of basic time values, (iii) regression and graph on major variables, and (iv) individual element regressions and tests on selected variables. From these data the project leader is able to construct statistically validated standard time tables which have a national application, but which also incorporate modifications which can be applied in local conditions.

Safety

Close liaison has been maintained with the Safety Officer in all development work including liaison with other Branches and with the Health and Safety Executive.

Communication of results

Situation report papers were presented to the HGTAC Technical Sub-Committee; these update progress on projects within forest management and harvesting and marketing activities. Seven technical notes were prepared and issued to the Technical Sub-Committee for publication.

INSTRUMENTATION

Further improvements have been made to the temperature control of the experimental seed germination tanks (Plate 3). Temperature control is fully solid-state using Nobel series EV proportional controllers; this type of controller is also used in the greenhouses and incubators. Short circuit and earth leakage protection is provided by circuit breakers and the relevant British and international standards for ingress protection have been rigorously applied. Any failed component can be replaced within 10 minutes.

Mechanical projects included an improved pattern microtome carriage for easier preparation of sections of hard woody materials, pliers and tags for insertion in squirrel ears, cutting heads for foliage sampling sets, and water-level dipsticks with engraved scales. The tree ring measuring instrument has been modified so that it is now on-line to the Prime computer enabling data to be stored directly. Work is in hand to provide simultaneous three-way communication between the computer, tree ring encoder and visual display unit.

R. CARNELL

STATISTICS AND COMPUTING

Data preparation and computing

Alice Holt

The increase of data processing for the Census of Woodlands made it necessary to bring forward the installation of a 160 megabyte fixed disk on the Prime 550 computer. At the end of the year a second magnetic tape drive was added to facilitate archiving and the taking of security copies of data files. Another half megabyte of memory was also added to cope with the increased general demand.

The use, for experimental data, of field data-capture devices has grown steadily and this has allowed the data-entry staff to tackle the keying of collections of data and references which have previously been regarded as non-urgent. Literature references and A. Mitchell's records of large specimen trees are examples.

Two software products from Sheffield University, their Pascal compiler and their version of the Prime editor, have been tried and found to be distinct improvements on the standard products.

Northern Research Station

A large Summagraphics digitizing pad was purchased and is currently controlled by a Tektronix 4051 console. Lack of an operating system is causing duplication of work so, when technical problems of incompatible IEEE interfaces are overcome, control will be taken over by a Sirius microcomputer running UCSD Pascal. Meanwhile, the recently acquired Sirius has been programmed as a reserve data preparation machine.

The Minitab statistical package and the Edinburgh University Easygraph package have proved convenient for inexperienced users and for a multitude of enquiries of the simpler sort. Networking became practical during the year. For example, remote use of the SAS statistical package on the Cambridge University IBM, with output returning to print at the Station, is now common.

Much data preparation and editing effort has gone into the mounting of a Rapport database which will eventually index all the Division's field experiments. Forms for over 1,500 experiments have so far been keyed. About 200 of these are being used as a pilot database during program development. The organizational work for this project is substantial.

Statistical service

As usual, advice on experiment design and analysis and interpretation of results continued to take up much of the statisticians' time.

Alice Holt

There has been a remarkable increase in the number of data-sets submitted for analysis. To speed the transfer of data to the computer, basic assessment forms have been redesigned and more use is being made of hand-held terminals (MSI, Microfin and Telxon).

Storage of silvicultural data on the Prime and their retrieval for analysis has been made much easier by the establishment of a special area of disk store for all current silviculture experiments. Data, programs and other information relating to each experiment are stored in its own directory. CPL programs have been written to transfer (to and from the user area), rename, search for and compare files, reporting as appropriate. The programs are initiated by simple commands. This system has allowed the data analysis for many more experiments to progress more quickly.

Analysis of data from the Clocaenog experiment on the effects of spacing on timber strength characteristics has continued and data from a second experiment at Brechfa are being added as they become available.

The fieldwork for the sample survey of chainsaw operators designed last year for the Civil Service Medical Advisory Service was completed during the year and analysis is in progress.

Linear and multiple regression programs were written in the Basic programming language for use on a microcomputer at the South Wales conservancy office.

Northern Research Station

Programs for Genetics Branch were developed to facilitate design and analysis of efficient alpha-designs in five replications. The standard program to analyse progeny trials was considerably improved.

Programming service

Alice Holt

The programs for the production of the Census of Woodland results were finalized for both the county and conservancy standard report formats.

Attention has now been turned to the production of supplementary analyses for other geographical domains and special aspects of the data-bank.

The two main routines which produce forecasts of wood production from the growing stock database at the University Computing Company (UCC) were transferred to, and are now running on the Prime. Use of the Rapport database system has increased during the year in terms both of the number of independent databases mounted for various purposes and in the extent to which these are used for research projects. As one example, a program was written to load data from the growing stock database at UCC as a Rapport database on the Prime and a deer damage modelling package based on forest structure was written using forecasting system concepts and run on the Rapport growing stock database.

The asynchronous communications program for the Microfin hand-held terminal was further developed to cope with the passage of information in both directions and is now working satisfactorily subject to vagaries of the telephone system in some parts of the country. An attempt to write a similar program for the Telxon T787 terminal has so far failed because of the difficulty of keeping the Prime and the Telxon in step.

Northern Research Station

Some old heavily used programs have been modernized by providing for interactive use, taking advantage of more modern compilers, planting diagnostic messages and by improving documentation and the comments in the source code. Organization of program libraries has also been improved. Plans were made to transfer a large, complex genetics database from IDMS (a Codasyl database system) to the Rapport system. Assistance was given to Silviculture (North) Branch to process very large files of automatically logged anemometer readings and to analyse calibration runs of equipment.

Various programs were developed for digitizer applications. As examples, one for Site Studies (North) Branch enters data from charts recording runoff over weirs, one for Work Study Branch analyses distance between flight paths of a helicopter spreading fertiliser and one for Physiology Branch traces angles of emerging roots back through cortical tissue to the xylem node.

Methods and models

Alice Holt

An estimation program for the nuclear home-range model (Don and Rennolls, 1983) has been extended to yield the variance-covariance matrix of parameter estimates and to facilitate the use of likelihood ratio tests to compare alternative models. Also, two families of non-parametric bivariate density estimators have been devised which make use of the Dirichlet tessellation corresponding to a plane point set. They are under evaluation and have been applied to squirrel activity data. A method of fitting a family of multi-linear functions to a set of data trajectories, with correlated errors, has been developed and implemented in an interactive program for up to three regressors. Theoretical derivations of standard errors of population estimators based upon capture-recapture data and Poisson and hypergeometric models, have been completed.

Northern Research Station

Recently described methods for coping with extra-binomial variation in proportions with widely different denominators (Williams, 1982) were used to analyse rooting percentage data from a designed experiment. While the methods as described involve generalized linear modelling, equivalent methods, with non-iterative model fitting based on the arcsine transformation, give similar results with consistently less computing time.

R. S. HOWELL, D. H. STEWART

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INTER-BRANCH PROJECT: STATISTICS — MENSURATION

Modelling forest growth

The objective is to develop an integrated biometric model of forest growth which may be used to forecast the response of forest stand variables and distributions to a wide range of silvicultural treatments, including those where few data exist. Optimal management regimes will also be investigated.

At the stand level, families of non-linear functions are being fitted to distance-independent data from the sample plot database, the functions being chosen so that their parameters may be related to environmental factors and treatments. These fitted functions are then taken as constraints in the fitting of a process based, individual tree, distance dependent competition/growth model. It is intended that this will predict the evolution of stand-variable distributions such as those represented in stand and stock tables. Additional features are being built into this model to reflect the effects and interactions of treatments and environmental factors. These include a generalized nutrient cycling submodel and access to data-banks giving the spatial distribution of major environmental and climatological variables.

Data on the joint growth of variables such as height, diameter and volume in mapped stands are being collected. Temporary sample plots will be needed to determine a tree's response to asymmetric canopy structure, such as arises after a line thinning.

A model-bank, to include the major forest growth models, is being built in order to provide a reference for judging the progress of this forest growth modelling project.

K. RENNOLLS, T. J. D. ROLLINSON

WOOD UTILISATION

The Joint Project with the Electricity Council (*Report* 1982, p.44) continued with the further development of the sap displacement process for the treatment of power transmission poles with copper-chrome-arsenate preservative. So far, about 1,000 poles of Corsican pine, Sitka spruce and Norway spruce have been treated by this method, and several of each species have been put into service for low voltage lines in Sussex (Plate 7).

The trials showed that, although 'hot-logging' is essential for the successful treatment of the spruces, delay in delivery appears to be of no consequence in Corsican pine. It was also found that sap-displacement treatment can be effected without applying suction to the butt end of the pole, that is, it is only necessary to apply pressure to poles within a treatment cylinder; however, provision must be made for the sap displaced by the preservative solution to drain away from the butt ends of the poles.

Norway and Sitka spruce poles which were ponded at three different sites (Dean, Dyfnant and Loch Tay) throughout the summer of 1981, and were allowed to dry out during the following year, were cut into halves. One half was treated under pressure with creosote, the other with copper-chrome-arsenate. The results for copper-chrome-arsenate have indicated a three-fold improvement in both the depth of penetration and salt retention. For creosote a similar increase in penetration together with a doubling of retention was observed. In view of the advantages of the sap-displacement method over ponding, no further work on this technique is contemplated.

Sampling for further destructive testing of Norway and Sitka spruce poles was undertaken at three sites.

J. R. AARON

COMMUNICATIONS RESEARCH INFORMATION

Library

A total of 159 books were acquired and a further eight journal subscriptions were taken out. Loan requests satisfied totalled 11,737 including 1,476 items borrowed from other libraries and 1,658 photocopied articles.

Information services

The domestic database of literature references continues to grow and online searches can go back to 1972 using the Oxford Decimal System of Classification for Forestry (ODC). The Forest Research Experiment Database (FRED), which gives details of forestry and arboricultural research projects, is being revised. The updated version should be completed by mid-1983 and will include a large addition of non-F.C. research work.

O. N. BLATCHFORD

PHOTOGRAPHY

Aerial photography

Flying to provide photographs for the census ended early in the period. Despite unseasonable weather a considerable number and area of targets were photographed. The aircraft is now to be retained to meet Field Survey Branch and Conservancy requirements. These are increasing as the number of air survey companies available for contract work declines and the current photographic cover available from Ordnance Survey and other sources steadily decreases. Though the Hasselblad camera with Zeiss lenses is adequate for our smaller up-date targets, it is not a survey camera. To help minimize the variables in plotting, the equipment (bodies, lenses, magazines) has been calibrated by the Department of Photogrammetry, University College London, to establish the origin of symmetry for each combination. The new camera mount and drift sight were tested and, after slight modification, give every indication of being highly successful (Plate 6). The needs of the census were met exclusively with black and white photography. Though monochrome will continue to predominate, a limited amount of colour will be called for; as far as possible this will be processed in-house.

Photographic and illustrator service

The main innovation has been the production of screened positives for printing by offset-litho. Now that the majority of the census requirements have been met work can be concentrated on up-dating parts of the collection. Again, most of the illustrator's time was taken up in work for publications.

I. A. ANDERSON

PUBLICATIONS

A distinction has been drawn between technical publications and popular publications or local forest guides. Dr E. J. Parker was appointed Technical Publications Officer in May 1982.

Reports

61st Annual Report and Accounts of the Forestry Commission 1980-81 (£8)
Report on Forest Research 1982 (£5.70)

Booklet

No 32 Thinning Control in British Woodlands, by R. T. Bradley (metric revision by G. J. Hamilton and J. M. Christie) 2nd impression (£1.50)

Bulletins

No 58 Conifer Lachnids, by C. I. Carter and N. R. Maslen (£3.50)
No 59 Seed Manual for Ornamental Trees and Shrubs, by A. G. Gordon (£5)

Forest Records

- No 110 Conifer Bark — Its Properties and Uses (revision), by J. R. Aaron (£1.40)
 No 123 Reptiles and Amphibians in Woodlands, by I. F. Spellerberg (£1.40)
 No 124 The Fallow Deer, by N. G. and D. I. Chapman (£1.35)

Leaflets

- No 80 Forest Fire Fighting with Foam, by M. J. R. Ingoldby and R. O. Smith (£1.35)
 No. 81 Aid Tools for Timber Harvesting, by D. J. Howard and F. W. Hayes (£1.50)

Research and Development Paper

- No 130 Notes on the Behaviour of Roe Deer (*Capreolus capreolus* L.) at Chedington, Dorset, 1970–80, by A. L. Johnson (£3)

Occasional Paper

- No 13 Broadleaves in Britain: Addresses, Supplementary Papers and Discussions, edited by A. J. Grayson (£1.50)

E. J. PARKER

OTHER HEADQUARTERS DIVISIONS PLANNING AND ECONOMICS

Private sector planting

An econometric analysis of the determinants of private sector planting has been undertaken. Two approaches to the explanation of private sector planting have been considered, one relating forest planting to returns in competing land uses and the other to returns on alternative assets. Some evidence of a connection between forest planting and both capital markets and competing land uses has been obtained, but the analysis has not produced an acceptable model of private sector planting. In particular, it has not been possible to identify satisfactorily the role of tax and grant instruments for the promotion of planting. The influence of real interest rates is also unclear in the analysis. The importance of non-quantifiable variables, such as confidence in the stability of tax arrangements, is a possible explanation of the rather poor performance of some of the theoretically appropriate variables in explaining private sector planting in the period.

A. J. MOON

Work done for the Forestry Commission by Other Agencies

FOREST SOILS

NUTRITION AND FOREST SOILS

By H. G. MILLER

The Macaulay Institute for Soil Research, Aberdeen

During the year under review the study of hydrogen ion cycles in heathland and in forests of various species (Scots pine of two ages, Sitka spruce, larch and birch) at Glen Tanar (Grampian) came to a close, while a new investigation on the input, retention and loss of elements in a forested catchment was initiated at Balquhider, Strathyre Forest (Central). This new work is being undertaken in conjunction with the Forestry Commission and the Institute of Hydrology.

A theoretical study of the nutrient cycle in short-rotation energy forests of alder species has been carried out for the International Energy Agency (Miller, 1983a). Models of the cycles of major elements based on published literature show that the ideas on nutrient cycling previously developed for evergreen pine also apply to this broadleaved species. Indeed, in fast growing alder, potassium demands on the soil were maximum as early as age 2 years, but by age 4 had fallen by 80 per cent and had become less than the likely rate of potassium input from the atmosphere. Management implications of recent developments in our understanding of nutrient cycling are being explored by the development of a simulation model of the nitrogen control of growth in pine.

A report has also been prepared for the International Energy Agency on the diagnosis of nutrient deficiencies, and on the prescription of fertiliser applications, in wood energy plantations (Miller, 1983b).

Large fluxes of hydrogen ions are ubiquitous in any plant-soil system and in view of this there is some controversy as to the significance of the further acidity introduced to a forest in polluted rainfall. An examination has been made, therefore, of the relative importance and likely consequences of introduced and internally generated hydrogen ions in forests using data from recent studies in both Scotland and Sweden. It was concluded that rainwater acidity is the more likely to lead to streamwater acidification whilst root uptake will primarily acidify the soil (Nilsson, Miller and Miller, 1982). It has subsequently been noted that, whereas spruce canopies generally neutralize a significant proportion of the rainwater acidity, in polluted regions this process can fail in late winter, thus accentuating the episodicity of the hydrogen ion input to the soil (Miller, 1983c).

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EFFECT OF HEAVY METALS ON SOUTH WALES FORESTS

by K. W. BURTON and E. MORGAN

Department of Science, The Polytechnic of Wales, Pontypridd

This three year project, which is nearing completion, has revealed several potentially very important aspects of the effect of heavy metal pollution upon tree growth in South Wales forests. Laboratory and greenhouse based experiments using Sitka spruce seedlings have been carried out and the results related to field situations.

Water culture techniques were used to determine the upper critical tissue concentrations of various heavy metals. Concentrations of several of these heavy metals in foliar and soil samples at South Wales forest sites were found to be higher than at a control site in mid Wales (Tywi Forest). A comparison of the foliar levels with the upper critical levels, the lowest level at which growth is affected by the heavy metals, showed that several sites were at risk to heavy metal toxicity (Burton *et al.*, 1983).

Interactive effects, studied by means of factorial experiments with combinations of heavy metals, have shown that the balance of nutrients may easily be disturbed. These experiments have revealed few synergistic or antagonistic effects upon growth. Greenhouse experiments, where seedlings were grown in peat with added copper, cadmium and lead, were carried out to model more closely the field situation. As well as effects by these metals upon growth, mycorrhizal associations were also disturbed at fairly low heavy metal levels in the soil indicating how plant growth may be affected even when the heavy metals have not been taken up into the roots.

The work was supported by the award of a SERC/CASE studentship.

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NITROGEN TRANSFORMATIONS IN FOREST SOILS

By R. REES

Department of Soil Science, University of Aberdeen

Northern coniferous forests are frequently under nitrogen stress because a large proportion of the nitrogen capital is immobilized in surface organic layers of the soil. Foliar analyses are used by the Forestry Commission to assess nitrogen status in Sitka spruce. However, whilst this may reflect nitrogen status at the time of sampling, it is not an effective method for predicting growth responses to added nitrogen. In this project, alternative methods of determining these responses are being sought. Two sites have been chosen for intensive field work and the following measurements are to be made: (1) litter bag incubations designed to follow decomposition to carbon, nitrogen and lignin, (2) litter fall and litter depth measurements, studying seasonal variation in the nitrogen content of litter fall, (3) foliar analysis to determine nitrogen status, (4) decomposition of cellulose discs as a measure of microbial activity, (5) measurements of pH, soluble NO_3^- , NH_4^+ and soluble carbon in litter from different depths, and (6) measurements of tree growth. To make the results more broadly applicable it is hoped to correlate litter fall with tree growth at other sites in north-east Scotland during the summer of 1983.

HYDROLOGY

EFFECT OF UPLAND AFFORESTATION ON WATER RESOURCES

By J. R. BLACKIE

Institute of Hydrology, Crowmarsh Gifford, Wallingford, Oxon

Forests and streamflow

Since the initiation of the Scottish study (*Report* 1982, pp.48–49) the main streamflow structures have been installed on the Monachyle (heather, bracken, grass) and Kirkton (40 per cent plantation forests) catchments at Balquhider, Strathyre Forest (Central) and data collection is under way. The third and final structure, in the upper Monachyle above the area due to be planted in 1985, will be completed in June 1983.

Results from wet-surface weighing lysimeter studies of the interception of rainfall by heather have been published and an analysis of historical data from Law's lysimeter at Stocks reservoir has shown the results to be compatible. Preliminary work on snow interception by spruce was carried out on a site at the Queen's Forest, Aviemore (Highland) in the the winter of 1982/83. This will be extended by the use of gamma-ray attenuation equipment under development at Hafren Forest, Plynlimon (Powys), in the 1983/84 winter. Soil moisture depletion studies of transpiration from spruce and heather are proceeding.

Forests and water quality

A pair of small catchments on Llanbrynmair Moor (Powys) were instrumented in 1982 and monitoring of water quality, sediment movement and the hydrological variables was initiated prior to ploughing and planting of 30 per cent of one of the catchments in 1983. Following detailed discussions, sediment and chemical monitoring of two instrumented sub-catchments within the Institute of Hydrology's Severn catchment on Plynlimon was initiated in April 1983, prior to the start of clearfelling operations in one of them (the Hore sub-catchment) in 1984. In addition to catchment scale sediment, nutrient and trace element studies, the Institute of Terrestrial Ecology, Bangor, will be conducting a series of plot scale process studies of the chemical effects of felling on this site.

EFFECTS OF FERTILISERS ON THE WATER QUALITY OF FOREST STREAMS

By J. H. N. GARLAND

Water Research Centre, Stevenage

In order to extend knowledge of water quality effects of forestry, work has begun at Glenorchy Forest (Strathclyde). The research has three objectives: (1) to measure the amounts of nutrients, particularly phosphorus, that enter forest streams before, during and after aerial application of fertilisers, (2) to determine the effects of this increased nutrient load on the water quality of upland reservoirs and more particularly to predict the quantities and species of algae most likely to occur, and (3) to assess the implications of the results of these studies for water treatment requirements in areas at risk. Glenorchy was chosen as being representative of the areas in Scotland where the majority of the Forestry Commission's future planting will take place. Two sub-catchments planted mainly with Sitka spruce were chosen. The unfertilised Ghail (850 ha, mainly planted 1971 and 1972) will act as a control for the fertilised Daimh (470 ha, planted 1971).

Stream gauging weirs, water level recorders and automatic water samplers have been installed on the stream leaving each sub-catchment and information on rain falling on the catchments is collected with a recording rain gauge. Stream samples are preserved in the sampler and then collected for subsequent analysis for total, total soluble and soluble reactive phosphorus. At monthly intervals manually taken samples are analysed for other determinands. The phosphorus content of rain water is also regularly determined. Aerial application of phosphorus and potassium fertilisers to the Daimh sub-catchment took place in July 1982 and coincident with the first rain thereafter in August a significant increase was observed in the mass of phosphorus transported by the stream. Concentrations have subsequently remained higher than in the pre-fertilisation period.

SILVICULTURE

FACTORS INFLUENCING ACCELERATED GROWTH OF
YOUNG TREES IN PLASTIC TUBE SHELTERS

By ELIZABETH RENDLE

Horticulture Department, Wye College

This project commenced during the year with a literature review and with the raising of young oak under glass and continuous illumination to provide material for experimentation. An experiment has been planned involving the use of corrugated polypropylene tubes, continuous light and hormone application, to study their effects on the growth in height, leaf area, leaf number, branch number and stem diameter of oak. Comparisons between trees grown in the field and in the glasshouse will also be made. Studies of environmental factors (temperature, light, humidity, CO₂) which affect the trees as they grow will also be carried out periodically throughout the year. Unfortunately continuous recording of these environmental parameters is not possible.

This is intended to be a preliminary study which should form the basis of more detailed studies of microclimate and the physiology of the oak under tube shelter conditions. Such studies require more control of the inherent variation in oak material and it is therefore intended to use cuttings.

HERBICIDES

HERBICIDE EVALUATION FOR FORESTRY USES

By I. D. CLIPSHAM and W. G. RICHARDSON

*Agricultural Research Council Weed Research Organization, Begbroke Hill,
Yarnton, Oxford**Weed control in seedbeds*

The activity of soil acting herbicides sometimes varies with soil pH. Most forest nurseries are on acid soils and may be given dressings of lime, so these variations may be of practical interest. Some results from a preliminary pot experiment are given in Table 8. The soil used was from acid heathland at Fleet (Hampshire) and the pH was adjusted by addition of ground limestone. In the absence of herbicide, liming improved the growth of Douglas fir, but not Japanese larch. Diphenamid tended to be more phytotoxic to both species at pH 6.0. Napropamide had more effect on Douglas fir at low pH but in contrast Japanese larch was more susceptible at high pH.

In another programme, attention is being given to the use of herbicides as seed dressings, applied to resistant crop species. In a preliminary experiment diphenamid applied in this way to conifer seeds had little effect on their germination and growth but provided good control of annual meadow grass and chickweed sown simultaneously with the crop.

TABLE 8

WEIGHT (g) OF SEEDLINGS PER POT TWO MONTHS AFTER SOWING

Treatment	Douglas Fir		Japanese larch	
	pH 3.6	pH 6.0	pH 3.6	pH 6.0
No herbicide	0.44	0.70	0.97	0.58
10 kg ai/ha diphenamid	0.51	0.41	0.56	0.46
4 kg ai/ha napropamide	0.27	0.46	0.82	0.33

Weed control in transplant lines and young plantations

The oil-surfactant mixture (*Report* 1982, pp. 49–50) applied with hexazinone against *Rhododendron ponticum* was tested as an additive for propyzamide. At 1 kg ai/ha this herbicide had no useful effect against *Molinia caerulea*. However, addition of 10 per cent of the 1:1:4 v/v Agral/Ethylan D252/paraffin mixture greatly increased the effect of 1 kg ai/ha propyzamide applied to *Holcus mollis* in spring and *Calamagrostis epigejos* in summer. It did not enhance the effect of the herbicide against two woody species, Japanese larch and Silver birch.

In a continuation of our study with ¹⁴C labelled hexazinone, the inclusion of paraffin in the mixture is found to be unnecessary. A simple 1:1 v/v mixture of the two surfactants Agral and Ethylan D252 is found to be at least as effective as the three component product (*Report* 1982, pp. 49–50).

TREE PHYSIOLOGY

RAPID VEGETATIVE PROPAGATION OF SILVER BIRCH AND SCOTS PINE

By A. CAMERON

Department of Forestry, University of Aberdeen

Single-internode cuttings excised from Silver birch seedlings (first year of growth) rooted and survived planting with a high level of success; shoot growth of rooted cuttings was orthotropic. In contrast, identical cuttings excised from older plants rooted and survived planting with a low level of success and shoot growth of rooted cuttings was severely plagiotropic. These phenomena were the consequence of ageing. Rejuvenation, however, is generally thought to occur in adventitious shoots near the base of a tree. Single-internode cuttings obtained from adventitious shoots with expressed juvenile (seedling) morphology were found to be comparable with cuttings derived from seedlings in respect of number rooting, rate of rooting and number of roots per cutting. However, shoot growth of cuttings derived from adventitious shoots was significantly plagiotropic indicating that only partial rejuvenation occurs. A straight stem is an essential characteristic of timber trees so a current programme of vegetative propagation must use seedlings as source plants. The successful vegetative propagation of Scots pine by cuttings

also depends upon the use of seedlings as source plants. By shearing seedlings, which induced fascicular shoots to develop, an average of ten cuttings were produced from a single seedling.

Tissue culture has been successful in propagating Silver birch and hundreds of rooted plants can be produced from a single seedling in a few weeks. Tissue culture could have a great impact in propagating this species. Tissue culture of Scots pine, through the culture of seed embryos, has been less successful with about ten unrooted shoots being produced from each embryo. Large-scale vegetative propagation of Silver birch and Scots pine is feasible if seedlings are used as source plants. Using seedlings derived from controlled crosses may be one method of achieving this and these plants possess desirable characteristics, so justifying their propagation.

INDUCTION OF CHANGES IN PHYSIOLOGICAL AGE OF SITKA SPRUCE BY GRAFTING

By M. J. STEELE

Department of Botany, University of Edinburgh

The juvenile, non-flowering phase in Sitka spruce commonly lasts 20 to 40 years and this long period is a major drawback in breeding programmes. Many methods (grafting, temperature control, chemical treatment, etc.) have been employed to shorten the juvenile period of woody plants. Flower induction in Sitka spruce, however, has been limited to material considered already to be sexually mature.

The grafting of seedling scions into the crowns of sexually mature trees has been claimed both to shorten and lengthen the juvenile period. But in most cases the only index employed has been the flowering or otherwise of the scion. Differences between juvenile and adult stages, however, are seen not only in flowering behaviour but in various other characteristics such as rooting ability of cuttings, leaf morphology and anatomy. The present investigation aims to develop quantitative indices that adequately reflect the gradual changes in the physiological age of Sitka spruce and to use the indices in assessing any changes in physiological age induced as a result of grafting juvenile scions into the crowns of mature rootstocks. Of the 160 homografts and 50 autografts made in the field at Glentress forest (Borders) in 1982, 50 per cent and 80 per cent survived respectively. Further grafting took place at Wauchope clone bank in May 1983.

Morphological, anatomical and physiological characteristics are being examined in apical lateral branches of Sitka spruce of different chronological ages at Glentress and at Kershope Forest (Cumbria) to develop the indices. Results to date have been encouraging; of especial interest is the difference in ability of needles to form callus *in vitro*.

ORGANIC ACID COMPOSITION OF *CALLUNA* HEATHLAND SOIL WITH SPECIAL REFERENCE TO PHYTO- AND FUNGITOXICITY

By M. A. F. JALAL and D. J. READ
Botany Department, University of Sheffield

The well known antagonism between *Calluna* and spruce which leads to spruce check may arise in part from soil toxicity. Qualitative and quantitative analyses of the content of potentially toxic 'free' organic acids of *Calluna* and spruce dominated soils have been carried out. A number of phenolic and simple fatty acid compounds of potentially high phytotoxicity have been isolated from both soils and identified by gas chromatographic and gas chromatographic—mass spectrometric methods. Amongst these the aromatic acids o-hydroxybenzoic (salicylic), p-methoxybenzoic and benzoic acid are reported for the first time in 'free' form in the soil, as are the fatty acids octanoic (caprylic) and decanoic (capric) acid. These short chain (C8 and C10) acids are known to have particularly strong phytotoxic properties. Nonanoic (pelargonic) acid was also extracted and identified. In addition to being phytotoxic this compound is known to have strong fungitoxic properties.

Levels of aromatic and aliphatic acids in both *Calluna* and spruce soils followed a seasonal pattern with maximum levels of both classes of compound being found in summer months and the highest quantities being found in *Calluna* soil. Fatty acid yields were generally higher than those of the aromatics and were particularly high in the *Calluna* Ah horizon where they reached 6 mg/100 g soil (\equiv 0.14 mM) in May and June. Collective and individual levels of both classes of compound in summer were higher than those which have previously been shown to produce considerable phytotoxicity in seedling bioassays. Fungitoxicity would be expected at these levels of nonanoic acid. It is considered likely that these compounds are produced by microbial degradation of ericaceous plant residues which are rich in phenols and lipids and that summer peak levels arise because temperature and redox conditions are favourable for microbial activity at this time. The possible role of these compounds in spruce check is being investigated in spruce seedling bioassays using a range of concentrations, mixtures and pH levels.

EFFECTIVENESS OF MYCORRHIZAL INOCULA ON *PINUS CONTORTA*

By P. D. DONNELLY
Botany Department, University of Sheffield

It is now widely accepted that many tree species benefit when in biotrophic symbiosis with mycorrhizal fungi. The primary reason for the enhanced growth responses observed is the increase in the nutrient and water absorbing efficiency of the association, although research has shown that the fungi can also deter root pathogens, protect seedlings from root toxins and promote seedling growth by production of growth regulators. It is still not fully

understood, however, to what extent the fungal symbionts differ in their effectiveness as mycorrhizal partners; work carried out so far has mostly been confined to pot experiments in growth rooms and glasshouses.

In this project we are synthesizing mycorrhizas on *Pinus contorta* using a variety of known mycorrhizal fungi. Once the extent and nature of the mycorrhizal development has been determined the plants are transferred to the field and replanted on a peat site at Moffat Forest (Borders) and a brown-earth site at Glentress Forest (Borders). Sequential harvests of whole plants are being taken and changes in the nature and extent of the mycorrhizal development and the effect of the different mycorrhizal types on plant survival, growth and nutrient composition are being assessed. In preliminary harvests after 3 and 6 months some significant differences have been recorded between the effects of the fungal symbionts, and even between strains of the same symbiont.

FOREST ZOOLOGY LONG-HAIRED FALLOW DEER

By R. H. SMITH and ELIZABETH JOHNSON

Department of Zoology, University of Reading

Five out of six crosses set up in enclosures in Mortimer Forest (Salop) in September 1981 produced fawns in summer 1982, although unfortunately one fawn died for reasons unknown before being found and classified as long or short-haired. In a New Forest (Hampshire) enclosure two fawns were caught and identified as long-haired in autumn 1982. None of the crosses gave a definite result in the sense of confirming or denying that long hair is genetically dominant (Smith, 1982). More data have been collected on the effects of inbreeding in fallow deer and will be published elsewhere. Two numerical errors occurred in the Table in Smith and Johnson (*Report* 1982, p.52); the inbreeding coefficients of the fawns L35 and L37 should have read 0.125 and 0.25 respectively. These values arise because the parents of L35 (L22 and L24) shared the same father (L11), and the parents of L37 (L22 and L26) were full sibs.

REFERENCE

- SMITH, R. H. (1982). Genetics and population genetics of the unique long-haired variety of fallow deer (*Dama dama*). In *Proceedings of the International Conference on Gene Reserves*, Debrecen Hungary, 6-9 September 1982. (5 pp.).

ECOLOGY OF RED AND ROE DEER IN A SCOTTISH COMMERCIAL SITKA SPRUCE FOREST

By M. HINGE

Department of Zoology, Aberdeen University

The aim of this project is to ascertain how two sympatric deer species, red and roe, interact and use the resources available to each in a second rotation Sitka forest. Since the start of this study in October 1981, 30 roe and six red deer have been marked individually, including some with radio collars. Using radio triangulation to locate animals without disturbance, data are being collected to show monthly home range fluctuations and movement within an area. By monitoring and recording the radio signals from each collar through 24 hours, information on the periodicity and length of bouts of activity is being accumulated.

Throughout the hind and doe cull in 1982/83 rumen samples were collected for botanical and chemical analysis to establish how important *Calluna* is to each species. Using dung clearance plots to sample different *Calluna* communities it is hoped to show changes in usage reflected in the dietary changes throughout the year. Early analyses suggest that while both species of deer increase their usage of *Calluna/Vaccinium* communities between autumn and early winter, red show increased usage of *Calluna/Agrostis* but roe show a decrease. The study is also looking at the characteristics of each major habitat type; assessing the diversity of plant species, cover and shelter from weather and insect attack.

PROTECTIVE ROLE OF ESSENTIAL OILS IN CONIFERS AGAINST DEER DAMAGE

By S. ELLIOTT

Department of Forestry and Natural Resources, Edinburgh University

Attempts to reduce deer damage to conifer plantations by fencing or population control are expensive and not always effective. Recently, therefore, the possibility of exploiting the conifers' natural defence mechanisms against deer damage has been considered. One such defence mechanism may be the production by conifers of essential oils rich in terpenes. Some of these compounds are thought to inhibit the activity of rumen microbes upon which deer are dependent to carry out digestion. The objectives of this project are threefold: (1) to investigate the response of rumen microbes to pine and spruce foliage and to isolated terpene components of their essential oils, (2) to assess the influence of terpenes on food selection by deer, and (3) to monitor changes in the production of terpenes by Sitka spruce seedlings in response to browsing.

In 1982 an artificial rumen (RUSITEC) was constructed (Czerkawski, 1977) and digestibility trials were carried out on diets containing varying proportions of dried hay and fresh chopped conifer needles. Rumen liquor was obtained either from a fistulated black-faced ewe or from a roe deer doe shot in a plantation of Sitka spruce. Sheep rumen microbes were slightly stimulated by Sitka spruce needles but were inhibited by Lodgepole pine needles with increasing severity as the proportion of Lodgepole pine needles in the diet rose. Roe deer rumen microbes appeared to be slightly inhibited upon initial exposure to diets of 40 per cent Lodgepole pine needles or 40 per cent Sitka spruce needles and 60 per cent hay but seemed able to adapt within 11–12 days to overcome any inhibitory effects.

The project is funded jointly by NERC, Edinburgh University and the Forestry Commission.

REFERENCE

- CZERKAWSKI, J. W. (1977). Design and development of a long-term rumen simulation technique — Rusitec. *British Journal of Nutrition* **38**, 371–374.

FOREST RODENT POPULATIONS

By J. GURNELL

Department of Zoology, Westfield College, University of London

Long-term studies on the dynamics of forest rodents at Alice Holt Forest (Hampshire) continue (*Report* 1981, pp. 61–2). These studies have demonstrated the importance of tree seed food for overwintering survival and spring litter production of grey squirrels, and its effect on the size of the population the following summer. Good seed years are unpredictable and in the main oak wood study area the acorn crop has failed during the last four years (1979–1982). The survival and fecundity of squirrels trapped in the oak wood varied markedly between those four years (Table 9) and alternative winter food supplies would therefore appear to be critical. Although this is a sound conclusion from the present studies it must be further qualified. Firstly, there are a few large beech and Sweet chestnut trees in the oak wood and an understorey of hazel. An input of seed food from these trees may influence the condition and survival of the squirrels, especially during early winter. This is believed to have been the case in 1982. Secondly, in 1979 and 1980 Knee (unpublished data) showed that 35–40 per cent of the squirrels regularly moved between the oak wood and neighbouring habitats which included mature conifer plantations. Consequently seed supplies in these neighbouring areas may mask any direct relationship between squirrel dynamics and food supply in the oak wood. Furthermore, temperature and rainfall will affect these relationships and the poor survival figures for 1981 to 1982 (Table 9) were undoubtedly influenced by the bad weather which occurred during December 1981.

Such factors similarly influence the mice and vole populations living on the forest floor although the scale of movement involved is naturally smaller than in squirrels. Knee has found that many mice and voles regularly moved in and

out of the oak wood and that roads and tracks reduced but did not stop such movements. In general the distribution of mice and voles within the oak wood and between the oak wood and neighbouring habitats was fairly even when overall numbers were high but became more patchy when numbers were low. Of interest is that body weight and survival of wood mice in an adjacent Norway spruce plantation were higher than in the oak wood but fewer females were captured there and juvenile recruitment was low. A series of studies on the energetics of mice, voles and squirrels by Knee has now been completed and has yielded data on food consumption and digestive efficiencies for reproductive, non-reproductive and young animals under different temperature regimes and at different times of the year (*Report 1981*, pp. 61–2).

TABLE 9
NUMBERS, SURVIVAL AND THE RECRUITMENT OF SPRING YOUNG FOR GREY SQUIRRELS TRAPPED IN AN
OAKWOOD AT ALICE HOLT FOREST

Year	Acorn crop	No. trapped in summer		Per cent surviving to following summer		Litter production the following spring
		Adults	Spring-born juveniles	Adults	Spring-born juveniles	
1979	Fail	36	49	36	29	No
1980	Fail	26	0	45	—	Yes
1981	Fail	53	24	25	4	No
1982	Fail	22	0	36*	—	Yes

*survival estimated only to April 1983

BEHAVIOUR OF SAND LIZARDS IN RELATION TO FOREST MANAGEMENT

By I. F. SPELLERBERG and S. WRIGHT

Department of Biology, University of Southampton

Field work during 1982 was largely concerned with assessing the distribution of Sand lizards (*Lacerta agilis*) within their habitat in relation to the vegetation and the light climate of an area. The habitats studies were those along ride verges and also those within compartments. Extensive searches of ride verges during 1982 revealed the importance of these areas as habitat for the Sand lizard. Evidence of successful breeding was found along considerable stretches of ride edge, including areas where the adjacent plantation, while still retaining some vegetation, would not be usable in its own right.

The preliminary analysis of comparisons of the habitat with which lizards are associated within a compartment with that around random points within the same area has been completed. Significant differences were found between 'lizard' and 'random' points for: vegetation height and structure ($P < 0.001$), percentage cover of *Calluna vulgaris* and percentage cover of open ground ($P < 0.01$), and openness of canopy and number of daylight hours received ($P < 0.05$). It is interesting that the most significant differences are

found for characteristics of the vegetation rather than of the light climate, and that those differences found for the vegetation are in agreement with the results of House and Spellerberg (1983).

A system of using small radio transmitters (weighing approximately 1.5 g) was successfully developed during 1982. These were used only on adult animals weighing more than 10 g and were used for seven day periods. It was possible to gain information on lizard movement in relation to weather conditions and to season. Work in 1982 was mainly carried out within compartments whereas in 1983 the emphasis will be on usage of ride verge and adjacent plantation habitats.

REFERENCE

HOUSE, S. M. and SPELLERBERG, I. F. (1983). Ecology and conservation of the Sand lizard (*Lacerta agilis* L.): Habitat in southern England. *Journal of Applied Ecology* 20 (2), 417-437.

RECREATION

EVALUATING THE EFFECTIVENESS OF VISITOR
CENTRE DISPLAYS

By T. LEE

Department of Psychology, University of Surrey

In 1979 work was commissioned on the subject of visitor reaction to the various interpretive techniques: flatwork models, audio-visual aids, etc., used in Forestry Commission visitor centres. The objectives were to assess the effectiveness of these techniques in promoting the understanding and enjoyment of forestry by visitors and to devise assessment techniques for forest staff to use. An evaluation package was devised which comprised: a visitor centre questionnaire which explored in detail visitor responses to displays (this was supplemented by a mapping technique to record visitor movements through the centre and the time spent looking at displays); a forest use questionnaire to explore how the visitor intended to use the forest and the role of the visitor centre in influencing this; a postal questionnaire (which summarized the main questions in the other questionnaires) to sample visitors who were not available for interview.

The package was devised during 1979/80 based on six centres and piloted at one centre during 1980. In 1981, between July and October, the full package was used at five centres and the visitor centre questionnaire at a further seven. Results were analysed by computer at Surrey University in 1982 and discussed with staff involved in visitor centre management. The results indicate that the package is a useful and practical means of assessing the effectiveness of displays and suggesting improvements. Valuable demographic data about visitors using visitor centres and forests have also been obtained. It is intended that a report on the visitor centre evaluation package and the results obtained will be published in due course.

TIMBER UTILISATION

JOINT RESEARCH PROGRAMME ON BRITISH-GROWN
TIMBER

By T. HARDING

*Princes Risborough Laboratory, Building Research Establishment,
Department of the Environment**The effect of spacing on stress-graded yields of Sitka spruce*

Work to examine the effects of planting distance on yields of structural grade timber (*Report 1982*, pp. 62–3) has continued. Some thirty trees were taken from plots at Clocaenog Forest (Clwyd) where Sitka spruce was planted in 1935 at 0.9, 1.4, 1.8 and 2.4 m and thereafter left unthinned. When converted to structural sawnwood, volume yields increased at the wider spacings but this was associated with a marked decrease in the proportion of the timber meeting acceptable levels of structural performance. As this interaction between overall yield and the proportion acceptable for structural use is a matter of great importance in an economic assessment of the effects of planting distance, it is being tested further using a somewhat larger number of trees from Brechfa Forest (Dyfed) where Sitka spruce was planted in 1935 at the same four spacings and also left unthinned.

Wood properties of Nothofagus timber

Wood studies to examine the potential uses for British-grown *Nothofagus* timber have been initiated using 50-year-old trees of *N. procera* and *N. obliqua*. Preliminary observations suggest that *N. procera* has the more attractive though lighter weight wood, but also that the timber of both species is prone to split, initially in the log and later on conversion and drying.

Conversion of British-grown timber

The computer controlled conversion aid developed at the Princes Risborough Laboratory and code-named LOCAS (Laser Optimiser and Cant Alignment System) has now been fully developed as a laboratory prototype system and has been tested, proved and demonstrated to the sawmilling industry in the sawmill of Lampeter Timber and Trading Co., cutting timber for the pallet market. Following the construction and installation of the hydraulic cant positioning system a series of intensively monitored production runs has been undertaken. Paired sets of data have been derived which compare the conversion yields of known batches of logs obtained with and without LOCAS control. The results show an average increase of 7.5 per cent in the amount of main sawn product and an overall increase of 5 per cent in the total amount of sawn timber produced at the Lampeter sawmill.

APPENDIX I

Publications by Forestry Commission Staff

Priced publications issued by the Forestry Commission are available from Her Majesty's Stationery Office at addresses shown on the back cover.

AARON, J. R. (1982). *Conifer bark: its properties and uses*. Forestry Commission Forest Record 110 (2nd ed.).

Possible uses for bark are considered in the light of development work undertaken by the Forestry Commission on extractives during the 1950s and, more recently, on various horticultural applications. The latter has become a commercial reality and a number of organizations are now supplying bark to both professional and amateur growers throughout Britain. The preparation of bark for horticultural use to ensure the removal of harmful volatiles is covered in some detail. Mention is also made of the use of bark for equestrian purposes, and in the manufacture of building blocks.

BALDWIN, E. (1983). 2, 4-D damage to Sitka spruce. *Scottish Forestry* 37 (1), 36–38.

2, 4-D applied by ultra low volume spraying in July 1977 for *Calluna* control caused serious leader distortion in a 5-year-old Sitka spruce crop. The damage highlighted the possible risk if Sitka spruce leaders have not 'hardened-off' prior to such treatment.

BEVAN, D. and KING, C. J. (1983). *Dendroctonus micans* Kug. — a new pest of spruce in UK. *Commonwealth Forestry Review* 62 (1), 41–51.

Dendroctonus micans Kug, has become established in the United Kingdom. The article outlines the insect's global distribution and its recent spread. Healthy spruce (*Picea*) as well as those already damaged may be chosen for attack. Behavioural differences between the species and others of the family result from the absence of an aggregation pheromone in the adult. Infected trees should be felled, the bark should be removed with exposed areas being sprayed. Biological control should be investigated using the predator *Rhizophagus grandis* Gyll. Stress in the tree resulting from perennial growing season soil moisture deficit is suggested as prerequisite to beetle establishment, and drought as a precursor to outbreak.

BIGGIN, P. (1982). Chapter 16. Weed control in forest nurseries and forests. In *Weed control handbook: Principles*, ed. Roberts, H. A., British Crop Protection Council, 416–427 (7th ed.).

Weed control in forest nursery seedbeds and transplant lines is discussed, emphasizing the role of management as well as herbicide use. Management is again emphasized in a discussion of forest weeding before and after planting. Principles are given for weeding poplar plantations and willow beds as well as for scrub clearance and chemical thinning of conifers. Application methods for herbicides used in forest weeding and the factors influencing choice of method are described.

BINNS, W. O. (1982). Reclaiming mineral workings for forestry. *Span* 25 (2), 74–76.

All reclamation is difficult and, though trees are tough and undemanding, success will come more easily if limiting factors are recognized and dealt with. These are: inadequate slopes, compaction, and nitrogen deficiency. Ridges 30 m wide with 5° slopes deep-cultivated across with winged tines deal with the physical factors. Nitrogen is ineffectively used by trees until established; alternatively nitrogen-fixing herbs and shrubs may be used to build up the nitrogen capital. Only uncompetitive, low-maintenance grasses such as Common bent and Crested dogstail should be used. On the poorest spoils 50 per cent of alders should be used.

BINNS, W. O. (1982). Restoration of mineral workings to forestry: treatment of surface workings. *Mineral Planning* 13 (December), 18–23.

Surface mineral workings are often more easily reclaimed for forestry than for agriculture because of infertility and difficult textures. Modern restoration usually produces compaction but techniques of ridge-forming and deep cultivation with winged tines have been developed to deal

with physical problems. Nitrogen, often deficient, should be used with care until trees are established, especially on grassed sites; swards should be low-maintenance types. Shrubby and herbaceous legumes are alternative nitrogen-fixing covers. Corsican pine, larch, alder and birch are the most successful species. A case history of lowland opencast coal reclamation for forestry is described.

BLATCHFORD, O. N. [and SCHENKER, R.] (1982). The Oxford system of decimal classification for forestry: past – present – future. *Commonwealth Forestry Review* 61 (3), 213–217.

The classification of forestry literature is discussed together with recent developments in information retrieval. A valuable aid in the past, the ODC continues to be used throughout the world and its future is assured.

BRASIER, C. M. (1982). Occurrence of three sub-groups within *Ceratocystis ulmi*. In *Proceedings of the 1981 Dutch Elm Disease Symposium and Workshop*, eds. Kondo, E. J., Hirotsuka, Y. and Denyer, W. B. G., Winnipeg, Manitoba Department of Natural Resources, 298–321.

Reviews present knowledge of the properties of the non-aggressive, NAN aggressive and EAN aggressive sub-groups of *C. ulmi*, their status and their identification by laboratory and field techniques.

BRASIER, C. M. (1982). Genetics of pathogenicity in *Ceratocystis ulmi* and its significance for elm breeding. In *Resistance to diseases and pests in forest trees*, eds. Heybroek, H. M., Stephan, B. R. and von Weissenberg, K., Proceedings of the 3rd IUFRO International Workshop on Genetics of Host-Parasite Interactions in Forestry, Wageningen, The Netherlands, 1980, 224–235.

Reviews present experimental evidence on the genetic control of pathogenic ability of the three sub-groups of *C. ulmi* and its implications for elm breeding as a means of combating Dutch elm disease.

BRASIER, C. M., [LEA, J. and RAWLINGS, M. K.] (1982). The aggressive and non-aggressive strains of *Ceratocystis ulmi* have different temperature optima for growth. *Transactions of the British Mycological Society* 76 (2), 213–218.

The aggressive and non-aggressive strains of *Ceratocystis ulmi* exhibit markedly different temperature-growth responses *in vitro*. The optimum temperature of the aggressive strain (both EAN and NAN races) was 20–22°C. and that of the non-aggressive strain was c. 30°. The upper limit for growth of the EAN aggressive was c. 32°, of the NAN aggressive c. 33°, and of the non-aggressive strain c. 35°. Two temperatures, 20 and 33°, are now recommended for separating the strains on the basis of growth-rate. The ranking order of the strains at 20° is the reverse of that at 33° and this provides a qualitative method for routine strain identification. The significance of the different temperature-growth responses of the two strains is discussed.

BRASIER, C. M. (1983). Problems and prospects in *Phytophthora* research. In *Phytophthora, its biology, taxonomy, ecology and pathology*, eds. Erwin, D. C., Bartnicki-Garcia, S., and Tsao, P. H., American Phytopathological Society, Minnesota, 351–364.

Examines current problems in *Phytophthora* research with special reference to topics fundamental to understanding how *Phytophthora* exists and behaves in populations, and to conceptual problems requiring an experimental approach (including: the nature of the individual, taxonomy, sexual reproduction, host-parasite interaction, selection mechanisms, and phyto-geny).

[CANNELL, M. G. R., THOMPSON, S.] and LINES, R. (1981). Heights of provenances and progenies of *Pinus contorta* in Britain correlated with seedling phenology and the duration of bud development. *Silvae Genetica* 30 (6), 1981, 166–173.

Differences in the duration of first-year seedling height growth among 15 provenances of *Pinus contorta* were correlated with 1 and 2 year heights in the nursery and with 3 and 6 year heights at five forest sites. Correlations were positive and accounted for a high percentage of the variation

in mean heights at 6 years. They were greatest when restricted to heights at sites favourable for growth. Thus duration of first-year seedling height growth may be a useful criterion in early selection of seed origins.

CARTER, C. I. (1982). Susceptibility of *Tilia* species to the aphid *Eucallipterus tiliae*. In *Proceedings of the 5th International Symposium on Insect-Plant Relationships*, Wageningen, 1982, Pudoc, 421–423.

The most commonly grown limes in Britain, *Tilia cordata*, *T. platyphyllos* and their hybrid *T. × europaea*, are all susceptible to attacks by the lime aphid. Aphid performance tests on other exotic limes has revealed two types of resistance. Scanning electron micrographs of leaf surface features illustrate various degrees of pubescence and the presence of glands along the veins where the aphids feed that appear to have an inhibiting property.

CARTER, C. I. [and MASLEN N. R.] (1982). *Conifer lachnids*. Forestry Commission Bulletin 58.

Field keys and morphological keys with descriptions and illustrations are given for the identifications of the 27 aphids of the family Lachnidae known to occur on conifers in Britain. The strong influence of their host plant upon these insects and the impact some of them have on the growth of forest trees and amenity plantations throughout the world is discussed. The importance of conifer aphid honeydew from various species in the production of forest honey is reviewed. Accounts of each species include recent synonymy, descriptions of morphs, type of life cycle, host plants, distribution and economic importance.

COUTTS, M. P. (1982). Growth of Sitka spruce seedlings with roots divided between soils of unequal metric potential. *New Phytologist* 92 (1), 49–61.

Seedlings were grown with roots divided between two containers of soil corresponding to wet/wet (–5 kPa), dry/dry (–30 kPa) and wet/dry. In both soils the wet/dry treatment had little effect on leaf water potential, or on total plant growth compared with the wet/wet, but produced very uneven root development. Most growth of primary and woody roots occurred in the wet soil. Water supplied to one-half of the root system did not increase growth of the half in dry soil. The extension of main root axes in the dry soil was only slightly slower than in the wet soil. However, in the dry soil some roots were dying while others were extending and at the final harvest no increase was recorded in total root length.

CROWTHER, R. E. (1982). Species, provenance and tree improvement. In *Broadleaves in Britain: future management and research*. Proceedings of a symposium held at Loughborough University, 7–9 July 1982, Institute of Chartered Foresters, Edinburgh, 131–140.

The geological and historical influences on our broadleaved tree flora are examined. The potential for improvement by selecting species, provenances, and by tree breeding is discussed and priorities for further research are indicated.

[DON, B. A. C. and] RENNOLLS, K. (1983). A home range incorporating biological attraction points. *Journal of Animal Ecology* 52 (1), 69–81.

The domain and utilization distribution of an animal's space-use pattern are distinguished and a review of some model-based methods of describing them is presented. A home range model is introduced which makes use of the biologist's knowledge of attraction points, termed nuclei, and assumes that each nucleus has a circular normal 'field of attraction'. The model is estimated using the maximum likelihood method and is applied to two data sets one of which is for grey squirrel (*Sciurus carolinensis* Gmelin). The variance-covariance matrix of parameter estimates is interpreted and 'best' models are selected using a likelihood ratio test.

DONNELLY, K. P. (1983). The probability that related individuals share some sections of genome identical by descent. *Theoretical Population Biology* 23 (1), 34–63.

A formal mathematical framework is presented for the study of linkage in man and the concept of chromosome pedigree is defined. Assuming no interference, all the crossover processes in the pedigree are viewed jointly as a continuous-time Markov random walk on the vertices of a hypercube the time parameter being map distance along a chromosome. The event that two related individuals have a chromosome segment in common corresponds to the random walk

hitting a particular set of vertices. The probability of this happening is calculated for various types of relationship.

EVANS, J. (1982). Tree growth and control of epicormics. In *Broadleaves in Britain: future management and research*. Proceedings of a symposium held at Loughborough University, Leics, 7-9 July 1982, Institute of Chartered Foresters, Edinburgh, 183-190.

Free growth, by allowing full crown development, can double volume increment of selected trees. A major problem is the development of epicormics; research into their control is described. If effective control methods are found there are good prospects for growing high quality hardwoods on significantly shorter rotations.

EVANS, J. (1982). The silviculture of oak and beech in northern France: observations and current trends. *Quarterly Journal of Forestry* 76 (2), 75-82.

Most high forest oak and beech is regenerated naturally. The regeneration period allowed is shorter than in the past and gaps still present after 20 years are planted. Regular cleaning and thinning are essential for satisfactory stand development. Increasingly, at the time of first thinning, potential final crop trees are selected and thinning done to these. In oak woodland side branches and epicormics are controlled, though the latter not always prevented, by maintaining a beech understorey and avoiding heavy thinning. Rotations are long by British standards: oak 150-220 years, beech 120-160 years.

EVANS, J. (1982). Epicormic branches and their control, with a report of current research. In *Report of 3rd Meeting of National Hardwoods Programme*, Oxford, 8 October 1982, Commonwealth Forestry Institute, 5-11.

Both genetic and environmental factors influence epicormic development. Thinning in broadleaved stands generally exacerbates the problem of epicormics. Change in a tree's water relations better accounts for the circumstances when epicormics are initiated than increased light falling on a stem. Current research into epicormic control compares stem wrapping and herbicide treatments with conventional pruning methods.

FAULKNER, R. (1982). Tree improvement research and development — some thoughts for the 1980s. In *Proceedings from 18th Meeting Canadian Tree Improvement Association*, Part 2, Duncan, British Columbia, Canadian Forest Service, Ottawa, 1-18.

A synopsis of the British tree breeding programme and a review of current and likely future developments in seed stand management and orchards. Emphasizes the need for breeders to pay more attention to timber quality, ideotypes and nutrient requirements. Risk factors associated with different sources of planting material are discussed as are the probable implications of the recently developing technologies of vegetative propagation, tissue and haploid culture, protoplast hybridization, biochemical research and genotype/mycorrhizal interactions.

FAULKNER, R. [KEAN, V. M. and FOX, D. P.] (1982). The accumulation mechanism of the supernumerary B-chromosomes in *P. sitchensis* and the effect of this chromosome on male and female flowering. *Silvae Genetica* 31 (4), 101-148, 126-131.

An account of the behaviour and phenotypic effects of supernumerary chromosomes. Amongst the findings were: increased numbers of B-chromosomes delay flowering; B-chromosomes do not pair with each other or with A-chromosomes; they do not behave in a Mendelian fashion; they are distributed at random in both male and female germ-lines; accumulation is probably due to preferential migration of B-chromosomes at the first mitotic division in the female to the pole giving rise to the functional megaspore.

FAULKNER, R. (1983). The improvement of broadleaved trees by selection and testing — past, present and future. In *Report of 3rd Meeting of National Hardwoods Programme*, Oxford, 8 October 1982, Commonwealth Forestry Institute, 12-17.

Reviews provenance experiments, seed stands and plus tree selection work from 1950 onwards. Highlights current problems of securing regular reliable supplies of selected oak and beech seed. Discusses the future role of seed stands, seed orchards and vegetative propagation and the possible direction of future research, particularly in respect of vegetative propagation and clonal plantations.

FORREST, G. I. (1982). Preliminary work on the relation between resistance to *Fomes annosus* and the monoterpene composition of Sitka spruce resin. In *Resistance to diseases and pests in forest trees*, eds. Heybroek, H. M., Stephan, B. R. and von Weissenberg, K. Proceedings of the 3rd IUFRO International Workshop on Genetics of Host-Parasite Interactions in Forestry, Wageningen, The Netherlands, 1980, 194–197.

A preliminary study was carried out in a Sitka spruce population heavily infected by *Fomes annosus*. Significant differences in monoterpene composition of the root cortical oleoresin were found between infected and uninfected trees, as judged by the presence or absence of *Fomes* in radial cores taken from the lower stem. In particular, *Fomes* was absent from nearly all those trees in which a-pinene formed at least 37 per cent of the root oleoresin monoterpene fraction.

GIBBS, J. N. (1982). An oak canker caused by a gall midge. *Forestry* **55** (1), 69–78.

In parts of southern England an annual canker is to be found in association with peck marks made by woodpeckers on the stems of young oak. Cross-sections reveal that this canker is the result of the death of a patch of bark during a single dormant season followed by the recovery growth of callus tissue. Evidence is presented that the cause of canker formation is a gall midge *Resseliella* sp. which lays its eggs in recently formed peck marks during the months of July and August.

GIBBS, J. N. and REFFOLD, T. C. (1982). *Gnomonia platani* and bark killing of London plane. *European Journal of Forest Pathology* **12** (6–7), 395–398.

Coniothyrium fuckelii, *Cylindrocarpon heteronema* and *Gnomonia platani* were isolated from strips of dead bark on stems of London plane (*Platanus × hispanica*) in a tree nursery. Stem inoculations conducted on surviving trees in early autumn showed that *G. platani* and to a lesser extent *C. heteronema* could cause bark necrosis. The lesions so produced ceased to expand with the onset of cambium activity in spring. It is considered that the very heavy summer pruning conducted on the trees may have reduced their ability to resist fungal invasion.

GIBBS, J. N. (1983). 'Sap-sucking' by woodpeckers in Britain. *British Birds* **76** (3), 109–117.

In Britain the Great spotted woodpecker *Dendrocopos major* produces rows of peck marks on the young stems of trees. On sycamore pecking occurs in winter and there is little doubt that xylem sap is taken. It is not clear, however, whether sap-sucking is the reason for pecking activities on other trees such as elm and oak. More observations of the birds at work are required.

GRAYSON, A. J. (ed.) (1982). *Broadleaves in Britain: addresses, supplementary papers and discussions*. Forestry Commission Occasional Paper 13.

A supplement to the book of the symposium proceedings *Broadleaves in Britain*.

GRAYSON, A. J. (1982). Wood demand and supply: the world scene. In *Wood using industries* (ed. D. C. Malcolm), Proceedings of a discussion meeting, April 1982, University of Edinburgh, Institute of Chartered Foresters, Edinburgh, 1–11.

A review of recent econometric and other studies on an international or country basis of the demand for and supply of timber products. The role of price and the main interest of this variable are emphasized.

GREGORY, S. C. (1982). Bark necrosis of *Acer pseudoplatanus* L. in northern Britain. *European Journal of Forest Pathology* **12** (3), 157–167.

Severe bark necrosis in large *Acer pseudoplatanus* was studied at a site in northern England. Bark death occurred late in the growing season or in the dormant season on two occasions and was preceded by a notably dry summer in both cases. Of several fungi isolated from cankers and areas of recent bark necrosis *Nectria coccinea* and *Diplodina acerina* were demonstrated to be capable of causing limited necrotic extension of physical wounds in healthy *A. pseudoplatanus*. A third fungus, *Phomopsis pustulata*, though the most frequently isolated, showed no such ability. It is proposed that summer drought in association with a variety of weakly pathogenic fungi can induce local bark necrosis in *A. pseudoplatanus*.

GREIG, B. J. W. [and FOSTER, L. E. P.] (1982). *Fomes annosus* in the pine plantations of Jamaica. *Commonwealth Forestry Review* **64** (4), 269–275.

A survey for *Fomes annosus* revealed that the pathogen occurred frequently in the *Pinus caribaea* plantations of the Blue Mountains. The disease was also discovered in two forests some 60 miles further west than it had previously been recorded. Trees were killed in first rotation crops following infection of thinning stumps and losses of around 30 per cent were recorded. In the future mortality on replanted sites may be considerable. The damage caused by Hurricane Allen in 1980 has increased the problem of *F. annosus*. Control is recommended by stump treatment but further research is required into several aspects of the disease.

HORNE, A. I. D. (1982). The use of remote sensing in forestry. *Digital Mapping and Remote Sensing IT82 Seminars*, Edinburgh and London, 3pp.

A brief resumé of photosurvey, digital mapping and other remote sensing systems in use or being investigated in forestry.

HORNE, A. I. D. (1982). Remote sensing in British forestry. In *Remote sensing — a short course on the use of remote sensing techniques for land cover mapping*, Part 8, Grampian Regional Council, 1–9.

A case study — review of use made of aerial photography and other remote sensing systems in forest survey, both current and future.

HORNE, A. I. D., THALLON, K. P., *et al.* (1982). *Remote sensing and resource planning in Scotland*. Report of a Working Party, Grampian Regional Council, 59 pp.

A report covering an introduction to remote sensing, methods of use, applications and application procedures, user needs and services available.

HOWARD, D. J. and HAYES, F. W. (1983). *Aid tools for timber harvesting*. Forestry Commission Leaflet 81.

A range of aid tools is described, compared and recommended for use in timber harvesting operations.

INGOLDBY, M. J. R. and SMITH, R. O. (1982). *Forest fire fighting with foam*. Forestry Commission Leaflet 80.

Alternative systems for fire fighting are discussed and detailed recommendations are made for ground based application of foam.

INSLEY, H. (1982). *The effects of stock type, handling and sward control on amenity tree establishment*. Ph.D. Thesis. Wye College, University of London, April 1982.

The effects of exposing seedlings before planting and the mechanisms involved were examined. Survival and growth were influenced by exposure, but tolerance varied between species. Container stock were investigated as a means of avoiding desiccation. Growth rates were similar to bare-rooted stock; survival advantages were limited. Road verges were found to be inherently fertile, although nitrate levels were low; their sward composition and succession were investigated. Field and greenhouse experiments investigated the effects of grass competition on young trees. Three years sward control after planting was required. Mulches tested were ineffective. Weed control by both mulches and herbicides increased soil water content during dry periods and increased soil temperature.

INSLEY, H. (1982). The influence of post planting maintenance on the growth of newly planted broadleaved trees. In *Cost effective amenity landscape management*. Horticultural Education Association Conference, Somerset College of Agriculture and Horticulture, Cannington, 74–80.

Newly planted broadleaved trees are adversely affected by competition exerted by grass swards. When the grass is removed they respond by growing faster. The addition of nutrients within the removal of the grass can reduce rather than increase tree growth by encouraging growth of the grass; the grass roots dry out the soil to a moisture tension above which the trees cannot take up water or nutrients and so the trees experience both moisture stress and nutrient deficiency.

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

Corsican pine, False acacia, Common alder, Goat willow and poplar 'Scott Pauley' grown on a domestic refuse landfill survived better when clayey subsoil was used as a cover material rather than composted refuse. Trees planted straight into 0.2 m of composted refuse used as a capping cover over 3-year-old refuse showed poor survival. The addition of another 0.5 m of soil cover significantly improved survival and mean height as measured after two growing seasons. However, further increases in the depth of cover did not produce significantly better results than the original 0.5 m.

JOBLING, J. (1982). Treatment of deep-mine colliery spoil. *Mineral Planning* 13, 23-25.

On reclaimed colliery tips limestone may be applied to ameliorate spoil acidity to pH 6.5. Compacted spoils are cultivated prior to planting. Further work is necessary on the effects of adding soil to reclaimed tips. Colliery spoil has a low water-holding capacity, thus choice of the right tree species for the site is important; pines, birch, oak and sycamore are leading contenders.

JOHN, A. and MURRAY, B. W. (1982). Micropropagation of Sitka spruce (*Picea sitchensis*) (Bong.) Carr. In *Colloque international sur la culture in vitro des essences forestières*. Proceedings of IUFRO Section S2.01.5. Fontainbleu, Afocel 1981, 65-70.

Shoots of Sitka spruce put into culture at the cotyledon stage elongate and produce axillary buds during their development. Subsequently, subcultures derived from the primary cultures develop differently. The differences in development of the apical and axillary bud subcultures through a series of subcultures are discussed.

LEATHER, S. R. (1982). Preliminary studies on the effect of host age and aphid generation on the reproduction and survival of the Bird cherry-oat aphid, *Rhopalosiphum padi*. *Annales Agriculturae Fenniae* 21 (1), 13-19.

When kept on seedling and flowering plants of oats, the emigrants and first three apterous generations arising from the emigrants of *R. padi* showed differences in fecundity, development time, survival time and mean relative growth rates. Emigrants were unable to survive longer than four days on flowering oat plants. On both seedling and flowering plants the later generations had higher mean relative growth rates than earlier generations. When different generations were compared on the same growth stage there were no differences in reproductive rates. However, those generations on seedlings were more fecund than those on flowering plants.

LEATHER, S. R. [and DIXON, A. F. G.] (1982). Secondary host preferences and reproductive activity of the Bird cherry-oat aphid, *Rhopalosiphum padi*. *Annals of Applied Biology* 101 (2), 219-228.

Of 15 species of grass, including cereals, alate exules and emigrants of *Rhopalosiphum padi* preferred to colonize *Lolium perenne*. Emigrants colonized cereals twice as readily as alate exules. Apterous exules preferred *L. perenne* to cereals. Although small when reared on *L. perenne*, *R. padi* was more fecund per unit weight than on any of the other grasses tested. On the later growth stages of *Dactylis glomerata* and *L. perenne*, *R. padi* developed faster and was more fecund than on *Phleum pratense* at the same growth stages. At low temperatures *R. padi* was more fecund on *P. pratense* than on *L. perenne* and *D. glomerata*.

LEATHER, S. R. [and LEHTI, J. P.] (1982). Field studies on the factors affecting the population dynamics of the Bird cherry-oat aphid, *Rhopalosiphum padi* (L.) in Finland. *Annales Agriculturae Fenniae* 21 (1), 20-31.

Populations of the Bird cherry-oat aphid *Rhopalosiphum padi* were followed on the primary host *Prunus padus* and in fields of barley, oats, rye and wheat. Predators were numerous on the primary host but had little effect on the populations, the decline in population being due to the effects of emigration to the secondary hosts. On *P. padus* in the spring the most common predators were *Coccinella 7-punctata* and *Adalia bipunctata*. In autumn spiders and syrphid larvae were most abundant. In cereals the most common predators were *C. 7-punctata* and *Tachyporus* spp. Aphid populations achieved the same levels on barley, oats and wheat, but were much lower on rye. Populations on *P. padus* in the autumn were approximately the same at all three sites.

LEATHER, S. R. [and LEHTI, J. P.] (1982). Abundance and distribution of *Yponomeuta evonymellus* (Lepidoptera: Yponomeutidae) in Finland during 1981. *Notulae Entomologicae* 62 (3), 93–96.

Prunus padus trees were sampled for *Yponomeuta evonymellus* (L.) at 87 and 110 sites throughout Finland, in spring and autumn respectively. *Y. evonymellus* was more abundant in the west on both sampling occasions, but numbers were much lower in autumn than in spring. The effect of the emerged larvae on *P. padus* was observed in the spring at Tikkurila, Viikki and Rusko. The trees sampled suffered approximately 60 per cent defoliation, although at many other sites in Finland trees were totally defoliated by the larvae. The results of a nationwide survey to assess the distribution of defoliation by *Y. evonymellus* during the summer of 1981 were significantly correlated with the number of larval shields counted in both spring and summer.

LINES, R. (1982). Performance of different species and seed origins in the industrial Pennines of northern Britain. *Polska Akademia Nauk Archiwum Ochrony Srodowiska* 2-4, 107–120. Joint meeting of the International Union of Forest Research Organizations, Zabrze, August 1979.

A series of species trials was planted in the southern Pennines between 1951 and 1977. Their object was to determine which species and seed origins would grow best in this industrially polluted region, and to investigate establishment techniques. Twenty-six species and four groups of seed origins of *Pinus contorta* and two of *Pinus nigra* were tested. Air pollution by sulphur dioxide was measured using lead dioxide candles. Exposure was estimated by tatter flags and anemometers. Performance of different species is discussed and comments made on their ability to withstand the combination of pollution and other site factors which characterize this area.

LINES, R. [and BROWN, I.] (1982). Broadleaves for the uplands. In *Broadleaves in Britain: future management and research*. Proceedings of a symposium held at Loughborough University, 7–9 July 1982, Institute of Chartered Foresters, Edinburgh, 141–149.

Natural broadleaved woodlands were largely cleared from the uplands centuries ago. Many species were included in Forestry Commission trials in the 1950s, but most grew slowly. Alders, birch and *Nothofagus* show promise for rapid growth, and other properties are currently being tested again to find the best seed origins and strains. A birch breeding programme is under way at Aberdeen University, aimed at improving *Betula pendula* for timber yield by reducing branchiness, stem fluting, etc., and selecting for superior stem form. Progeny from the first part of the programme are now ready to be selected for superior phenotypes and these will be induced into early flowering.

McINTOSH, R. (1982). Effect of different forms and rates of nitrogen fertiliser on the growth of Lodgepole pine. *Forestry* 55 (1), 61–68.

Application of four forms of nitrogen fertiliser each at three rates produced significant positive responses in shoot growth in a 7-year-old *Pinus contorta* Dougl. stand on a deep infertile peat in south Scotland. The response was shortlived (4 years) and was followed by a period (1–2 years) when shoot growth fell below the control level. Form of N did not affect the result but rate of N did and these effects are discussed with respect to annual shoot growth, foliar N levels and shoot growth:foliar N correlations.

McNEILL, J. D. and THOMPSON, D. A. (1982). Natural regeneration of Sitka spruce in the Forest of Ae. *Scottish Forestry* 36 (4), 269–281.

Sample counts of Sitka spruce *Picea sitchensis* (Bong.) Carr. seedlings were made across small (0.04 ha) circular clearings in mature stands. Survival of seedlings was found to vary with time after germination, position in the clearing, and micro-site conditions.

[MALCOLM, D. C.] EVANS, J. and EDWARDS, P. N. (eds.) (1982). *Broadleaves in Britain: future management and research*. Proceedings of a symposium held at Loughborough University, 7–9 July 1982. Institute of Foresters, Edinburgh.

A collection of 30 papers and 12 abstracts.

MITCHELL, A. F. (1982). Leaves from a tree measurer's diary 1981. *International Dendrology Society Yearbook 1981*, 89–93.

MOBBS, I. D. (1982). Simulation of cable-crane operations. In *Proceedings of the seminar on the planning and technique of transport and its relation to operational activities in forestry*, Sandefjord, Norway, June 1982, 24–30.

A computer simulation program has been written which can be used as a management tool, to calculate the optimum spacing of cable-crane rackways and provide information relevant to secondary extraction decisions. It is capable of composing costs associated with various patterns of extraction and investigating interactions with secondary extraction machines in a harvesting system.

PATCH, D. (1982). Trees for the future. *GC & HTJ* **191** (24), 15–16.

In 1981 a survey was made of local authority spending on tree and shrub purchases for the period 1977–1982. The data, adjusted for inflation, are presented and interpreted suggesting declining expenditure and numbers of trees being planted.

PATCH, D. (1982). In support of trees. *GC & HTJ* **191** (24), 20–21, 24.

The results of research on tree staking are reviewed and their significance to amenity tree establishment are considered. Recommendations are made for the intensity and duration of support for newly planted trees. (Published initially as *Arboriculture Research Note 40/82/ARB*).

PEARCE, M. L. (1982). Coppiced trees as energy crops. Part of Proceedings of European Communities contractors meeting, Brussels, May 1982. Progress report on coppice experiments. *European Communities Solar Energy R&D Series E 3*. D. Reidel.

PEPPER, H. W. [and WILLIAMS, P. V.] (1982). Plastic mesh for urban trees. *Arboricultural Journal* **6** (3), 211–215.

Describes plastic tree guards' advantages over wire netting guards in urban situations. Plastic guards were cheaper, lighter, accumulated less litter and were more vandal proof.

PHILIPSON, J. J. (1983). The role of gibberellin A4/7, heat and drought in the induction of flowering in Sitka spruce. *Journal of Experimental Botany* **34** (140), 291–302.

Mature 5-years-grafted Sitka spruce plants were treated with gibberellin A4/7 in conjunction with cultural treatments of heat and/or drought in a factorial experiment with eight treatments. Heat and drought each stimulated the production of male cones; drought appeared to be the more effective cultural treatment, and a decrease in leaf water potential of only about 0.5 MPa enhanced flowering. By contrast, the GA4/7 application failed to induce flowering unless applied together with a cultural stress treatment, when all clones responded and the mean number of cones per treated plant rose to 8.8 females and 16.2 males.

PHILIPSON, J. J. (1983). Flowering stimulated in Sitka – FC research. *Forestry and British Timber* **12** (2), 21.

When gibberellin A4/7 was applied to potted Sitka spruce grafts heavy cropping occurred, provided that an environmental stress such as heat or drought was also applied. The grafts were stressed by placing them in a polythene house and restricting the water supply. The response illustrates the potential for using this approach for the breeding programme. GA4/7 was also injected into 8 m tall grafts at the Wauchope clone bank; following a good flower-inducing summer all clones responded, with mean values of 350 male and 140 female cones per tree.

[PHILLIPS, D. H. and] BURDEKIN, D. A. (1982). *Diseases of forest and ornamental trees*. Macmillan, 435 pp.

A comprehensive reference book on British tree pathology.

PRATT, J. E. (1982). *Fomes annosus* butt-rot of Sitka spruce. IV. Observations on the distribution of *Cryptosporiopsis abietina* (Petra) in the stems of rotted trees. *Forestry* **55** (2), 183–187.

Cryptosporiopsis abietina was isolated from the heartwood of 12 out of 18 Sitka spruce suffering from butt rot caused by *Fomes annosus*, but from none of eight healthy trees from the

same plantations. *C. abietina* was present in a distinct zone above the tissue colonized by *F. annosus*. It was present in both sound wood and in wood with stain or incipient decay. *C. abietina* inhibited the growth of *F. annosus* on malt agar, and to a lesser extent in autoclaved Sitka spruce heartwood. The possible influence of this potentially antagonistic fungus on infection by *F. annosus* is briefly discussed.

RATCLIFFE, P. R. [and STAINES, B. W.] (1982). Red deer in woodlands: research findings. In *Roe and red deer in British forestry*, British Deer Society and Forestry Commission Study Day, 16 June 1982, Edinburgh, 42–53.

Describes current work relating red deer numbers to forest structure and damage.

REDFERN, D. B. (1982). Infection of *Picea sitchensis* and *Pinus contorta* stumps by basidiospores of *Heterobasidion annosum*. *European Journal of Forest Pathology* **12** (1), 11–25.

Infection of *Pinus contorta* and *Picea sitchensis* stumps by basidiospores of *Heterobasidion annosum* is extremely variable, both within and between sites, but *P. sitchensis* stumps are less susceptible than those of *P. contorta*. Measurement of the cross-sectional area occupied by *H. annosum* on each stump provides a more sensitive test of species susceptibility than assessment of the proportion of stumps infected. *P. sitchensis* stumps become infected on a variety of soils but there is evidence to suggest that infection may be reduced by high rainfall. In both species some stumps remain alive for at least 2 years after felling, particularly on peat soils, due to the presence of root grafts with neighbouring trees. Results for *P. sitchensis* suggest that infection occurs more readily in living stumps than in those which die rapidly after felling.

REDFERN, D. B. [and CANNELL, M. G. R.] (1982). Needle damage in Sitka spruce caused by early autumn frosts. *Forestry* **55** (1), 39–45.

Autumn frosts preceded by warm weather cause distinctive needle browning symptoms on young Sitka spruce trees which have completed shoot elongation. Damage is invariably confined to needles of the current year and typically consists of pink or reddish-brown patches in the centre of needles. Needles clustered around the apical buds are usually unaffected but in extreme cases all current year's needles may be entirely reddish-brown. These symptoms were reproduced on young plants by experimentally freezing them in a programmed chamber. Widespread damage was observed in the field in October 1971, September 1972 and September 1979; assessments of field trials showed that damage was most severe on southerly provenances and on trees deficient in phosphorus.

RENNOLLS, K. (1983). The prospects of an integrated forest process model. Forest growth modelling and simulation. *Mitteilungen der Forstlichen Bundesversuchsanstalt* **147**, 159–171.

Though the modelling efforts on numerous forest processes have progressed considerably, a synthesis of such models has not been attempted or, alternatively, such attempts have been unsuccessful and therefore have not been repeated. Either way, it is argued that improvements upon current competition growth models can only come about from such a synthesis. A brief review of competition growth models so far developed is followed by a new mathematical model which includes nutrient cycles and individual competition. These directly influence growth and mortality models. Future work is outlined with particular emphasis on the problem of calibration.

ROWE, J. J. (1982). Roe research in relation to management in British woodlands. In *Roe and red deer in British forestry*, British Deer Society and Forestry Commission Study Day, 16 June 1982, Edinburgh, 25–41.

Describes ecological research in relation to management objectives. Identifies the need for measures of effectiveness of management and flexibility in the tactics used, as habitat and population change.

SALE, J. S. P. (1982). Chemicals: a review of herbicides used for forest weed control. Herbicides in forest plantations. *Farm Contractor* **81** (September), 59.

A condensed account of the main forestry weed types, herbicides available for their control and methods of application.

SMYTH, B. J. (1982). Computers aid forest research. *Forestry and British Timber* 11 (10), (November), 21–22.

Description of the computing facilities at the Forestry Commission's Alice Holt Research Station.

TABBUSH, P. (1983). When, where, how to kill heather. *Forestry and British Timber* 12 (3), 8–9.

Current recommendations for heather control are given, concentrating on use of 2, 4-D and glyphosate. Guidance is given on the need to control heather on different site types, with a distinction drawn between heathland mineral soils and unflushed peats and peaty gleys. From an examination of crop tolerance considerable effort seems justified to improve current technology for heather control.

THOMSON, J. H. and MAYHEAD, G. J. (1982). Toxicity of five granular herbicides to Sitka spruce and Lodgepole pine. *Forestry* 55 (2), 173–182.

Experimental plots in young plantations of Sitka spruce and Lodgepole pine were over-dosed with five granular herbicides to ascertain the margin of crop safely involved in the use of propyzamide, chlorthiamid, dichlobenil, dichlobenil/dalapon mix and atrazine. It is concluded that if the five herbicides are applied according to the standard rates and dates used in the experiments, tree damage will be kept to an acceptable minimum. Better shoot growth resulted from herbicide treatment than from hand weeding, particularly where atrazine was used.

TULEY, G. (1982). New ways of establishing and managing young broadleaved crops. In *Proceedings of the Tenth International Forestry Students Symposium*, University of Aberdeen, 5–8 January 1982, 135–140.

We should take the best techniques of the 19th century and add the material and practices of the 20th century to try and devise silvicultural systems for the 21st century. We can grow broadleaves. We can grow them faster. We can grow better crops. Let's grow better crops of broadleaves faster.

TULEY, G. (1982). Tree shelters increase the early growth of broadleaved trees. In *Broadleaves in Britain: future management and research*. Proceedings of a symposium held at Loughborough University, Leics, 7–9 July 1982, Institute of Chartered Foresters, Edinburgh, 176–182.

Shelters more than double the height growth of many broadleaves during their first two seasons in the forest. After three years, oak has grown 2.9 times more in height and 1.6 times more in cross-sectional area than individually protected but not sheltered trees. Large-scale trial is recommended.

WEBBER, J. F. (1982). Natural biological control of Dutch elm disease by *Phomopsis oblonga*. In *Proceedings of the 1981 Dutch Elm Disease Symposium and Workshop*, eds. Kondo, E. S. Hiratsuka, Y. and Denyer, W. B. G., Winnipeg, Manitoba Department of Natural Resources, 24–35.

In some areas of Britain the fungus *Phomopsis oblonga* is a frequent, extensive primary colonizer of the bark of dying elms, its presence usually revealed by the characteristic zone lines it produces. Field observations and laboratory experiments have shown that when bark is colonized by *Phomopsis* it has a severely detrimental effect on any *Scolytus* broods developing in the bark, retarding their development and usually resulting in their death. *Phomopsis* colonization also renders bark unattractive as breeding material to scolytid females, thereby reducing amounts of available breeding material.

WHITE, J. E. J. *et al.* (1982). *Autumn colour trail guide*. Forestry Commission.

Folded A4 map and guide to autumn colours of maples at Westonbirt Arboretum.

WHITE, J. E. J. (1982). A guide to Westonbirt Arboretum. Forestry Commission. 20 pp.

A revised guide with map and colour photographs.

WHITE, J. E. J. *et al.* (1982). *Westonbirt Arboretum*. Forestry Commission.

Folded A4 map of Westonbirt Arboretum.

WINTER, T. G. (1982). *Cacoecimorpha pronubana* (Hübner) (Lepidoptera: Tortricidae) on conifers. *Entomologist's Gazette* **33** (3/4), 229–230.

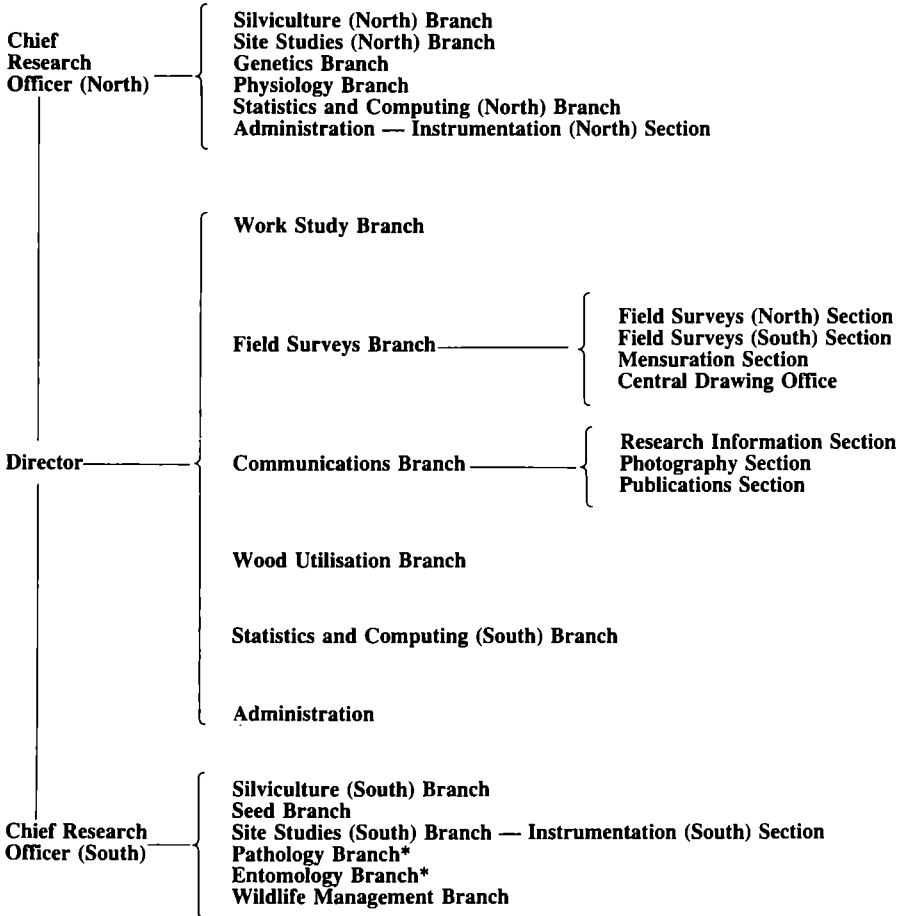
Details are given of *Cacoecimorpha pronubana* larvae feeding on container-grown *Picea glauca* × *Cupressocyparis leylandii*, *Thuja occidentalis* and also on *Juniperus squamata* growing in a garden.

WINTER, T. G. (1982). *Cydia pactolana* (Zeller) (Lepidoptera: Tortricidae) breeding in Windsor Forest. *Entomologist's Gazette* **33**, (3/4), 212.

Describes the first breeding record of *Cydia pactolana* in Great Britain on *Picea abies* in Windsor Forest.

APPENDIX II

Research and Development Divisional Organization



*Branches with sections at the Northern Research Station.

APPENDIX III

Staff Engaged in Research and Development

As at 31st March 1983

The main centres for research and development are:

FORESTRY COMMISSION RESEARCH STATION

Alice Holt Lodge
Wrecclesham
Farnham, Surrey GU10 4LH. Tel. 0420-22255

FORESTRY COMMISSION NORTHERN RESEARCH STATION

Roslin
Midlothian EH25 9SY
Scotland. Tel. 031-445 2176

Some staff engaged in research and development are also stationed at:

FORESTRY COMMISSION HEADQUARTERS

231 Corstorphine Road
Edinburgh EH12 7AT. Tel. 031-334 0303

 RESEARCH AND DEVELOPMENT DIVISION

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

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

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

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

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

STAFF AT ALICE HOLT LODGE

SILVICULTURE BRANCH (SOUTH)

R. E. Crowther, B.Sc., F.I.C.For., Head of Branch

R. J. Davies, B.Sc. M.I.C.For., J. Evans, B.Sc., Ph.D., M.I.C.For., J. Jobling, B.Sc., A.F. Mitchell, B.A., B.Agric., V.M.H., J.S.P. Sale, M.A., M.I.C.For., G. Tuley, B.Sc.(For.), M.I.C.For.

*Foresters:**East England Region*

P. W. W. Daborn, B. F. Edwards,
D. Elgy, J. B. H. Gardiner,
P. D. Howard, P. Marsh,
P. G. Risby, C. W. Shanks
R. E. Preston, M. J. Scott
P. R. Barwick, I. H. Blackmore

Centre

Alice Holt

Bedgebury
Theiford

West England Region

M. L. Pearce, M.I.C.For.,
J. I. MacDonald, C. W. Webber,
J. E. J. White,
K. F. Baker, D. J. Lyons
R. E. Warn

Westonbirt

Exeter
Dean

ARBORICULTURE ADVISORY SERVICE (Department of the Environment)

D. Patch, B.Sc., M.Sc., M.I.C.For., N.D.Arb., F.Arbor.A., F.R.W. Stevens

SITE STUDIES BRANCH (SOUTH)

W. O. Binns, M.A., B.Sc., Ph.D., F.I.C.For., Head of Branch

M. A. Anderson, B.Sc., R. Carnell, A. Willson, B.Sc., Ph.D., K. Wilson, B.Sc., M.I.C.For.

Foresters:

N. Best, D. W. H. Durrant, B.A., D. F. Fourt

Laboratory:

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Transfers in: H. W. Bell (Forest Officer I) from North Scotland Conservancy to Field Surveys, Culloden. D. W. H. Durrant (Forester) from South West England Conservancy to Site Studies South, Alice Holt. B. F. Edwards (Head Forester) from the Agricultural Show Unit to Silviculture South, Alice Holt. R. A. Farmer (Forest Officer I) from South Scotland Conservancy to Work Study, Alice Holt. N. Fearis (Forester) from Harvesting and Marketing to Field Surveys, Alice Holt. P. W. Gough (Forester) from North East England Conservancy to Silviculture North, Kielder. F. W. Jackson (Forester) from West Scotland Conservancy to Work Study, Inverness. R. Leslie (Forest Officer II) from North East England Conservancy to Work Study, Thetford. A. B. Lewis (Head Forester) from South Scotland Conservancy to Silviculture North, Kilmun. A. F. Martin (Forester) from East Scotland Conservancy to Entomology, Alice Holt. G. W. Munford (Forester) from North East England Conservancy to Field Surveys, Rothbury. J. E. Pratt (Head Forester) from North Scotland Conservancy to Pathology, NRS. J. R. Price (Principal) from Headquarters to Administration, Alice Holt on promotion. E. R. Robson (Chief Forester) from North West England Conservancy to Silviculture North, Brecon. J. A. Walmsley (Forester) from East Scotland Conservancy to Field Surveys, Inverness. P. R. A. Whitfield (Forester) from South Wales Conservancy to Silviculture North, Lairg.

New Appointments: K. P. Donnelly (Higher Scientific Officer) Statistics, NRS. R. M. A. Gill (Higher Scientific Officer) Statistics, Alice Holt. P. G. Gosling (Higher Scientific Officer) Seeds, Alice Holt. L. M. Halsall (Scientific Officer) Statistics, Alice Holt. S. R. Leather (Higher Scientific Officer) Entomology, NRS. D. Ray (Scientific Officer) Site Studies, NRS.

Transfers out: D. G. Caird (Forester) from Field Surveys, Glengarry, to North Scotland Conservancy. J. R. C. Colledge (EO) from Administration NRS, to Headquarters. P. N. Edwards (Forest Officer I) from Field Surveys, Alice Holt, to South Scotland Conservancy. D. J. Furness (Forester) from Silviculture North, Kielder, to North East England Conservancy. D. R. Harper (HEO) from Administration, Alice Holt to Audit Branch, Headquarters. D. J. Howard (Head Forester) from Work Study, Brockenhurst, to South East England Conservancy. H. Inasley (Forest Officer I) from Silviculture South, Alice Holt, to West Scotland Conservancy. M. Roe (Forester) from Wildlife, Alice Holt, to South West England Conservancy. K. G. Shuker (Forester) from Site Studies, Alice Holt, to South East England Conservancy. R. O. Smith (Forest Officer I) from Work Study, Alice Holt, to South Scotland Conservancy. P. J. Williams (Forester) from Field Surveys, Clunes, to North Scotland Conservancy. D. Yeats (Forester) from Silviculture North, to East Scotland Conservancy.

Promotions: R. Carnell (Site Studies, Alice Holt) to Senior Scientific Officer. S. A. Kirk (Pathology, Alice Holt) to Scientific Officer. J. R. Lacey (Accounts, Alice Holt) to Executive Officer. R. Leslie (Work Study, Thetford) to Forest Officer I. T. J. D. Rollinson (Field Surveys, Alice Holt) to Forest Officer I.

Resignations: D. J. Billany (Head Forester) Entomology, Alice Holt. S. Hankin (Executive Officer) Statistics, Alice Holt. N. C. Henderson (Scientific Officer) Pathology, A.R.C. A. G. Nairn (HSO) Statistics, NRS. S. Pickett (Scientific Officer) Statistics, Alice Holt.

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Death: R. F. E. Bartlett (Chief Forester) Field Surveys, Dumfries.

GLOSSARY

Latin names of trees cited by common name in this Report

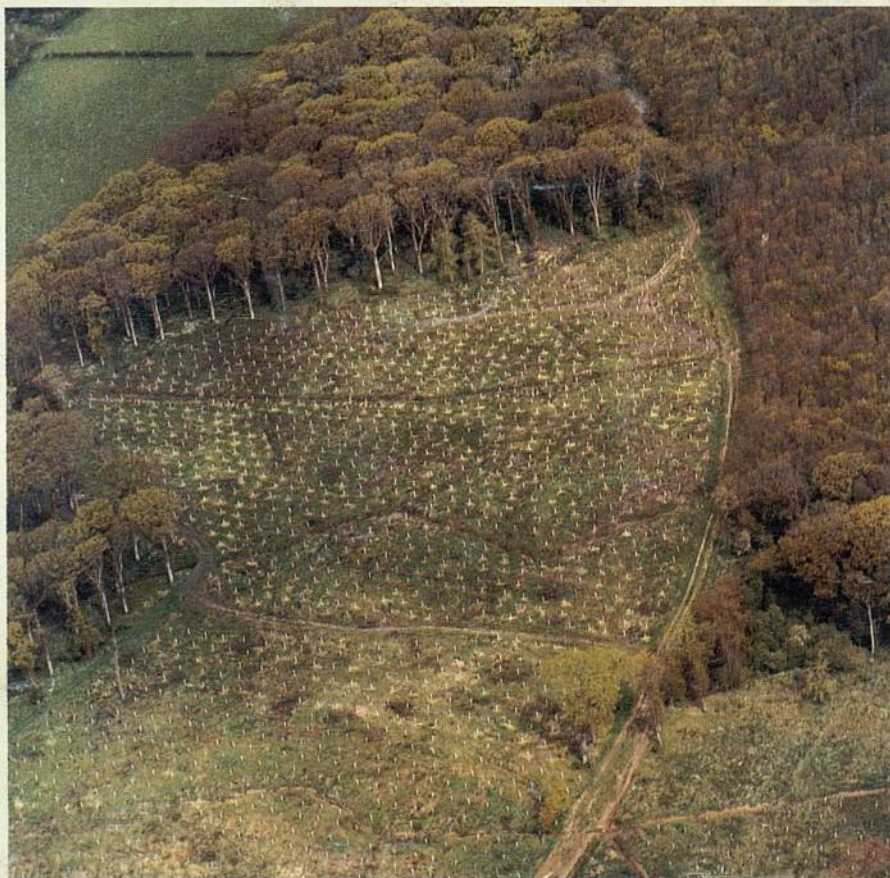
Broadleaves

Alder, Common	<i>Alnus glutinosa</i>
Italian	<i>A. cordata</i>
Red	<i>A. rubra</i>
Ash	<i>Fraxinus excelsior</i>
Beech	<i>Fagus sylvatica</i>
Birch, Silver	<i>Betula pendula</i>
Cherry, Wild (Gean)	<i>Prunus avium</i>
Bird	<i>P. padus</i>
Chestnut, Sweet	<i>Castanea sativa</i>
Elm, English	<i>Ulmus procera</i>
Hazel	<i>Corylus avellana</i>
Hawthorn	<i>Crataegus monogyna</i>
Lime, Common	<i>Tilia × europea</i>
Maple, Japanese	<i>Acer japonicum, A. palmatum</i>
Oak, Pedunculate	<i>Quercus robur (Q. pedunculata)</i>
Sessile	<i>Q. petraea (Q. sessiliflora)</i>
Plane, London	<i>Platanus × hispanica</i>
Sycamore	<i>Acer pseudoplatanus</i>
Whitebeam	<i>Sorbus aria</i>
Willow	<i>Salix spp.</i>

Conifers

Cypress, Lawson	<i>Chamaecyparis lawsoniana</i>
Leyland	<i>× Cupressocyparis leylandii</i>
Fir, Douglas	<i>Pseudotsuga menziesii (P. taxifolia)</i>
European Silver	<i>Abies alba</i>
Grand	<i>A. grandis</i>
Noble	<i>A. procera (A. nobilis)</i>
Hemlock, Western	<i>Tsuga heterophylla</i>
Larch, European	<i>Larix decidua (L. europaea)</i>
Hybrid	<i>L. × eurolepis</i>
Japanese	<i>L. kaempferi (L. leptolepis)</i>
Pine, Corsican	<i>Pinus nigra var. maritima</i>
Lodgepole	<i>P. contorta</i>
Radiata	<i>P. radiata</i>
Scots	<i>P. sylvestris</i>
Spruce, Engelmann	<i>Picea engelmannii</i>
Norway (Christmas tree)	<i>P. abies</i>
Sitka	<i>P. sitchensis</i>
White	<i>P. glauca</i>

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