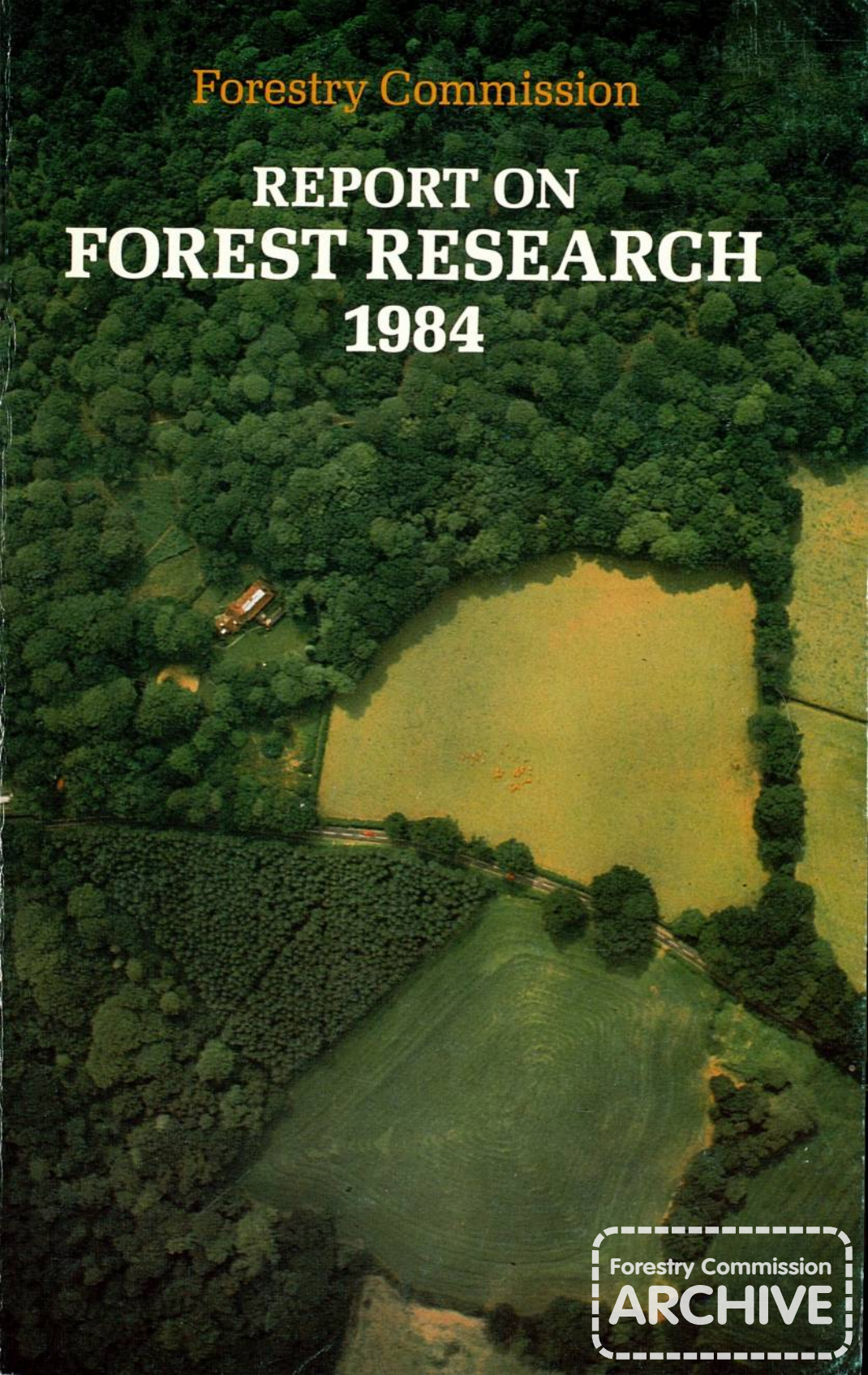
Forestry Commission

REPORT ON FOREST RESEARCH 1984



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Forestry Commission, Alice Holt Lodge, Wrecclesham,
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REPORT ON FOREST RESEARCH

for the year ended
March 1984

LONDON
HER MAJESTY'S STATIONERY OFFICE

First published 1984

The abbreviated title of this Report is:
Rep. Forest Res., Edin. 1984

Front Cover: **New Forest woodland and outlying trees on arable land. Interpretation of vertical aerial photographs assisted in the provision of data on area of woodlands and distribution of non-woodland trees for the Census of Woodlands and Trees, 1979–82. (*31464*)**

Back Cover: **A Telxon 787 programmable data capture terminal, as used by Silviculture (South) Branch for the collection of tree measurements in field experiments. The data are transmitted over the public telephone network to the research computer at Alice Holt Lodge for subsequent collation, checking and analysis. (*CN181*)**

ISBN 0 11 710130 3

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INTRODUCTION

By A. J. GRAYSON
Director of Research and Development

Advisory Committee on Forest Research

The Advisory Committee meets formally once a year and more frequent informal contact is maintained with members. The Division uses the method of visiting groups to review particular fields of research in which it is engaged. I am indebted to Professor Hirst, a member of the Advisory Committee, and his colleagues on the group, Professor P. Day and Dr J. Rishbeth, for their assessment of the organisation and work of the Pathology Branch. No major change in programme was recommended. However the point was made that, because of the size of the forestry research budget and the necessity to conduct work at the advisory end as well as the more strategic, this Branch in common with the other more heavily science-dependent Branches has to maintain strong links with colleagues in Research Councils and Universities if it is to keep abreast of problems.

Forestry Research Co-ordination Committee

In its second year the Committee has reviewed two areas and established reviews in two further fields. It has also considered sources of additional funds and it has embarked on the difficult but ever-important matter of determining the emphasis to be given to different research areas. The subjects so far reviewed are wood science and processing and the integration of farming and forestry in lowland Britain. The subjects of the succeeding reviews are tree physiology in relation to tree improvement and propagation, and forestry and the environment. Thus far, adjustment of research funds resulting from a review by the Committee has been limited to the subject of wood research where a combination of substitution within existing finances and the devotion of new resources has proved possible. The hoary question of desirable total research expenditure, and its corollary the allocation to different fields within forestry research, has been approached at two levels. In the first place the Committee has considered the claims of areas identified by the House of Lords Committee and by the Co-ordination Committee itself as being either of special topical interest or ones distinguished by rapid current advance. Secondly, it has begun the process of establishing the relevant dimensions by which the value of research may be more objectively assessed. The classical problem remains of combining values in such incommensurable dimensions as potential contribution to G.D.P. and scientific merit. As part of the development of the discussion about allocation, Mr J. N. R. Jeffers, Director of the Institute of Terrestrial Ecology, organised a workshop for scientists and managers in mid-career on the subject of research priorities.

New sources of finance

Two new sources of finance for work conducted by scientists under Forestry Commission direction became available in the course of the year. Dr J. F. Webber has been able to continue her work as a Southampton University Research Fellow through the support of the Cecil Pilkington Charitable Trust. Secondly, Mr R. Worrell is undertaking a study of the growth performance of

Sitka spruce at high elevations under the terms of an award by Fountain Forestry Ltd. This is jointly supervised by the Department of Forestry and Natural Resources at Edinburgh University and the Head of Silviculture (North) Branch at the Northern Research Station where the work is carried out. We are pleased to acknowledge these welcome initiatives in the field of forest research and are glad that Commission research stations should have been chosen as the locations for the work.

The Department of the Environment contract for arboricultural work was renewed on 1st January 1984 for a further period of 3 years, at a slightly lower level than that for 1981–83. Hunting Surveys have sub-contracted part of a Department of the Environment project concerned with landscape monitoring to Field Surveys Branch.

IUFRO meeting on technology transfer

The concern of researchers must be not only to see that their message is transmitted but that it is also received. A growing amount of attention is being devoted to this matter of technology transfer. This is perfectly right and proper, since the communication of research results is a necessary condition for the continued existence of a research organisation. It is the function of the organisation to decide whether the actual job of transfer is that of the researchers or a special extension service of the Research Division. A useful exchange of views and experiences on techniques of transfer was achieved at a meeting of IUFRO 6.08, organised by Mr D. T. Seal, Chief Research Officer (North), and held in Edinburgh in July 1983. This attracted an attendance of 40 from 15 countries. The proceedings and conclusions have been published as Forestry Commission Bulletin 61 *Technology transfer in forestry*.

Timber Growers United Kingdom

A new link was forged with the representative body for United Kingdom woodland owners through a meeting with the organisation's Technical Committee. This Committee is one of those formed to represent the interests of owners in a number of fields following the merging of the organisations covering Scotland and England and Wales respectively. The aim is to consult with the Technical Committee on the Division's programme and the communication of research findings.

Westonbirt Arboretum

Professor J. P. M. Brenan, a member of the Advisory Committee on Forest Research since 1976 and former Director of the Royal Botanic Gardens, Kew, accepted the post of Chairman of the Arboretum's Consultative Committee. This arrangement replaces the relatively recent innovation whereby the chair was occupied by the Director who was thus concerned with consulting himself on a variety of policy and management matters.

It was with deep regret that the Committee learned of the death of the 10th Duke of Beaufort in February 1984. The Duke had been a valued member of the Committee since its formation in 1956.

Visitors

A total of 840 visitors came to Alice Holt Lodge during the year. This included an attendance of 330 at two very successful Arboricultural Research Days held

in May and September. Among the parties visiting were the Biometric Society's summer meeting and the Harvesting and Silvicultural Committee of the Timber Grower's Organisation. The Northern Research Station received 376 visitors, including the EEC Timber Committee and delegates to the IUFRO Conference 'Applying the results of forestry research' noted above.

Conferences and tours

Divisional staff attended a total of 117 meetings and conferences in Britain at which they presented 27 papers. Overseas visits totalled 26 as in 1982, plus 7 EEC meetings connected with plant health, forestry research in general and the CREST programme in particular. A tour of an unusual kind was made by Dr A. J. Low for the Overseas Development Administration to the Falkland Islands.

Staff

At year end the Division employed 313 non-industrial staff (80 of whom are regarded as project leaders) and 144 industrial staff. Names of Forester, Forest Officer and Scientific staff are listed by branch in Appendix III.

PART I

The Work of the Forestry Commission

RESEARCH AND DEVELOPMENT DIVISION

SEED

Research

Laboratory experiments

Work has continued on the effect of pre-chilling on the subsequent germination of seeds over a range of temperatures. Figure 1 shows that the maximum percentage germination of unchilled Scots pine (SP) is not affected by temperature over the range 15–30°C whereas unchilled Sitka spruce (SS) seed has a pronounced optimum germination temperature between 20–25°C. There is also a difference between the two species in their response to pre-chilling. The maximum percentage germination of SP is only significantly promoted ($p < 0.025$) by pre-chilling at 10°C, whereas SS germination is significantly promoted at 10°, 15° and 30°C (the significance level quoted is used in accordance with International Seed Testing Association convention). It

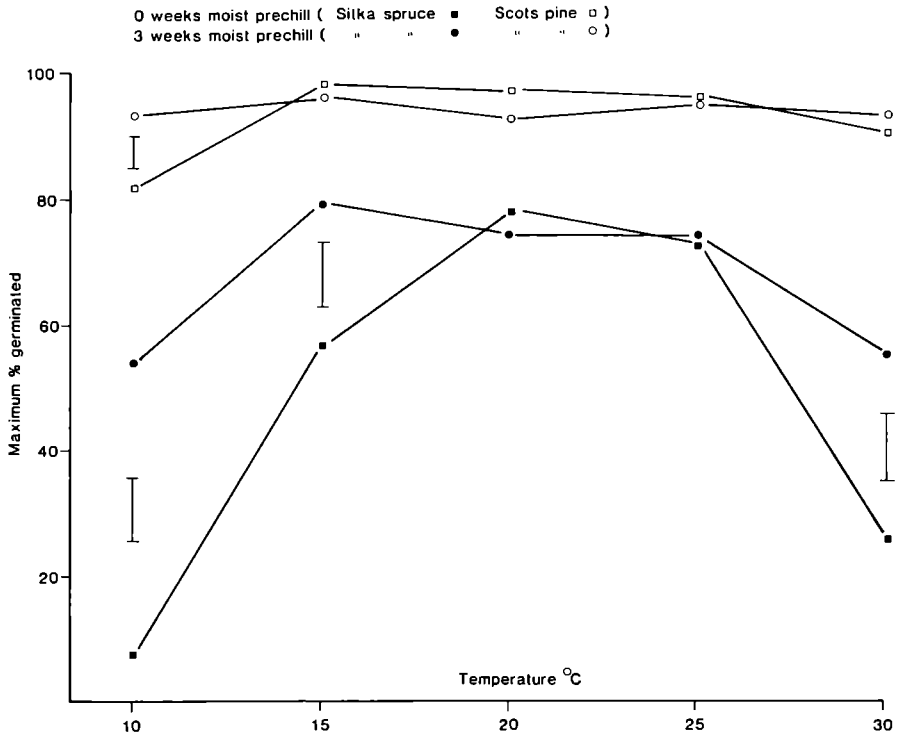

Figure 1. **Maximum percentage germination of Sitka spruce and Scots pine seeds, with and without pretreatment, at different temperatures. (Bars signify 97.5 per cent confidence limits).**

has been previously shown that pre-chilling can increase the rate of germination at the optimum germination temperature of SS (*Report* 1971, p. 27), but this is the first demonstration that, in addition, pre-chilling increases the maximum percentage germination at the extremes of temperature over which germination is possible. These results help to explain observations from nurseries that SP emergence is generally less variable than that of SS. The reported results are however founded on single collections of the two species. In addition, it should be noted that differences in maximum percentage germination arise because *c.* 10 per cent of the SS seed were dead or empty at the start of the germination test.

Nursery experiments

Three field experiments were laid down at Headley Research Nursery together with their laboratory counterparts. Accumulated germination and survival percentages, seedling height and seedling root collar diameter were measured in all instances. One experiment assessed the feasibility of precision sowing high quality SS seed with the intention of producing forest plantable stock in 2 years without the current need for transplanting. It was concluded that precision sowing offered no significant advantages to any of the growth or survival parameters measured, and that factors affecting germination, seedling losses and seedling growth cannot be sufficiently controlled at present to warrant precision sowing of this species. In the second investigation, normal quality SS seed was graded using a seed gravity table into two fractions. The field performance of the densest fraction (containing 1/6th of the total seed) was compared with a sample of the remaining lower density 5/6ths. Contrary to results previously noted (*Report* 1970, p. 32) it was found that no significant benefits resulted from selecting the more dense fraction of seeds ($p > 0.05$). However a probable explanation is that current processing techniques give rise to better seed uniformity than was used in the 1970 experiments, and this negated the benefits of further grading. The third experiment tested whether polythene cloches with buried edges would influence seedling production of SS and SP in southern England to the same extent as in northern England (see *Reports* for 1977–80 inclusive). The benefits of cloches were much greater for SP than for SS. In particular, cloches improved the germination and survival of SP ($p < 0.01$), seedling height ($p < 0.001$) and seedling root collar diameter ($p < 0.05$). Cloches over plants until August, rather than June, produced the best overall growth of SP.

Service

Official Seed Testing Station

In conjunction with Statistics Branch a database has been created to store routine conifer seed test information derived from statutory and advisory seed tests. Various computer programmes have been developed concurrently to facilitate easy input, analysis, and retrieval of stored data. It is now possible to make objective assessments on the interpretation of test results which it is hoped can subsequently be linked to better predictions of field emergence.

P. G. GOSLING, D. C. WAKEMAN

SILVICULTURE (SOUTH)

Plant production

Raising oak in paperpots

Acorns pretreated by chilling for 0, 3 and 9 weeks were sown in paperpots of two diameters at full stocking (every pot filled) and 25 per cent density (one pot in four filled on a rectangular pattern). None of the treatments significantly affected survival or height growth but the stocking density, as expected, significantly influenced root collar diameter. There were also significant differences in seedling above-ground volume (diameter squared × height) with low density stocking resulting in the largest volume, fully stocked small paperpots the lowest and fully stocked large paperpots intermediate.

J. S. P. SALE

Vegetative propagation

A greenhouse trial designed to examine techniques for improving the survival, root initiation and development of softwood cuttings of oak yielded useful evidence. The greatest increases in survival and rooting rates were achieved by reducing light intensity to 30 per cent of full daylight and increasing humidity to 90–95 per cent over the trays of cuttings. This apparently desirable environment was obtained by totally enclosing the mist bench with either an opaque polythene sheet (250 gauge) or cloche film combined with green shade netting suspended on metal hoops 70 cm above the bench surface. Improvements in rooting rates were also gained, regardless of bench environment, by dipping the base of the cuttings prior to insertion in hormone 2-naphthyl acetic acid (NAA) dust in talc. Further increases were obtained when the cuttings were given an application of a fungicide (Benomyl) following the hormone treatment. Long apical cuttings (> 15 cm), short apical cuttings (< 15 cm) and subapical cuttings had similar survival and rooting rates. All three types of cutting rooted better in June than in July. More than 2000 cuttings were used in the trial. Since all were taken from old, though annually trimmed, roadside hedges, and some treatment combinations led to rooting rates as high as 90 per cent, the results are encouraging.

To ensure an adequate supply of uniform reproductive material from young stock plants for future oak work in greenhouses, an increased programme of budding and grafting was undertaken. Some 50 oak clones, eight selected for colliery spoil research and more than 30 for the Oxford Hardwood Improvement Project, were propagated during the year.

J. JOBLING

Lowland silviculture

Epicormic branches on oak

Initiation of research into ways of controlling epicormic branches on the boles of oak trees was referred to in *Report* for 1982 (p. 7). Experiments are in progress comparing conventional pruning methods, wrapping the trunk in opaque materials and application of chemicals—herbicides, plant hormones and growth retardants.

All trees, except controls, were pruned in late winter to cut off side branches and epicormics to a height of 5 m up the stem. Pruning alone led to increased

production of new epicormic shoots in the following year. Stem wrapping with black polythene or woven polypropylene (Mypex) reduced the numbers of epicormics but did not prevent their emergence altogether; black bitumastic paint effected no control at all. Both the herbicide glyphosate and the hormone NAA (naphthyl acetic acid) in aliphatic alcohol ('Tip-off', developed to control water shoots in fruit trees), applied in mid-season (July) killed newly emerged epicormic shoots but had little subsequent suppressing effect. The growth retardant maleic hydrazide (Burtolin), also applied in July, halted shoot development and greatly suppressed production of new epicormics in the following year. Autumn application of fosamine ammonium (Krenite) was ineffectual. Additional growth retardant chemicals are under trial. The time of application and dosage of maleic hydrazide, to give optimum long-term suppression of epicormics, is under investigation.

A studentship has been awarded to East Malling Research Station to investigate the anatomy and physiology of epicormic bud development.

Oak underplanted with conifers

Two surveys, in 1982 and 1983, have tended to confirm that the diameter growth of heavily thinned pole-stage oak is enhanced when there is a well-stocked conifer understorey, typically of Western hemlock or Western red cedar. Few sites were available and an absence of formal experimentation precluded direct measurement of the benefit. Therefore comparison was made of crown diameter : stem diameter relationships of trees of similar age and height in three different silvicultural environments, namely dominants in conventionally thinned stands, free growth trees, and oak in very heavily thinned stands (similar to free growth) underplanted with Western hemlock. Highly significantly different relationships were found and are plotted in Figure 2. These indicate that, for the range of tree sizes concerned,

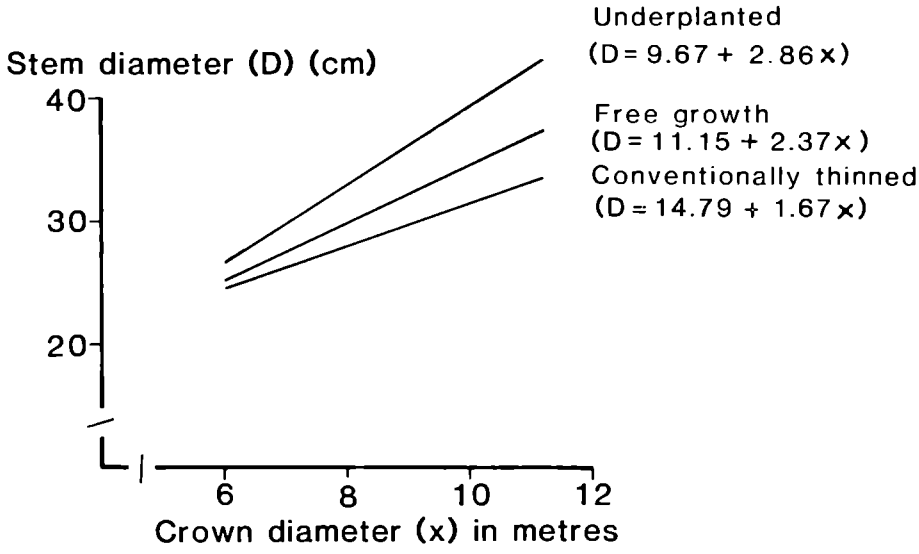

Figure 2. **Crown diameter : stem diameter relationships in pole-stage oak (40–55 years old) managed under three different silvicultural regimes. (The relationships are only valid within the ranges shown).**

underplanted oak have the most efficient crowns, that is the smallest crown diameter needed to achieve a particular stem diameter. The explanation for this may lie in more favourable water relations, but how it occurs is obscure.

A well replicated, long-term experiment has been established to evaluate the effects of five different understorey management regimes in heavily thinned pole stage oak.

Nutrition of broadleaves

Two new experiments have been laid down in pole-stage ash of Yield Class 4 investigating fertilising with nitrogen and potassium and the value of clearing understorey shrubs. First year results indicate a significant improvement in diameter growth due to the nitrogen application.

J. EVANS

Tree shelters

A further year's growth in the experiments established 4 and 5 years ago confirms that tree shelters are an effective way of improving the growth of recently planted trees of many broadleaved species. Once the tree emerges from the top of the shelter, girth is added to the stem and at the end of 5 years the tree is able to stand unsupported by the shelter.

New materials and fastening systems are still being developed and will require at least 5 years of field trials to confirm their suitability. The shelters and supporting stakes are subjected to the greatest strain when the tree starts to produce a crown before it has thickened its stem. Corrugated polypropylene and PVC shelters will require additional strengthening of the top edge to minimise failure. It is not known whether the two extruded polypropylene tubes which are new materials for 1984 will be adequate without additional strengthening.

A feature of the work on tree shelters is the keen interest taken by foresters, arboriculturists and plastic materials' makers. This has led to the extensive use of tree shelters: it is estimated that a million were used in the 1984 season.

G. TULEY

Forest weed control

In an experiment on a freely draining sandy soil at Thetford to test the effect on Corsican pine of repeated use of atrazine for weed control, 3-year-old trees which had already been treated with two applications of atrazine in earlier seasons were subjected to a further treatment. At the end of the season, trees on weeded plots were slightly better than unweeded controls in terms of survival, health, height and diameter but none of the differences was significant. Different rates of herbicide (from 2.5 to 10 kg a.i. per ha), the presence of a wetting agent and the application of fertiliser (KCl) made no significant difference to the responses. Further applications are to be made in 1984 to the same plots.

J. S. P. SALE

Arboriculture

Department of the Environment contracts

Arboricultural research and the Arboricultural Advisory Service have been the subject of two consecutive contracts over 8 years ending on 31st December

1983. A further 3 year contract has been awarded which will continue research into improving methods of establishing trees and maintaining them, and continues the advisory service though with a reduction in staff of 25 per cent.

Advisory and information service

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

46. Anthracnose of London plane.
47. Crown damage to London plane.
48. A definition of the best pruning position.
49. Shelters improve the growth of young trees—1982 results.
50. Nutrition of broadleaved amenity trees. I. Foliar sampling and analysis for determining nutrient status.
51. Ash dieback survey—summer 1983.
52. Nutrition of broadleaved amenity trees. II. Fertilisers.
53. Chemical weeding—hand-held direct applicators.

The number of enquiries answered was 1760; there was no marked change from last year in the subjects raised. During the latter part of the year a system of charges for advisory visits was introduced.

D. PATCH

Amenity tree establishment and maintenance

Good progress was made in establishing a series of experiments comparing black polythene mulching with chemical weed control. The experiments, on a range of soil types, are designed to test different sizes of polythene and herbicide spot, the effect of weeds outside the mulch rooting under it, and the effect of cultivation.

Several experiments on grassy sites have suffered continuing vole damage despite the use of Warfarin. These trees are now being protected by plastic guards. An experiment comparing various guard designs has been established.

The broad-scale survey examining the stability of trees growing on motorway and trunk road verges has revealed a few cases of poor rooting in shallow soils over cuttings through rock and on waterlogged sites. Close initial spacing and delayed thinning has resulted in many cases of tall thin stems with small live crowns and of plantation edge trees leaning outwards.

R. J. DAVIES

Colliery spoil

All experiments were assessed at the end of the growing season. Most continue to yield useful evidence. In the earliest planted cultivation experiment, at North Beechburn (County Durham), 5-year-old Scots pine in spoil ripped to 60 cm before planting had a significantly higher survival rate, were significantly taller and showed a significantly greater height increase since planting, than Scots pine in unripped spoil. Neither the survival rate nor the vigour of trees had been significantly improved by planting in cross-ripped spoil (Table 1).

Table 1 Survival, total height, and height increase since planting, of 5-year-old Scots pine in ripped and unripped spoil. North Beechburn (County Durham)

Experiment treatment	Per cent survival (after angular transformation)	Total height (cm)	Height increase (cm)
Co	41.0	87.6	77.2
C60	60.8***	118.5**	110.6***
C60x	61.1***	122.7**	119.8***

Co = no ripping; C60 = ripping to 60 cm along planting lines; C60x = ripping to 60 cm along planting lines and at right angles (plant at intersection).

Differences from the control Co are statistically significant at the 1 per cent level (**) or the 0.1 per cent level (***). There are no significant differences between C60 and C60x treatments.

Similar results confirming the benefits of pre-planting ripping were obtained in three other experiments started one year after that at North Beechburn.

Silver birch is an early coloniser of, and often becomes the commonest species on, ungraded tips, but its survival has been poor in several reclamation schemes and current planting rates are low. It was thought that container stocks might reduce failure rates. However, in four experiments planted in 1980, Silver birch in Japanese paperpots had lower survival rates than bare-rooted trees, and in three of the four experiments birch in amenity pots survived less well than the bare rooted plants. In three experiments, bare rooted trees had significantly better survival rates than Japanese paperpot trees ($p < 0.001$). In experiments comparing different sizes of Silver birch bare-rooted stock, trees in the height range 45–60 cm survived better than trees graded as 60 cm+, but there was no clear relationship between root collar stem diameter and survival.

Assessments of total height and of current height increment of major species in early reclamation plantings have revealed that, although tree establishment is usually erratic and slow on regraded pit heaps, annual height growth, total height and breast height diameter after about 10 years, may be similar to those of trees on undisturbed forest sites. Forecasts of tree dimensions and production may thus be facilitated.

J. JOBLING

Coppice for energy

Department of Energy contract

Coppice cutting was carried out on several of the experiments and dry weight yields are being assessed.

M. L. PEARCE

Dendrology and Arboreta

Dendrology

During the year 180 estates, gardens and collections were visited, 93 of them for the first time. 6305 trees were recorded of which 3874 were additions to the Register and 2431 were remeasured. The National Register now has 64 442 specimens of 1484 species and 948 varieties. The Giant sequoia extended its lead over all other species as the biggest entry with 244 additions and a current total of 2278 specimens. Five of these are 50 m tall, all in Scotland.

Advice on planning, planting and rehabilitation was given to about 25 estates and more detailed planning of planting to three. Data for the revision of *Trees and shrubs in the British Isles* (W. J. Bean) was supplied for two volumes and compiled for the remaining two. The entries relating to trees in the *Guinness book of records* were revised for two editions during the year.

A. F. MITCHELL

Bedgebury National Pinetum, Kent

Additional new paths have made walking in the Pinetum much easier, a feature much appreciated by both the old and very young. Some progress has been made on removing the many years' accumulation of silt in Marshall's Lake. Clearance of an area of rhododendron and Scots pine to extend planting of specimens continues.

M. J. SCOTT

Westonbirt Arboretum, Gloucestershire

Six years of intensive surveying, mapping and data processing have culminated in the first comprehensive catalogue of the collection. A microcomputer at Westonbirt was used to record the data which were rearranged by the Alice Holt Prime computer into a generic listing. This latter stage has produced camera-ready copy for publication. There are 13 200 listed specimens, and 325 genera including 2835 taxa. Some notable inclusions are 182 species and cultivars of *Acer*, 255 species and cultivars of *Prunus*, 10 species and hybrids of *Nothofagus* and, in spite of Dutch elm disease, 19 species, hybrids and cultivars of *Ulmus*. This latter genus is also represented by a large trial of 50 clones of elm.

M. L. PEARCE

SILVICULTURE (NORTH)

Species

Seed origin experiments: Abies

Eleven experiments, with up to 36 seed origins per experiment, of Grand fir collected by IUFRO were planted in 1978 and 1979. Height growth for each regional group of origins after 3 years is shown in Table 2. Seed origin differences were significant ($p < 0.001$) in every experiment. From its characteristics, it seems likely that the Danish provenance belongs to regional group I. Group VII includes a provenance from Dunkeld Forest (Tayside) of Campbell Lake origin. Although this Dunkeld stand has a Local Yield Class of 34, its progeny have been out-grown by seed origins from group I in most of the experiments.

A nursery experiment with 33 seed origins of Pacific silver fir showed considerable height differences both at 1½ and at 3 years. Although regional group differences were significant ($p < 0.001$), there were also significant differences between origins within groups. Sources from Forestry Commission seed region (7975) in Washington were among the tallest, as were some from

Table 2 Mean height at 3 years for eight regional groups of Grand fir, expressed as a percentage of the experiment mean on 11 sites

Regional group		No. of origins	Speymouth	Inchnacardoch	Drummond Hill	Benmore	Dalmacallan	Wark	York	Mathrafal	Thetford	Alice Holt	Brendon	Mean[a]
Olympic Peninsula and Puget Sound	I	8	122	118	123	125	127	119	122	119	118	119	112	120.4
Washington Cascades	II	7	89	90	89	97	92	86	88	93	106	102	99	93.7
NE Washington/Idaho	III	2	98	105	90	99	88	86	85	93	—	—	—	(93.0)
Oregon east of Cascades	IV	3	87	86	78	87	79	75	77	83	96	82	90	83.6
NE Oregon/Idaho	V	2	94	77	75	71	69	87	76	87	—	—	—	(79.5)
Oregon west of Cascades	VI	4	91	87	86	92	88	83	87	95	98	83	92	89.3
Vancouver Island	VII	6	104	115	116	112	115	124	119	115	113	119	110	114.7
N Coast Mts Oregon	VIII	2	95	93	94	81	99	95	97	89	72	75	86	88.7
S Oregon Coast	IX	2	110	108	129	104	124	118	127	101	97	119	111	113.5
Denmark	D	1	112	122	119	132	120	128	122	126	—	—	—	(122.6)
Mean height (m)[b]			0.54	0.39	0.63	0.43	0.46	0.51	0.66	0.50	(0.40)	(0.65)	(0.69)	

Note: Bracketed and unbracketed mean values are not directly comparable.
Bracketed mean percentages[a] are derived from fewer experiments, and bracketed mean heights[b] from fewer regional groups than other means.

Vancouver Island (7116), although the two shortest were also from Vancouver Island.

For both these species of silver fir, plants from the Darrington, Washington area have grown poorly, although Douglas fir from this origin is outstanding.

Species trials on polluted sites

Although pollution from smoke and sulphur dioxide in the central Pennines is now considerably lower than it was in the 1950s (Lines, 1984), only a few species grow well on high and exposed sites. A 1972 experiment at Don Forest (South Yorks) on an ironpan soil was damaged by fire in 1980. The burnt areas have been restocked to include a third origin of Lodgepole pine, and birch and *Nothofagus* species. Sawfly attack on the older Lodgepole pine was severe, as was attack by *Elatobium* on Sitka spruce. Nevertheless, height growth at 10 years was equivalent to General Yield Class 8–10 for Lodgepole pine, 6 for Japanese larch and 14–16 for Sitka spruce. After a rapid start, Red alder is now moribund.

The 1977 experiment at Don on poor peat contains six species, with Lodgepole pine represented by eight seed origins. Some species are included both as pure plots and in mixtures of two species. After 6 years Hybrid larch was tallest (1.48 m) followed by Sitka spruce (1.36 m when pure and 1.28 m when in mixture). Lodgepole pine heights ranged from 1.21 m (Queen Charlotte Islands origin) to 0.69 m (Alaska). Scots pine (0.89 m) showed severe potassium deficiency, while Japanese larch, after considerable beating-up, was only 0.82 m. Red alder (1.05 m) is clearly failing. Unreplicated small plots of *Nothofagus procera* (1.22 m), aspen (1.17 m), *Betula pubescens* (1.69 m) and *Alnus sinuata* (1.02 m) show some promise and in these plots *N. procera* in mixture with Hybrid larch is much taller (1.57 m) than when pure.

Public interest in the effects of pollution, especially acid deposition, on forests and catchment areas has involved a considerable increase in advisory and liaison work during the year.

R. LINES

Production of planting stock

Vegetative propagation of conifers

In a continuation of the field scale trial of Sitka spruce propagation at Newton Nursery (Grampian) (*Report* 1983, p. 13), 90 000 cuttings were inserted and rooting was again successful, at 84 per cent. Cuttings from 2-year-old seedling stock plants rooted much more readily than those taken from cuttings rooted two seasons previously (90 per cent as compared with 55 per cent successful rooting). 86 per cent of all cuttings rooted were considered suitable for lining out in late July. A preliminary study of the effects of different propagation regimes and media on rooting success with Sitka spruce cuttings was made in the Newton plastic house and in three propagation houses at Banff and Buchan Nurseries, Portsoy (Grampian). Details of regimes, media and results are given in Table 3.

There were significant differences in rooting between media ($p < 0.001$) and a significant medium × house interaction ($p < 0.05$) in rooting success. Little

Table 3 The effect of propagation regime and medium on percentage rooting success with Sitka spruce cuttings: Experiment Newton 2/83

Location	Regime[1]	Medium[2]				
		G100%	G75%P25%	G50%P50%	G25%P75%	P100%
Newton	N	99	100	100	100	99
Banff and Buchan	W	97	99	99	98	85
	L	81	97	93	92	69
	C	76	95	93	94	68

Notes: [1] N: intermittent mist in house with clear polythene cover.
W: hand watering; white polythene house cover plus base heat (18°C).
L: hand watering; clear polythene house cover plus white polythene suspended immediately over cuttings.
C: as L, but with white polythene house cover.

[2] G = grit (2–3 mm average diameter); P = sphagnum moss peat.

difference was apparent between media at Newton, but quadratic regressions fitted to the Banff and Buchan data ($p < 0.05$) suggest a maximum percentage for mixtures between 75% grit 25% peat and 50% grit 50% peat. The results overall suggest that Sitka spruce can be successfully rooted using less capital intensive facilities than have been used hitherto. If confirmed, this would improve the economic viability of large-scale vegetative propagation of the species by cuttings.

At Bush Nursery (Lothian), an experiment investigating effects of nutritional regimes on rooting of Sitka spruce (*Report* 1983, p. 14) was extended to the open nursery where all cuttings received standard treatments after lining out. Although differences at the time of lining-out had proved non-significant, the mean root and shoot dry weights of all fertilised treatments were greater ($p < 0.01$) at the end of the growing season than those of the unfertilised controls.

Rooting performance of hardwood cuttings of Hybrid larch was examined in experiments at Bush and Newton. At Bush, cuttings collected between November and late May were inserted at intervals from January to late May after differing periods of cold storage. A shorter period of collection and insertion was used at Newton. Results of both experiments were encouraging, with mean rooting percentages of 80 per cent at Bush and 75 per cent at Newton; the best treatments producing over 90 per cent rooted cuttings. In general, any date of collection between January and April gave good rooting, with results enhanced by cold storage periods of up to 4 weeks.

Precision sowing and undercutting

A re-evaluation of precision sowing and undercutting regimes for planting stock production was begun at Wykeham Nursery (North Yorkshire) where a Summit precision sower was under trial. Initial tests in March 1983 proved that the machine could produce spaced sowing of most conifer species, although it had difficulty coping with very small seed. In May, large scale sowings of three species with different seed sizes (Scots pine, Douglas fir, Sitka spruce) were undertaken using three different spacings within the drill.

W. L. MASON

Planting (including herbicides and natural regeneration)

Plant handling

An experiment was planted at Wykeham (North Yorkshire) in spring 1983 to assess the performance of bare-rooted transplants of Sitka spruce and Douglas fir after exposure to drying conditions with or without rewetting. Preliminary investigation in the laboratory had shown that rewetting of desiccated plants by immersion of their roots in water in darkness increased root moisture content, although severely desiccated plants did not recover to pre-treatment levels. At Wykeham, plants were exposed for different periods up to a maximum of 5 hours, and then either planted immediately or rewetted for 1 hour and then planted. The experiment was carried out on two dates, 15 March and 26 April, so as to test plants during and after dormancy.

Survival at one year after planting was not consistently increased by rewetting: indeed this occasionally reduced survival. Survival of Douglas fir was generally lower than that of Sitka spruce, the latter showing a sharp drop in survival when root moisture content at planting was below 160 per cent dry weight, whereas Douglas fir showed a more gradual drop beginning at around 180 per cent root moisture content. These results indicate a possible use for root moisture content in assessing planting stock viability, provided plants are not rewetted before assessment.

An experiment at Bush Nursery (Lothian) compared the survival and growth of transplants of Sitka spruce and Douglas fir after 3 or 5 months cold storage in polythene bags. The plants had been top dipped in Gamma-Col or Strykol BHC insecticide, or in water as a control, before being bagged and placed in store either wet or after allowing the foliage to become surface dry.

After one year, the Strykol BHC emulsifiable concentrate formulation reduced the survival of Douglas fir to zero in both wet and dry treatments, and that of Sitka spruce to 2.5 per cent in the wet treatments. In contrast, Gamma-Col did not affect the survival of either species. Storage of Douglas fir for the longer period and especially with wet foliage was deleterious, whilst Sitka spruce survived better after 5 than 3 months cold storage with either wet or dry foliage.

Forest weed control

Experiments on the control of *Rhododendron ponticum* at Dyfi Forest (Gwynedd) and Benmore Forest (Strathclyde) have shown that 'mixture B' (1:1:4 Ethylan D252 : Agral : domestic paraffin) enhances the effect of foliage-applied glyphosate when included as 10 per cent of the spray volume, for either medium or ultra low volume treatment. These results indicate that rates as low as 6 l/ha of Roundup may be effective and, because the rate of uptake is increased, the treatment should be more rain-fast.

Three experiments compared the toxicity to Sitka spruce of atrazine/dalapon granules (Herbon Lignum) and dichlobenil/dalapon granules (Fydulan) at up to four times the recommended rate. The only toxic effects observed (basal swellings, dead needles, and some plant deaths) followed Fydulan application on a brown earth soil at Mynydd Du (Gwent). The other two experiments were on peat soils and no damage was observed in any treatment.

In an experiment at Kielder Forest (Northumberland), glyphosate was applied to a dense grass sward in August 1982 at a range of volume rates using

the new 'VLV' as well as conventional 'polytip' knapsack sprayer nozzles. Control varied with the amount of chemical applied and a rate of 2 l/ha of Roundup was optimum, but volume rate (nozzle type) did not affect the result.

Natural regeneration

The use of paraquat, glufosinate, glyphosate, 2,4-D, and hexazinone to control unwanted Sitka spruce natural regeneration was examined at Clocaenog Forest (Dyfed). Only paraquat and glufosinate appeared capable of killing seedlings at economically acceptable foliage application rates.

At Glasfynydd Forest (Powys) glyphosate was applied every other month from November 1981 until September 1982 to the stumps of young Sitka spruce which had been cut leaving a live whorl to simulate clearing-saw work. The herbicide has been effective in suppressing growth of this whorl at all application dates and at dilutions down to 10 per cent Roundup in water.

P. M. TABBUSH

Nutrition

Species mixtures

A review of all existing experiments investigating the effects of species mixtures on the growth and nutrient status of Sitka spruce on poor sites has confirmed the value of such mixtures in helping to overcome the effects of nitrogen deficiency in the spruce. However, available evidence is confined largely to the use of Lodgepole pine, Scots pine and Japanese larch as nurse species mixed in the proportions 75 per cent nurse to 25 per cent Sitka spruce. Three new long-term experiments have therefore been established to study different mixture proportions (33, 50 and 66 per cent nurse) and different nurse species (Alaskan Lodgepole pine, Central Interior Lodgepole pine, Scots pine, Hybrid larch, birch and Sitka alder *A. sinuata*).

Thinning/fertiliser interactions

Four year results are now available from four thinning/fertiliser interaction experiments established in pole-stage stands of Sitka spruce (three experiments) and Lodgepole pine (one experiment). Fertiliser application significantly increased basal area increment per hectare in the Lodgepole pine experiment and in two of the spruce experiments; thinning significantly increased basal area production in one spruce experiment but resulted in a reduced rate of production in all others. In the spruce experiments the effects of thinning and fertiliser application were simply additive and no interaction was indicated. A significant interaction has occurred in the Lodgepole pine experiment, however, where 4 years' basal area increment per hectare showed an increase of 11 per cent due to fertiliser treatment, a decrease of 6 per cent due to thinning treatment and an increase of 22 per cent due to a combination of thinning and fertiliser application.

Copper deficiency

In 1980 copper deficiency was identified in two Sitka spruce stands of about 1.5 m height; experiments were laid down to determine the effect of a number of different copper treatments including the use of both copper sulphate and chelated copper applied broadcast or as a foliar spray, and of copper nails

hammered into the tree stem. To date there is little indication of any treatment effect; all trees, both treated and control, appear to be overcoming the deficiency and returning to normal growth.

R. McINTOSH

Cultivation, drainage and site preparation

Preliminary analysis of root development in 7-year-old Sitka spruce has been carried out in an experiment at Moffat Forest (Borders), containing five spaced-furrow ploughing treatments on a range of soil types. Vertical tree pulling was used to remove 60 trees from the surface water gleys for root analysis. Although there were distinct differences in root architecture and uprooting forces between individual sample trees, mean treatment differences were not significant. (See pp. 29-31.)

Analysis of 3-year height growth in a restocking site preparation experiment at Falstone Forest (Northumberland) indicates that mound planting gave a height growth advantage over D60/T90/t ploughing followed by mole draining and ripping. All site preparations gave significantly better results than direct planting. Planting in late May gave significantly better growth than late March planting, but pre-soaking of roots had no significant effect.

Stability

Following completion in September 1983 of the first thinning operations at the main aeromechanical experiment at Moffat Forest (Borders) (*Report* 1983, p. 17), further wind and tree oscillation data have been recorded and analysed. The thinning involved removal of 25 per cent of the crop (alternate trees in alternate rows) and altered the surface roughness of the study forest by increasing the mean stand spacing:height ratio (S/H) from 0.17 in the unthinned stand to 0.21 after the first thinning. A second systematic thinning subsequently removed a further quarter of the original crop, and increased surface roughness further by raising the S/H ratio to 0.26. During December 1983 and January 1984, very strong winds were recorded over the forest (wind speeds in excess of 45 ms^{-1}) and approximately 3 per cent of stems were wind-thrown. Analysis of data has concentrated on the calculation of the basic aero-dynamic parameters using wind profile analysis and eddy correlation techniques. In particular, changes in zero plane displacement, roughness length, frictional velocity and profile shear stress following thinning have been calculated from profile analysis, and local shear stress coefficients indicating the effectiveness of momentum transfer to the forest at different points in the profile calculated using eddy correlation methods. Momentum transfer between wind and the forest is examined by analysis of the wind and accelero-meter data which indicate the extent of uptake of energy by the stand, and may be used to explain the mechanics of momentum coupling under different stand structures. Forest results are being compared with those from wind-tunnel studies using a 1:75 scale model forest.

Analysis of data derived from wind damaged stands over the past 3 years was undertaken to determine the relationship between actual critical height (i.e. crop height at onset of windthrow) and critical height as indicated by the windthrow hazard classification (Miller, 1985). A statistically significant regression between critical height and windthrow hazard class has been

calculated, but as expected there was a wide dispersion of observed critical heights around the predicted mean critical height.

K. F. MILLER

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

Nursery herbicides

Joint experiments were carried out at Bush (Lothian) and Headley (Hampshire) nurseries to screen 10 potential herbicides for use on standover seedbeds. Five herbicides (chloridazon, metamitron, metoxuron, oxyfluorfen and pyridate) appeared promising and will be tested further in 1984.

Cloches for broadleaves

Seven broadleaved species (ash, beech, Sessile and Pedunculate oak, sycamore, birch and Common alder) were sown under polythene tunnel cloches and in beds without cloches at Bush and Headley (*Report* 1983, p. 14). Only beech at Bush and Common alder at Headley showed improvement in end of season numbers as a result of cloche treatment. When cloches were removed in July, all cloched treatments (apart from birch at Bush) were taller than controls. At the end of the growing season, cloched trees of all species at Headley remained taller and had a greater root collar diameter than uncloched treatments. However, at Bush the height differences noted in July had largely disappeared by November; only for beech and Common alder were cloched trees still significantly ($p < 0.05$) taller.

W. L. MASON, J. S. P. SALE

SITE STUDIES (SOUTH)

Chemical analysis

Service

The decline in the number of samples presented for analysis during recent years has continued although the range of sample type and of analysis required has continued to diversify. A total of 8400 samples was analysed during the year; the proportion from Forestry Commission managers and private growers remained low, the bulk arising from research projects.

Methods

Distillation apparatus for the bulk extraction of secondary plant compounds has been developed, together with the necessary separation techniques for isolating individual compounds or groups from the mixture. The isolated compounds are used in studies of plant/insect relationships.

Soil

The subject of research into the phosphate status of upland forest soils was reviewed by a visiting group in 1982. Following their report, it was decided to narrow the area of study to the one remaining line described below. A pot

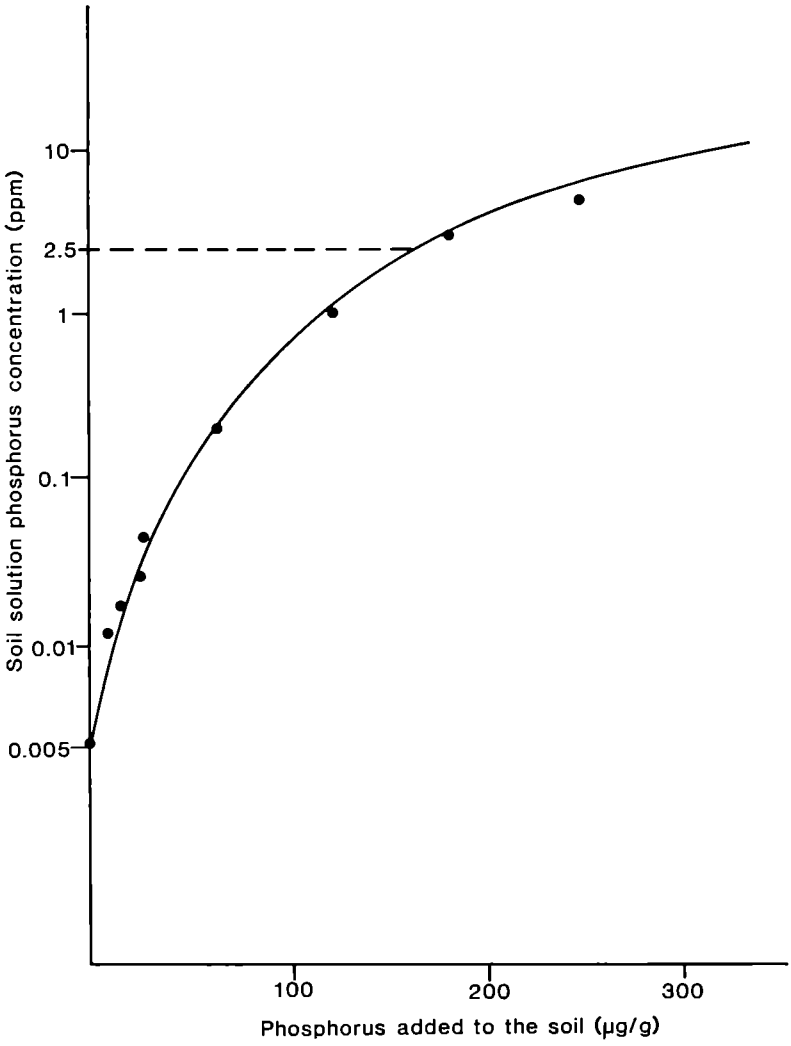

Figure 3. **The relationship in a forest soil between added phosphate and the soil solution concentration.**

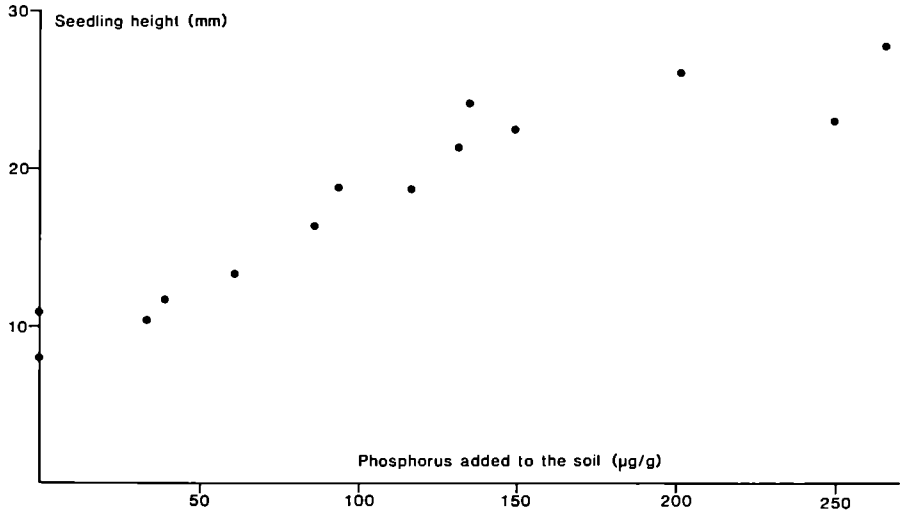

Figure 4. **Height of Sitka spruce seedlings grown in a forest soil supplied with different rates of phosphate, derived from Figure 3, to produce known soil solution concentrations. Each point is the mean of three measurements.**

experiment with three replicates has demonstrated that the response of Sitka spruce seedlings to applied phosphate can be predicted from a soil test measurement. Earlier work demonstrated that extractable phosphate was not related to tree growth or response to fertilisers, except in the forest nursery where conditions are akin to agriculture. The new method is based upon measuring the ability of the soil to maintain the concentration of phosphate in the solution surrounding the soil particles. The rates of phosphate needed to maintain particular soil solution concentrations were derived from the experimentally determined curve for the soil used in the pot experiment (Figure 3).

Growth of the Sitka spruce seedlings, as shown in Figure 4, increased with increasing soil solution phosphate concentration. The optimum appeared to arise at a level of P addition of about 175 $\mu g\ g^{-1}$. As seen from Figure 3, this is equivalent to a concentration of about 2.5 ppm P, a level higher than has previously been found in hydroponics experiments.

Soils from 45 sites representing a wide range of soil types and lithological origins were analysed in like manner. The curves were all of similar shape to that shown in Figure 3 and very few of the lines crossed each other, the position of a curve being more dependent upon the particle size distribution of the soil than either the soil type or lithological origin. Soils from sites where trees have shown large responses to phosphate fertiliser had low inherent concentrations of phosphate in the soil solution and required large quantities of phosphate in order to increase the solution concentration.

A. WILLSON, D. A. WADDELL

Effects of trees on sites

Impact of clear felling

Experimental measurement of clear felling impact on ironpan soils at Beddgelert Forest (Gwynedd) (*Report* 1983, p. 18) has been extended to

surface water gleys at Torridge Forest (Devon) and peaty gleys at Kershope Forest (Borders). Crops of Sitka spruce were felled at these sites during 1983; instruments have been established by the Institute of Terrestrial Ecology to monitor nutrient fluxes and by Site Studies (South) Branch to monitor soil oxygen. Early results from our work show differences in the depth to root-limiting oxygen flux values depending upon the location. Thus, three months after harvesting, the depth to this level in the ironpan soil at Beddgelert was 11.2 cm in clear felled areas compared with 6.2 cm in unfelled controls, whereas in the surface water gley at Torridge the oxygen limit had risen to 9.5 cm in felled areas compared with 23.9 cm in unfelled controls. Comparisons of the success of second rotation Sitka spruce transplants in these soils will be conducted during the year.

Effects of tree species on soil aeration

Studies of soil aeration, using flux electrodes and rates of iron corrosion, have been carried out in a surface water gley at Gisburn Forest (Lancashire). Under the ploughed turf, Scots pine had lowered the depth at which soil oxygen becomes limiting to root growth 10 cm further than had Norway spruce, after 30 years. Investigations will now be made to find whether this effect continues beyond clear felling so that transplant rooting in the next rotation is improved on sites previously planted with pines.

M. A. ANDERSON

Lowland forestry

Reclamation: machinery

Most equipment used for cultivating restored sites has been modified from existing models, for example the winged tine boots to fit on the standard Caterpillar D8 (or equivalent) shank. A low drag version using directly welded wings and a sharper leading edge has been made and the standard wear tips for the tines have also been given a delta form, with welded attachments, which improves disturbance still further, while reducing draw-bar pull.

For cultivating older sites where it has not proved practicable to increase the slopes, an adaptor plate has been made to allow a standard Parkgate single mouldboard tine plough to be attached to a standard D6 size tractor.

The development of the 6 × 4 and 6 × 6 frame-steered dumper trucks, which are now available, cheap in use, and fast between loading and dumping, has proved of assistance in constructing loose-tipped ridges. These appear to promise a better method when restoring overburden of heavy clay, an operation which has not proved satisfactory using the existing box-scraper and dozer constructed ridges. Dump loads tipped to create a pattern of overlapping heaps of loose spoil remove the need for further cultivation and present convenient planting sites.

Reclamation: nitrogen fixation studies

Four alders, Common, Grey, Italian and Red, can grow well, provided they have access to an adequate volume of rootable, loosened spoil which can supply mineral nutrients and 150 mm of rainfall equivalent from storage; growth rates of around 1 m a year for several years have been obtained (see Plate 2). However, poor height growth and heavy 'distress' flowering have

been seen on many sites where soil physical conditions are bad (see Plate 3). In addition two shrubby alders, *Alnus viridis* and *A. sinuata*, are likely to compete less and may therefore have some advantages when used in mixture. Trials are in progress.

Trees adjacent to alders are able to gain access to the fixed nitrogen as soon as leaf litter is broken down by soil micro-organisms and it is important to ensure that such litter is trapped on the site by plough furrows or natural irregularities rather than blown away. The benefit to Corsican pine growing on coal spoils is shown in Figure 5. Colour and growth have both improved compared with trees well away from the alders. Japanese larch has also shown improved colour and growth in similar situations.

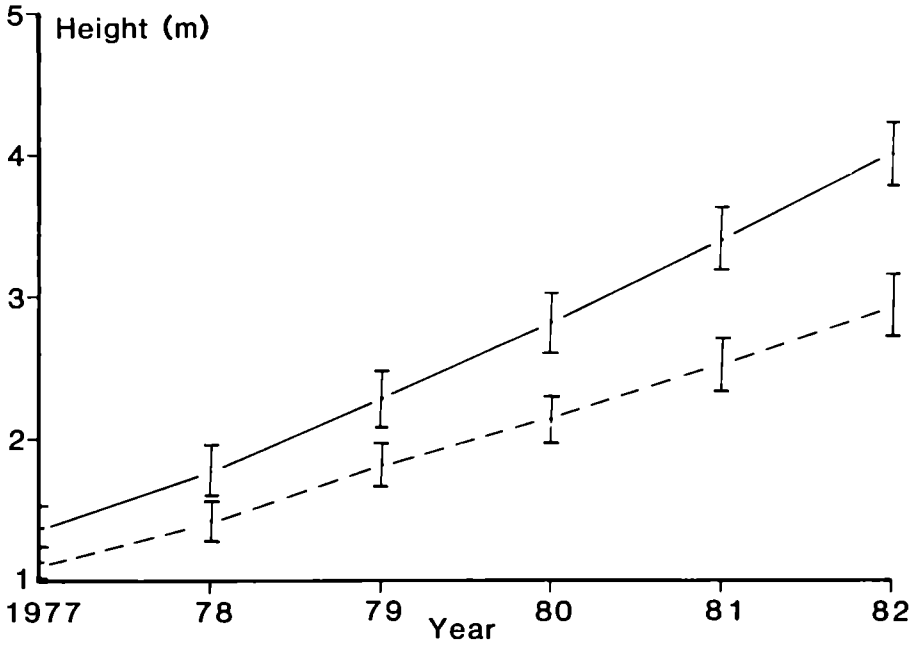

Figure 5. **The effect of Red alder on height growth of Corsican pine planted in 1972 on spoil from open-cast mining at Tumble, Pembrey Forest (Dyfed).**
——— dark green foliage, pine adjacent to alders.
— — — — — — pale yellow-green foliage, pine away from alders.
Mean of 30 trees (bars show 99 per cent confidence limits).

Adequate nodulation of alders is essential and normally occurs naturally in open-grown seedlings. However, alders grown in peat composts in containers may have few or no nodules and such trees grow poorly when planted on raw spoils. Examination of natural seedlings of Common and Red alders shows a concentration of nodule tissue just below the collar, on the main stem, while nursery transplants usually carry their nodules on more vulnerable lateral roots. It follows that inoculation of paperpot media may be necessary to ensure both nodulation and its most favourable positioning on the plant. (See also Entomology, page 41—the Lupin aphid).

Reclamation: peat-covered sites

On opencast coal sites with a deep cover of peat, removal and replacement of the overburden is difficult and messy. In collaboration with National Coal Board staff and Forestry Commission managers a system has been developed which enables reclamation to continue in winter, while improving drainage and access. One metre high mineral bunds are constructed just off the contour with a box-scraper, on a 4° to 8° slope, at 50 m spacing. About 1 m depth of peat is then loose tipped between them and graded with a side-acting bucket on a tracked excavator, or a low ground pressure dozer, to give 0.7 to 0.8 m thick cover over the spoil base. A drain is then dug above the bund to complete the operation. The peat surface is protected from erosion with a fertilised grass sward to await replanting. Conservation of peat as a nitrogen source should enable Sitka spruce to be grown instead of the alder/Japanese larch mixture used on raw shale spoils in South Wales.

D. F. FOURT

Reclamation: contract study

A short contract from the Department of the Environment was completed during the year. The study reviewed the existing state of knowledge concerning the reclamation of surface mineral workings to forestry, in order to provide guidance for central and local government and the minerals industry on planning conditions and after-care schemes. The final report considers the factors affecting survival and growth of trees on restored sites, recommends techniques which have proved successful, notes the requirements for successful after-care, and lists criteria to be considered when assessing the success of the afforestation. The Department plans to publish a version of the report as a general guidance document in due course.

K. WILSON, D. F. FOURT, W. O. BINNS

Upland forestry

Drainage: peaty gleys

Further analysis of the data from the drainage experiment at Crychan Forest (Powys) (*Report* 1982, p. 19) has revealed a striking relationship between timber volume and the computed infiltration rate at saturation; a range of 0.04 to 0.12 m^3 per tree was associated with 5 to 100 mm per day ($p < 0.0001$). Another drainage experiment in the same series at Hafren Forest (Powys) has been prepared for readings, in order to see whether these confirm the results from Crychan.

R. CARNELL

Acid rain, forestry and fish

Concern over the decline of forests in central Europe has continued, although no evidence has been found of similar effects on trees in Britain. There has in addition been increasing awareness of acidification of fresh waters in parts of south and west Scotland and central Wales. The Branch has consequently been much involved in meetings, briefings, and answering worried enquirers. An introduction to the subject has been prepared (Binns, 1984).

W. O. BINNS

Advisory

Reclamation

The most important group of enquiries has concerned tree planting on pits filled with or heaps made up of domestic refuse. Failures have been observed on such sites over a prolonged period after planting. Rooting is almost always shallow, irrespective of cover type or thickness. Limited trials and site investigations have shown that we are not yet in a position to specify treatments which will avoid damage arising from the products of decomposition.

Motorway borrow-pits have given rise to reclamation problems for many years; work is in progress on the M27 to improve site preparation for planting.

D. F. FOURT

Meteorology

Further improvements have been made to data storage and retrieval by changing to a RAPPORT data base. When final updating has been completed later this year it will offer direct access to any user.

D. DURRANT

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SITE STUDIES (NORTH)

Classification and improvement of upland soils

Clay soils

The experimental work on a peaty gley soil at Kershope Forest (Borders) in collaboration with the Institute of Terrestrial Ecology (*Reports* 1982, p. 19; 1983, p. 24) has continued. Clear felling half of the experiment was completed in December 1983. Data for 2 years before felling have been collected on the quantity and chemical composition of water received as rain and snow and in the various stages of its passage through the canopy, soil and drains. The water balance for 1981 given in *Report* 1982 (p. 20) has been slightly amended and is given in Table 4 with the 1982 results.

Table 4 Water balance (mean of three 2 ha plots). Crop: Sitka spruce, top height 18–20 m
Units: mm equivalent depth of water

Year	Gross rainfall P	Throughfall T	Stemflow S	Net rainfall N=T+S	Drain discharge R	N–R	P–R
1981	1403	740	122	862	692	170	711
1982	1568	841	137	978	769	209	799

The difference (N–R) comprises transpiration, evaporation from the soil surface and any gains or losses to or from the plots. Since this estimate is derived from two much larger components, it is liable to the greatest proport-

ional error. The difference (P−R) is the estimate of total evaporative loss. The ratios T/P, S/P, N/P and R/P are virtually identical for both years, hence the estimates for (N−R) and (P−R) for each year are similar proportions of P.

As felling has progressed through three of the four hydrology plots during 1983 we have begun to detect the increase in runoff from the felled plots, but the full effect will not be evident until the lop and top has died down. At the same time the soil water table has become shallower in the felled area compared with that under the remaining crop.

Detailed measurements of the soil water potential at 15 different depths down to 230 cm have been made at six locations which were chosen to cover the range of soil wetness found by similar but less intensive measurements throughout the experiment. On most occasions the depth at which zero matric potential* occurs corresponds closely with the water table observed in boreholes. During 1982 the maximum depth reached by the zero matric potential varied greatly between the six locations, the shallowest being 50 cm, the deepest 165 cm. The degree of dryness (magnitude of the matric potential) of the overlying soil varied in a similar way. At greater depth the matric potential becomes increasingly positive, but when depth (gravitational potential) is taken into account it is evident that there is a small but consistent downward gradient of hydraulic potential. Although more work is needed on measurements of hydraulic conductivity at the appropriate depth, the best estimate of the rate of leakage of water through vertical percolation is 3 mm/year. This is therefore a negligible component of the water balance and the plots can be considered watertight beneath.

Water leaving six of the plots is sampled weekly and analysed for important elements and pH. On a few occasions pH measurements have been made downstream at intervals of 100 or 200 m for a distance of 2 km, still within the forest, to a point where the stream becomes permanent and has a fish population. It seems that when flow rates are fairly low, as they are most of the time, water leaving the plots has a pH about 4.0 and this rises rapidly within the first kilometre and exceeds 7.0 thereafter. During heavy rainfall in the autumn and winter when flow rates are up to a hundred times greater than the 'normal' range, water leaves the plots at a pH of slightly below 4.0 and increases more slowly downstream such that the fish experience short periods where the pH is below 6.0 and, exceptionally, as low as 4.5.

Deep peats

The use of a polarographic electrode for analysis of the oxygen concentration of samples of soil air or water (Blackwell, 1983) offers advantages of speed and convenience over the previous method using gas-liquid chromatography (Pyatt and Smith, 1983). The new method has been tested using samples from an afforested deep peat soil. The most important factor examined was the effect of sequential sampling on the results obtained. Where oxygen concentration was either high (about 20 per cent) or low (< 5 per cent) it was possible to extract several 5 cm^3 samples each day without having much effect on the prevailing values, but at intermediate concentrations the values were liable to

*Matric potential is the pressure difference relative to atmospheric pressure across the air-water interface in the soil pores.

increase as sequential samples were taken, and soil oxygen did not then recover overnight. Taking one 5 cm^3 sample per day seemed to be the most frequent sampling which would give reliable results.

D. G. PYATT

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GENETICS

Testing

Pollinations

Flowering in the clonal tree banks of larch, Sitka spruce and Scots pine was again very good and allowed several large pollination programmes to be undertaken. Larch flowering in the 6-year-old seed orchard at Exeter (Devon) was very heavy and especially on grafts which had been girdled 12 to 18 months previously. The programme included pollinations on both European and Japanese larch grafts with pollen dried and stored by Aberdeen University for 12 months using a range of techniques (see page 64). The number of full seed produced by each treatment was very low indicating that the problems of storing both European and Japanese larch pollen have not been solved.

Sitka spruce at Ledmore (Tayside) and Wauchope (Borders) again flowered heavily allowing the programme of Sitka spruce × White spruce crosses using pollen from British Columbia and Ontario, Canada to be completed. In addition a diallel mating design using six progeny-tested clones was completed along with a factorial crossing programme on 15 tested clones. The Scots pine programme concentrated on finishing the series of disconnected partial diallels amongst tested clones with 13 groups of six clones. At Wareham (Dorset) pollen was collected from 105 selected Lodgepole pine trees of Alaskan origin to put into store for use in spring 1984.

In addition to the main pollination programmes for larch and spruce a supplementary programme was carried out, its aim being to produce seed of genetically superior families for vegetative propagation. The achievements of the 1983 programme included 762 artificial crosses which involved 12 040 isolations and 34 222 flowers; 323 separate pollen lots were extracted.

Advantage was taken of the good flowering in many Scottish Sitka spruce stands to collect cones from 153 previously selected but untested plus trees. In addition several stands of seedlot 40/5 from British Columbia were located and found to be flowering heavily. This population has done particularly well in progeny tests and it was decided to increase the size of the base population by selecting a further 205 trees in Dunkeld Forest (Tayside); sufficient seed was collected for sowing in the spring 1984 series of progeny tests.

Forest progeny tests

Polycross families of a further 78 untested Sitka spruce candidate trees were planted in replicated tests on three sites: a surface water gley at Craigellachie Forest (Grampian), a peaty ironpan at Strathyre Forest (Tayside), and a brown earth at Glasfynydd Forest (Powys), bringing the number of candidate trees with families in test to 1322. Open-pollinated families of 106 untested Scots pine candidate trees were also planted in replicated tests on three sites: a peaty gley at Culloden Forest (Highland), a sand at Thetford Forest (Norfolk), and a peaty gley at Naver Forest (Highland), bringing the number of candidate trees with half-sib families in tests to 945. The Lodgepole pine testing programme continued with 63 unrelated specific inter-provenance crosses between trees of Skeena (British Columbia) and Sonora Island (British Columbia) origins together with 38 open-pollinated families from some of the same trees of Skeena origin being planted in replicated tests on three sites: a deep peat at Shin Forest (Highland), a deep peat at Strathyre Forest (Tayside) or at Angus Forest (Tayside), and a peaty gley at Craigellachie Forest (Grampian).

In addition, the first full-sib families of Sitka spruce since the diallel crosses of 1971 were planted on up to four sites. The 59 families are derived from crosses among a population of South Strome Forest (Highland) provenance and Queen Charlotte Islands (British Columbia) origin (described by Samuel and Johnstone, 1979) and include a North Carolina Model I mating design. The aims of the test are:

a. to provide estimates of the levels of additive and non-additive control of growth characteristics, and

b. to identify outstanding specific combinations which may be recreated and bulked for commercial use by vegetative propagation.

Sixth-year height was assessed in a number of Scots pine progeny tests planted in 1978, some of these were of half-sib polycross families derived from previously untested candidate trees. The mean 6-year height across three sites of 106 of these families was 98 per cent relative to a standard control derived from seed collections from selected trees in a Culbin, Laigh of Moray Forest (Grampian) seed stand. Earlier progeny tests have shown that this is typical of the performance of the families of phenotypically selected candidate trees relative to this high-quality control. The 1978 tests included 27 specific crosses between parents of high general-combining-ability, identified from earlier half-sib tests. The mean 6-year height of these crosses relative to the same standard control was 115 per cent. This improvement indicates the success achieved in selecting for high general-combining-ability and is typical of the output that can be expected from the first tested clonal seed orchard of Scots pine which was established in 1977 (*Report* 1977, p. 26). Predicted mean performance of the 27 specific crosses based on the breeding values of parents estimated in previous half-sib tests (and assuming cancelling out of any reciprocal and non-additive effects) was 107 per cent relative to the standard control. No reason for the apparent underestimate of the prediction is evident, other than residual reciprocal and non-additive effects and experimental error.

Seed production

Seed stands and seed orchards

A very heavy crop of cones developed on numerous plantations in west and south Scotland and north England and there were many applications for stand

registration for seed collections. One hundred and two Sitka spruce stands totalling 840 ha and mainly of Queen Charlotte Islands, British Columbia, origin were registered; 11 applications were refused.

Four hectares of clonal Sitka spruce orchards were planted in Scotland and 4 ha of seedling Lodgepole pine orchards were planted in Wales. Supplemental pollination of superior clones in a young Sitka spruce orchard in Brechfa Forest District (Dyfed) resulted in the production of 50 000 seeds; seedlings from these crosses will be bulked-up by rooting cuttings for commercial use.

Biochemical variation

In a joint project with Pathology Branch on the biochemical basis of the resistance of Sitka spruce to the decay fungus *Heterobasidion annosum*, capillary gas chromatography (GC) analysis of the terpenoid constituents of the main stem xylem and cortical oleoresin systems of individual trees has been completed. After felling, the stumps were infected with basidiospore suspensions of the fungus, and statistical analysis has begun on the association of the degree of infection with oleoresin composition. Early indications are that some of the trees most highly susceptible to infection exhibited oleoresin compositions of an unusual kind.

Attempts are being made with Silviculture Branch (North) to use biochemical criteria to characterise Sitka spruce families used in vegetative propagation; the aim ultimately is to fingerprint clonal mixtures in order to detect possible adulteration with inferior transplant stock.

Several origins of Sitka spruce and Lodgepole pine are being used in a study of the variation in oleoresin composition over the early years of tree growth. Sampling of this material is continuing, and the data are also being used in capillary GC studies of variation within and between origins and of within-tree variation.

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

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PHYSIOLOGY

Root growth and form

Root anchorage

Work was continued on root anchorage in a 20 m tall Sitka spruce plantation on a peaty gley soil, employing winching and other techniques outlined in *Report* 1983 (p. 27). The main components of anchorage in the predominantly plate-shaped root systems are shown in terms of the resistance they afford at different stages in the uprooting process (Figure 6). The turning moment required to cause soil failure, mainly underneath the root/soil plate, is seen to have formed the major resistance in the early stages of uprooting, and reached a maximum when the plate had been levered up about 0.5 cm. Failure in the soil represents an important stage because the tree then becomes liable to rocking or 'pumping' by wind action.

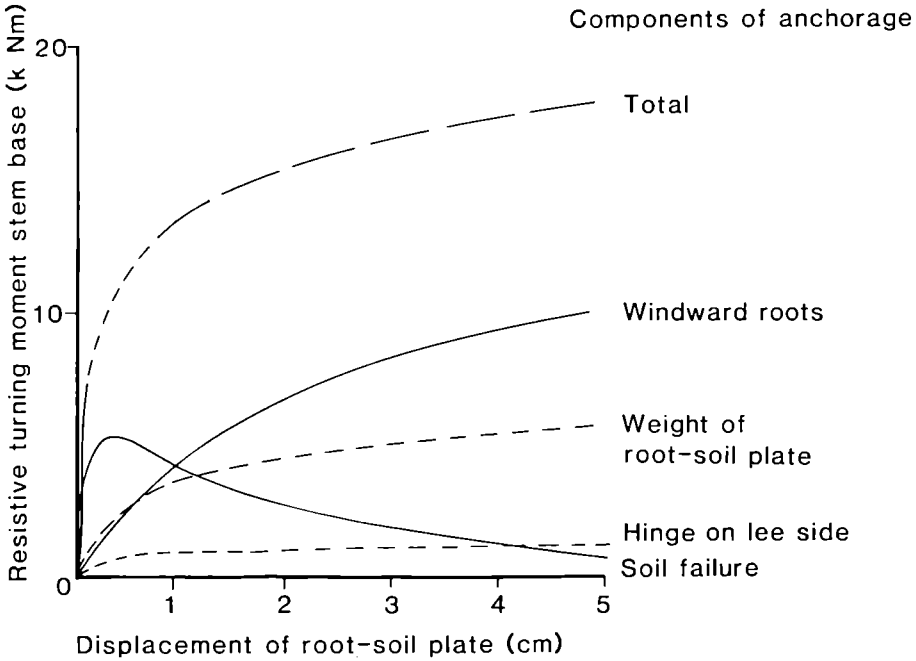

Figure 6. **The mean resistive turning moment for ten trees resulting from force applied horizontally to the stem with a winch. Displacement represents vertical displacement of the root-soil plate at a point 75 cm from the stem centre on the 'windward' side.**

By the time the applied force (and total resistive turning moment) had approached a maximum, part of the plate had been raised 4–5 cm and most of the soil had been broken. The main contributions to anchorage were then made by the roots on the 'windward' side (i.e. the opposite side of the tree from the direction of pulling with a winch), and by the weight of the root/soil plate. The weight component was very variable. It depended on the shape, dimensions and total weight of the root soil plate. In trees rooting to a depth of 50 cm (which was deeper than average for the site) the weight of soil lifted by the roots was equivalent to about three times the weight of the entire tree.

The fourth component measured, resistance to bending in the 'hinge' or fulcrum region on the 'lee' side of the tree, contributed little to total anchorage. However, the distance of the hinge from the stem base had a substantial effect because it influences the mechanical advantage of the three main components. The effects on anchorage of changing the distance between the hinge and the stem base can be calculated now that the sequence of events shown in Figure 6 has been quantified.

It is debatable whether the turning moment at soil failure, or the larger maximum turning moment achieved later in the uprooting process, is the most relevant to tree stability. Possibly the former is more important; pumping by wind action after soil failure is expected to cause root loosening and may progressively weaken anchorage. If this is the case, it will help to explain why the forces believed to cause windthrow during gales are smaller than those required for uprooting with a winch (Oliver and Mayhead, 1974). Winching

may have a more useful application in estimating tree stability if the various components of anchorage are measured.

M. P. COUTTS

Vegetative propagation

Micropropagation

Sitka spruce can be vegetatively propagated *in vitro* by the subculture of axillary and apical buds from established junvenile cultures (*Report* 1983, p. 28). A very large clonal variation in the rate of subculture production was found. Extrapolation of the data obtained by experiment showed that annual multiplication rates of individual clones may vary from 15× to 5000×, and for a clonal mixture an overall multiplication rate of 500× appears to be feasible.

Rooting of the micropropagules remains a problem. Neither a transient auxin treatment nor a decrease in the level of nutrients in the medium resulted in an enhanced level of rooting *in vitro*. Rooting attempts are being made under non-sterile mist conditions with micropropagules that have been pre-conditioned by reductions in temperature, light intensity, and day length, and with a cold treatment at 2°.

Vitrification is a phenomenon that occurs in tissue cultures. It is characterised in Sitka spruce by a decrease in surface waxes, a change in colour and a wet appearance to the plant surface. It can occur in response to disinfestation treatment, or to ethanol, or may arise spontaneously on subculture. The phenomenon results in an increase in the rate of extension of the shoots. The rate of axillary bud formation is enhanced and some adventitious buds may be formed. Vitrification in Sitka spruce, unlike the situation found in many other species, is reversible and it is possible that this could be incorporated into the micropropagation techniques that have been developed.

Rejuvenation

The work on the rejuvenation of Sitka spruce by sequential grafting on to juvenile rootstocks has continued. The plant material was grafted for a fourth time in March 1984 and tests are now under way to determine the physiological age of the scion material in the various graft generations.

A. JOHN

Flower induction

Application of the gibberellin A4/7 mixture plus girdling to mature Sitka spruce grafts in the Wauchope (Borders) clone bank stimulated the production of large numbers of male and female flowers in the first year after treatment (*Report* 1983, p. 29). This enhanced flowering was largely attributed to the GA4/7 treatment alone. In the second year after treatment the control trees flowered lightly, with averages of only 1.5 male and 0.2 female cones per tree, and neither the GA4/7 nor girdling alone produced significant flowering. However, where both GA4/7 plus a girdle had been applied 2 years previously a significant stimulation of the numbers of both male and female cones did occur, with averages of 66 male cones per tree produced in response to 100 mg GA4/7 and 80 female cones with 250 mg GA4/7. Thus with GA4/7 plus a girdle enhanced flowering can be expected for two consecutive years.

Experiments on flowering in Sitka spruce have been made on grafted scions collected from mature trees, but the effects of flower induction treatments on juvenile plants are also of interest. In a trial, 7-year-old Sitka spruce seedlings of Queen Charlotte Island origin were given three applications, each of 2 mg GA4/7 dissolved in ethanol, during June and July; the controls received ethanol only. All the seedlings were girdled and maintained in a polythene house under hot, dry conditions. Three of the nine treated seedlings bore male cones, with a total of 27 cones produced, but no females, and none of the control trees flowered. This is the first report of flower induction in Sitka spruce seedlings of that age, though seedlings of other members of the Pinaceae have been reported to flower in response to induction treatment.

J. J. PHILIPSON

Mycorrhizas

Inoculation trials on Sitka spruce cuttings in the greenhouse have shown that it is possible to produce mycorrhizal cuttings by injecting an aqueous mycelial suspension into the rooting medium after the first roots are 3–5 cm long. In 1982, the untreated control cuttings also became mycorrhizal. To establish the source of the fungus, half the medium used for an experiment in 1983 was irradiated. Nevertheless, again the control cuttings still became mycorrhizal, indicating that the inoculum came from the greenhouse environment, and not from the medium. In spring 1983, the 1982 cuttings were transplanted to boxes of peat outdoors. Measurements made at the end of the winter showed no significant differences in growth between the inoculated plants and the controls.

Laboratory trials confirmed that containerised Sitka spruce can be successfully inoculated by injecting an aqueous suspension of mycorrhizal fungus into the potting medium 5 weeks after the radicle emerges. This method was used to inoculate an unsterilised nursery seedbed of Sitka spruce seedlings with two mycorrhizal fungi, *Thelephora terrestris* and a *Laccaria* species. The inoculum for this trial was produced by Tate and Lyle PLC under the supervision of Dr R. M. Jackson, University of Surrey.

Co-operative work continued with the Institute of Terrestrial Ecology, and a second greenhouse study of mycorrhizal growth responses in Sitka spruce was established. Preliminary results indicate that growth effects related to differences between soils, as well as between fungi, have been obtained.

C. WALKER

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PATHOLOGY

Advisory services

Southern England and Wales

The common but rarely troublesome fungus *Phaeocryptopus gäumannii* caused widespread yellowing and sometimes severe defoliation of Douglas fir

in Devonshire during the first few months of 1983. In this same period, serious *Lophodermium seditiosum* damage developed on Corsican and Scots pine transplants raised respectively in a West Sussex and a Shropshire nursery.

As in 1981, the spring of 1983 was very wet and similarly gave rise to many inquiries on leaf diseases. Those recorded most frequently were Apple scab *Venturia inaequalis*, Willow scab *Venturia chlorospora* on *Salix fragilis*, Marssonina blight *Drepanopeziza sphaeroides* on *S.* x *chrysocoma*, and Blossom wilt *Sclerotinia laxa* on ornamental cherries. In addition, there were occurrences of the infrequently recorded leaf blight *Sclerotinia crataegi* on hawthorn *Crataegus* sp. In contrast, the hot dry weather of the summer caused drought damage to Leyland cypress 'Stapehill 20', Western red cedar, *Nothofagus* spp. and Tulip tree *Liriodendron tulipifera*.

The powdery mildew *Microsphaera platani* was found on London plane in central London. This is the first record for Britain and follows its recent appearance in Italy, Portugal and France (Gullino and Rapetti, 1978; Viennot-Bourgin, 1982).

Following the first report of Coryneum canker *Seiridium cardinale* on Leyland cypress in 1982 (*Report* 1983, p. 31) two further cases were reported, one from Buckinghamshire on two trees, and one affecting at least 12 trees in Surrey. The trees ranged from 3 to 14 m in height. Most of the damage dated from 1979 or later, but the earliest examined occurred in 1969.

Inonotus dryadeus was found growing on a beech in South Glamorgan. This seems to be the first record on this host in Britain. *Ganoderma lucidum*, a fungus we rarely see, was found fruiting at the base of a large oak in Worcestershire.

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

Scotland and northern England

Following the mild, windy winter of 1982–83, Top-dying of Norway spruce was more common than usual. Two cases of injury were of particular interest, one involving graft failure in *Sorbus intermedia* leading to wind-snap and the other death of 15-year-old Douglas fir due to a high salt water table in a coastal plantation.

The most common cause of damage by living agents was stain and decay of wood caused by *Armillaria* spp., *Heterobasidion annosum, Meripilus giganteus, Inonotus dryadeus* and other wood rotting fungi. There were occasional records of a variety of other fungi, particularly *Lophodermium* spp. on Scots pine and *Brunchorstia pinea* on Corsican pine. Both caused serious damage in nurseries and on infected planting stock which was subsequently transferred to the forest. *Seiridium cardinale* was found fruiting on the foliage of 30 cm tall Western red cedar in Morayshire. This is the first record on this host in Britain and also the first record of the fungus in Scotland.

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

Winter cold damage to pines

Damage to trees caused by exceptionally low temperatures in the winter of 1981–82 became evident during the following growing season (*Report* 1983, pp. 35–36). In 1983 several cases of delayed damage were investigated in

Corsican and Lodgepole pine; neither of which species has previously been found to be sensitive to low temperature injury in Britain.

Damage occurred on Corsican pine in Shropshire, south-east Clwyd, North Yorkshire and north Northumberland, and on Lodgepole pine in Rannoch Forest (Tayside).* Most affected crops were relatively young (5–20 years old), although in one case damage occurred on trees more than 30 years old, and most consisted of mixtures with other species. Losses in the Corsican or Lodgepole pine component of the mixture were frequently high and in several cases reached 100 per cent whereas the other species, principally Scots pine, escaped injury. In both Corsican pine and Lodgepole pine, injury involved death of phloem and cambium on the lower main stem rather than direct killing of shoots and foliage, and sections through affected stems (Plate 5) confirmed that injury had occurred during the 1981–82 dormant season. Trees which were girdled completely died sporadically over an extended period, presumably reflecting both the degree of cambial damage and the ability of the sapwood to continue supplying water to the crown. Those which lingered until 1983 were able to form reduced leaders and narrow growth rings above the point of injury during 1982. Trees with non-girdling lesions showed no foliage symptoms but some lesions were extensive enough to cause a marked growth reduction in 1982. Lesions tended to be long and narrow, frequently extending from just above ground level to a height of 1.0–1.5 m, with slight resinosis from fissures in the bark at the lesion margin, particularly in Corsican pine. By the end of the second growing season after damage, continued growth of the remaining live bark had resulted in stem deformation and this may render affected trees liable to breakage, particularly where multiple lesions are present.

The winter of 1981–82 was notable for two periods of intense cold which occurred in December 1981 and January 1982 and the areas in which damage occurred generally experienced the lowest temperatures recorded in Britain. Temperartures fell to −20°C or less and the lowest temperature recorded in the vicinity of a damaged plantation was −26.1°C at Newport, Shropshire. However, at one site (Wensley, North Yorkshire) damage identical with that observed elsewhere was associated with minima of only −14.7°C in December and −13.8°C in January (recorded at Leeming, 12 km east of the affected plantation and 100 m lower in altitude). It is possible that other factors such as the duration of the cold weather (Warrington and Jackson, 1981) may also have been important in the development of damage.

Pinus nigra agg. is not very cold hardy (Sakai, 1983) and it is probably significant that in Britain Corsican pine is well to the north of its natural range. Similarly, damage in Lodgepole pine at Rannoch (Tayside) was confined to a south coastal provenance whereas inland provenances in the vicinity were undamaged.

D. B. REDFERN, D. R. ROSE

Resin top caused by *Peridermium pini*

In Thetford forest (Norfolk and Suffolk) the incidence of *Peridermium* lesions on the stem of Scots pine has increased markedly during the last few decades

*Since this report was prepared similar damage has also been observed on 20-year-old Douglas fir near Kelso (Borders).

(*Report* 1980, p. 33). In 1982 a series of plots was established to follow any further progress of the disease, and by 1983 it was apparent that a number of trees were dying quite rapidly as a result of girdling by lesions present on the stem in the lower part of the crown. Current available data indicate that a significant proportion of the older (50 to 60-year-old) Scots pine carry established stem lesions which have the potential to cause death within the next few years. By contrast, other trees have no lesions either on stems or branches.

B. J. W. GREIG, J. N. GIBBS

Fomes root and butt-rot

Heterobasidion annosum in young Sitka spruce and Grand fir

In a 10-year-old stand of Grand fir (GF) and Sitka spruce (SS) planted in intimate mixture on a site infested by *H. annosum* in Tentsmuir Forest (Fife) 5.6 per cent of the GF (10 of 181) and 8.2 per cent of the SS (15 of 182) had early stages of *H. annosum* butt-rot. These trees were less than 4 m tall but infection had reached a mean height of 11 cm in the GF and 17 cm in the SS with maxima of 30 cm and 45 cm respectively. Mortality due to *H. annosum* was low and this unusually early expression of the disease as butt-rot was therefore of some interest, especially in GF which is generally considered resistent to *H. annosum*.

More detailed observations were made on disease development in 112 further SS in the same experiment by winching trees out of the ground. *H. annosum* was found in the stems of 10 (8.9 per cent) of these trees: in a further 15 (13.4 per cent) of trees it was present only in the roots, where it was restricted to vertically oriented sinker roots and tap roots. No disease was found in horizontally-growing lateral roots, which were abundant and long (up to 3 m) on this freely-rooted sandy soil. The presence of *H. annosum* in those parts of the root systems close to the main stem suggests that butt-rot could be expected to develop rapidly in this stand and that the incidence of butt-rot as determined by felling could be expected to double within a few years.

J. E. PRATT

Dutch elm disease

Vegetative (somatic) incompatibility in Ceratocystis ulmi

Investigations have begun into the vegetative or somatic incompatibility system of *C. ulmi*. This system either allows or prevents fusion between individual mycelia of different genotypes, and is likely to be a crucial factor in determining the success of d-factor (cytoplasmic disease) transmission in nature (Brasier, 1983). This is particularly the case in elm bark, where the fungus exists as a mosaic of genotypes (Lea, 1977; Brasier, 1984). As in many other eukaryotic organisms including mammalian tissue matching systems, vegetative incompatibility in *C. ulmi* appears to be controlled by a polygenic-multiallelic genetic system which promotes the existence, via recombination, of a large number of vegetative incompatibility (v–c) groups in the population. Mycelia of the same group have all v–c genes in common (but may otherwise be genetically different). Their mycelia fuse readily and d-factor transmission is facilitated. Individuals of different v–c groups have one or more v–c genes different. Their mycelia do not fuse but antagonise each

other, and d-factor transmission is restricted, the degree of restriction depending on the degree of vegetative incompatibility. In fully incompatible reactions (Plate 4b) d-factor transmission occurs in only *c.* 4 per cent of pairings between adjacent mycelia. In partially incompatible reactions transmission occurs in 20–40 per cent of cases. In slightly incompatible and in compatible reactions (Plate 4a) it occurs in 100 per cent of cases (Brasier, 1984).

A further potentially very significant feature of vegetative incompatibility in *C. ulmi* is the 'penetration effect'. In fully vegetatively incompatible reactions antagonism between two mycelia does not appear to be confined to the demarcation line between them: one isolate frequently invades the other, producing lines of synnemeta or perithecia (fruit bodies) in the other colony (Plate 4b). The ability of one isolate to penetrate another appears to be under independent genetic control from the v–c genes themselves (Brasier, 1984). Thus individual *C. ulmi* isolates in elm bark and beetle feeding grooves probably not only antagonise and compete with each other in the 'selfish gene' sense: they may also attack and perhaps even replace each other. It is possible that this characteristic of *C. ulmi* could be exploited for biological control purposes. If it occurs in other outbreeding forest pathogens it is likely to have similar and possibly far-reaching ecological implications.

C. M. BRASIER

Dimorphism in C. ulmi

(EEC contract)

After inoculation on to an agar medium or when colonising the phloem tissue of elm bark, *C. ulmi* typically grows in a mycelial form, eventually sporulating by producing sympodially-formed conidia (the *Sporothrix* form). However, it is also capable of multiplying purely in a budding yeast-like phase and it does this within the xylem of an infected host tree (Banfield, 1941). Recent experiments have indicated that the switch from mycelial to yeast phase occurs largely in response to nutrient levels.

Conidia of both the aggressive and non-aggressive strains of *C. ulmi* were able to germinate in near starvation conditions on tap water agar, but did so only by budding (Plate 4c). In contrast, if supplied with a nutrient rich agar such as 2 per cent malt extract agar for germination, the majority of conidia produced germ tubes and subsequently mycelia (Plate 4d). A similar contrast was observed if conidia were germinated on xylem or phloem sap solidified in agar. The former contains very few nutrients (Singh and Smalley, 1969) and most of the conidia supplied with this substrate germinated by budding (> 85 per cent). However, when supplied with nutrient rich phloem sap the majority (> 90 per cent) of conidia germinated via germ tubes.

J. F. WEBBER

Decay in amenity trees

(Department of the Environment contract)

Current recommendations for pruning are based on the belief that, by causing excessive injury to a main stem, flush pruning encourages the development of extensive staining and decay above and below the wound (Shigo, 1982). In order to identify the anatomical effects of flush pruning, the structure of the

branch/stem junction was microscopically examined in seven tree genera. The course of the vascular strands in the main stem was such that they would be severed above the branch junction by a flush cut, but not by a cut made distal to the external demarcation structure known as the branch bark ridge. This interpretation was supported by dye injection experiments which helped to trace the courses of the vascular strands.

The effects of pruning position on the rate of wound occlusion were studied in *Sorbus intermedia*, comparing flush wounds with wounds made distal to the branch collar. On flush wounds, vertical occlusion slowed down considerably after being initially faster than horizontal occlusion during the first growing season. On collar wounds, the vertical and transverse occlusion rates were similar over three seasons and compared well with the rates on flush wounds, thus producing a more satisfactory circular pattern of wound closure.

D. LONSDALE

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ENTOMOLOGY

Population studies

The Great spruce bark beetle, Dendroctonus micans

Control measures against *D. micans* concentrated on locating infestations and felling infested trees. In the first survey (1982/83) 289 infested sites involving some 30 000 trees were discovered while in 1983/84 more than 1100 infested sites were found with 23 000 trees attacked, although the majority of infested sites contained one attacked tree only. The beetle's range has increased slightly but, except for the 1982/83 Bowland Forest (Lancs) attack, no further outbreaks have been discovered outside the area controlled by legislation. Conservancy survey data have been entered on computer files, thus providing a means for producing distribution maps and for testing ideas about the spread of this new pest.

Dispersal of adults takes place locally by crawling, and over longer distances by flight or in infested timber. Emerging adults require a flight threshold temperature of 23°C but, once airborne, fly rapidly to above tree top height. Infested stands remote from approach roads indicate that flight range extends to at least 1 km.

Larval broods were subject to variety of mortality factors. Resin drowning of eggs and small larvae, predation by woodpeckers, parasitism by the ichneumonid *Dolichomitus terebrans* and infection by the entomophagous fungus *Beauveria bassiana* all combined to reduce populations.

Success of *D. micans* populations varied widely between sites. Studies over two breeding cycles indicated that the majority of individual attacks were abortive, probably limited by tree form and health. Residual populations following sanitation operations were found to breed in stumps and felled material left on site. At least 13 species of spruce are known to be susceptible although the effects on Sitka spruce are generally the most serious.

H. F. EVANS, R. S. HOWELL*, R. M. BROWN, C. J. KING, A. F. MARTIN, N. J. FIELDING

The Pine beauty moth, Panolis flammea

Population monitoring by pheromone traps indicated that in about 60 per cent of blocks the rise in population noted in 1982 continued in 1983 while in 20 per cent of blocks the population fell. Autumn pupal surveys were carried out in three blocks having high trap catches. One of these blocks had a maximum population density of 28 m^{-2} in 1983 (13 pupae m^{-2} in 1982). Although control measures have previously been considered necessary where pupal counts exceeded about 15 m^{-2}, a spring survey showed particularly high mortality of overwintering pupae and no control measures are planned in 1984.

The life-table study was continued for a third year at the plot in Shin forest (Highland). Populations were high, and egg numbers averaged 633 per tree in May 1983 although only minor defoliation of the trees occurred. In autumn 1983 the pupal count was 31 m^{-2}, indicating a further significant increase in population. A second life-table plot was started in Craigellachie Forest (Grampian), where the autumn pupal count was only 0.77 m^{-2}.

An experiment to investigate the interactions between host plant condition and moth population development was set up in Craigellachie Forest (Grampian). Plots were set up at six locations on two soil sites (deep unflushed peat and ironpan) in pole stage crops of Lodgepole pine, each including four 1 ha plots (thinned, fertilised, thinned and fertilised, and control). Results indicated that, despite equal egg numbers, final populations were higher on deep peat than on ironpan sites.

Laboratory studies indicated that high pupal mortality occurred at temperatures less than -10°C and also following prolonged waterlogging. In water frozen at -10°C, 100 per cent mortality resulted from exposure of more than 10 days. Pupae overwintering in needle litter had greater survival rates than those in peat or mineral soils.

Feeding adult moths with saturated honey solution increased fecundity, and also longevity of both males and females. In starved moths egg resorption

*Statistics Branch

reduced total achieved fecundity. Female moths presented with different Lodgepole pine provenances selected trees arising from the south coastal region as opposed to the north coastal region of British Columbia. The highest larval growth rates were obtained on south coastal provenances.

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

The Pine looper moth, Bupalus piniaria

The pupal survey revealed many increased populations and few reductions. Culbin, Roseisle and Tentsmuir were highest in 1983/84 with 20.0, 45.6 and 184.0 pupae per m^2 respectively. Counts at Montreathmont increased to 15.6. In England, counts included Cannock at 11.2, with Swynnerton at 11.6, whilst Sherwood IV rose to 10.0.

The increase in Cpt 108 at Tentsmuir is revealing. In 1982 it was 0.8, 1983 at 21.2 and in 1984 176.8 per m^2. This together with an additional compartment at 184 per m^2 indicates that depending on egg counts a control operation will be required at Tentsmuir in 1984.

R. M. BROWN, D. A. BARBOUR

The Winter moth, Operophtera brumata

Winter moth has been studied on Sitka spruce up to 12 years old in south and west Scotland for 2 years. Larval feeding results in defoliation, distortion and in the worst cases destruction of current shoots. Winter moth normally feeds on a wide range of broadleaved trees and shrubs, and the current outbreaks on Sitka spruce are unusually large.

A newly identified single-component sex-attractant pheromone 1, 3, 6, 9-nonadecatetraene (Bestmann *et al.*, 1982; Roelofs *et al.*, 1982) was tested and proved highly attractive to males. In a second heavily infested block, experiments on trap design, trap height and dosage response were carried out by Mr N. Ellis of Southampton University.

J. T. STOAKLEY

Host plant susceptibility

The Horse chestnut scale, Pulvinaria regalis

Four common town trees, Horse chestnut, lime, sycamore and London plane were tested for susceptibility to the leaf feeding stage of *Pulvinaria regalis*. Larvae were placed in small cages on the undersides of leaves in June and percentage establishment and size of larvae determined in September. On London plane an average of 2.4 per cent of larvae became established compared with >70 per cent on the other trees. The dense hairs on the leaves of London plane were probably a physical barrier to larval establishment. However, those larvae that fed appeared to grow normally as their size ($0.5-1.0$ mm^2) was similar to those developing on the other trees. London plane therefore appears to be relatively resistant to *P. regalis* and seems unlikely to be attacked in the field.

D. WAINHOUSE

Biological control

The Great spruce bark beetle, Dendroctonus micans

The predatory beetle *Rhizophagus grandis* is an efficient regulator of *D. micans* populations on the European mainland. Following advice from J. C. Gregoire of Brussels University, a trial release of 27 pairs of *R. grandis* into infested spruce trees was made in July 1983. Larval progeny were recovered in October 1983 giving some cause for optimism that the predator could become established.

Two new units incorporating controlled environments were established in Marches Forest District (Salop) to propagate *R. grandis* for field release. It is hoped that several thousand predators can be reared and released during 1984.

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

Chemical control

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

Experiments using the pyrethroid insecticides Permethrin, Cypermethrin and Deltamethrin as alternatives to gamma HCH for protecting young transplants against *Hylobius abietis* and *Hylastes* spp. were continued. Analysis of lower stem sections from sample plants showed the pyrethroids were appreciably more persistent than gamma HCH.

J. T. STOAKLEY, S. G. HERITAGE, A. F. MARTIN

The Winter moth, Operophtera brumata

Following severe damage in 1982, 340 ha of privately owned Sitka spruce plantations were sprayed at the end of May 1983. Application was by helicopter fitted with Mini-Micronair rotary atomisers, using 300 g a.i. of the organophosphorus insecticide fenitrothion at a volume of 1 l/ha. Problems arose over achieving optimal spray conditions and large numbers of larvae survived the treatment. However, by comparison of damage at the end of the larval feeding period with that in 1982 the treatment appeared to be 80–85 per cent successful.

J. T. STOAKLEY

Advisory services

Severe stunting and death of large numbers of conifer seedlings was reported from Rogate Nursery (W. Sussex). Investigations with the help of the Nematology Department of Rothamsted Experimental Station revealed widespread presence of a Tylenchorhynch nematode, probably *Dolichorhynchus microphasmis*. One 250 g soil sample contained 642 of these nematodes.

The Pine needle midge *Contarinia baeri* caused considerable defoliation to vertical shoots of Scots pine particularly in Thetford Forest (Norfolk, Suffolk).

Forestry Commission plant health inspectors found *Ips typographus* and *Cydia pactolana* in *Picea abies* bark from Europe. The scolytids *Dryocoetes affaber* and the first record of a *Scierus* species (probably *S. pubescens* Swaine) were found on timber from Canada.

The usual large numbers of cynipid oak gall enquiries in the autumn was swollen by 28 relating to *Andricus quercuscalicis* (Knopper gall) on *Quercus robur* acorns. Knopper gall, however, is not known to occur on *Q. petraea*.

The Lupin aphid *Macrosiphum albifrons*, a North American species, has spread over much of England and Wales resulting in serious dieback of lupins, and threatens the use of *Lupinus arboreus* and *L. nootkatensis* as pioneer species during afforestation of open cast reclamation sites. A brief study indicated that winter temperatures below $-10°C$ were necessary to bring about effective mortality.

Forestry Commission staff sent 106 enquiries to Alice Holt and 52 to the Northern Research Station. The number of private enquiries received was 208 at Alice Holt and 36 at the Northern Research Station.

T. G. WINTER, R. M. BROWN, C. I. CARTER, M. R. JUKES, D. WAINHOUSE, J. F. A. NICHOLS, J. T. STOAKLEY

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INTERBRANCH REPORT: ENTOMOLOGY AND SITE STUDIES (SOUTH)

Secondary chemicals and resistance to the Beech scale, *Cryptococcus fagisuga*

The bark of beech trees was analysed for the presence of phenolic compounds that may have a role in the expression of tree resistance to this insect. Bark was taken from grafted trees of known susceptibility to beech scale and from both infested and uninfested trees in the forest. A specific phenolic glycoside was present in the infested trees in proportion to the intensity of infestation. Further work is needed to determine if this is a causal relationship.

D. WAINHOUSE, A. WILLSON

WILDLIFE MANAGEMENT

Management of deer, squirrels and other mammals

The age-distribution of red deer shot in successive years is being used to estimate minimum populations of cohorts of calves born in the same year, as a means of checking indirect methods of determining red deer numbers. The method of determining age from lower jaw-bones is being used by rangers in some areas as a preliminary to its widespread introduction for red deer management. The importance of accurate age-class differentiation between kids, yearlings and adults is confirmed by analyses of roe deer culls from populations in Scotland, Yorkshire and southern England. The interpretation of mis-classified animals produces an under-estimate of numbers especially in

more productive forests. The study of roe deer performance has been extended to the areas of invasion of Dartmoor (Devon) where roe range extension has been slow over the last two decades, and to Shropshire where an introduction in the mid-1970s has resulted in range expansion mainly westwards into Powys of the order of 6 km a year. As well as adding considerably to the time and cost of forest damage prevention, this will have a major ecological impact on Welsh woodlands where browsing ungulates (apart from straying sheep) have previously been absent.

The current status and distribution of forest Sika deer has been described following a Forestry Commission Workshop attended by personnel concerned with their day-to-day management. A number of muntjac have been marked in a Warwickshire woodland with a high population density to contrast with the lower density marked population being studied in more extensive woodlands in East Anglia.

The field use of Phostoxin for rabbit control was investigated as a safe alternative for Cymag in gassing burrows.

The quinquennial questionnaire on mammal and bird distribution was sent to all forests in 1983 for completion on a 10 km square basis for each square containing Forestry Commission managed woodland. The final report will be based on forests prior to the 1984 amalgamations. Returns of both this and the annual squirrel questionnaire were delayed and it was not possible to analyse the effects of the 1983 squirrel hazard warning and to forecast the likely behaviour of squirrels before the 1984 control season.

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

Bird studies

Most of the year was spent in reviewing current literature and knowledge of bird communities in upland woodlands. The main field studies are concerned with tawny owls and goshawks in upland spruce forests during the establishment of the second rotation. There were no differences in tawny owl productivity between natural sites and nest-boxes although there was a seasonal decline, with earlier clutches being larger and producing more fledged young. There have also been annual differences in the time of egg laying which may be related to food supply prior to breeding. Pellet analysis showed that the main prey is the field vole with frogs and birds providing additional food sources in spring and summer. A population of goshawks under study continued to increase owing to low adult mortality and to attention paid to maintaining undisturbed nesting areas which continued to result in good production of fledged young.

S. J. PETTY

Damage assessment and evaluation

Grey squirrel bark stripping damage was surveyed in 10–40-year old woodlands on private estates and in Forestry Commission forests in 1983. The scale and type of squirrel control practiced was also investigated for the areas on which damage was assessed. Similar levels of damage were observed in both private and Forestry Commission woodlands sampled since the damage assessed had accumulated over the first 40 years of the life of the stands. Beech and sycamore stands were by far the most commonly attacked whereas oak,

poplar, ash and birch were less frequently damaged. Within affected beech and sycamore stands not all trees were damaged. The evidence on control measures suggested that there is more awareness of current recommendations in Forestry Commission woodlands. In many private woodlands squirrel control is of lower priority than pheasant rearing in the day-to-day running of the estate. Since grey squirrel damage produces timber degrade rather than tree death, a preliminary study was made of the potential volume loss in beech and oak.

Final assessment of Norway spruce subjected to 4 years of simulated side-shoot browsing suggested that protection by tree-guards produced taller trees than unprotected trees damaged to the same extent.

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

Chemical and mechanical repellants

After 3 years, a comparison of rabbit fencing to Ministry of Agriculture and Forestry Commission standard specifications has shown no differences in effectiveness of the cheaper Forestry Commission fence. Enclosure studies have shown that 0.75 m high rabbit fences are as effective as 0.9 m fences. Field trials are now in progress and the early results (winter 1983/4) confirm the enclosure findings. A high tensile polypropylene mesh netting has proved an effective rabbit barrier in enclosure trials and has not been gnawed by caged or enclosed rabbits.

A trial of different heights and types of tree-guard has begun in order to protect trees in motorway plantings where field voles proliferate on grassy sites in which the alternative methods of increasing predation or of applying poison control do not have sufficiently rapid effects.

H. W. PEPPER, L. A. TEE

General

The 1984 amalgamations of Forests and Districts within the Forestry Commission estate has required a major up-date of the Forest Names database which contains the names of Forestry Commission woodlands by location over the period 1949–83.

J. J. ROWE, L. A. TEE

FIELD SURVEYS

FIELD SURVEYS AND APPLICATIONS

Normal survey output continued to be affected by special surveys of plantations identified for disposal and by the higher rate of sample plot measurement necessary to catch up the backlog caused by previous Census involvement. The hard winter also depressed final quarter performance. Despite these interruptions, survey output was almost 10 per cent up on last year with 52 000 ha being completed. Surveys on disposal subjects were completed on 6000 ha during the year. Additional disposal data were collected on a further 1400 ha during routine survey.

Growing stock database and production forecasts

The value of the Growing Stock database was extended by the input of 'other land' information and the database now covers all Commission land. The form of summaries was improved to cover this data extension and to provide full land use description on completion of survey. Use of the database for project purposes continues to increase, particularly at district and conservancy level.

Production forecasting was of a project nature and included the forecast of private production using Census data and assessment of potential material for the Shotton pulpmill. The introduction of lists of subcompartments to be thinned, together with volumes, is proving of help to local staff in preparation of annual production programmes.

Remote sensing developments

Study of the potential of remote sensing data continues. Initial tests with data from the thematic mapper aboard the recently launched Landsat 4 satellite indicate that the improved system resolution (30 m) will help to define woodland boundaries and smaller woodland blocks more clearly. This brings closer the prospect of forest cover monitoring by satellite.

The aerial photography coupled with the experience gained during the Census was instrumental in the Commission gaining a sub-contract with Hunting Survey for the Department of the Environment's landscape monitoring project.

Site surveys

Site surveys were completed on 8800 ha in Scotland, mainly on plantable land reserves. In England and Wales, survey teams collected generalised site information on soils and terrain, and to a lesser extent wind hazard, on nearly 24 000 ha during routine crop assessment.

A. I. D. HORNE

MENSURATION

The benefits of mounting the sample plot database on computer are now being realised. Graphs of top height against age and mean annual increment against age for all sample plots of the major species were plotted and analysed. Preliminary results indicate that the importance of assessing production class in yield forecasting has been underestimated in the past.

Analysis of measurements of annual height increments and ring widths from 47 Sitka spruce trees planted in 1949 confirmed that strongly suppressed trees continue vigorous height growth although basal area growth may cease. Analysis of changes in ranking of individual trees from the time of planting shows a higher degree of correlation between ages for basal area growth than for height growth. Stem analysis data collected from a P.35 spacing experiment which had been in check for about 15 years after planting indicated that there was no difference in the time at which trees came out of check from spacings of 0.9 to 2.4 m.

A demonstration of respacing following General Moore's 'Oceanic system' was established at Arecleoch Forest (Strathclyde). Growth and yield will be monitored in sample plots established in the respaced area and in a control

area which has been left at the original planting spacing of about 1.7 m. Two major respacing experiments at Kershope Forest (Cumbria) and at St. Gwynno Forest (Mid Glamorgan) were measured for the first time. Results of data analysis will be published during 1984.

Plot plans showing the locations of individual trees are now available for 60 sample plots of Sitka spruce. These are for use in the modelling work described on pages 53–55. The outstanding major respacing and thinning experiments are planned to be mapped during 1984.

The data collection programme for the Epson HX-20 microcomputer was substantially improved to incorporate checks on data input. Three machines are undergoing field tests.

The tariff and assortment forecasting services were widely used by field staff. 251 tariffs were checked and 189 assortment forecasts were processed. A Research Information Note describing the assortment forecasting service and how to use it was published. Tariffing seminars were run in South Scotland and South Wales conservancies with a view to increasing understanding of the measurement procedures and the interpretation of tariff results.

The use of computer image analysis to estimate the biomass of open-grown trees from photographs was tested using a Magiscan image analyser at the Department of Forestry, Oxford University. The results indicate that image analysis may have considerable potential for volume and weight estimation. The main advantages are that the technique is non-destructive and fast. The technique will be tested more extensively during 1984 using photographs and biomass data for plantation-grown oak trees from northern France in collaboration with the Institut National de la Recherche Agronomique at Orléans, France.

T. J. D. ROLLINSON

CENSUS OF WOODLANDS AND TREES

During the year under review the major part of the data processing was completed and results became available for all counties in England and Wales, all regions in Scotland and, in addition, summarised totals for all Forestry Commission conservancies and countries. The results of the present Census show that there have been major changes in the area and character of British woodlands when compared with the results of the immediate post-war survey in 1947. Direct comparison with the results of previous surveys is not possible owing to differences in the minimum size of wood adopted for survey, changes in classification, etc.; nevertheless it is possible to draw some firm conclusions.

The area of woodland in blocks of 0.25 ha and over in Great Britain has increased from about 1.48 million ha in 1947 to 2.11 million ha in 1980, a rise of over 40 per cent in the last 30 years. This has resulted in the woodland area as a percentage of land and inland water, excluding Orkney, Shetland and the Western Isles on which there is very little woodland, rising from 6.7 per cent in 1947 to the current figure of 9.4 per cent. The most substantial rise has been in the woodland area of Scotland (390 000 ha) but England with 143 000 ha and Wales with 100 000 ha have also shown substantial increases. The Forestry Commission's share of the total has arisen from about 18 per cent in 1947 to 42 per cent in 1980.

The area under coniferous crops has risen very substantially from just under 400 000 ha to over 1.3 million ha. Most of this increase has been by afforestation. The broadleaved area, on the other hand, has remained virtually unchanged in England and Wales but has shown a slight reduction in Scotland. The character of the broadleaved resource has, however, altered. The area of coppice and coppice with standards has declined further since 1965. Oak, although still the major broadleaved species over most of the country, is now less prevalent than it was while species such as ash and sycamore have substantially increased in area, often by colonisation.

The area of unproductive crops, which in 1947 totalled over 500 000 ha, is now little more than a third of that total; this has come about partly by conversion to other forms of land use, partly by replanting and partly by a natural development of scrub into broadleaved high forest.

The current distribution of area by forest type and ownership is shown in Table 5 for Great Britain as a whole. The Table shows that while over 60 per cent of the coniferous high forest area is in Forestry Commission ownership the greater part of the area of all the remaining forest types is in private hands.

Table 5 Summary results of census of woodlands over 0.25 ha, Great Britain 1980. (Areas in 000 ha)

	Forestry Commission woodlands		Private woodlands		Total woodlands	
	Area	% of type total	Area	% of type total	Area	% of total
Mainly coniferous high forest	819	62	498	38	1317	62
Mainly broadleaved high forest	54	10	510	90	564	27
Total high forest	873	46	1008	54	1881	89
Coppice with standards	—	< 1	11	100	11	1
Coppice	1	4	27	96	28	1
Scrub	6	4	142	96	148	7
Cleared	12	29	28	71	40	2
Grand total	892	42	1216	58	2108	100

A survey of non-woodland trees occurring either as isolated trees or in the form of clumps, avenues or narrow belts was carried out at the same time as the main woodland survey. The results indicate that there are about 88 million trees in these categories in Great Britain which are of measureable size, that is 7 cm diameter at breast height or over. There are, in addition, some 20 million well grown trees below this diameter limit. England accounts for about 70 per cent of the combined tree total.

Despite the very substantial losses in both numbers of trees and volume resulting from Dutch elm disease it appears that the present broadleaved volume in Great Britain has fallen only slightly from that found at the time of the last full assessment in 1951 and, in terms of tree numbers, the recruitment position is rather more encouraging than it was at that time.

G. M. L. LOCKE

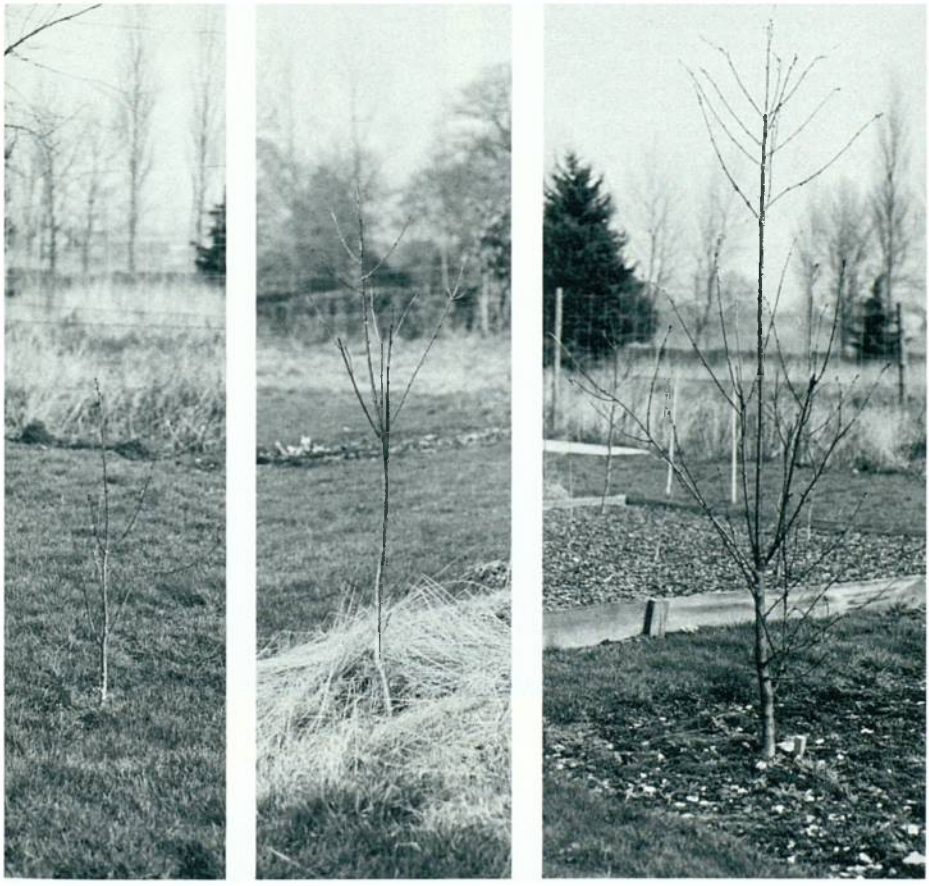

Plate 1: The effect of grass sward control on the growth of cherry *Prunus avium* 2 years after planting. The mown sward (*left*) is more competitive than the unmown sward (*centre*) but tree growth is best in bare soil (*right*). (*B9161/2/3*). See *Report* 1983, p. 10.

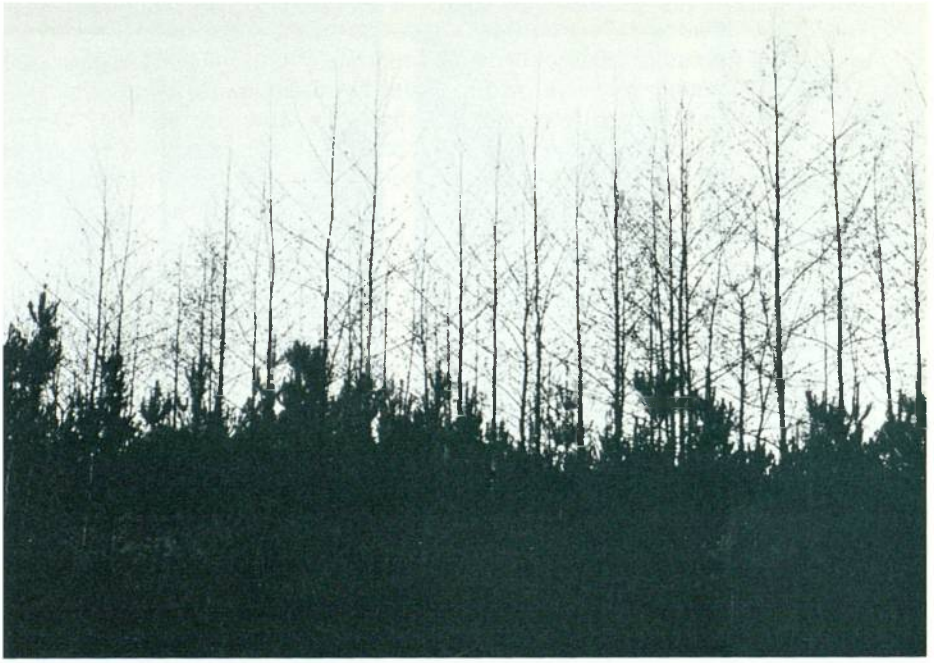

Plate 2: Excellent height growth and straight stems of 8-year-old Italian alder on reclaimed and cultivated gravel workings (p. 22). (*C5248*)

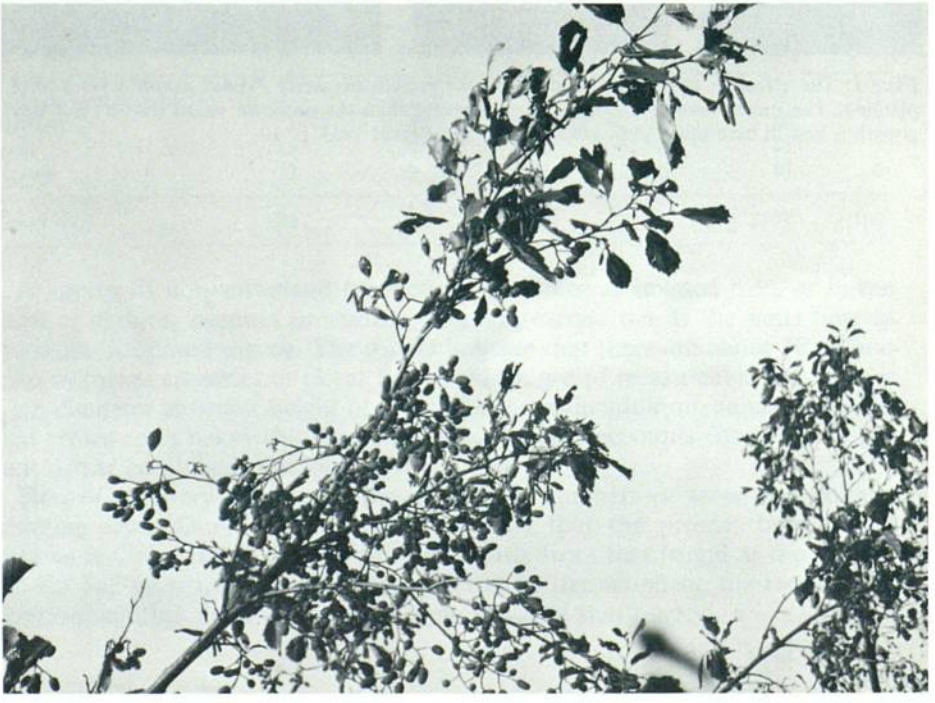

Plate 3: Distress flowering of Common alder on compacted clay (pp. 22–23). Note loss of vertical axis. (*C5249*)

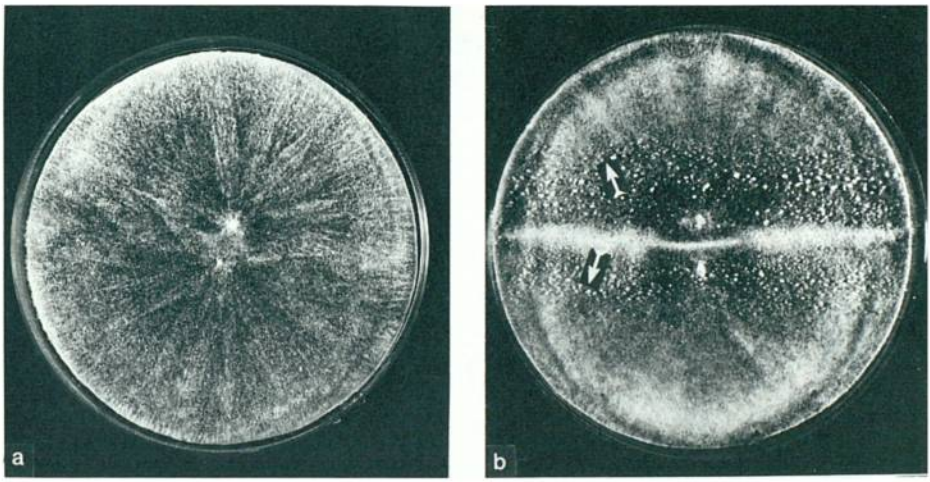

Plate 4 a & b: Vegetative incompatibility and the penetration effect on *Ceratocystis ulmi* (p. 36).

(a) Vegetatively compatible or c-reaction. Pairing of two different but compatible isolates (of the NAN aggressive sub-group of *C. ulmi*). No visible interaction occurs. (*A10663*)

(b) Vegetatively incompatible or w-reaction. Pairing of two different and incompatible isolates showing the white barrage zone of the incompatible reaction (antagonism) along their junction line, and the subsequently developed lines of synnemata (arrowed) resulting from mycelial penetration of one isolate's colony by the other. (*A10664*)

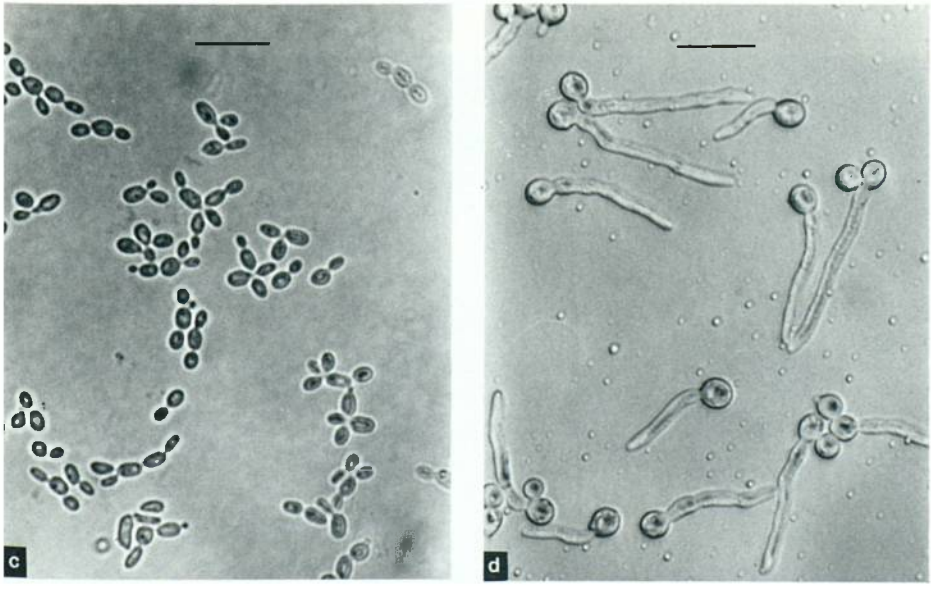

Plate 4 c & d: Spore germination in the aggressive strain of *C. ulmi* (bar = 20μm). (p. 36).

(c) Budding conidia. (*A10665*)

(d) Germ tube production. (*A10666*)

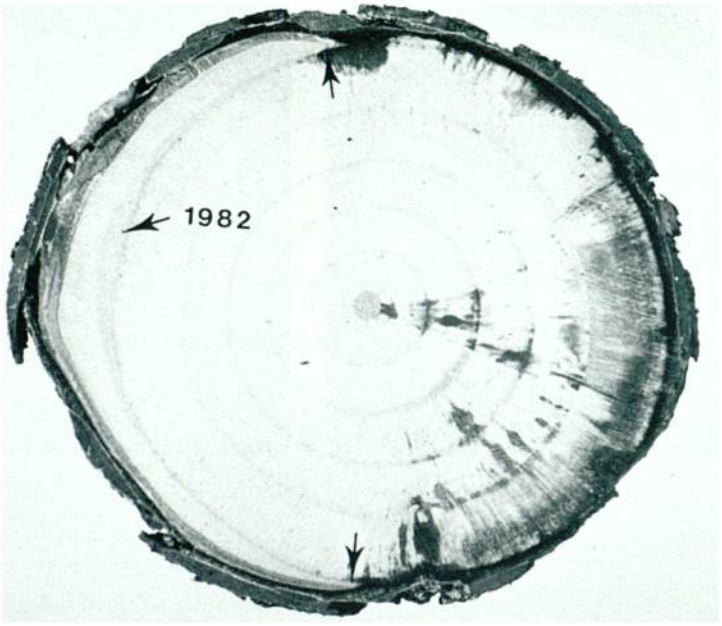

Plate 5: Death of cambium (to right of arrows) on 14-year-old Corsican pine in Northumberland caused by low temperatures during the 1981-82 winter (pp. 33–34). Note very narrow 1982 ring with broader 1983 ring beyond it. Scale = 5 cm. *A. John*

Plate 6: Star shake in oak (p. 59). The splits are stained and run deep into the log. *G. S. Henman*

DRAWING OFFICE

Further development of the MAPLE map digitising system has taken place and installation was almost complete at year end. This has affected photo interpretation and mapping programmes, the completion of final maps at 42 000 ha not quite keeping pace with the area surveyed. On the map recording side, the Forest District reorganisation, necessitating the merger of previously separate Forest areas, and continuing disposals have generated a considerable increase in the programme of maps maintenance.

A. I. D. HORNE

WOOD UTILISATION

Wood quality of British grown sawn softwood

The main work under this heading is carried out at the Princes Risborough Laboratory of the Building Research Station (PRL) and is described in Part II of this Report.

Transmission poles

The electricity supply industry has acknowledged the suitability of Norway and Sitka spruce, treated with preservative by sap displacement, for use as transmission poles. Sitka stems must be carefully selected to ensure sufficiently wide sapwood. TRADA tests on copper-chrome-arsenate treated poles have indicated higher mean bending strengths than those from earlier ponded/sprayed samples. This suggests underestimation of the weakening action of bacteria which can also improve permeability for preservation. Results should be incorporated in a revised BS 1990.

BS 1722 fences

Considerable effort has been made to ensure the continued use of British softwoods in the fencing market by way of a revised and more appropriate British Standard.

Pinus peuce

A preliminary investigation concerning the properties and utilisation of this species has been undertaken in co-operation with PRL. The timber shows poor strength characteristics, but very low dimensional movement once cut. Suggested uses, all of which are non-structural, include: internal decorative building finishes, cabinet making, pattern stock, etc.

R. G. HANDS

WORK STUDY

METHOD STUDY

Forest management

There have been method studies on a wide range of activities. Work on methods of seed collection has continued. Much attention has been directed to

the various nursery operations. The Summit precision sower, with various modifications to improve its performance, has been installed at Wykeham nursery (North Yorkshire). The Famo line lifter has been shown capable of handling a wider range of size of transplant than the Zijlstra and Bolhuis, and at lower cost, and a unit has been installed for evaluation at Dornoch nursery (Highland). Work has begun on major nursery projects investigating all aspects of handling, storage, and transport of transplants — with initial work concentrating on grading systems, insecticide application methods, packaging and in nursery transport.

There has been extensive monitoring of Conservancy aerial fertilising programmes using the newly recommended Work Study sampling equipment; the results confirmed that the spreading was unacceptably variable. Trials were begun with the Decca Flagman guidance system to assess the benefits of improved flight control, and with granular formulations of fertiliser, which Work Study trials had shown could be spread with greater consistency. Various techniques for the aerial application of foam for fire fighting have been investigated; of the alternatives, a modified Canadian Bambi bucket, with a new superconcentrate foam and an automatic foam injection system installed on board the helicopter, seems most promising. With this system it has been possible to lay foam barriers at the rate of 800 m an hour, extending the use of foam to remote and inaccessible locations.

A modified Dondi DBR ditcher with coal cutter type teeth to improve cutting action shows promise for restocking sites and for certain types of mineral soil, although problems remain in obtaining the ideal motive unit. A national survey of weeding practice showed that in many cases new weeding techniques were not being adopted, with more than 40 per cent of weeding still done by hand. Investigation into herbicide applicators has continued with the drench gun now being recommended for spot application. Further work on the Weedwiper included study of flow rates with different types of wick and the use of marker dyes to show areas treated. An air driven CDA sprayer which may be suitable for use on slopes, where feed problems have been encountered with the Herbi, is under investigation. Weeding seminars run jointly by Work Study and Education and Training Branches have been held in various Conservancies to explain the recommended weeding techniques.

Harvesting and marketing

The organised felling system for steep terrain referred to in *Report* 1983 (p. 46) was demonstrated widely to field staff at a Mountain Logging Seminar in November 1983. This has now been accepted as the felling system to be adopted for all shortwood cable crane working in future and is currently being installed in a joint project with Education and Training Branch. Trials have continued to determine whether the contour felling presentation can be adopted for pole length working in cable crane terrain. Evidence from work to date indicates that in the smaller tree sizes, up to 0.3 m^3, the system can work, but as pole size increases there is an increasing cost penalty associated with achieving the ergonomic and safety advantages. With the increased use of forwarders in steeper terrain, trials have been conducted to determine whether shortwood contour presentation, as for cable cranes, is compatible with forwarder extraction. Initial results from clear felling in spruce crops have

confirmed the output advantages with cable cranes, both for felling and extraction.

The evaluation of mechanised harvesting systems has continued with further development of the Gremo SK 35 thinnings harvester and evaluation of a large clear felling harvester, the Kockums 88–65. The SK 35 thinnings harvester head has been developed in conjunction with the manufacturers to a reliable unit capable of working satisfactorily in unthinned spruce crops. The compact base machine has limitations in terms of stability, but has proved successful on sites up to 25 per cent slope with outputs of 5–6 m^3/hr giving lower costs than motor manual systems. A 2 months trial of the Kockums 88–65 harvester clear felling a range of species and crop sizes proved successful, confirming the high potential outputs of such a machine. The trial took place in the spring of 1983 to ascertain the delimbing quality achieved when the sap was rising, but no problems were encountered with the feed rollers fitted with chains to give the necessary grip on the trees. An interesting feature was the capability of safely working windblown crops with an insignificant drop in output levels. Two new forwarders on the British market were looked at briefly, the Rottne Blondin 750 model 600 FD and the 8-wheeled version of the Ösa 250. Both machines were seen to operate efficiently giving comparable results to other machines in the same class, the 8-wheeled Ösa 250 confirming the advantages of this wheel configuration on very soft ground.

The regular monitoring of new chainsaws and ancillary equipment has been maintained, with detailed testing of suitable saws for approval. Two new replacement models were approved during the year, the lightweight Husqvarna 234 SG and the powerful Husqvarna 181 SG for very large trees, mainly hardwood felling. In addition, the long term trials of the Husqvarna 154 SG, which has been monitored from the prototype stage, were nearing completion.

Work measurement

The work measurement programme has continued to play an important role in the work programme with approximately 20 per cent of Branch resources devoted to this work. The major method developments and machinery evaluation have required comparative time studies, and revised and new tables were produced for ongoing operations. With the switch to shortwood working a major development is the provision of simplified felling tables based on end product working.

Safety

Close liaison has been maintained with the Safety Officer in all the development work to ensure that safe working practices have been established. Assistance has been given in the revision and drafting of Forestry Safety Council Guides.

Communication of results

In addition to the internal reports on projects, major projects have been reported to the HGTAC Technical Sub-Committee. A number of articles have been published in *Forestry and British Timber* including joint HGTAC/FC Technical Notes.

A. J. G. HUGHES

INSTRUMENTATION

Seven seed incubators have had their temperature regulatory systems fitted with Nobel series EV proportional controllers, which are common to most other environmental control systems in use at the station.

Equipment projects have included a lance for spraying tree trunks to control epicormic shoots and a medium scale steam distillation plant capable of producing 20 litres of condensed steam per hour for the recovery of essential oils from coniferous foliage.

R. CARNELL

STATISTICS AND COMPUTING

Statistics

Alice Holt

Hand-held data collection terminals have speeded the transfer of data to the computer. Exceptionally, the delay in reporting back with statistical analyses to project leaders can now be reduced to one day.

A study making use of polynomial flow models (that is families of functions relating growth and time which may be fitted to sets of trajectory data) of the growth of unthinned Sitka spruce stands was completed. The variables studied included top height, total volume production and total basal area production. Quadratic flow models provided adequate descriptive fits to the top height and total volume data but could not be fitted adequately to the basal area data. Flow models using Chapman-Richards equations of the form

$$y = a(1\text{-}m.\exp(-bt))^c$$

were found to give better fits.

Programs were written to analyse the data from several surveys. These included a survey of the success of restocking at Thetford Forest, a survey of squirrel damage and control measures in private and Commission woodlands, and one on the estimation of Sweet chestnut coppice yield.

Recently described methods for fitting logistic models to ordered categorical variables (Anderson, 1981) were used to analyse data from the Chainsaw Operator 'White Finger' survey. Similar results were obtained using simple contingency table analyses.

Dendrological data for three more species (Report 1983, p. 48), Norway and Sitka spruce and Corsican pine, have been put into computer files. The analysis done so far has suggested that the height/age curves currently used for these species and Douglas fir have too low an asymptote to fit the data for these specimen trees well.

Tolerated range tables extending those given in the International Seed Testing Association Rules have been constructed for use in seed germination tests.

Northern Research Station

In the context of an experiment on chemical thinning, artificially generated data were used to test the feasibility of fitting a logistic model to explain mortality in terms of dose rate and tree diameter. Difficulties were found in fitting the model, the algorithms provided by the GENSTAT and GLIM

packages for fitting generalised linear models failing to converge within the usual number of iterations. Direct inspection of the likelihood function suggested that the reason for this in some cases is an excessively flat-topped (non-quadratic) likelihood near the maximum. With sparse data the behaviour of the likelihood depends crucially on the parameterization chosen.

Modelling

The distinction between modelling and statistics is often arbitrary but is made in order to distinguish work in which there is a particular emphasis on model synthesis rather than data analysis.

Alice Holt

Theoretical models of diffusion have been reviewed in relation to the aerial spray dispersal model developed at the Cranfield Institute of Technology. An alternative approach based on computer simulation was developed for comparison. The simulation model follows spray particles over and through a multilayered canopy, the components of particle velocity being sampled from empirically observed distributions of turbulence velocities. The model includes evaporation and size-dependent droplet absorption. The simulation enables predictions to be made of the deposition throughout the canopy and the amount of spray lost by throughfall to the ground and by dispersal into the atmosphere.

In conjunction with Site Studies (South) Branch further efforts have been made to develop physically based mathematical models of the drainage process using borehole data. One model, based upon the Dupuit approximation to the ground water flow equations, proved to be of some use for horizontal surfaces but encountered numerical and boundary-value problems when used for sloping surfaces. The full flow equations (i.e. the continuity equation and Darcy's law) were therefore solved numerically. The resulting model was used to predict the response of the phreatic surface to a time series of rainfall inputs for a sloping soil profile having many horizons.

A model of the life history of an insect has been developed which involves arrival, maturation and survival distributions. The model uses a continuous time variable and its parameters can be estimated stage by stage from census data collected at irregular intervals. The estimation procedure was validated by estimating the parameters from data randomly generated by the model. Work is continuing on the simultaneous estimation of the parameters of the model for all stages.

Survey data on the occurrence of *Dendroctonus micans* in the Forest of Dean were combined with data extracted from the growing stock database and with data from the national soil survey. So far the main positive result of analysis has been to show that the sequence of outbreaks within the forest was related to distance from the initial infestation in the forest, but no clear evidence has been found of other predisposing factors of site or of the crop itself beyond some favouring of crops beyond the thicket stage. Outside the Forest of Dean analytical work has been hampered by the variety of ways in which different Conservancies reported attacks, but editing and transcription work is proceeding. Work started on a simulation of the spread of attacks over the susceptible population of Norway and Sitka spruce forest areas using data

from the growing stock database and the results of the recent Census of Woodlands.

In some systems of harvesting shortwood by bench felling it is impossible to identify from which tree each product piece was cut. In order to allow comparisons to be made with other felling methods this difficulty was tackled by building individual tree times synthetically from the study data.

Northern Research Station

FC Booklet 48 gives mean diameter and top height for plantation spacings up to 3.0 m. In order to provide a basis for extrapolation to wider spacing, a relationship between top height and mean diameter was fitted to these data for unthinned Sitka spruce, of the form

$$D = a_1(S)H + a_2(S)H^2 + a_3(S)H^3$$

where H is top height in excess of 1.3 m, S is spacing, D is mean diameter, and $a_1(S)$, $a_2(S)$, $a_3(S)$ are polynomials (quadratics) in S^{-1}. This equation holds only after canopy closure. Before canopy closure, the relationship is assumed independent of spacing, i.e. the same as for open-grown trees, and is given by the locus of points (H_s, D_s) as S varies, where D_s is the diameter at which canopy closure occurs at spacing S, and H_s is the corresponding top height obtained from the appropriate cubic equation.

Computing

Alice Holt

A new version of the RAPPORT relational database system with backup and recovery facilities was installed with interfaces to both Pascal and Fortran 77 mainly to meet the requirements of the growing stock database users. Work also started to bring the database entirely in-house and to add extra facilities. These include allowing area summaries to be related to volume estimates from the forecasting program and allowing complex data processing to be accomplished with a minimum of computer knowledge.

The tree records of the Westonbirt arboretum were transferred from the floppy discs of the Transdata CX400 system to the Prime computer in order to conduct a complete sorting of the records and to enable an alphabetic catalogue to be prepared.

An interactive analysis system for seed tests designed to process, store and retrieve all future test results was introduced. Details are given on page 6.

Several user-friendly programs have been written combining the use of Prime CPL and GENSTAT to allow the user to direct the running of the program. They include multiple linear and polynomial regression analyses with various options and a single program to cope with some common balanced experiment designs with and without covariates. Another user-friendly program was written to allow staff of the Census section to answer miscellaneous queries rapidly from the non-woodland data files.

Northern Research Station

The Station's digitiser was successfully connected to a Sirius microcomputer, with a software interface written to facilitate the writing and maintenance of applications programs. General programs were written to calculate areas and lengths of curves and to turn part of the digitising area into a keypad, but most

use is in the form of programs tailored to specific projects, such as calculating the proportion of *Fomes* rot in stumps, or parameters of conifer needle shapes.

The Experiment Register database was set up using Rapport. It so far contains information on 2000 experiments, just over half the northern total.

Other developments on the mainframe computers have included the writing and improvement of programs to monitor computing costs, search for old data sets, convert national grid reference to latitude and longitude, draw coloured graphs, tabulate deer damage for areas of South Scotland Conservancy, provide utilities to manipulate and list neatly database-type information, and convert a Genetics database from IDMS to ordinary file format.

For microcomputers, developments have included writing routines which transfer files directly between Tektronix and Sirius, and writing menus of available programs and facilities which interactively guide the choices of new or occasional users starting up a Sirius or Superbrain.

R. S. HOWELL, D. H. STEWART

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INTER-BRANCH REPORT: STATISTICS—MENSURATION

Modelling forest growth

The objective and overall structure of this project were described in *Report* 1983 (p. 51). Progress has involved restructuring, de-bugging and refining of the computer simulation model, IFPM (Integrated Forest Process Model). The model is based upon spatially distributed individual trees each of which has its own biologically structured state variables. Figure 7 illustrates the development of the state of a tree through year t. X and Z are state variables representing the canopy structure and the litter layer whilst the parameters λ_i, γ_i and δ_i characterise the process of internal cycling, litter fall and uptake, respectively. The trees compete with each other for available resources, the competition being dependent on the relative sizes, distances between trees and the canopy structure of the trees.

One of the competition models considered generalises that of Ford and Diggle (1976). New aspects of the generalised model are:

(i) the introduction of a non-linear dependence of dominance class (and hence growth) on the azimuthal angle between the top of a tree and a neighbouring tree,
(ii) the possibility that a tree's smaller neighbours may affect its growth, and
(iii) the possibility that a tree with a few very much larger neighbours may still continue to grow quite successfully.

Considerable effort has also been expended in combining the IFPM with a flexible interactive optimising routine in order to estimate the model's para-

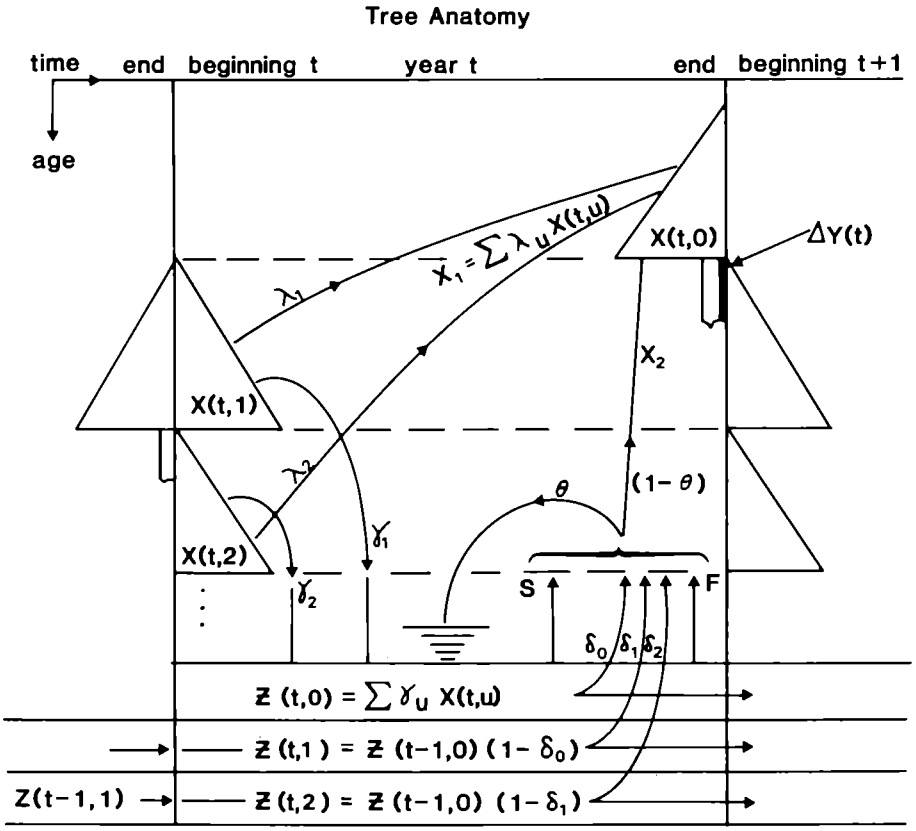

Figure 7. **The state variables and process parameterizations of a single tree.**

Key

State variables: X(t,u) and Z (t,u) are measures of a resource in the canopy and litter layers respectively, each of age u at the beginning of year t.

Process parameters:

- λ_u is the proportion of resource transferred in a year from the canopy layer of age u to the newly formed canopy layer.
- γ_u is the proportional loss of resource through leaf fall of u-year old needles.
- δ_u is the proportional resource release from the litter layer of age u.
- θ is the proportion of the available resource lost from the system by leaching.
- S and F represent inputs of a nutrient resource directly from the soil and through fertilisation respectively.
- ΔY(t) is the increment in measurable timber production in year t.

meters from sample plot growth data. Test data for this development work have been taken from the Dyfi Sitka spruce thinning experiment sample plots. The results from this initial work have shown that the model is quite well able to reflect the observed growth trends including the crossing of growth trajectories resulting from changing competitional status. Mortality patterns, in terms of which trees die, and when, are also adequately represented. The fitted parameters of the generalised competition model mentioned above rejected the

need for properties (i) and (ii) while strongly endorsing the need for the model to include properties (iii). However there is still room for some improvement in fit and current developments include the introduction of more realistic competition and litter/soil models. The model is being validated on other plots which have had different treatments.

Exploratory use has been made of the model to examine the effect of non-standard thinning regimes and defoliation. Such studies will eventually lead to the estimation of optimal management practices. Also, when the model is fitted to species other than Sitka spruce, the predicted performance of mixtures will be investigated.

Work is also proceeding on the task of relating the parameters of the IFPM to available climatological variables.

K. RENNOLLS, T. J. D. ROLLINSON

COMMUNICATIONS

RESEARCH INFORMATION

Library

A further 228 new books were acquired and five more journal subscriptions were taken out. Loan requests satisfied reached an all time record of 12 697. This was made up by 8213 loans from stock, 2435 photocopies and 2049 items borrowed from other libraries (665 of these for staff at the Northern Research Station).

The success of the various information services is reflected by the twelve-fold increase in loans of literature over the last 20 years. This has been achieved with a reduction of staff and at a cost of approximately 1 per cent of the total research budget. This compares very favourably with the average expenditure by research organisations of 4–6 per cent on library and information services. In addition, the same literature is used by the Arboricultural Advisory and Information Service which this year increased the number of photocopies to 3114.

Information

The Forest Research Experiment database (FRED) of research projects in forestry and arboriculture was updated. Staff have been involved in the work of IUFRO Project Group 6.01.00 which produced a seventh amendment to the Oxford System of Decimal Classification for Forestry (published in *IUFRO Newsletter* 40), and will produce an eighth amendment in 1984.

O. N. BLATCHFORD

PHOTOGRAPHY

Aerial photography

Flying to meet Field Survey, Conservancy and R&D Division requirements continued.

Following the successful use of video as a drift sight, consideration is being given to the use of video tape recording for those purposes where quick assessment and instant playback is needed rather than a permanent photographic

record. It is relevant to note that because of likely interference with on-board navigation equipment, any use of video or other electronic equipment must be at the discretion of the aircraft captain.

Photographic service

This continues within the limitations imposed by staffing levels and the over-riding priority which must be given to aerial photography.

I. A. ANDERSON

PUBLICATIONS

There are over 200 titles currently in print in the Commission's seven series of technical publications. The published information covers a broad range of forestry subjects, providing a comprehensive reference source for foresters, managers and scientists. The following were published during the year ending 31 March 1984.

Report

Report on Forest Research 1983 (£6.20)

Census Reports

Twenty-three out of a proposed 65 national, Conservancy and county reports on the Census of Woodlands and Trees 1979–82 have been issued, the remainder being in preparation (£3 each report).

Bulletin

60 Research on Dutch elm disease in Europe, edited by D. A. Burdekin (£6)

Booklets

49 Timber measurement—a field guide, by P. N. Edwards (£2.20)
50 A key to eucalypts in Britain and Ireland, by M. I. H. Brooker, with notes on growing eucalypts in Britain, by J. Evans (£2)
51 The use of herbicides in the forest-1983, by J. S. P. Sale, P. M. Tabbush and P. B. Lane (£1.50)
52 The use of chemicals (other than herbicides) in forest and nursery—1983 edited by O. N. Blatchford (£1.50)
53 A catalogue of phytophagous insects and mites on trees in Great Britain, by T. G. Winter (£2)

Record

125 Rabbits, by A. M. Tittensor and H. G. Llyod (£1.75)

Leaflets

12 Taxation of woodlands, 6th edition (£1)
82 Assessment of wildlife damage in forests, by R. C. Melville, L. A. Tee and K. Rennolls (£1.15)

Arboricultural Leaflet

2 Honey fungus, 2nd edition, by B. J. W. Greig and R. G. Strouts (£1.80)

Research and Development Papers

131 Acid rain and forest decline in W. Germany, by W. O. Binns and D. B. Redfern (£1)
132 Reclamation of mineral workings to forestry (£1.50)
133 The Westonbirt Arboretum catalogue in the 1980s, by J. E. J. White (25p)

Miscellaneous

Autumn colour at Westonbirt (Westonbirt Leaflet 1, revised) (35p)
A guide to Bedgebury national pinetum (40p)
Forestry Commission catalogue of publications 1984

E. J. PARKER

OTHER HEADQUARTERS DIVISIONS
PLANNING AND ECONOMICS

Price size curves

The relationship between the value of standing timber and mean tree size is of considerable significance for forestry economics. The empirical derivation of this relationship is complicated by the variety of other factors affecting value, such as timber quality, species, distance from markets and the effect of terrain on extraction cost. The relationship is also known to vary over time. Some recent research within P&E Division has investigated these issues by means of regression analysis of standing sales data over recent years. Equations were estimated in which price is dependent not only on mean tree volume but also on species and location, with allowance for variations over time and a thinning price difference. Preliminary results are encouraging, although problems remain in estimating the relationship for the smallest sizes of timber. In combination with results from similar, though less detailed, analyses of long run average data, this work may assist in modification of price assumptions for appraisal and valuation purposes. It has also been used to explore other dimensions of price variation, such as price differences associated with alternative methods of sale.

Price elasticity of demand for forest cabins

A study has been carried out using multiple regression analysis to examine the responsiveness of occupancy in forest cabins run by the Forestry Commission to changes in the prices charged. The data cover the period 1978 to 1983 and all four sites are considered. Other variables included in the analysis are substitute prices, advertising, personal disposable income and the time of year. The main conclusion of the study is that the price elasticity of demand is low, probably not more than (−) 0.3.

D. S. GRUNDY

PART II

Work done for the Forestry Commission by Other Agencies

SILVICULTURE

Control of wood quality in the British oaks

by G. S. HENMAN and M. P. DENNE

Department of Forestry and Wood Science,
University College of North Wales, Bangor, Gwynedd, LL57 2UW

This project aims to quantify some variations in wood structure of Sessile and Pedunculate oaks in relation to ring and star shakes. These defects (splits which develop in the wood of the standing tree—Plate 6) are economically very important, being a major problem in many woodlands throughout Britain.

The first year of the 3 year project has been devoted to an information survey and to collection of material for anatomical analyses. From the preliminary survey it appears that shakes are caused by a variety of 'triggers' acting upon weak points in the wood. The weakness may be inherent (genetic) or environmentally induced (e.g. associated with wounding, or rapid change in growth rate). Triggers appear to include stresses due to fluctuating water tables (associated with a variety of site conditions), or bending of the tree by wind.

Ribs or grooves in the oak bark were generally found to be reliable indicators of shake in our preliminary field surveys, but high proportions of trees believed sound from external appearance are also found to be shaken.

If the formation of shakes is associated with anatomical structure, it may be possible to select for soundness of timber at an early stage. With that aim we have collected material from the FC oak provenance trial at Penyard, Forest of Dean (Gloucs.) for analysis of variations between species, provenances, and with growth rate within provenances. We are also comparing the structure of shaken with unshaken timber. An experimental plot has been established to compare the juvenile wood of oaks grown in tree shelters with that of unsheltered trees.

Factors influencing accelerated growth of young trees in plastic tube shelters

by E. RENDLE

Horticulture Department, Wye College, Kent

A factorial experiment involving corrugated polypropylene tubes, continuous light, hormone, and a comparison between field and glasshouse, was carried out. Pendunculate oak raised from seed in the glasshouse were planted out in May 1983 and harvested in October of the same year.

After 5 month's growth in well-watered, weed-free conditions many of the tube trees had already grown out of their tubes (height 1.2 m), confirming the significant increase in height growth that can be achieved with the use of tubes. This effect on height growth was enhanced with the use of hormone and continuous light. In the glasshouse, oak trees were grown to a much greater

height than in the field, particularly if hormone is used. Increase in height growth of tube and glasshouse trees is not at the expense of stem diameter. Other parameters of tree growth, e.g. number of flushes, number of nodes, internode length, branch number, leaf area, were also measured but have not yet been fully analysed. Dry matter production of all the trees was assessed after harvesting. Greater total dry matter production was obtained in glasshouse (mean 147.7 g) compared with field grown trees (mean 72.3 g). No significant differences were found between field treatments. Tubes however did have a significant effect on stem:root ratio.

Aspects of the tube environment have also been investigated. Temperatures within the tube are more extreme; during sunny weather tube temperature rises significantly above that outside. During the hot weather of the 1983 summer temperatures up to 48°C were recorded within the tubes; the humidity was also increased. When the tree is in leaf the humidity within the tube tends to remain above that outside.

Herbicide evaluation for forestry uses

by D. J. TURNER and W. G. RICHARDSON

Agriculture and Food Research Council Weed Research Organization, Begbroke Hill, Yarnton, Oxford

Weed control in seed beds

No new herbicides have been investigated, but the technique of dressing seeds of crop species with herbicides has been followed up (*Report* 1983, p. 59). In some instances seed dressing with diphenamid, napropamide or other herbicides did not adversely affect conifers but selectively controlled weeds sown with the crop species. Some of the treatments appeared to stimulate crop growth. Effects with Sitka spruce were particularly promising. A new experiment to investigate the technique in more detail has been initiated. Although at first sight seed dressing does not appear to have much advantage over spray applications it has attracted some interest from foresters who intend to establish trees by direct seeding.

Weed control in transplant lines and young plantations

Most attention has concentrated on methods of improving the efficacy of established herbicides. The 1:4:4 mixture of Agral, Ethylan D252 and paraffin discussed in *Report* 1983 (p. 60) has been tested with a wide range of herbicides, including glyphosate. In studies with *Rhododendron ponticum*, the addition of 10 per cent of this mixture to a solution containing Roundup and ^{14}C labelled glyphosate improved leaf entry by almost 400 per cent. Increases were also observed in other weed species; for example in *Calamagrostis epigejos* leaf uptake of ^{14}C glyphosate was increased from 0.3 to 35.1 per cent of the applied dose. It appears that oil/surfactant additives may be very useful where foliage applied herbicides are used in forestry, particularly for pre-planting weed control where selectivity is not required.

A number of new herbicides have been tested against important weeds and crops. Of these probably the most interesting is a new grass killing herbicide from Dow, haloxyfop, formerly Dowco 453. This appears to be reasonably

active against *Molinia caerulea* and *Deschampsia caespitosa*. Other WRO research has shown that this herbicide is able to control Annual meadow grass *Poa annua*. In this respect, Dowco 453 differs from other aryloxy phenoxy grass herbicides.

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Behaviour of tree stem and crown in response to wind loading and artificial loading

by P. BLACKBURN

Department of Forestry, University of Aberdeen

The shape of the curve assumed by a deflected stem is of great importance to tree stability since it determines the contribution by stem and crown weight to the total turning moment at the base of the tree. Theoretical curves have been devised by Petty and Worrell (1981) using the assumptions that stems bend to maintain uniform strain in the outer wood and that the stem is firmly anchored in the ground. These allow calculations of the forces required to cause stem breakage.

In this project, the Petty-Worrell model is being tested and developed together with tree pulling studies and is being used to investigate the contribution of tree weight to the total turning moment for a range of tree sizes. In an experiment on a brown earth site at Glentress Forest (Borders), horizontal loads were applied at 70 per cent of tree height to five sample trees and the resulting stem curvature was photographed. The theoretical deflection curves gave a reasonable approximation to the actual curves.

Analysis of data from FC tree-pulling experiments has revealed that on sites where stem breakage and uprooting occurred the turning moments causing stem breakage and uprooting were similar. Further research is in progress in order to investigate the transfer of bending forces from the stem to the root system for trees growing on a peaty gley.

The interaction of tree motion with the wind is being investigated in the major FC aeromechanical experiment at Moffat Forest (Dumfries and Galloway) (see pp. 29–31). Information on tree displacement in strong winds has been recorded on cine film, with simultaneous wind recording.

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SITE STUDIES

Nutrition and forest soils

by H. G. MILLER

The Macaulay Institute for Soil Research, Aberdeen

During the year a grant was received from the Commission of European Communities (EEC) as partial support for a major new study to be carried out jointly with the Forest and Wildlife Service of the Republic of Ireland. Planned in conjunction with the Forestry Commission, this study aims (i) to elucidate the processes that enable nitrogen and other nutrients to cycle more rapidly in mixed spruce-larch and spruce-pine stands than in pure spruce stands; (ii) to suggest means by which such knowledge might be used to develop low input but high productivity silvicultural systems, and to design the field trials necessary to test such proposals; (iii) by comparing results from widely separated sites, to identify the disturbance to nutrient cycles and tree growth that are ascribable to acid rain. The cycle of nutrients is now being monitored in experimental plots of Sitka spruce, planted both pure and in mixture, at Inchnacardoch (peat soil) and Culloden (mineral soil) Forests (Highland) and at Avondhu Forest (mineral soil) in the Republic of Ireland. Particular attention is being given to differences in litter decomposition and nitrogen mineralisation in the various mixtures.

Processing of earlier work on nutrient cycling in spruce continues and the project to model nutrient cycling in pine is now virtually complete. Some of these results have recently been brought together in a discussion of the maintenance and improvement of forest productivity (Miller, 1983). Considerable effort continues to be directed towards investigation of the environmental consequences of forest operations and, in particular, the interaction with acid rain. Trees may have a profound effect on rainwater acidity, usually decreasing it, but with older trees acidification may result (Miller, 1984). This aspect is attracting increasing attention and plans have been completed for a large new study to be funded primarily by the Department of the Environment.

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Nitrogen transformations in forest soils

by R. REES and J. W. PARSONS

Department of Soil Science, University of Aberdeen

In the final year of this 3 year project, work has continued on a field experiment using analytical and sampling techniques developed earlier in a stand of mature Sitka spruce at Durris Forest (Grampian). The effects of

carbon and nitrogen application on litter decomposition and litter fall are being examined. In a related study the influence of live roots on litter decomposition processes is being investigated.

Whilst application of 200 kg N ha^{-1} as ammonium sulphate had little effect on the rate of litter breakdown, as indicated by litter bag studies, applications of 1000 kg C ha^{-1} as starch increased the rate of litter breakdown and caused a substantial increase in the rate of nitrogen mineralisation.

Contrary to expectations, the establishment of trenched plots to exclude live roots has had no effect on rates of litter breakdown. However there is some evidence for a mycorrhizal mobilisation of nitrogen unavailable to non-mycorrhizal micro-organisms.

Input of litter through litter fall has, as expected, decreased in response to nitrogen application. A slight decrease in litter fall in response to carbon application has also occurred.

On completion of this project it is hoped to relate tree growth, as measured by increase in breast height diameter, to the nitrogen transformation processes described above.

Effects of afforestation on water resources

by J. R. BLACKIE and I. R. CALDER

Institute of Hydrology, Crowmarsh Gifford, Wallingford, Oxon

Effects on quantity

With the installation of the upper Monachyle streamflow structure in June 1983, instrumentation of the Balquhidder catchments in Strathyre Forest (Central) was completed. Data on streamflow, rainfall, snowfall, forest canopy interception, sediment transport and the meteorological variables are now being accumulated and analysed. In phase II of the study, scheduled to start in 1986, changes in hydrological response resulting from clear felling in the Kirkton catchment and initial planting in the Monachyle catchment will be monitored.

In the physical process studies, results indicate that interception loss rates from heather exceed those from grassland but direct transpiration rates from heather are considerably lower. Total evapotranspiration is likely to be similar at 1500 mm annual rainfall but progressively greater from heather above this level. Preliminary results from the gamma-ray attenuation equipment (*Report* 1983, p. 57) in the Queen's Forest, Aviemore (Highland), indicate that snow interception by forest canopies is a significant hydrological process. Storage of snow on Sitka spruce can exceed 20 mm water equivalent, ten times the rainfall interception capacity, and loss rates exceeding 0.5 mm/hour have been observed in warm front conditions.

Effects on quality

The initial planting of some 30 per cent of the experimental catchment on Llanbrynmair Moor (Powys) resulted in no significant change in streamflow quality during the first 6 months. A further 50 per cent of the catchment is scheduled for planting in 1984. After an extended period of comparison with a neighbouring control, clear felling of 50 per cent of the Hore catchment in Hafren Forest (Powys) is scheduled to start in 1984/85.

GENETICS

Collection, storage and viability of larch pollen

by I. R. BROWN and D. A. WILLIAMS
Department of Forestry, University of Aberdeen

Storing larch pollen from one season to the next markedly reduces its viability and hence the yield of seed from artificially controlled pollinations. The aims of this project were: to determine the optimum times and methods of collecting pollen from excised branches; to assess *in vitro* pollen viability testing procedures; and to test pollen storage regimes.

Using tetrazolium chloride (2,3,5, triphenyltetrazolium chloride) staining and *in vitro* germination of pollen, it was found that the most viable pollen was obtained by standing male flower-bearing shoots in water and maintaining an air temperature of 17–19°C and a 24 hour photoperiod. Best results were obtained with shoots collected no more than 3 weeks before natural shedding of pollen. Viability tests consisted of comparisons of: tetrazolium staining, which reflects cytoplasmic enzyme activity; U.V. absorption of pollen leachates, which estimates the integrity of the pollen membranes; and germination. All three methods indicated similar patterns of variation in 'viability' during the period of pollen storage.

Pollen was stored at 5°C and 20°C, at five relative humidities varying from 5–75 per cent, with some samples air- or freeze-dried and stored at −15°C. Over the first 6 months pollen at 34 per cent R.H. at 5°C gave the best results but after 9 months, tests indicated that none of the stored pollens had remained viable.

Variation and inheritance of wood properties in Sitka spruce

by P. E. WOOD
Department of Agricultural and Forest Sciences, University of Oxford

In order to establish techniques and sampling methods for estimating the variation in wood properties of Sitka spruce grown under progeny test conditions, samples of wood were taken from 10 trees in each of two plots in a 30-year-old Sitka spruce progeny test in Clocaenog Forest (Gwynedd). One plot was derived from a general seed importation from the Queen Charlotte Islands and the other a very fast-growing family derived from a wind-pollinated clone. Sample discs were removed at breast height and at 5, 15, 25, 45 and 65 per cent of the total tree height; two cores, each having an end section of 5 mm × 5 mm were removed along two radii. They were then reduced to a moisture content of 12 per cent.

Wood density was measured by X-ray densitrometry, using a MK VI Joyce Loebl microdensitometer scanning every 100 μm or 200 μm from pith to bark. Samples were scanned both before and after resin extraction.

Currently under investigation are the inner 25 rings of all samples taken at 5 per cent of tree height and the inner nine rings at all sampling levels. Initial results indicate that mean density is greatly influenced by distance from the pith and the origin of the material and that between-tree differences are also

significant. There were no significant differences between radii, levels, or before and after resin extraction. The mean density of the Queen Charlotte Island material was considerably greater than that of the fast grown plus tree progeny.

PHYSIOLOGY

The development of quantitative indices relating to the physiological age of Sitka spruce

by M. J. STEELE

Department of Botany, University of Edinburgh

Seedling scions grafted into the crowns of sexually mature trees in 1982 and 1983 (*Report* 1983, p. 61) are still being examined to determine if the scions have undergone accelerated physiological ageing. It has been necessary to repeatedly investigate a number of characteristics during the past two growing seasons in an effort to develop quantitative indices that will offer the best potential for adequately reflecting gradual changes in the physiological age of Sitka spruce.

A total of 12 morphological, anatomical and physiological characteristics have been or are still being examined in apical, i.e. first whorl, lateral branches sampled from stands of Sitka spruce of different ages. Most of the relationships of the characteristics with age are of an asymptotic nature and Figure 8 shows the variations for four of these characteristics (mean needle

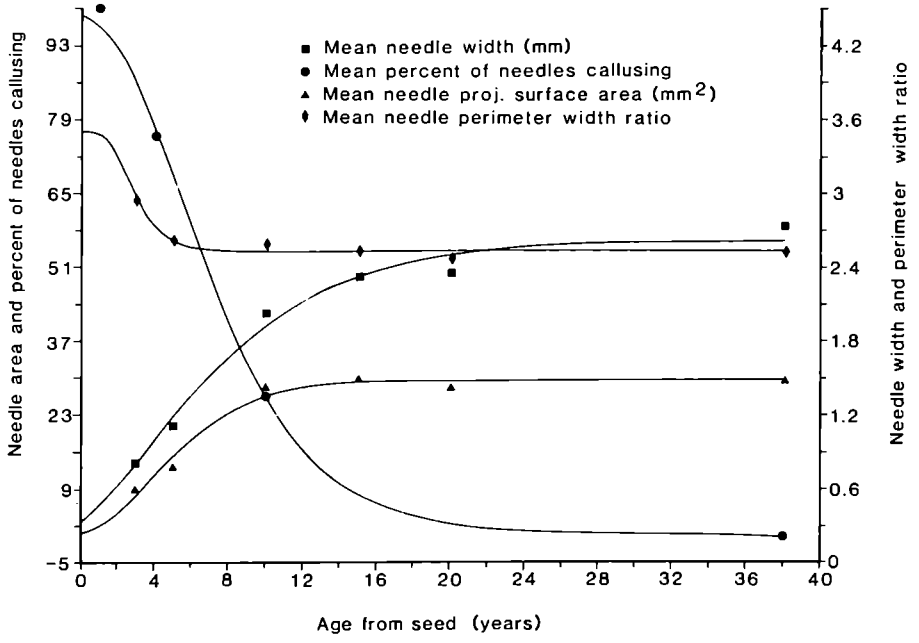


Figure 8. **Changes with age for some characteristics of Sitka spruce.**

width, mean needle projected surface area, mean percentage of needles producing callus *in vitro* using a defined medium and the mean ratio of the perimeter to the width in transverse sections of needles). It has been possible to describe the data from all but one of the characteristics using a modified Gompertz function.

Figure 8 illustrates that not all characteristics change together or at the same rate. Interestingly, however, several of the characteristics do appear to change in parallel, as illustrated here by the mean needle width and mean percentage of needles callusing; both reaching their respective asymptotes at approximately 20 years from seed.

Further work is obviously required to establish to what extent those characteristics appearing to change together are in fact correlated. This will indicate whether or not the use of simple linear measurements (e.g. needle width) rather than the use of labour-intensive physiological indices (e.g. needles callusing *in vitro*) can be used to determine the physiological age of scions or even individual trees. Additionally, it needs to be ascertained which value for a single characteristic or, more likely, which values for a number of specified characteristics, must be attained before an individual scion or tree is in a state of readiness to flower.

ENTOMOLOGY

Regulating interactions of the pine aphid *Schizolachnus pineti* Fabricius and host plant growth

by G. B. LEWIS

Department of Zoology, University College, Cardiff

Tree growth experiments

Thompson (1977) suggested that the aphid *Schizolachnus pineti* Fabricius could produce a marked reduction in the growth of Scots pine *Pinus sylvestris*. This prompted an investigation into the effects of aphid numbers on the growth of pine trees and this was initiated in 1981. Two experimental plots were planted. The first comprised five species of pine: *P. sylvestris, P. nigra, P. muricata, P. radiata* and *P. contorta*. These were treated with three levels of aphid infestation: control, low and high. Aphid numbers were recorded throughout the growing season after which various tree growth parameters were measured. The trees were then maintained aphid free for a second year, measured as before, and then harvested for dry weight analysis. The second experiment involved only *P. sylvestris* and was designed to investigate various effects of aphid infestation over 3 years. For example, the effect of one year's infestation on two subsequent aphid-free years, and two cumulative aphid-infested years on subsequent aphid-free growth.

The results show that *S. pineti* was able to achieve high numbers on *P. sylvestris* and *P. nigra* but not on the other three species. These high numbers resulted in a reduction in growth, to varying degrees under the various experimental conditions. At high levels of infestation this deleterious effect was most significant in the second aphid free year. The low level infested trees, however, appeared to have been able to compensate, to some degree, for the losses of

the first year, showing higher unit growth rates in the second year than the control trees.

Aphid performance

A second approach to this plant-insect interaction has been to assess aphid performance in terms of growth, development and fecundity. In addition to the influences of the different pine species, factors affecting aphid performance such as temperature, plant growth stage, between tree variation, colony size, parental weight and previous infestation have been studied.

The results support the preferences shown in the tree growth experiments, see Figure 9. Chemical (amino acids, phenols and terpenes) and physical com-

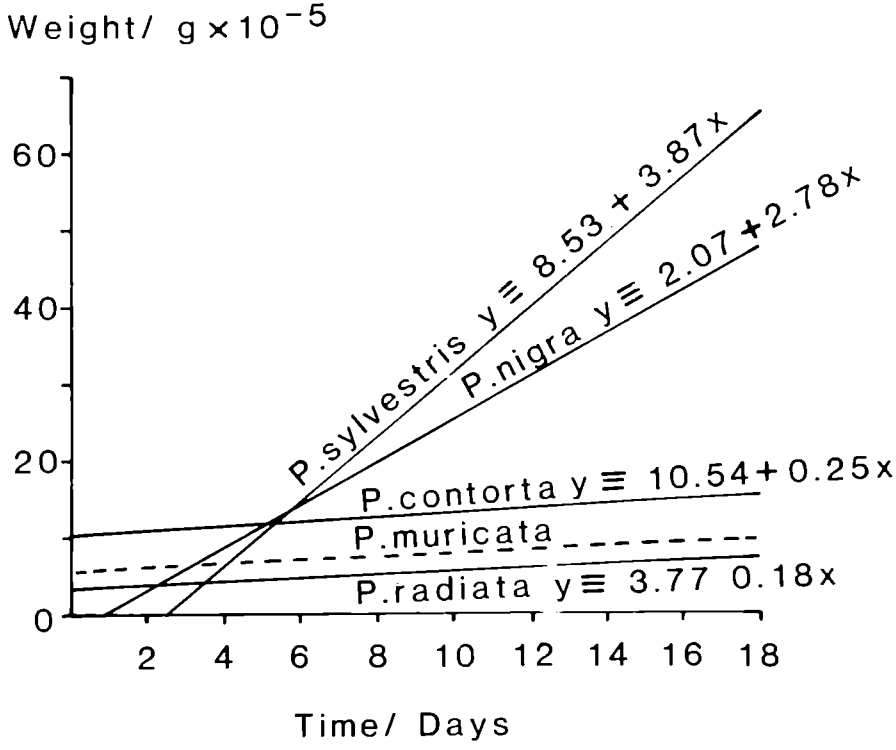


Figure 9. **Growth rate of *Schizolachnus pineti* on five species of pine.**

parison of the five pine species is currently being undertaken. The aphid performance data will be used to construct a simulation model to assess the influence of the host plant on aphid population dynamics.

REFERENCE

Thompson, S. (1977). The effect of an attack by the aphid *Schizolachnus pineti* Fabricius on the growth of young Scots pine trees. *Scottish Forestry* **31**, 161–164.

WOOD 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 timber from unthinned stands (*Report* 1983, p. 68) has continued. Earlier work, using trees from Clocaenog Forest (Clwyd) demonstrated a reduction in the proportions of sawn wood meeting acceptable levels of structural performance as planting distance widens and this has been confirmed using trees from Brechfa Forest (Dyfed) planted at spacings of 0.9, 1.4, 1.8 and 2.4 m and thereafter left unthinned. The importance of log quality, especially straightness, in influencing sawn timber quality was also confirmed. Nevertheless there were differences in the structural performance level of the battens from the two sites at comparable spacings and explanations for this are being sought in terms of the pattern of growth and anatomical differences in the timber from the two sites.

Conversion of British-grown timber

The working laboratory prototype of LOCAS was demonstrated in March 1983 to the sawmilling industry in the sawmill of Lampeter Timber and Trading Company. Following the demonstration and subsequent publicity in the trade press, many enquiries have been received from potential users and sub licensees of the system, together with further enquiries specifically for the scanners. However, although discussions are continuing, to date no firm commitment to manufacture either the complete system or the scanners has been received from any British company.

With a view to optimising dimensional accuracy of British structural softwood a survey has been started to assess the sawing accuracy achieved in British mills.

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.

BEVAN, D. (1984). Coping with infestation. *Quarterly Journal of Forestry* **78** (1), 36–40.

Large scale afforestation started in Britain in 1919. Over the past 30 years 'new' pests have appeared at the rate of about one every 5 years. All are of European origin and two are native. Their host plants are all exotic except one. Some outbreaks have been relieved by the arrival in the country of a natural enemy, others are suspected as instances of poor adaption of the host plant to a foreign pest species. It is concluded that site acting through the host is often the primary factor in the dynamics of a pest.

BIGGIN, P. (1983). Tunnel cloches—development of a nursery technique for growing conifers. *Forestry* **56** (1), 45–59.

Clear polythene used as a cloche with buried edges to cover seedbeds is an effective method of improving growth of some species of conifer seedlings. Cloches can reduce time for producing planting stock by one year. Pines give consistently good results, but response of other species varies.

BILLANY, D. J., CARTER, C. I., WINTER, T. G. and FIELDING, N. J. (1983). The effect of climate and parasites in *Gilpinia hercyniae* (Hartig) (Hymenoptera: Diprionidae) in Britain. *Entomologist's Monthly Magazine* **119**, 117–120.

A comparison is made between the climate in Wales where *G. hercyniae* has one generation per year, with continental Europe where two are normal. The population collapse in Wales coincided with lower temperatures and higher rainfall than usual. The ichneumonid *Lamachus marginatus* is recorded as a parasite of *G. hercyniae* for the first time in Britain. Six ichneumonid species were introduced from Europe and released in Wales during 1977 to 1979 but sawfly populations were low due to climatic factors and a nuclear polyhedrosis virus.

BINNS, W. O. (1983). Immissionschaden in Grossbritannien (Pollution damage in Great Britain). *Allgemeine Forst Zeitschrift* **26/27** (2 July), 701–712.

Summarises (for German readership) the occurence and concentration levels of atmospheric pollutants (SO_2, NO_x, O_3, etc.) in relation to possible tree damage in Great Britain.

BINNS, W. O. (1983). Acid rain: ecological effects—forests and soils. In *Proceedings of the 50th Annual Conference, National Society for Clean Air.*

Rainfall is naturally acid, but pollutants have increased acidity in the northern hemisphere. Dry deposition is dominant near sources but wet deposition becomes important in remote areas. The concentrations at which different pollutants affect trees are uncertain and interactions between them poorly understood.

Tree canopies modify rainfall composition and may reduce or increase its acidity. Evidence of damage to forests or forest soils in Britain is lacking, but pollutants appear to have acidified some fresh waters and forestry sometimes seems to be associated with this effect. The causes of forest decline in Central Europe are not understood; damage to tree crowns by pollutants seems a more credible cause than damage to soils.

BINNS, W. O. (1983). Establishing trees on damaged soils. In *Tree establishment*, ed. Thoday, P. R. Proceedings of a Symposium at the University of Bath, 14/15 July 1983, 32–39.

Root growth can be restricted by adverse physical or chemical characteristics of the soil (e.g. through compaction, waterlogging, removal and stacking). The method of reinstatement and the design of landforms for the restoration of worked sites are discussed. Soil cultivation and tree planting and tending techniques are described.

BINNS, W. O. and REDFERN, D. B. (1983). *Acid rain and forest decline in W. Germany.* Forestry Commission R&D Paper 131.

Reports a visit made in 1983 to Lower Saxony, Bavaria and Baden-Wurttemberg. Symptoms are described for spruce, fir and beech. While some damage could be due to known biological agencies or unusual weather patterns, some seems to be due to pollutants, acting either through the soil (by aluminium release following acidification) or directly through tree crowns. Experimental evidence to support either route is lacking, but ozone and acid pollutants acting together on crowns appear to be damaging. The age and altitude of the affected stands, and the different species and climate, suggest that British forests are unlikely to be in immediate danger.

BLATCHFORD, O. N. (Ed.) (1983). *The use of chemicals (other than herbicides) in forest and nursery.* Forestry Commission Booklet 52.

General notes are given detailing safety precautions, safe working methods, protective clothing and personal equipment for use with tree protection chemicals. These are followed by specialist sections listing insecticides, fungicides, fertilisers and chemicals (both poisons and repellants) for protection against wildlife damage. Within these sections are recommendations on the control of named forest insect pests, diseases and wildlife. There is an index to damaging agents and chemicals, and an index to manufacturers and suppliers of the recommended chemicals.

BOOTH, T. C. (1984). Natural regeneration in the native pinewoods of Scotland. A review of principles and practice. *Scottish Forestry* **38** (1), 33–42.

Information on factors affecting the natural regeneration of native Scots pine woods is reviewed. Management action to promote natural regeneration must be tailored to suit each site. Fencing is essential to prevent browsing damage, and some form of cultivation or scarification is commonly required to expose patches of soil. A 20–30 year regeneration period is almost inevitable.

BRASIER, C. M. (1983). The future of Dutch elm disease in Europe. In *Research on Dutch elm disease in Europe.* Forestry Commission Bulletin 60, 96–104.

An account of the possible outcome of the present Dutch elm disease epidemic, in terms of the form of the Dutch elm disease fungus (*Ceratocystis ulmi*) likely to survive into the post-epidemic period and the implications of this for the future of the elm.

BRASIER, C. M. (1983). A cytoplasmically transmitted disease of *Ceratocystis ulmi. Nature* **305** (5931), 220–223.

This paper describes the transmission characteristics and phenotypic effects of a cytoplasmically transmitted disease discovered in the NAN race of the aggressive strain of *C. ulmi*, and discusses its potential impact upon the current Dutch elm disease epidemics in the Northern Hemisphere.

[BROOKER, M. I. H. and] EVANS, J. (1983). *A key to eucalypts in Britain and Ireland; with notes on growing eucalypts in Britain.* Forestry Commission Booklet 50.

Well-illustrated botanical key covering 35 species of eucalypts which are hardy enough to grow in parts of the British Isles.

[BUCKLEY, G. P. and] INSLEY, H. (1984). Sward control strategies for young amenity trees. In *Aspects of Applied Biology* **5**. Weed control and vegetation management in forests and amenity areas, Association of Applied Biologists, 97–107.

Sward control around young trees is a potent aid to establishment. First-year treatments are critical, as is the position of the weed-free area. Position is a function of both the size of the weed-free area and its relation to tree roots developing radially. This has implications for the effects of strip-weeding along tree rows compared with spot-weeding around individuals, and is considered in an investigation using sycamore. Results of several field experiments, using broadleaved tree species planted into grass swards, are used to illustrate these points and to suggest a practical weed-control strategy.

CARTER, C. I. (1983). Some new aphid arrivals in Britain's forests. *Proceedings of the Transactions of the British Entomological and Natural History Society* **16**, 81–87.

Records of 48 species of aphids that are established on 16 species of introduced conifers are compiled with an indication of their present status in Britain. This information is set against a background of forest tree species area composition and introduction dates. The increase in forest area from 4 to 8 per cent of the land surface by afforestation and reclamation is discussed in the context of enriching the forest insect fauna.

CARTER, C. I. and GIBBS, J. N. (1984). Chapter 15. Pests and diseases of forest crops. In *Pest and disease control handbook*, eds. Scopes, N. and Ledieu, M., British Crop Protection Council, 575–591.

Pests and diseases of forest crops, nurseries and Christmas trees are described and control recommendations given.

COUTTS, M. P. (1983). Development of the structural root system of Sitka spruce. *Forestry* **56** (1), 1–16.

Growth ring analysis was carried out on root systems of Sitka spruce trees which had been planted 8 and 34 years previously. Differentiation into roots of widely different radial growth rates took place during the first 6 years, resulting in 3 to 11 'major' woody roots and a large number of small 'minor' ones, with some of intermediate vigour, radiating from the stump. The major roots established during the first few years constituted the main structural root system at 34 years. Many of the minor roots stopped growing in diameter after a few years, but were still alive and extending at 34 years.

COUTTS, M. P. and LEWIS, G. L. (1983). When is the structural root system determined in Sitka spruce? *Plant and Soil* **71**, 155–160.

Growth ring analysis was carried out on root systems of Sitka spruce trees. The differentiation into major and minor roots is discussed with reference to their origins and the local environment.

COUTTS, M. P. (1983). Root architecture and tree stability. *Plant and Soil* **71**, 171–188.

Root anchorage is discussed with a view to determining the optimum use of root material for enhanced stability. The physical properties of roots and soils are reviewed and observations on failure in the root-soil system when trees are pulled over with a winch are described. A theoretical model is developed which includes the sequence of changes which occur in the main components of anchorage during the uprooting process.

DAVIES, R. J. and GARDINER, J. B. H. (1983). Amenity planting on French motorways. *Arboricultural Journal* **7** (3), 211–216.

The methods used to establish trees and shrubs on some French motorway verges are described. Intensive soil cultivation and mulching with black polythene film are widely employed. Standard-sized trees are heavily pruned at planting. Unrooted cuttings are used and research is in progress to extend this technique to a wide range of species. These practices have also been used to re-establish farm hedgerows. Early growth rates are impressive.

DAVIES, R. J. (1983). Transplant stress. In *Tree establishment*, ed. Thoday, P. Proceedings of a Symposium at the University of Bath, 14/15 July 1983, 40–50.

Two sources of stress for the newly planted tree—poor plant handling and weed competition—are discussed. Desiccation during plant handling reduces survival and growth, and is generally more detrimental than physical root loss. Container-grown plants survive no better than bare-rooted stock when planted between October and April. Competition for moisture and nutrients also reduces survival and growth. Fertilising is generally less beneficial than effective weeding without which it may be harmful. Mowing grass weeds can increase their vigour and further stress the tree. On wet sites mulches may accentuate anaerobic soil conditions.

DAVIES, R. J. (1984). Weed control for amenity trees on man-made sites. In *Aspects of Applied Biology* **5**. Weed control and vegetation management in forests and amenity areas, Association of Applied Biologists, 55–64.

Soil conditions on man-made sites, often with a vigorous grass sward, limit the available moisture and nutrients for which amenity trees must compete. The effects of sward control treatments on

soil moisture are reported. Tree growth is related to soil moisture availability, but competition also affects nutrition. The effects of varying the area of weed control around individual trees, and the percentage cover of surviving weeds within that area are discussed. The interactions between fertilising and weed control are also reviewed. Fertilising generally provides less benefit than effective weed control without which it may indeed be ineffective.

EDWARDS, P. N. (1983). *Timber measurement—A field guide*. Forestry Commission Booklet 49.

Describes the measurement methods which may be needed in the forest for measuring standing trees and felled timber.

EVANS, J. (1983). Le contrôle des gourmands—Etat actuel des recherches en Grande-Bretagne. *Revue Forestière Française* **35** (5), 369–375.

Both genetic and environmental factors influence epicormic development. Thinning in broad-leaved 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. The growth retardant maleic hydrazide shows most promise in suppressing epicormic growth.

EVANS, J. (1983). More trees for the tropics. *Country Life* **CLXXIII** (4468), 868–869.

Outline of plantation programmes and new tree planting in tropical countries for industrial purposes, soil protection, and domestic needs for firewood, fodder, and building and fencing materials.

EVANS, J., HAYDON, L. and LAZZERI, M. (1983). Propagating and planting eucalypts in Britain. *Arboricultural Journal* 7 (2), 137–147.

An account about growing eucalypts in Britain covering species choice, seed collection, supply and storage, sowing and germination conditions, methods of raising plants, and plantation establishment.

EVANS, J. (1978). Long-term productivity in tropical and sub-tropical plantations. In *Proceedings of the 8th World Forestry Congress, Jakarta, Indonesia* (1978) **5**, 856–865.

The question of maintenance of long-term productivity in fast-growing tropical plantations is reviewed along with a detailed report of research carried out in Swaziland over the last 10 years, comparing the growth of two rotations of *Pinus patula*. The most recent (1977) reassessment of second rotation growth in Swaziland, made at the end of the rotation, indicates a small decline in yield (6–8 per cent) compared with the previous crop. Recent abnormal rainfall patterns are thought to be partly responsible for this drop. In view of the small size of the decline, as well as the rainfall factor, there is little evidence yet to suggest any serious long-term productivity problem arising from site degrade.

[FAIRHURST, C. P. and] KING, C. J. (1983). The effect of climatic factors on the dispersal of elm bark beetles. In *Research on Dutch elm disease in Europe*. Forestry Commission Bulletin 60, 40–46.

From observations mainly at four weather stations with different geographical characteristics in north-western England and Wales, an attempt is made to assess in broad terms the number, character and distribution of potential flight days (defined as days when the maximum temperature is at least 22°C) for scolytid vectors (especially *Scolytus scolytus* (F.) and *S. multistriatus* (Marsham)) of Dutch elm disease (caused by *Ceratocystis ulmi)* in elms (*Ulmus* spp.). The known northern limit of the disease (and by implication *S. scolytus*) correlated well with the line representing 10 such days. For *S. multistriatus*, there was some evidence that the corresponding limit might be the 20-day line. The major northward spread of a non-aggressive epidemic of the disease in about 1930–50 coincided with a period of warm summers.

FORESTRY COMMISSION/HOME GROWN TIMBER ADVISORY COMMITTEE (1983). Technical Note 42. Prinz chainsaw mounted bark stripper. *Forestry and British Timber* **12** (5), 21–22.

FORESTRY COMMISSION/HOME GROWN TIMBER ADVISORY COMMITTEE (1983). Technical Note 43. The Hytrad 'Hy Point' stake pointer. *Forestry and British Timber* **12** (11), 27.

FORESTRY COMMISSION/HOME GROWN TIMBER ADVISORY COMMITTEE (1984). Technical Note 44. Holder C500/GMI scrubcutter. *Forestry and British Timber* **13** (1), 41–42.

GIBBS, J. N. and BURDEKIN, D. A (1983). De-icing salt and crown damage to London plane. *Arboricultural Journal* 7 (3), 227–237.

During the post-war period, crown dieback has occurred periodically in London plane planted in London and other British cities. Much of the damage can be attributed to the effect of de-icing salt applied to roads during severe winters. The main symptoms of this disorder is the death of foliage shortly after flushing, with some branches typically being more affected than others. Later in the summer remaining leaves may develop marginal and interveinal scorching. Chloride levels in leaves from affected trees are between 1 and 3 per cent of the dry weight, well above the 0.1–0.3 per cent found in unaffected trees.

GIBBS, J. (1983). Not to be confused. *GC&HTJ* **15** (2), 27, 29.

Describes two separate causes of the crown damage which has recently marred the reputation of London plane as an urban tree: salt damage, and anthracnose caused by the fungus *Gnomonia platani*.

GIBBS, J. N. (1984). Brunchorstia dieback in Europe. In *Scleroderris canker of conifers*, ed. Manion, P. D., The Hague, Martinus Nijhoff/Dr W. Junk.

Brunchorstia dieback caused by *Gremmeniella abietina* is a disease of economic importance and biological interest. Infection of current shoots of *Pinus nigra* occurs in early summer, but symptoms are not usually expressed until the following winter. Damage is most severe in trees that are shaded or sheltered. More research is required on the influence of environmental factors on both infection and host invasion. Knowledge is also required on the extent of variation in *G. abietina* and its geographic origins.

GILL, J. G. S. (1983). Comparisons of production costs and genetic benefits of transplants and rooted cuttings of *Picea sitchensis*. *Forestry* **56** (1), 61–73.

A system has been developed for bulking-up plant numbers from scarce seedlots by rooted cuttings. Commercial-scale trials of the system are now under way. Costs are compared of producing planting stock by two methods; traditional nursery rearing of transplants (1 + 1) and vegetative propagation of stock material to produce cuttings (C1 + 1). Genetic gains are predicted and compared for both systems, predictions being based on quantitative estimates of genetic variables from progeny tests and on the current progress of the breeding programme. The implications of the economic comparison for the future breeding programme for Sitka spruce are discussed.

GILL, J. G. S. (1983). Genetic improvement in some forestry practices—with special reference to natural regeneration. *Scottish Forestry* **37** (4), 250–258.

Natural regeneration provides an alternative to planting restocking sites where the original choice of species and provenance were appropriate. It removes the opportunity to introduce the genetically improved planting stock which is beginning to flow from breeding programmes for major coniferous species. Against this, natural regeneration allows limited genetic improvement through selection of parent trees and offspring. Theoretical gains are compared for Scots pine and Sitka spruce. It is concluded that natural regeneration has a greater present potential advantage, but not in 10–15 years' time as seed from tested orchards becomes increasingly available.

GRAYSON, A. J. (1983). Wood requirements and domestic production. In *Indigenous raw materials for industry*. Metals Society Book 311, 45–48.

Britain has long depended on overseas sources for wood products. A high degree of self-sufficiency in wood cannot be achieved in this country owing to competition for land. In any event, a realistic target for increasing production of wood has to take account of the costs of growing in relation to world market prices. In addition to a continuing programme of afforestation, efforts are being devoted to improved management of existing crops and the selection of the processing techniques most likely to ensure profitable use of home resources.

GREIG, B. J. W. and COXWELL, R. A. G. (1983). Experiments with thiabendazole (TBZ) for control of Dutch elm disease. *Arboricultural Journal* **7** (2), 119–126.

Thiabendazole (TBZ) hypophosphite, marketed as Ceratotect, gave good curative results when injected as a low concentration, high volume treatment. Bioassay of twigs showed that some fungicide persists into the following summer after treatment.

GREIG, B. J. W. and GIBBS, J. N. (1983). Control of Dutch elm disease in Britain. In *Research on Dutch elm disease in Europe*. Forestry Commission Bulletin 60, 10–16.

Results of successful control campaigns in southern England are given for Brighton, Hove and East Sussex. Control centres on the prompt sanitation felling of diseased trees, the prohibition of movement of elm timber into the control areas and root severance. Limited trials with the fungicide Ceratotect gave good results as a curative treatment. In northern Britain, control failed on Merseyside but good results were achieved in West Yorkshire, Tyne and Wear and some Scottish cities.

[GURNELL, J. and] RENNOLLS, K. (1983). Growth in field and laboratory populations of woodmice (*Apodemus sylvaticus*). *Journal of Zoology* **200**, 355–365.

Intrinsic growth rate and asymptotic body weight parameters were estimated for two laboratory and three field populations of the Wood mouse *Apodemus sylvaticus* using a logistic model fitted by an ordinary least squares method. The data upon which the growth equations were based were differences in body weight for individual animals between sampling occasions. Males tended to have higher growth rates, and to a lesser extent, higher body weight asymptotes than females in all groups. Growth rates were highest in the autumn field population with good seed supply: differences between the other groups were less marked. These results are discussed and it is suggested that, despite the approximation inherent in the method, the model is a useful tool for studying the productivity of wild populations of small mammals.

[HANS, A. S.,] PARKER, E. J. [and KUMAR, V.] (1978). Potentialities of Zambian forest fruit trees. In *Proceedings of the 8th World Forestry Congress, Jakarta, Indonesia* (1978), FFF/9–8.

About 20 species are potentially useful for conserves and beverages (fruit), and oil, protein and carbohydrates (seed). A tree improvement programme is aimed at changing from food gathering to crop production.

HUGHES, A. J. G. (1984). The mechanisation of forest harvesting. *The Agricultural Engineer* **39** (1), 15–19.

A general article on mechanised harvesting in British forestry.

[JENNING, A. C. S. and] PATCH, D. (1983). Insurance for practising consultants and contractors. *ICF Newsletter* **4**, 21–23.

Insurance is expensive and therefore often overlooked by consultants and contractors. However, the cost of a simple claim involving litigation can be enormous and may exceed the financial implications of an award made by the Courts. This note reviews types of insurance cover recommended for forestry consultants and contractors.

JOBLING, J. (1983). Treatment of deep-mine colliery spoil. In *Reclamation of mineral workings to forestry*. Forestry Commission R&D Paper 132, 17–19.

Regraded colliery spoil heaps are extremely compacted and may become intensely acid. Spoil has a low water-holding capacity and risks of drought damage to trees are increased by the presence of a grass sward. These and other factors affecting tree survival and growth, and the research being carried out to resolve the problems, are reviewed.

JOBLING, J. (1984). Which way Leyland? *Nurseryman & Garden Centre* **172** (4), 28–30.

A previously recommended Leyland cypress clone 'Stapehill' has proved to be susceptible to damage by drought. Its withdrawal from horticulture, the introduction of other clones to take its place, and some associated nomenclatural problems are discussed.

JOHN, A (1983). Tissue culture of coniferous trees. In *Tissue culture of trees*, ed. Dodds, J. H., Croom Helm, 6–21.

The chapter is a review of the current status of the tissue culture of conifers and discusses callus culture, suspension culture, bud induction, rooting and the application of *in vitro* techniques to conifer plant production.

KING, C. J. and FIELDING, N. J. (1983). Trap design and experimental layout in pheromone research in Britain. In *Research on Dutch elm disease in Europe*. Forestry Commission Bulletin 60, 67–71.

The experimental designs and equipment used in the field in England since 1977 to study aggregation pheromones in the vectors *Scolytus scolytus* (F.) and *S. multistriatus* (Marsham) of Dutch elm disease (caused by *Ceratocystis ulmi*) in elms (*Ulmus* spp.) are described. The conditions of climate in Britain and diminishing elm populations, irregular beetle flight in a rapidly changing climate, and increasingly unsuitable elm populations are among the factors that conspire to make pheromone experiments difficult.

[KOSKE, R. E., MILLER, D. D. and] WALKER, C. (1983). *Gigasporea reticulata*: a newly described endomycorrhizal fungus from New England. *Mycotaxon* **16**, 429–435.

Populations of mycorrhizal fungi were examined at two sites planted with poplar trees. The species present, along with the numbers of their propagules were recorded at fortnightly intervals. The effect of herbicide treatment on spore populations was examined at one of the locations.

A new species of mycorrhizal fungus is described from sand dunes and apple orchards in the United States.

LANE, P. B. (1984). Application update: new systems for the forester. *Forestry and British Timber* **13** (2), 16, 17, 26.

A technical update on recent herbicide applicator developments.

[LEA, J. and] BRASIER, C. M. (1983). A fruiting succession in *Ceratocystis ulmi* and its role in Dutch elm disease. *Transactions of the British Mycological Society* **80**, 381–387.

A succession of fruiting of *Ceratocystis ulmi* was observed within beetle breeding galleries in the bark of diseased elms between the time of beetle colonisation in summer and emergence in the following spring. Mycelial conidia and synnemata were predominant in the warm period following colonisation. They declined rapidly at the onset of winter, and were replaced by perithecia. The perithecia declined by the end of winter, and with the onset of higher temperatures prior to beetle emergence there was a resurgence of the mycelial conidia. Two periods of active growth of *C. ulmi* were indicated, one following beetle colonisation and the other in the spring. It is thought that the succession is governed largely by temperature and nutrients.

LEATHER, S. R., [WARD, S. A. and DIXON, A. F. G.] (1983). The effect of nutrient stress on life history parameters of the black bean aphid, *Aphis fabae*. *Oecologia* **57**, 156–157.

Experiments were conducted to investigate the effects of brief spells of starvation on the longevity and age-specific reproduction of *A. fabae*. Increasing the duration of the starvation period reduced the aphids' ability to resettle when returned to a host, but no longer-term effects on mortality were found. Secondly, as predicted, starvation reduced life-time fecundity, but increased the reproductive rate immediately after nutrition improved.

LEATHER, S. R., [WELLINGS, P. W. and DIXON, A. F. G.] (1983). Habitat quality and the reproductive strategies of the migratory morphs of the Bird cherry-oat aphid, *Rhopalosiphum padi* (L.), colonizing secondary host plants. *Oecologia* **59**, 302–306

Emigrants and alate exules of *Rhopalosiphum padi* were kept on good and poor quality hosts. Alate exules on good hosts were more fecund than those on poor hosts. Host quality did not affect the fecundity of the emigrants. The number of ovarioles in the gonads of the emigrants varied from 10–16, that in alate exules from 4–10, and neither was correlated with morph weight. On poor quality hosts the aphids with most ovarioles suffered the greatest mortality.

There was no significant difference in the time of wing muscle autolysis of emigrants on good or poor hosts. However, alate exules on poor hosts retained their flight capability for longer than those on good hosts. On poor hosts alate exules retained their flight capacity for longer than emigrants.

LEATHER, S. R. (1983). Evidence of ovulation after adult moult in the Bird cherry-oat aphid *Rhopalosiphum padi*. *Entomologia Experimentalis et Applicata* **31**, 386–390.

A series of dissections at different times throughout the life span of individual aphids indicated that in the Bird cherry-oat aphid, ovulation carried on after the adult moult. Ovulation had, however, ceased by the tenth day of adult life.

LEATHER, S. R. (1983). Forecasting aphid outbreaks using winter egg counts: an assessment of its feasibility and an example of its application in Finland. *Zeitschrift für Angewandte Entomologie* **96**, 282–287.

During the autumn of 1981, 110 sites containing *Prunus padus* trees were sampled for eggs of *Rhopalosiphum padi*. In spring 1982, 16 sites were resampled in the main cereal growing areas to obtain an estimate of egg mortality. The density of eggs laid in autumn 1981 in the whole of Finland was 40 eggs/100 buds. In the major cereal growing areas the density was approximately 75 eggs/100 buds in autumn and had fallen to approximately 43 eggs/100 buds in spring.

The feasibility of using aphid egg counts to predict outbreaks was considered in the light of this and other published data. It was concluded that this method could only be used for host-alternating aphid species, totally or greatly dependent on the egg stage for successful over-wintering.

LEATHER, S. R. and BARBOUR, D. A. (1983). The effect of temperature on the emergence of pine beauty moth, *Panolis flammea* Schiff (Lep. Noctuidae). *Zeitschrift für Angewandte Entomologie* **96**, 445–448.

At each of three controlled temperatures tested (20°, 25°, 9–18°C) emergence of *Panolis*-moths began from 7–10 days after the commencement of these conditions. In the laboratory, emergence did not begin until the last week of February. There was a positive and significant relationship between temperature and pupal emergence. The timing and duration of emergence was significantly related to the sex of moths: females emerged earlier than males on average.

LINES, R. and BINNS, W. O. (1983). Acid rain—a comment on the paper by Fred Last in the May Journal. *Scottish Wildlife* **19** (3), 24–25.

The effects of coniferous forests on acid deposition vary with species and location. Sitka spruce in rural areas can cause a net reduction in acid input to the soil. Aluminium toxicity to tree roots appears unlikely at levels < 40 ppm. Acidity of lakes in Galloway bore no relation to the percentage of forest on the catchment.

LINES, R. (1984). Species and seed origin trials in the industrial Pennines. *Quarterly Journal of Forestry* **77** (1), 9–23.

A series of species trials was planted in the southern Pennine Hills 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, including ground preparation. Twenty-six species and four main groups of seed origins of *Pinus contorta* and two of *Pinus nigra* were tested. Relative air pollution by sulphur dioxide was measured using lead dioxide candles. Exposure was estimated by tatter flags and anemometers. Pollution decreased during the mid-1960s, particularly from smoke. Performance of different species is discussed and comments made on their ability to withstand the combination of pollution and other site factors which characterise this area.

LONSDALE, D. (1983). Pruning: a rule of thumb. *GC&HTJ* **194** (2), 18–19.

Describes how to prune to get the best results from the decay resistance mechanisms of a tree. An angled cut just beyond the branch bark ridge is recommended.

LONSDALE, D., MERCER, P. C. and GIBBS, J. N. (1983). Treatments for decay prevention in amenity trees. In *Proceedings of the 10th International Congress of Plant Protection, Brighton*, 1069.

Wound dressings might, in theory, protect trees against infection by decay organisms, perhaps through mechanical exclusion of spores, through fungicidal action, or through restriction of gaseous exchange. The results of experiments involving a wide range of proprietary and other treatments are summarised. Most materials delayed colonisation by decay fungi in wounds on

beech trees, in a few cases for over 9 months. None, however, achieved long-term control except for the fungus *Trichoderma viride* which gave significant protection for at least 4 years.

LONSDALE, D. (1983). Some aspects of the pathology of environmentally stressed trees. *International Dendrology Society Yearbook* 1982, 90–97.

In the absence of environmental stress or in the commonly occurring presence of slight stress, the only micro-organisms which can seriously attack trees are the specialised parasites. Under more severe stress, 'opportunistic' parasites can also cause disease and some of them can sustain their attack long beyond the period of stress. The relationships between stress, especially drought stress or nutritional stress, and particular diseases, can be illustrated by reference to *Armillaria* root rot, to cankers caused by organisms such as *Nectria* spp. and to 'strip cankers' caused by pathogens of outer sapwood. Diagnosis, prognosis and possible therapy for some disorders are discussed.

LONSDALE, D. (1983). Wood and bark anatomy of young beech in relation to *Cryptococcus* attack. In *Proceedings, IUFRO Beech Bark Disease Working Party Conference, Hamden, Connecticut, USA*, 1982, 43–49.

Within a sample of European beech, partial resistance to attack by the beech scale *Cryptococcus fagisuga* was associated with a smooth bark which had a regular, vertical pattern in its surface 'growth lines'. Such bark contained relatively little unlignified outer parenchyma, and the main stone cell layer was strongly developed. The 'dimpling' symptom of infested stems was brought about by locally reduced and abnormal xylem development.

LONSDALE, D. and SHERRIFF, C. (1983). Some aspects of the ecology of *Nectria* on beech. In *Proceedings, IUFRO Beech Bark Disease Working Party Conference, Hamden, Connecticut, USA*, 1982, 59–68.

Observations of the mycoflora of beech bark infested with *Cryptococcus fagisuga* suggested that *Nectria coccinea* can colonise sites on and in the outer tissues, and that invasions of inner bark could later develop. Although these sites harboured fungi antagonistic to *N. coccinea*, experiments suggested that it is well adapted under some circumstances to escape serious competition.

LONSDALE, D. (1983). Fungal associations in the build-up and decline of *Cryptococcus fagisuga* populations. In *Proceedings, IUFRO Beech Bark Disease Working Party Conference, Hamden, Connecticut, USA*, 1982, 99–104.

The fungal flora of *Cryptococcus fagisuga* colonies on *Fagus sylvatica* bark included the entomogenous species *Verticillium lecanii* wherever infestation was or had been very heavy. This fungus seemed to accelerate insect mortality *in vitro*. *Cladosporium cladosporioides* was present at all stages of insect colony development and, with other fungi, caused blackening of the wax secretion.

McINTOSH, R. (1983). Nitrogen deficiency in establishment phase Sitka spruce in upland Britain. *Scottish Forestry* **37** (3), 185–193.

The occurrence of nitrogen deficiency in Sitka spruce stands is discussed with respect to site type, visual symptoms and critical foliar nitrogen concentrations. Results of fertiliser experiments in such stands are discussed with respect to rate of nitrogen application, length of response period and time of year of application. Methods of preventing nitrogen deficiency by the use of liming treatments, leguminous species and nursing mixtures are also discussed.

[MASON, P. A., WILSON, J., LAST, F. T. and] WALKER, C. (1983). The concept of succession in relation to the spread of sheathing mycorrhizal fungi on inoculated tree seedlings growing in unsterile soils. *Plant and Soil* **71**, 247–256.

From work done by the Institute of Terrestrial Ecology on birch, and by them and the Forestry Commission on Sitka spruce, the concept of a succession of mycorrhizal fungi, dependent on the age of the host plant, is discussed.

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

Describes a method of estimating the numbers of damaged trees in forest crops.

MITCHELL, A. F. (1983). All in a year's work. *Quarterly Journal of Forestry* **77** (2), 106–109.

Describes some 'newly found' trees notable for their size or shape including the two contenders for the tallest tree in Britain, as well as those claiming notice as rarities.

MITCHELL, A. F. (1983). West coast giants in eastern Scotland. *Scottish Forestry* **37** (2), 107–116.

The Pacific slopes of North America are the home of almost all of the biggest conifers in the world. Growth of these introduced species is particularly good in east Scotland. A summary of the location and dimensions of best specimens is given.

MITCHELL, A. F. (1983). Big trees in Scotland. *Scottish Forestry* **37** (4), 288–292.

Scotland is incomparable in its wealth of immense conifers. Measurements of fine trees made during a 6-day excursion in 1982 are catalogued.

PARKER, E. J. (1983). Beech bark disease in Great Britain. In *Proceedings, IUFRO Beech Bark Disease Working Party Conference, Hamden, Connecticut, USA*, 1982, 1–6.

The status of beech bark disease in Great Britain is summarised with respect both to historical perspectives and to the contemporary situation. Features of the disease which relate particularly to its occurrence in Great Britain are listed. Some tentative findings from recent observations and experimental work are presented.

PATCH, D. (1983). Tree roots—their role in establishment. In *Tree establishment*, ed. Thoday, P. Proceedings of a Symposium at the University of Bath, 14/15 July 1983, 68–78.

Without an adequate and living root system trees are unlikely to survive transplanting. Cultural techniques, handling and planting practices, can have sudden and adverse effects on the form of a root system and the ability of nursery grown trees to become established after transplanting. These influences are reviewed and it is concluded that there is need for greater considerations of roots in both specifications and cultural practices.

PYATT, D. G. and SMITH, K. A. (1983). Water and oxygen regimes of four soil types at Newcastleton Forest, south Scotland. *Journal of Soil Science* **34**, 465–482.

The water and oxygen status of four upland soils under Sitka spruce plantations was studied for 2 years. In a brown earth, waterlogging only occurred ephemerally and oxygen concentrations were generally high. Waterlogging and near-anaerobic conditions persisted for much of the year in surface water gley and peaty gley soils. In a peaty ironpan soil small concentrations of oxygen occurred in wet layers above the thin ironpan while larger oxygen concentrations persisted in the less wet subsoil. Depths of rooting were related to the soil oxygen conditions.

ROLLINSON, T. J. D. (1983). Algerian foresters battle against the Sahara. *Forestry and British Timber* **12** (11), 12–13.

Description of the forestry scene in Algeria and the problems facing its forestry service.

ROSE, D. (1983). Web of intrigue. *GC&HTJ* **15** (2), 20.

Cobweb-like patches on the bark of urban trees are caused by the fungus *Athelia* which is parasitic on a pollution tolerant lichen *Lecanora conizaeoides* and on a *Protococcus* alga. It has no detrimental effect on tree health.

ROWE, J. J. (1983). Squirrel management. *Mammal Review* **13** (2/3/4), 173–181.

The management of *Sciurus* species is related to three main strategies: utilisation, damage prevention, conservation. The tactics which have been used to implement these strategies and their effectiveness in different situations are briefly discussed. It is concluded that management strategies lack flexibility since monitoring is usually related to the current strategy. There is also a considerable time lag in translating biological knowledge and recommended changes in tactics into effective practice.

ROWE, J. (1983). Grey squirrel: bark-stripping damage in southern Britain up to 1983. *Timber Grower* **90**, 41–42.

Results of a survey of damage on private estates and in Forestry Commission woodlands are summarised. Much damage occurred before the introduction of Warfarin treatment in 1973. Beech and sycamore were the most commonly attacked trees. The scale and type of squirrel control practised was also investigated. There is more awareness of currently recommended control measures in the FC than amongst private woodland owner/managers.

SALE, J. S. P., TABBUSH, P. M. and LANE, P. B. (1983). *The use of herbicides in the forest—1983*. Forestry Commission Booklet 51.

The main herbicides recommended for use with the Forestry Commission are described. Each forest weed type forms the subject of a separate section within which details of the appropriate herbicide are individually set out with information on approved trade products, crop tolerance, rates, methods and dates of application, protective clothing and safety precautions. Applicators and their calibration are described and the introduction includes a summary of the voluntary and statutory regulations governing the use of herbicides in this country. Details of manufacturers and suppliers of herbicides, applicators and ancillary equipment are included as well as a glossary of general and technical terms.

TABBUSH, P. M. (1984). Experiments on heather control. In *Aspects of Applied Biology* **5**. Weed control and vegetation management in forests and amenity areas, Association of Applied Biologists, 223–230.

Experiments are described which were designed to improve methods for the control of heather using 2,4-D and glyphosate. The Micron 'Herbi' resulted in poorer heather control than the Micron 'ULVA', when used with 2,4-D but caused less damage to the crop trees and, by increasing the rate, the 'Herbi' may be used to extend the spraying season in the early part of the year. Heather was easier to kill on peat than on mineral soils, and different herbicide rates declined by late August on sites with mineral soils whereas glyphosate was at its most effective in late August.

TABBUSH, P. M. and SALE, J. S. P. (1984). Experiments on the chemical control of *Rhododendron ponticum* L. In *Aspects of Applied Biology* **5**. Weed control and vegetation management in forests and amenity areas, Association of Applied Biologists, 243–253.

Experiments on the chemical control of *Rhododendron* carried out in 1982 in west Scotland, Wales and southern England are described. Among the chemicals tested, glyphosate and triclopyr showed the most promise. Recommendations for the application of glyphosate using the Micron 'ULVA' are given. An additive, 'Mixture B', containing domestic paraffin and a mixture of surfactants, greatly enhanced the effectiveness of glyphosate.

TABBUSH, P. M. (1984). Effects of different levels of grass-weeding on the establishment of Sitka spruce. In *Proceedings Crop Protection in Northern Britain Conference*, 339–344.

Experiments on three widely separated forest sites compared the effects of different levels of weed control on the survival and early growth of Sitka spruce (*Picea sitchensis*). No response was found on a moist, ploughed, valley site at Tummel (Tayside), but significant effects were recorded at Ae (Dumfries and Galloway) and Brycheiniog (Powys). Delayed weed control for one year greatly reduced these effects, and it is concluded that an 80 cm diameter spot around the tree kept free of weeds throughout the first growing season, represents the optimum weeding intensity.

TULEY, G. (1983). Shelters improve the growth of young trees. *Quarterly Journal of Forestry* **77** (2), 77–87.

Shelters are plastic tubes 1.2 m tall and between 8 and 10 cm diameter which are erected over young trees. After two growing seasons, the height growth of many broadleaves has been more than doubled by shelters and for oak there has been a continued response in the third season. There has been some improvement in the growth of conifers. The cost of the plastic, plus a stake, is 50p per tree. Research continues to find and test different plastics. Some advice is given on using shelters and the implications of wider initial spacing are raised. Large scale trial of the techniques is recommended for broadleaves.

TULEY, G. (1983). A sheltered start. *GC&HTJ* **194** (15), 39–40.

An indication of how tree shelters improve growth of newly planted broadleaved trees, and a guide to the materials available for their construction.

TULEY, G. (1984). Trees in shelters do need to be weeded. In *Aspects of Applied Biology* **5**. Weed control and vegetation management in forests and amenity areas, Association of Applied Biologists, 315–318.

Shelters increase the growth of many broadleaved trees. The responses of trees inside shelters to weed control can be dramatic. The choice of herbicide as well as the date and way in which it is applied may be different when trees are grown in shelters.

WAINHOUSE, D. and HOWELL, R. S. (1983). Distribution of attack by beech scale *Cryptococcus fagisuga* in beech progeny trials. In *Proceedings, IUFRO Beech Bark Disease Working Party Conference, Hamden, Connecticut, USA*, 1982, 33–37.

Surveys of beech scale infestation among progeny of single beech trees demonstrated significant variation in susceptibility between the progenies. Relative differences in susceptibility of some progeny were maintained on three different sites in southern England.

WAINHOUSE, D. (1983). Interaction between beech and beech scale. In *Proceedings, IUFRO Beech Bark Disease Working Party Conference, Hamden, Connecticut, USA*, 1982, 31–32.

Trees heavily infested with beech scale are commonly observed either singly or in small groups within infested forests. This appears to be due partly to the presence of resistant trees and also, in the UK at least, to the existence of sub-populations of scale insects, some of which appear to be adapted to individual host trees. It is suggested that the greater susceptibility of American beech to attack by beech scale may be due in part to the absence of co-evolved defence mechanisms.

WAINHOUSE, D. and HOWELL, R. S. (1983). Intraspecific variation in beech scale populations and in susceptibility of their host *Fagus sylvatica*. *Ecological Entomology* **8**, 351–359.

Within a seed orchard in southern England, beech trees belonging to three clones were artificially infested by introducing beech scale larvae into small cages attached to the bark. Some larvae developed to fecund adults on trees of two susceptible clones but all failed to develop on a third, resistant clone. Larvae deriving from several separate trees differed significantly in their ability to survive when inoculated onto trees of susceptible clones. Five forest trees which acted as both donors of larvae and as hosts for artificial inoculation were each inoculated with larvae from all five trees. Survival of larvae reinoculated on to their original host was significantly higher than that of larvae originating from other trees.

WALKER, C. (1982). Species in the Endogonaceae: a new species (*Glomus occultum*) and a new combination (*Glomus geosporum*). *Mycotaxon* **15**, 49–61.

A new species of mycorrhizal fungus is described from several parts of the world. An already existing taxon is raised from varietal status to full-species status.

WALKER, C. [MIZE, C. W. and McNABB, H. S. Jnr.] (1982). Populations of endogonaceous fungi at two locations in central Iowa. *Canadian Journal of Botany* **60**, 2518–2529.

Populations of mycorrhizal fungi were examined at two sites planted with poplar trees. The species present, along with the numbers of their propagules, were recorded at fortnightly intervals. The effect of herbicide treatment on spore populations was examined at one of the locations.

WALKER, C. (1984). Taxonomic concepts in the Endogonaceae: spore wall characteristics in species descriptions. *Mycotaxon* **18**, 443–455.

A new, standardised, terminology for use in descriptions of endomycorrhizal fungi is proposed and illustrated.

WEBBER, J. F. [and KIRBY, S. G.] (1983). Host feeding preference of *Scolytus scolytus*. In *Research on Dutch elm disease in Europe*. Forestry Commission Bulletin 60, 47–49.

Beetles derived from a southern population of *Scolytus scolytus* show a marked preference for *Ulmus procera* as feeding material when both *U. procera* and *U. glabra* are available. This

observation helps to explain the lower incidence of Dutch elm disease in *U. glabra* compared with *U. procera*, despite the former's greater susceptibility to the Dutch elm disease pathogen.

WEBBER, J. F. and GIBBS, J. N. (1984). Colonisation of elm bark by *Phomopsis oblonga*. *Transactions of the British Mycological Society* **82**, 348–352.

The high frequency of *Phomopsis oblonga* in elm outer bark in the north and west, compared with southern Britain, enhances its potential to act as a biological control of the beetle vectors of Dutch elm disease in these areas. It is also more prevalent in the outer bark and a more active coloniser of the inner bark of Wych elm than English and Wheatley elm. Thus potential disease control by *P. oblonga* is further increased in Wales, north and west England and Scotland where Wych elm is most abundant.

WHITE, J. E. J. (1983). *The Westonbirt Arboretum catalogue in the 1980s*. Forestry Commission R&D Paper 133.

Presentation of the philosophy and methodology of cataloguing over 13 000 tree specimens.

WHITE, J. E. J. (1983). *Autumn colour at Westonbirt*. Forestry Commission.

Description of Japanese maples and guide to autumn colour trail at Westonbirt Arboretum.

WINTER, T. G. (1983). *A catalogue of phytophagous insects and mites on trees in Great Britain*. Forestry Commission Booklet 53.

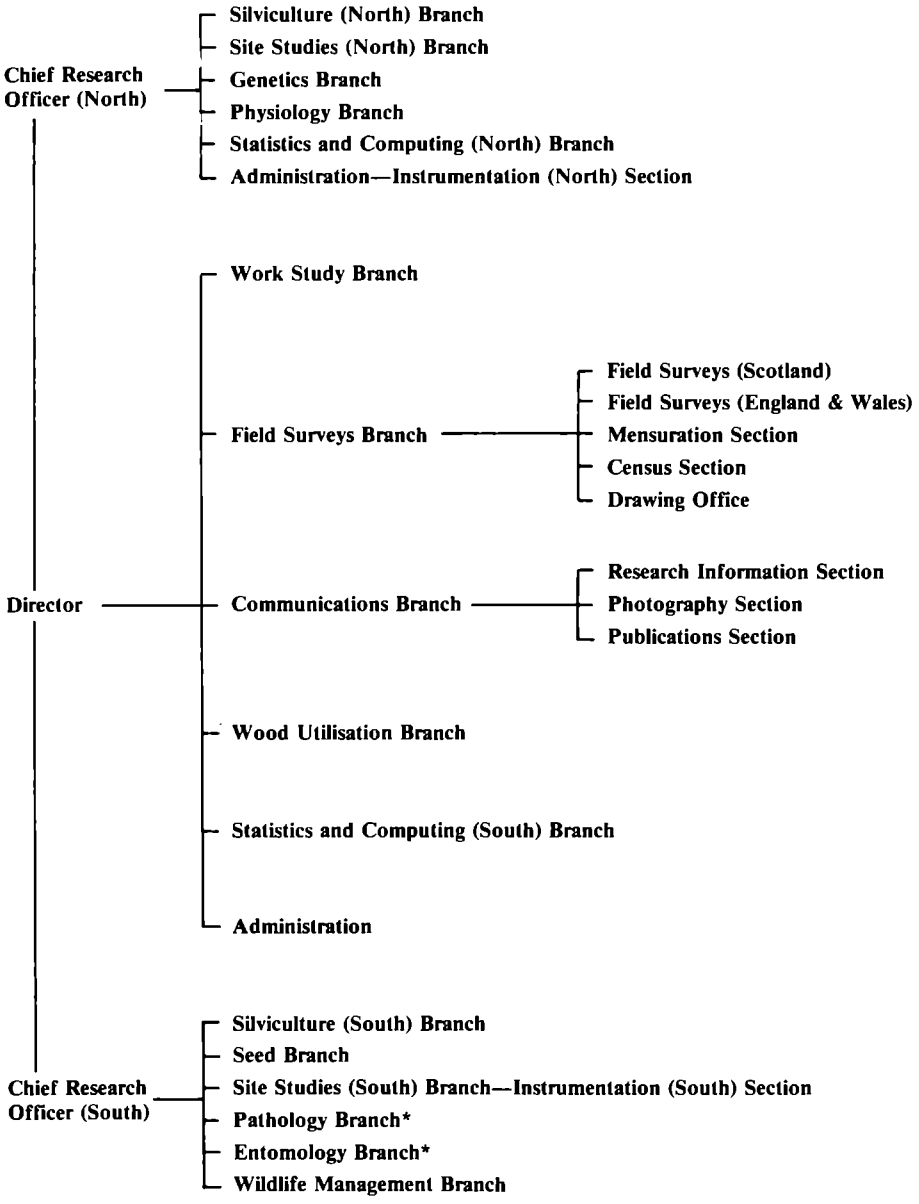
This catalogue is comprised of three lists. The basic list of phytophagous insects, mites (and a few nematodes), is arranged by scientific name and gives genus, species, authority, order, common name or synonym, and host plants. The species included show great variability in status, some being pests of economic importance while others are of interest only. The supplementary lists are by common name and by host woody plant.

WINTER, T. G. (1983). Early appearance of *Orthosia stabilis* (D&S) (Common Quaker) in Surrey. *Entomologist's Record and Journal of Variation* **95**, 125.

Records the early appearance in January 1983 of this species in a Rothamsted light trap.

APPENDIX II

Research and Development Divisional Organisation



*Branches with sections at the Northern Research Station.

APPENDIX III

Staff Engaged in Research and Development

As at 31st March 1984

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

SEED BRANCH

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

Laboratory: Miss A. Pocock, Mrs Y. K. Samuel, Miss K. Spriggs, D. C. Wakeman

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.

Foresters:		*Centre*
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	Alice Holt
	M. J. Scott, R. E. Preston	Bedgebury
	S. E. Malone, T. D. Cooper	Thetford
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GLOSSARY

Latin names of trees cited by common name in this Report

Broadleaves	
Alder, Common	*Alnus glutinosa*
Grey	*A. incana*
Italian	*A. cordata*
Red	*A. rubra*
Ash	*Fraxinus excelsior*
Beech	*Fagus sylvatica*
Birch, Silver	*Betula pendula*
Chestnut, Horse	*Aesculus hippocastanum*
Sweet	*Castanca sativa*
Lime, Common	*Tilia* × *europea*
Oak, Pedunculate	*Quercus robur (Q. pedunculata)*
Sessile	*Q. petraea (Q. sessiliflora)*
Plane, London	*Platanus* × *hispanica*
Sycamore	*Acer pseudoplatanus*
Conifers	
Cedar, Western Red	*Thuja plicata*
Fir, Douglas	*Pseudotsuga menziesii (P. taxifolia)*
Grand	*A. grandis*
Pacific Silver	*A. amabilis*
Hemlock, Western	*Tsuga heterophylla*
Larch, European	*Larix decidua (L. europaea)*
Hybrid	*L.* × *eurolepis*
Japanese	*L. kaempferi (L. leptolepis)*
Pine, Corsican	*Pinus nigra* var. *maritima*
Lodgepole	*P. contorta*
Scots	*P. sylvestris*
Sequoia, Giant	*Sequoiadendron giganteum*
Spruce, Sitka	*P. sitchensis*
White	*P. glauca*

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Printed in the UK for HMSO
Dd 737631 C15 11/84 10170 (1915)

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ISBN 0 11 710130 3