

Forestry Commission

Forestry Commission

ARCHIVE

**REPORT ON
FOREST RESEARCH
1985**

REPORT ON
FOREST RESEARCH

for the year ended
March 1985

LONDON
HER MAJESTY'S STATIONERY OFFICE

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First published 1985

The abbreviated title of this Report is:
Rep. Forest Res., Edin. 1985

Front Cover: Open grown oak, age 45 years, at Crumblands Plantation, Gwent Forest District, in an experiment laid down in 1950 to investigate the effects of very heavy crown thinning (free growth). This method of growing oak offers the prospect of a substantially earlier return of valuable timber than from conventional thinning. (29280)

Back Cover: 'Dollop' mounding technique used in ground preparation for restocking on Culm clays at Torridge Forest, Cornwall. The 'dollops', laid by a backacting digger from drains at 18 m spacing, provide planting positions in drained and aerated soil. (36882)

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INTRODUCTION

By A. J. GRAYSON

Director of Research

Visiting Groups

Two Visiting Groups were formed and reported in the course of the year. Both concerned features of silvicultural research. The first covered work aimed at increasing the stability of plantations against windthrow. The group was led by Mr D. A. Mithen, recently retired Forestry Commissioner, and included Mr Lawson (Department of Industrial Aerodynamics, Bristol University), Dr Wood (Department of Engineering, Oxford) and Mr Castle (Field Drainage Unit, ADAS). The group examined research by Physiology and Site Studies (North) Branches bearing on the subject as well as that carried out by Silviculture (North). The subject is a highly specialised one since trees and their anchorage are very different from most man-made structures in their response to wind stresses. A particular area of concern was that of aero-mechanical studies. The group made a number of useful recommendations on ways of improving current investigations and the direction of future research and good progress has been made in implementing the bulk of their proposals.

The second Visiting Group was more specifically concerned with the role of physiological support to Silviculture (South) Branch and was led by Dr B. H. Howard of East Malling Research Station (AFRC) with Dr Cannell (ITE, Bush) and Dr Loughman (Department of Agricultural Science, Oxford). The group made a firm recommendation in favour of the appointment of a new member of Physiology Branch to Alice Holt: this was accepted. The group emphasised the possibilities of 'genetic lift' through clonal selection: it will be an important function of the new physiologist to determine the traits to be given attention in the first instance.

Air pollution

Apart from the research and monitoring functions reported elsewhere in this Report, the year was marked by a major increase in activity of a parliamentary, consultative and advisory kind on the subject of trees and air pollution. (The term is used in preference to 'acid depositions' because the latter description does not cover certain substances such as ozone and hydrocarbons which appear likely to be implicated in damage to trees in continental parts of Europe, and in preference to 'acid rain' which has obvious journalistic appeal but equally obvious deficiencies in terms of comprehensiveness.) The determination of certain observers to prove that pollution effects exist where careful observation shows them not to has been an interesting feature of the decade. We would naturally be most concerned if damage were occurring to trees because of the very large stock that exists in relation to the annual output of wood and the scale of the habitat at risk. Our country-wide survey conducted in the autumn of 1984 showed no condition on three major species that could be considered out of the ordinary or identifiable with the German symptoms.

Parliamentary attention to the subject was intense. The environment sub-committee (G) of the House of Lords European Communities Committee,

and the House of Commons Environment Committee took oral evidence concentrating on the possibility of damage to British forests, our views of German forest decline and water quality in certain upland areas. An unprecedented number of parliamentary questions were put on the interrelation between air pollution, tree health and water quality, and on research bearing on these subjects.

Research project evaluation

Adam Smith's invisible hand, at least in the sense he wrote of it, has little influence over the choice of research projects. Though there have been some noteworthy initiatives in government research with the aim of simulating a market, the distance of research from a marketed consumption good or service often makes the Smithian hand too remote to be effective. The attempt to simulate a market may well make the decision to contract work a sub-optimal one because the choice is not so much based on comparing reward and cost as emphasising cost once the decision to undertake a given project or programme has been taken. The older alternative, and no doubt still widely adopted in much research planning apart from the most applied cases, has depended largely on a broad brush appreciation that the project or the project leader promised useful rewards. Both are fairly crude methods of selection. Quantitative methods centring on assessment of likely economic benefits have been widely used in the more applied areas of manufacturing industry research and agricultural research. In addition, and again relating to the contribution to the market value of output, there has been a growth over the last 20 years of econometric research into the clearly economic gains from research in industrial and agricultural R&D. This is based on the calculation of functions linking production with the various inputs used in a particular industry. Little such work has been done in forestry, partly because the concepts used to measure, and hence statistics on, net output in forestry are lacking.

The production function approach being barred, attention turns to cost-benefit analysis. A virtue of this approach is that it automatically directs attention at the less tangible gains from research, namely those such as gains in environmental quality, that are not measured by (direct) reference to markets and statistics derived from them. In connection with the wish of the Forestry Research Co-ordination Committee to assess the relative costs and values of programmes in the nine fields that have been distinguished, an attempt has been made to apply a cost-benefit analysis type of approach. The qualification of 'type' is necessary since it is clear that a rigorous analysis on classical social cost-benefit lines cannot be achieved: instead subjective indices are ascribed to benefits which elude evaluation and weights applied to enable benefits in different dimensions to be added to produce a numerical score or a money value. The components of benefit that are assessed are: gains in value of wood production, gains through reduction in the costs of forest operations, gains in environmental benefits and additions to scientific knowledge not already accounted for under the first three heads. These benefits are both orthogonal to one another and comprehensive. The method is necessarily crude owing to the subjectivity implied by both scoring and translation into money values. This is not however an unfamiliar position for economists to find themselves in: the need is to ensure that the methods

of ascribing the requisite values to components are made as critical as possible and that open-mindedness is maintained when the overall results of the process are compared across projects or other entities of research activity. Apart from these difficulties there are the familiar problems of estimation of the life of the research result, the likely extent of its application, the probability of success (which no doubt varies as the particular piece of research progresses), and the assessment of the present value of calculable benefits. Despite these challenging and in some cases difficult points of methodology, some useful explorations have been undertaken at the project level.

Farming and forestry

The predictable and rapid increase in output of food in Britain under the influence of technical advance and continuing price incentives has led in the past year or two to wider than ever concern and scepticism about the intensity with which the growth of agricultural output is pursued. Although the recent rise in output has been accompanied by a declining farm income in real terms, and some adjustment will occur through this kind of change, there is a clear need to identify ways of maintaining farmers' net incomes by methods avoiding continued excess production even at supported prices. One way is to reduce the intensity of, and hence the level of inputs into, farming, the other is to widen the range of crops whose production is not in immediate danger of becoming surplus. Whatever the outcome over the coming decades, it seems clear that tree growing in one form or another will be expanded in areas and types of farm and among types of owner that have not been involved in forestry, agroforestry or arboriculture for many years past.

In preparation for the changing conditions that may be expected, we have started work on various uses of trees on farms ranging from spaced coniferous tree planting combined with sheep grazing in the uplands to single tree and widely planted broadleaves in lowland grassland. While some silvicultural problems remain, particularly those concerned with rapid establishment to gain independence from grazing and browsing damage, research is particularly called for on species and provenances of tree most capable of responding to more fertile growing conditions, on tree improvement and on protection. Interactions with farm management operations and especially with the farmers' attitudes and experience create a special class of problem requiring attention.

Visits to Alice Holt

The Commissioners visited Alice Holt on 9 and 10 May 1984. They saw the work of all the Branches represented at Alice Holt, including plantations on reclaimed gravel workings at Bramshill where Site Studies (South) Branch had carried out some of the pioneering work with deep tine ripping now practised countrywide. The Chairman, Sir David Montgomery, and the Chairman of the Advisory Committee on Forest Research, Professor P. F. Wareing, planted specimens of, respectively, *Liquidambar styraciflua* and *Malus tschonoski* to commemorate the occasion.

M René Souchon, State Secretary in the French Ministry of Agriculture with responsibility for forestry, visited the Research Station on 27 June 1984 for a brief introduction to the work of the Division. The performance of

certain oak, planted in 1979, which in 5 years had grown out of the tops of special 4 metre tree shelters, proved a severe test of our visitor's credulity: French silviculture is not used to producing such effects.

Open Days were held at Alice Holt on 28 and 29 June 1984 by invitation and on 1 July when the general public were invited: 1000 people attended on the first two days and some 2200 on the public day. In addition 34 visits were made to Alice Holt in the course of the year and 25 to the Northern Research Station.

Organisation and staff

I regret to report the loss of a valued and respected colleague, J. R. (Dick) Price, our Administration and Finance Officer, who died on 12 February 1985.

As a result of a reorganisation of Headquarters Divisions, the Field Surveys Branch, apart from the Mensuration Section, was moved to Planning and Surveys Division from 1 March 1985, although the Chief Forest Surveys Officer remains based at Alice Holt. Work Study Branch became part of Private Forestry and Services Division from 1 April 1985 and the post of Chief Work Study Officer relocated in the headquarters office at Edinburgh. In consequence the number of non-industrial staff engaged in Research and Development Division fell from 317 to 235. The number of industrial staff employed was 117, a reduction of 22 as a result of the reorganisation.

Dr C. M. Brasier received the degree of D.Sc. from the University of Hull.

Conferences and tours

Divisional staff attended a total of 114 meetings and conferences in Britain at which they presented 43 papers. Staff made 38 overseas visits, plus 7 EEC business meetings concerning forestry research, the CREST programme of Directorate General XII and plant health.

PART I

The Work of the Forestry Commission

RESEARCH AND DEVELOPMENT DIVISION

SEED

Research

Laboratory experiments

Evidence was obtained which it is hoped will lead to an amendment of the International Seed Testing Association (ISTA) prescription for the germination of broom, *Cytisus scoparius*. This species has the typical dormancy of a legume where a hard seed coat prevents or retards both the imbibition of water and embryo emergence. ISTA therefore recommend chipping or scarifying seeds to overcome the coat imposed dormancy, followed by soaking for 3 hours in water, and then incubation at an alternating temperature of 20°/30°C.

In addition to the above method the germination of three seed lots was compared at three other incubation temperatures. Results (Table 1) confirmed that chipping was necessary, since the germination of chipped seeds was significantly greater ($p < 0.001$) than unchipped seeds at all temperatures tested. However, it was also shown that the ISTA recommended temperature of 20°/30°C was the least suitable of the temperatures tested. Chipped seeds of all three seed lots germinated significantly better at 15°C, 20°C, or alternating 15°/20°C, than at an alternating temperature of 20°/30°C ($p < 0.05$).

The moisture contents (MC) for the storage of many deeply dormant species moving in international trade currently tend to be between 11–16 per cent (on a fresh weight basis). There is little evidence that this is the optimum for storage: it merely reflects how, after processing, the moisture content of

Table 1 Maximum percentage germination of chipped and unchipped broom seed at different temperatures

FC identity No. of seed lot	Treatment	Percentage germination at temperature of			
		15°C	20°C	15°/20°C	20°/30°C
81(439)	chipped and soaked	66	57	66 ⁽²⁾	29 ⁽¹⁾
	unchipped and soaked	20	17	n.d.	n.d.
80(30)	chipped and soaked	85	70	86 ⁽²⁾	42
	unchipped and soaked	5	6	n.d.	1
83(439)	chipped and soaked	73	68	71 ⁽²⁾	46 ⁽¹⁾
	unchipped and soaked	12	7	n.d.	n.d.

(1) Using 400 seeds.

(2) Using 100 seeds.

All other percentages derived from 200 seeds.

n.d. = no data.

the seeds tends to equilibrate with the ambient air at about this level. A drying and storage experiment was initiated to compare the suitability of c.11-16 per cent MC with c.7-9 per cent MC for both short and long term storage of seven deeply dormant hardwood species at +2°C. These were *Carpinus betulus*, *Cornus mas*, *Crataegus monogyna*, *Liriodendron tulipifera*, *Prunus avium*, *Tilia platyphyllos* and *Sorbus aucuparia*.

Pretreatment and germination of these species can take up to 18 months to complete, therefore their potential performance is normally measured in the laboratory by the use of more rapid viability tests such as tetrazolium and/or excised embryo tests. However, in this study, supporting laboratory and nursery germination tests were conducted in addition to the viability tests.

The following constitute interim results. Undried seeds of all seven species showed no deterioration in quality after one year's storage at +2°C and therefore for short term storage further drying was unnecessary. Nevertheless, it was demonstrated that it is possible to dry all species to 7-9 per cent MC without damage, and store them for a year without further change in quality. It is envisaged that the benefits of reduced MC may become apparent on longer storage.

Nursery experiments

In a continuation of an experiment reported last year (*Report 1984*, p. 6) Scots pine and Sitka spruce (SS) seedlings raised under sealed cloches were transplanted and shown to be capable of producing usable 1 + 1 plants.

The feasibility of precision sowing high quality SS seed to produce forest plantable stock in 2 years without the need for transplanting was investigated again (*Report 1984*, p. 6). Once more there were no significant differences between precision or broadcast sown material in any of the germination, survival or growth parameters measured. Adoption or rejection of precision sowing must rest on economic considerations.

Service

Official Seed Testing Station

At approximately three year intervals every OSTs throughout the world must participate in what is called a 'Referee Test'. The main purpose of this is to monitor the ability of stations to employ the testing methods prescribed by ISTA. This year the Forestry Commission organised the event and distributed two samples of Douglas fir seeds to all stations. It also took the opportunity to ask stations to compare results from the ISTA germination method with results from a widely used non-ISTA viability test. Results will be summarised in a subsequent Report.

P. G. GOSLING, D. C. WAKEMAN

SILVICULTURE (SOUTH)

Plant production

Vegetative propagation

Assistance was again given to the Oxford Hardwood Improvement Project by establishing stocks of selected oak clones at Alice Holt Lodge. Twenty-three clones were grafted in October and a further 18 clones were grafted in March, some of them for the second time. More than 50 clones are now successfully stored at the Research Station. Several clones were propagated from softwood cuttings under mist during the summer. Though some clones proved to be difficult to root, perhaps because the cuttings were of poor quality, rooting percentages on the whole were acceptable. In some cases 90 per cent rooting was achieved. Sequential nodal cuttings rooted as well as apical cuttings and a few cuttings taken from etiolated shoots showed rapid root initiation and development. Some propagation was undertaken for other Branches. The programme included stock production of two elm clones as well as two clones established by grafting; softwood cutting propagation of two clones of Wild cherry and two clones of Bird cherry raised by grafting; four species and one cultivar of lime propagated from softwood cuttings, and stock production of Grey alder, mulberry and Tree lupin from softwood cuttings.

J. JOBLING

Nursery herbicides

Joint experiments were carried out at Bush (Midlothian), Fleet (Dumfries and Galloway) and Headley (Hampshire) Nurseries to test various herbicides for use in nurseries. Four herbicides, metamitron, napropamide, oxyfluorfen and a mixture of propham, fenuron and chlorpropham, were tested on Sitka spruce (SS) and Japanese larch (JL) with a standard (diphenamid) for pre-emergent use on seedbeds. Oxyfluorfen appeared particularly effective while metamitron and napropamide showed some promise. Five herbicides, chloridazon, metamitron, metoxuron, oxyfluorfen and pyridate, were assessed on standover seedbeds of SS and JL. Chloridazon and oxyfluorfen performed best. Four herbicides, napropamide, a mixture of napropamide with simazine, oxadiazon and oxyfluorfen, were applied to SS and JL transplant lines. All gave weed control comparable to that of simazine with virtually no crop damage.

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

Intensive nursery research

Paperpots of nominal 4 cm diameter are the currently favoured containers for intensive raising of Corsican pine. Productivity per greenhouse unit and cost per tree are strongly influenced by pot diameter. A marginally smaller diameter paperpot and also some new types of plug container are now available.

Corsican pine raised in two sizes of paperpot showed little difference at the end of the growing season although the seedlings in the smaller 308 container were a little taller than those in the slightly larger 408 size. In a

comparison of containers, Corsican pine, Japanese larch and Douglas fir grown in paperpots were taller and generally healthier after 18 weeks growth in an unheated polyhouse than those grown in two sizes of plug container.

J. S. P. SALE

Lowland silviculture

Working former oak coppice

In many parts of western Britain there are substantial areas of oak woodland which were formerly coppiced. Frequently the last coppicing, mostly for the production of tan bark or fuel wood, occurred at or just after the First World War. How best to manage these woods for some continuing wood yield while ensuring their survival as major landscape and conservation features has been under investigation since 1980, mainly in the old oak coppices around Dartmoor and Exmoor. Three experiments examining aspects of nutrition, thinning, and regeneration have been established in 45 to 75-year-old coppice to supplement information from surveys and field observation. Interim conclusions are:

1. Knowing the past history of a stand is essential to its management. Many apparently even-aged woodlands show, when stump ring counts are made, that there are several different age classes associated with the coppice cutting cycles and recruitment of trees as standards.
2. On most sites the age of the trees is somewhat younger and yield class rather higher than their appearance (old, wizened trees draped with lichen) would suggest. Few stands are poorer than Yield Class 4, and many growing on lower slopes are at least Yield Class 6.
3. Storing oak coppice to grow large sized timber, probably in the past as standards, is quite feasible.
4. In general the age of a stump appears not to influence its coppicing potential, at least up to 100 years. Provided there is adequate overhead light and protection from browsing, resumption of coppicing even in old crops is feasible (see also below).
5. In both 1983 and 1984 abundant natural regeneration of oak was present.
6. Foliar analyses to determine nutrient concentrations have been carried out for four successive years. Although phosphate levels appear low (0.1–0.15 per cent oven dry weight) there is considerable year-to-year variation. Adding phosphate as a fertiliser has not led to a measurable increase in growth after 3 years, though foliar concentrations were increased.
7. There are no fundamental problems in perpetuating these former coppice woodlands. The main requirement is resumption of active stand management—thinning and protection of regeneration, whether seedlings or coppice.

A survey of coppicing ability of 1387 stumps of recently thinned or felled maiden oak in Alice Holt Forest, Hampshire, and Micheldever Forest, Hampshire, has also been carried out. For all ages between 30 and 120 years between 70 and 80 per cent of the stumps produced coppice. Of the oldest stumps examined (160 to 165 years) about 50 per cent produced vigorous coppice.

J. EVANS, K. F. BAKER

Tree shelters

Interest in tree shelters continues to expand and an estimated 1.5 million were used in the 1984/85 planting season. Recent trials, in addition to continued evaluation of different types of shelters, have concentrated on their use as a means of enrichment. Under conditions of heavy shade, either in scrub or under a mature tree canopy, shelters confer improved survival but do not obviate the need for cleaning or other treatment to provide adequate light. Defining the minimum light levels for reasonable growth with trees in shelters is currently under investigation. Tree shelters, although an important silvicultural aid, will not compensate for poor plants or plant handling nor for slack weed control. Splitting of corrugated polypropylene shelters has occurred in several of the older experiments. The problem is more severe on exposed sites and where trees grew out of the shelter very rapidly. The wide fluted Corriboard type is more prone to develop serious splits than the narrow fluted Correx type; the problem is unlikely to occur with modern designs.

J. EVANS

Forest weed control

Further applications of atrazine to the Thetford experiment (*Report* 1984, p. 9) were made in spring 1984. The higher rates of atrazine significantly worsened the health (loss of needle colour and glossiness, needle necrosis and twig dieback) of the Corsican pine crop without affecting height or diameter growth. The addition of a wetting agent (Actipron) very significantly reduced both height and diameter growth and also worsened health. The crop consistently fared better when treatments were applied using a brass VLV 100 nozzle on the sprayer compared to a standard plastic nozzle. Addition of 100 kg/ha KCl increased height growth but otherwise showed no significant influence on crop responses. Lack of significant growth improvement in treated plots compared to untreated controls indicated that the economic benefits of atrazine application at normal rates are exhausted well before the threshold of crop damage.

Rhododendron regrowth was treated with herbicides. Early results indicate that excellent control was achieved with glyphosate, triclopyr and fluroxypyr when a mixture of surfactants (Mixture B) was added. Use of a lower applied volume (50 l/ha) through brass VLV nozzles further improved the glyphosate treatments compared to medium volume applications (500 l/ha).

J. S. P. SALE

Arboriculture: Department of the Environment contracts

Arboricultural Advisory and Information Service

The number of enquirers using the Advisory Service was 1989, a 13 per cent increase on the previous year. Following the introduction of charges for advisory visits to sites the number of such visits has fallen by 50 per cent and fewer local authorities are being visited. The emphasis of problems dealt with continued to be on damage caused to trees, while careers in forestry and arboriculture, and information about the growth of trees, especially roots, were frequent questions. Information was published as Arboriculture Research Notes, new titles are listed on page 54. Several existing Arboriculture

Research Notes were revised. Liaison and communication with the arboriculture industry continued, with development of a programme for a research seminar at York University in April 1985 being a major function.

D. PATCH, F. R. W. STEVENS

Colliery spoil

A five-year programme of research was completed at the end of February. Thirty experiments were started and regularly assessed during the contract, most of them on regraded spoil heaps in the north of England, and a large amount of supporting work was undertaken both in the field and at Alice Holt Lodge. Research was carried out on cultivation practices, planting methods and root growth in compacted spoil, type and size of planting stock, choice of species and choice of ground cover, and tree nutrition. The final report submitted to the Department of the Environment included an annotated bibliography containing 379 references.

J. JOBLING

Amenity tree establishment and maintenance

Two experiments were established comparing the effects of various proprietary soil ameliorants on tree establishment. Another new experiment investigates the effects of different intensities of shoot pruning and staking on tree establishment.

In the series of herbicide/polythene mulching experiments no adverse effects of large (10 × 8 m) black polythene mulching sheets were apparent in the first year. Of the various sheet materials tested, clear polythene resulted in the highest soil temperatures and reduced the survival of ash transplants, although the survivors grew significantly more than those mulched with other sheet materials.

A series of experiments is examining the effects of fertilising, soil augering (which may relieve compaction) and sward removal with herbicides on foliar nutrient levels and growth rates of various species of broadleaved trees up to 100 years old.

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

Department of Energy contract

Coppice for energy

The early results from this series of experiments show variation in production of coppiced biomass, attributable to species, site and crop density. Table 2 shows production in fresh and dry weight of all above ground growth and includes some figures for single stem maiden growth (i.e. pre first coppice cut). Dry weight percentages were obtained by oven drying sub-samples of freshly cut biomass for 24 hours at 100°C.

Arboreta

Westonbirt Arboretum, Gloucestershire

During the last two planting seasons 1293 trees and shrubs were added to the collection, including 209 that are new to the arboretum. A record number of 186 000 visitors came to the arboretum during 1984, including over 12 000 children from 256 schools. A liaison officer for schools is now employed to

Table 2 Coppice biomass production
Tonnes (fresh) ha⁻¹ yr⁻¹ See note (b). Figures in parenthesis show dry tonnes ha⁻¹ yr⁻¹

Stool age	Coppice age	Maiden age	Populus 'RAP'		Salix 'AG'		Eucalyptus archerii ^e	
			10 000/ha	2500/ha	10 000/ha	2500/ha	10 000/ha	2500/ha
2 ^a	1	—	15.20 (7.11)	10.30 (4.51)	11.20 (5.08)	8.30 (3.65)	8.30 (3.71)	3.10 (1.32)
3 ^a	1	—	12.80 (5.99)	9.70 (4.25)	7.61 (3.45)	11.17 (4.91)	11.82 (5.28)	5.90 (2.51)
3	2	—	14.99 (7.02)	9.33 (4.09)	8.77 (3.98)	5.07 (2.23)	15.58 (6.96)	7.71 (3.28)
2	—	2	2.05 (0.90)	0.43 (0.20)	0.91 (0.40)	0.13 (0.06)	6.12 (2.60)	1.34 (0.60)
3	—	3	12.26 (5.37)	6.47 (3.03)	11.31 (4.98)	5.50 (2.50)		
2	—	2					5.78 (2.46)	1.77 (0.79)
4	—	4					23.26 ^d (9.88)	5.80 ^e (2.59)

Notes: (a) Results refer to single plot (unreplicated) values. All other results are from replicated plots.

(b) All values extrapolated from nett plot areas (excluding buffer rows).

(c) *Eucalyptus* values include leaves.

(d) 5100/ha

(e) 1275/ha

provide a more comprehensive service for schools and other groups. Following the retirement of Mr Alan Mitchell during the year Mr John White, who is based at Westonbirt, has taken over as dendrologist. An encouraging trend in the establishment of new arboreta was manifest in the steady stream of requests for advice.

M. L. PEARCE

Bedgebury National Pinetum, Kent

Good progress has been made in surveying all trees in the pinetum as the first stage in preparing a revised comprehensive catalogue. The work of removing silt from Marshall's Lake was completed, the banks reshaped and grass sown. During September the car park was occupied by a band of itinerants with their vehicles and caravans. They eventually left but not before a court order had been obtained.

M. J. SCOTT

SILVICULTURE (NORTH)

Species

Seed origin experiments:

SITKA SPRUCE

The 'Top Ten' IUFRO experiments (Lewis and Lines, 1976) at Glentress (Borders) and Tywi (Dyfed) received their final assessments at 10 years. At both locations height and diameter growth were significantly better for Washington and Oregon seed origins than for those from north of 54° latitude. At Tywi a Vancouver Island origin was tallest. The main series of IUFRO Sitka spruce experiments (Lines, 1980) included up to 69 seedlots on 18 sites (only 27 origins at the five southern sites). At each of the 15 surviving sites, very highly significant differences ($p < 0.001$) were found between seed origins. There was a high origin x site interaction and regression analysis showed a clear pattern of regional variation in behaviour. The best growth of northern origins was on northern sites; origins such as Queen Charlotte Islands, Vancouver Island and north Washington performed well on a range of sites; while the southern group was more erratic, growing extremely fast on the most favourable sites and very poorly on the most severe sites. Papers on both series of experiments were presented to a meeting of the IUFRO Sitka spruce Working Party in Edinburgh, and experiments in south Scotland and north-east England were inspected.

ABIES

A IUFRO collection of 18 seed origins of Noble fir showed little variation at the nursery stage, but there were some differences between trees from the main part of the range and those from the southern area, where introgression occurs with Red fir. The trees have now been planted on seven sites ranging from the Moray Firth to the Forest of Dean.

DOUGLAS FIR

Seven experiments with a IUFRO set of seed origins were each found to have very highly significant differences in 10-year height growth. There was also very highly significant origin x site interaction. In contrast to the Sitka spruce experiments (where much of the interaction was associated with southern origins), Douglas fir origins from the central part of the range showed the greatest variation with site. The tallest origins came from western Washington and the Puget Sound area.

R. LINES

Production of planting stock*Vegetative propagation of Sitka spruce*

An experiment at Newton nursery (Grampian) examined the comparative rooting performance of cuttings from first, second, third and fourth propagation cycles (*Report* 1984, p. 14). After 26 weeks, first cycle cuttings had a higher percentage rooted, a greater height and greater root volume than those in other treatments. Ninety-five per cent of first cycle cuttings were suitable for lining-out compared with 83 per cent for the other treatments. The reasons for this difference may be due to a carbohydrate:nitrogen imbalance in second and later cycle cuttings induced by frequent nitrogen top-dressing after lining-out.

Experiments at Bush (Lothian) and Newton nurseries investigated the effects of different propagation media on speed of rooting of Sitka spruce cuttings. Results are shown in Table 3.

Table 3 The effect of different propagation media on rooting percentage of Sitka spruce cuttings
Experiments Bush 7/84 and Newton 13/84

Medium*	Bush		Newton	
	Weeks after insertion			
	12	20	14	20
	<i>Rooting percentage</i>			
Peat-grit	56	96	78	95
Peat-sand	50	90	75	92
Peat-bark	63	95	95	100
Bark-grit	56	98	94	98
Bark-sand	62	97	84	96
Sand-grit	56	97	77	92
Standard error \pm	5.3	2.2	3.8	2.6

*Note: Results are averaged for four mixture ratios per medium ranging from 80%:20% to 20%:80% in 20% intervals.

The results suggest that incorporating bark in the rooting medium gives more rapid rooting and higher rooting percentages overall than for other media tested including the peat-grit medium currently recommended (Mason, 1984). The earlier rooting could be of considerable practical importance in reducing the period for which cuttings were at risk from mist breakdown or other failures. Media containing high proportions of peat tended to affect rooting adversely.

In the ongoing field scale trial of Sitka spruce propagation at Newton nursery (*Report* 1983, p. 13 and 1984, pp. 14–15), 85 000 cuttings including first and second cycle material were inserted with 87 per cent rooting successfully. However, because of the differences in rooting performance noted earlier, only 62 per cent of second cycle cuttings were suitable for lining-out as compared with the first cycle figure of 90 per cent. Cuttings propagated at Newton in 1982 were planted out in large scale forest trials at five sites in upland Britain. These follow an extensive series of forest experiments which have so far shown no practical difference in the performance of cuttings and transplants. Facilities for commercial scale vegetative propagation of improved Sitka spruce are being developed at the Forestry Commission's Delamere Nursery (Cheshire) and at Bogallan Nursery (Highland), owned by Elite Trees Ltd. Both enterprises aim to produce around 500 000 rooted cuttings a year by the late 1980s.

Vegetative propagation of Hybrid larch

Experiments at Bush and Newton investigated the optimum time for collecting and inserting Hybrid larch hardwood cuttings and the use of fertilisers during propagation. Results were again encouraging, the mean rooting of 80 per cent at Newton and 92 per cent at Bush being an improvement on 1983 (*Report* 1984, p. 15). The best result was from collection in late February followed by insertion in early March after two weeks cold storage. Cuttings fertilised during propagation showed higher rooting percentages (from 2 to 7 per cent, although differences were not significant), greater root volume ($p < 0.05$) and better height growth ($p < 0.01$) than unfertilised controls. Both incorporated slow-release fertiliser and liquid top dressing proved effective.

Precision sowing and undercutting

The large scale trial at Wykeham Nursery (*Report* 1984, p. 15) continued with further sowings of the same species, each at four spacings within the drill (2.8, 5.2, 7.0 and 10.8 cm). The dry spring affected germination with only 50–60 per cent emergence achieved by July; broadcast controls were even poorer, averaging 44 per cent. Seedbeds sown in 1983 were undercut and wrenched at 10 cm depth from the beginning of July (Scots pine) or August (Sitka spruce, Douglas fir). Results (shown for one spacing in Table 4) suggest that precision sowing and undercutting can produce better-balanced plants than conventional transplanting regimes. However, improvement in the number of usable seedlings per unit area is required if the system is to prove cost effective, particularly for Sitka spruce.

Table 4 Large scale trial of precision sowing and undercutting
Experiment Wykeham 2/84, 5.2 cm spacing within lines^a

Species ^b	Plant type	Height (cm)	Root collar diameter (mm)	Shoot dry weight (g)	Root dry weight (g)	Sturdiness ratio ^c	Usable seedlings per m ²
Sitka spruce	1u1	23.1	4.3	14.36	7.48	53:1	72
	1+1	27.3	3.8	13.71	6.24	74:1	102
Douglas fir	1u1	24.2	4.6	14.23	7.59	53:1	86
	1+1	25.5	3.9	13.41	6.26	65:1	101
Scots pine	1u1	14.5	4.4	14.37	6.55	33:1	90
	1+1	11.0	4.2	12.89	6.02	26:1	101

Notes: a. Each value is the mean of 20 plants assessed in January 1985.

b. Scots pine was wrenched four times after initial undercut: Douglas fir and Sitka spruce were wrenched twice.

c. Sturdiness ratio is the ratio between height (mm) and root collar diameter (mm).

Planting

Plant handling

Following earlier work on damage to transplants caused by drying (*Report* 1982, p. 12, 1983, pp. 14–15 and 1984, p. 16), the effects of heating and mechanical damage were examined. At Bush Nursery (Lothian), bundles of Sitka spruce transplants were fitted with thermocouples and packed into clear polythene bags, foil laminate bags or white cardboard boxes. On exposure to strong sunlight in May, higher temperatures were recorded amongst shoots than amongst roots. After 75 minutes, shoot temperatures were 41.5°C inside clear polythene, 23.9°C in cardboard boxes and 19.3°C in foil laminate bags.

Mechanical damage was produced experimentally by dropping sealed polythene bags of transplants, roots downwards, from a height of 3 m on to a hard floor once, 5 times or 15 times. Root growth potential (RGP) (Burdett, 1979) was reduced by all treatments but the one-drop treatment recovered rapidly (Table 5). One year after planting, survival was reduced in the 15-drop treatment ($p < 0.05$), and mean increment was also reduced in both 5 and 15-drop treatments, but not significantly. Rough handling of transplants can result in reduced survival and there is a suggestion that early growth of transplants can be reduced.

Table 5 Effects of rough handling damage on root growth potential (RGP), survival and growth of Sitka spruce

	Severity of treatment (number of drops)			
	0	1	5	15
RGP score (1 week test)	2.7	2.2	1.1	0.7
RGP score (2 week test)	4.1	4.2	2.8	1.5
1 year survival (%)	100	97	100	87
1 year height increment (cm)	11.1	11.4	6.6	7.3

Forest weed control

Experiments on Sitka spruce less than 10 years old and suffering from *Calluna* check were established in 1983 at Wykeham (Yorks), Glentress (Borders) and Speymouth (Grampian). Treatments included two rates of atrazine (4 and 8 kg a.i./ha) with and without 10 per cent 'Actipron' and applied in June or August; and a very high rate of glyphosate (2.5 kg a.e./ha) applied with trees protected. Marked site differences emerged, with most treatments achieving better control at Glentress than at Speymouth or Wykeham. The 8 kg rate of atrazine with 'Actipron' gave promising results (82 per cent kill at Glentress) on actively growing *Calluna*. The 'atrazine effect', an improvement in nitrogen nutrition resulting from the use of this herbicide but not related to its herbicidal action (Sands and Zed, 1979), was apparent at Speymouth and Wykeham (but not at Glentress) with foliar nitrogen percentages at the end of 1983 consistently higher in the best of the atrazine plots than in the glyphosate plots, despite the higher kill with glyphosate. The effect had disappeared by the end of 1984. A 1982 experiment at Glentress examined later dates of glyphosate application to *Calluna* (Report 1983, p. 15) and indicated that this chemical can be effective through to October. In a subsequent trial of helicopter application on 15 September 1983, using 'raindrop' nozzles to reduce drift, and applying 2 kg a.e./ha glyphosate in a total volume of 60 l/ha, *Calluna* kill was 70-100 per cent and tree damage negligible.

Natural regeneration

An experiment at Glasfynydd (Powys) in 1983 investigated the use of glyphosate to prevent regrowth of live branches left below the cut surface when Sitka spruce regeneration is respaced using a clearing saw. This work complements the development by Work Study Branch of a clearing saw attachment for applying chemical as the sawblade passes over the stump. Solutions of 0-30 per cent 'Roundup' (36 per cent a.e. glyphosate) were applied by paintbrush immediately after cutting at bimonthly intervals throughout the year. A 30 per cent solution in water was effective for all application dates except May, and a 20 per cent solution was effective from November-March. Best results were obtained with March application when complete control was obtained even with 10 per cent concentration.

P. M. TABBUSH

Nutrition

Second rotation deep peat sites

Restocking experiments on deep peat sites at Naver (Highland) and Inchnacardoch (Highland) indicate that the nutritional status of the peat is now substantially better than when the first rotation Lodgepole pine crops were planted. At the Naver site an 18-year-old Lodgepole pine crop was felled and replaced by Sitka spruce given two fertiliser regimes. The 6 year results are shown in Table 6 along with data from an afforestation experiment at Shin (Highland) on a similar deep peat.

Satisfactory early growth has been obtained at Naver without fertiliser input since replanting, whereas on the similar first rotation site at Shin, fertiliser application has been essential to achieve reasonable growth. These early results, confirmed at Inchnacardoch, hold out promise of reduced

Table 6 Height and foliar nutrient levels for 6-year-old Sitka spruce growing with and without fertiliser application on deep peat sites at Naver (second rotation) and Shin (first rotation)

Site	Fertiliser input	Mean height (m)	Foliar levels		
			N	P	K
Naver (second rotation)	nil	1.27	1.63	0.20	0.88
	PK at years 0 and 6	1.17	1.88	0.24	0.99
Shin (first rotation)	nil	0.42	1.94	0.10	0.69
	PK at year 0	1.48	1.69	0.21	0.85

fertiliser input for second rotation crops on deep peat, even when a relatively demanding species such as Sitka spruce is used.

Sewage sludge application

Results from the first three growing seasons of the pole-stage Scots pine experiment at Angus (Tayside) (*Report* 1983, p. 16) indicate that whilst sewage sludge application has improved foliar nutrient concentration, basal area growth has declined with increasing rate of application. This effect does not appear to be related to heavy metal toxicity and other possible causes are being explored in conjunction with the Water Research Centre and Aberdeen University.

A further experiment involved pre-ploughing applications of sewage sludge on a *Calluna*-dominated heathland site which has since been ploughed and planted with Sitka spruce. The sewage-treated plots stand out dramatically because of their rich vegetation, including 'exotics' such as strawberries, tomatoes and raspberries; and the colour and vigour of the Sitka spruce in these plots is excellent.

Lime application on basalt

It has long been recognised that Sitka spruce suffers chronic phosphate deficiency on some soils derived from basalt. An experiment established on Mull (Highland) in 1978 has shown that foliar phosphate concentrations can be kept at higher levels when phosphate is applied in conjunction with lime. This effect will be observed closely over the next few years to determine its practical significance.

C. M. A. TAYLOR

Cultivation, drainage and site preparation

Vertical tree pulling of 5 to 9-year-old Sitka spruce from three experiments on gley soils has allowed further examination of the influence of various cultivation treatments on root system development. Preliminary appraisal has indicated that mole draining and ripping are likely to produce poorly developed shallow root systems with slender and often distorted roots. Although radial symmetry was better for these subsoiling treatments than

Table 7 Aerodynamic parameters of a Sitka spruce stand before thinning (T_0) and after systematic removal of 25 per cent (T_1) and 50 per cent (T_2) of the trees

Thinning stage	Stand density (trees ha ⁻¹)	Zero plane displacement (d) (m)	Roughness length (Z_0) (m)	Frictional velocity (U^*) (ms ⁻¹)	Canopy shear stress (τ) (N.m ⁻²)	Mixing length (ℓ) (m)	Canopy drag coefficient (r) (non-dimensional)
T_0	3584	9.54	0.55	1.35	2.28	0.75	0.11
T_1	2681	7.48	1.52	2.22	6.13	1.61	0.19
T_2	1809	6.30	2.31	1.62	3.28	2.10	0.26

for spaced furrow ploughing, both categories had restricted root spread at right angles to the cultivation direction. Trees established without cultivation had developed extremely shallow, but wide spreading and radially symmetrical large-diameter roots. Taking into consideration early survival and growth as well as potential stability this preliminary evidence does not suggest that subsoiling treatments on their own will provide an acceptable alternative to spaced double mouldboard ploughing when afforesting gley sites.

K. F. MILLER, M. P. COUTTS*

Stability

Processing of data from the major aeromechanical experiments at Moffat Forest (Borders) (*Report* 1984), p. 18) is nearing completion. Table 7 summarises some results from analyses of turbulent windspeed profiles measured above a Sitka spruce plantation of 11 m mean height.

The systematic reductions in stand density and consequent alteration in canopy geometry have produced a progressive fall in zero plane displacement height (d), associated with increased wind penetration into the canopy and increased tree crown projection into the turbulent wind. In addition, progressive increases in calculated roughness length (Z_0) indicate increased surface roughness of the forest with decreasing stand density. Behaviour of frictional velocity (U^*) and the related canopy shear stress values (τ) are less easily explained, showing marked increases after the first thinning, but partial reversion after the second. The progressive increase in the mixing length estimates (l) as stand density falls indicates increasing canopy-top eddy size, and the calculated canopy drag coefficients (η) also show clear increases with reducing stand density, probably due to increasing canopy roughness.

Spectral analyses of wind data have been undertaken to resolve the fluctuating turbulence structure into its characteristic frequency components. In the upper crown space, pronounced shifts in the frequency composition of the turbulent gust structure occurred as stand density was reduced. There was a clear trend of increasing high frequency fluctuations in the wind field, with a balancing attenuation in low frequency spectral energy, following the thinnings. The mean fundamental response frequency of trees under dynamic wind loading was found to be 0.48 Hz (range 0.80–0.36 Hz), suggesting that turbulent wind fluctuations within the frequency range 1.0–0.01 Hz are likely to couple effectively with individual trees in the momentum exchange process. Spectral energy within this range had increased by 27 per cent after the first thinning, and after the second was 41 per cent higher than in the unthinned stand. Tree responses to dynamic wind loading in this study are reported more fully on p. 59. These results help to explain why increased windthrow commonly follows thinning, and provide an essential basis for current work on the aeromechanical implications of wider initial tree spacing and stand replacement in relation to plantation stability.

K. F. MILLER

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REFERENCES

- Burdett, A. N. (1979). New methods for measuring root growth capacity: their value in assessing lodgepole pine stock quality. *Canadian Journal of Forest Research* 9, 63-67.
- Lewis, A. B. and Lines, R. (1976). Provenance of *Picea sitchensis* (Bong.) Carr. IUFRO 'Top ten' provenances. Great Britain (North). First year results. In *IUFRO Sitka spruce international ten provenance experiment—nursery stage results*, ed. J. O'Driscoll, 90-105. Forest and Wildlife Service, Dublin.
- Lines, R. (1980). The IUFRO experiments with Sitka spruce in Great Britain. In *Proceedings of the IUFRO Joint Meeting of Working Parties, Vancouver, Canada, 1978* 2, 211-225. Ministry of Forests, British Columbia.
- Mason, W. L. (1984). *Vegetative propagation of conifers using stem cuttings. I. Sitka spruce*. Forestry Commission Research Information Note 90/84/SILN.
- Sands, R. and Zed, P. G. (1979). Promotion of nutrient uptake and growth of radiata pine by atrazine. *Australian Journal of Forest Research* 9, 101-110.

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

Broadleaved species: *Nothofagus*

Assessment of 5-year height and survival for up to 18 seed origins of *Nothofagus procera* and nine seed origins of *N. obliqua* showed very large differences in performance on 11 upland sites ranging from Margam (West Glamorgan) to Speymouth (Grampian). A *N. procera* seed lot from Lanin, Argentina, had a mean height of 4.37 m (tallest tree 6.2 m) at Ystwyth (Dyfed) compared with only 1.68 m on a more testing site at Inchnacardoch (Highland). There were highly significant height differences between the *N. procera* seed origins, the poorest being three seed lots from the northern province of Nuble, Chile. The tallest *N. obliqua* seed lot was from west Scotland.

All northern experiments suffered severe shoot dieback and some suffered heavy losses in the severe winters of 1979/80 and 1981/82. Despite replacement of failures, some experiments still have a stocking below 60 per cent. However, many experiments have over 80 per cent stocking and are now well above the level of ground frosts. In the southern experiments it is *N. obliqua* that is providing the more impressive results, with good provenances among seed lots originating from Llanquihue, Malleco and Cautin. *N. procera* has generally performed less well, the Lanin (Argentina) and Cautin sources out-growing others of the species on a range of sites. Severe and prolonged bad weather during the past winter has clearly caused damage, though the extent of crown die-back will not be evident until after flushing, and frost kill of cambium at the base of the stem may take 2 to 3 years to display its full effects.

Frost damage is a major factor restricting wider use of *Nothofagus* species and this set of seed origins is being tested in freezing chambers by the Institute of Terrestrial Ecology. In the 1981/82 winter, a severe frost at Flaxley in the Forest of Dean caused considerable bark death, killed many large trees and caused crown dieback on *N. procera* planted in 1956. (The exact seed origin in Chile is unknown.) Surprisingly, no damage occurred in two younger experiments planted nearby in 1979 and 1981, even though these contain the susceptible origins from Nuble. Stem form of the best *N. procera* is particularly good, but it is less satisfactory for most of the *N. obliqua*.

SITE STUDIES (SOUTH)

Chemical analysis

Service

The steady decline in the number of foliar samples presented for analysis during the last few years seems to have halted. Approximately 5000 samples were received during the year and all had been analysed by the beginning of April. Samples are routinely analysed for N, P, K, Mg, Ca and average needle weight, with a smaller number of determinations for chloride, carbohydrate and copper.

Methods

The analytical results are placed in a databank and it is intended to computerise the whole of the sample reception and service. The more rapid throughput of the samples this year has allowed more joint work with Entomology Branch (see inter-branch report, p. 40).

J. P. WRIGHT

Effects of trees on sites

Impact of clear felling

Measurement of change in site properties following the clear felling of Sitka spruce crops on poorly drained upland soils has continued in collaboration with the Institute of Terrestrial Ecology (ITE). Work at the sites in Snowdonia (north Wales), the Borders and north-west Devon (*Report* 1984, p. 22) has shown nitrate leaching down the profiles of peaty gley and ironpan intergrade soils, although little of this has found its way into streams. On the ironpan soil in Snowdonia (Beddgelert Forest) clear felling has again depressed to 25 cm the level in the soil at which tree roots become limited for oxygen during the summer months. This is 10 cm deeper than in unfelled areas and 5 cm deeper than in whole-tree harvested plots. In peaty and surface-water gleys the oxygen limit (oxycline) again rose to within 10 cm of the soil surface in the summer following felling. There is therefore a marked contrast in the rooting potential of the gley and ironpan soils during summer immediately after felling; it remains to be seen whether the differences persist throughout the period during which the next crop is establishing its root system.

In another joint study with ITE gaseous denitrification has been detected in frequently anaerobic acid soils. Although there is evidence of bacterial denitrification under the crops themselves, the process appears to predominate a few months after felling. Early indications are that losses are unlikely to amount to more than $10 \text{ kg N ha}^{-1} \text{ yr}^{-1}$.

M. A. ANDERSON

Reclamation

The dry season ripping of ridges on the reclaimed gravel workings at Bramshill (Hampshire) was completed, using low-drag rippers (Figure 1; *Report* 1984, p. 22). In addition a set of D6 shanks has been fitted with welded wings for use on heavy spoils or where rainfall is high, when a 50 cm cultivation depth suffices.

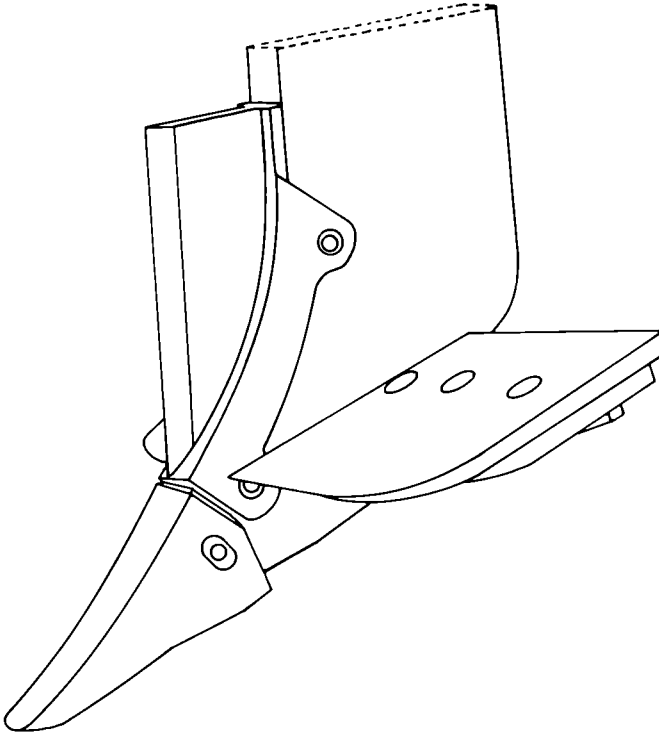


Figure 1. Winged tine as used with Caterpillar D8 (or equivalent) with a plate extension welded to the front of the protector to reduce drag.

New reclamation studies have been started on several difficult mine wastes lacking topsoil. On Callow clay at Elstow (Bedfordshire), where spoil has been used to cover domestic waste, trials have been laid down in collaboration with the County Council to examine ways of establishing trees in the absence of topsoil. Oak (as acorns), sycamore, Corsican pine, and Lawson cypress (as 1 + 1 transplants) have been planted into a matrix of Common and Grey alders on loose-tipped Callow on disced ridges (*Report 1984*, p. 22) and into ground ripped with winged tines, with 3° to 4° slopes. The broadleaves survived well in the dry year of 1984, the conifers badly.

At St. Austell (Cornwall) quartz sand wastes from china clay workings slope near the angle of repose at 30° to 32° and were previously sown for erosion control with a grass/clover mixture. In collaboration with English China Clays Ltd., work has started on the development of methods of establishing alder stands, to be interplanted later with pines or other species. The primary problem in this coarse sand with high exposure is moisture storage and early growth depends on a period of low stress for root extension before drought sets in. Once established, the nodulated alder should shelter the pine or other tree species and nourish them with fixed nitrogen. Plantings in autumn and spring at normal and greater depths are being compared, together with mulching and weed control to conserve the small amount of stored moisture.

Coarse limestone rubble has also been planted in collaboration with the Burleigh Estate at Stamford (Lincolnshire) following assessments of existing trials. After deep ripping the graded floor of a quarry in Jurassic oolite, fine quarry waste has been spread on top as a rooting medium, and though this lacks both soil forming materials and topsoil, it is more or less weed free. Several alder species have been planted with Corsican pine and the survival in 1984, at about 85 per cent, was excellent.

In collaboration with foresters of the Defence Land Agent, a mound of chalk spoil near Winchester (Hampshire) was sown with *Buddleia* and a hydraseeded grass/lucerne mixture. Where *Buddleia* was hand sown many seedlings appeared, but none where it was incorporated into the hydraseed tank mixture.

D. F. FOURT

Upland forestry

Drainage: peaty gleys

A finite element model has been developed which describes water movement in drained forest soils accurately, by taking a grid of 1600 elements (squares or rectangles) to represent a two-dimensional cross-section of a drained soil. An equation of state involving all soil parameters (which can be different in each element) as well as pressure, volume and flow of water is solved for each element through time, taking into account the effects of neighbouring elements. This results in a two-dimensional representation of a phreatic surface and the effects of soil type and topography can be studied in relation to variable rainfall inputs. The model was developed because of the lack of objective information about the effects of drainage on thin sloping soils, and in particular the absence of any experience relating drain spacing to drainage rate. The model has already helped in understanding the processes involved and in demonstrating what is likely to happen under a range of conditions (e.g. slopes of different gradient). However, it is stable only under a fairly narrow range of conditions and for some parameters (e.g. conductivity) does not work with realistic values. Eventually it should find a use in predicting what is likely to happen under a wide range of conditions, from various simple peaty gleys, through mineral soils where conductivity varies with depth, to artificial situations such as rigs and furrs and reclaimed soils.

R. CARNELL

Air pollution

Experimental studies

Experiments to study the effects of air pollutants on tree species which are important commercially or in the landscape, are being established on three sites. The trees will be grown in open-topped chambers (3.2 m in diameter and 2.3 m high), the air being changed four times a minute. This ensures that the growing conditions within the chambers are as close as possible to those outside. Air quality within the chambers is closely controlled and monitored so that treatments can include clean filtered air or air to which a pollutant has been added. It is intended initially to investigate the range of

susceptibility of a population of trees to concentrations of air pollutants lower than those at which visual damage to the foliage might be expected. Trees representing a range of susceptibilities will be selected for clonal propagation and subsequently used with other woody indicator species in more detailed studies of physiological changes caused by air pollutants.

A. WILLSON

Forest health (air pollution) survey

Evidence that 'forest decline' was not only increasing in its intensity in central Europe but that outbreaks were also reported from Sweden and the Netherlands, combined with strong public interest in the subject, led to the organisation of a survey of forest health in 1984. A consensus on criteria and methods of assessment reached at an FAO/ECE Working Group 'Effects of air pollution on forests' in June laid the foundation for this and a visit from Dr G. Hartmann of the Lower Saxony Forest Research Institute in September allowed us to test out German methods in British forests. Ninety-nine plots of Sitka and Norway spruces and Scots pine, distributed as shown in Figure 2, were surveyed in November and December by foresters of Field Surveys Branch. (See Plate 3.)

Stands were assessed for a number of characteristics, the most important being crown density (or needle loss), age to which needles were held, and needle yellowing. The survey showed no symptoms similar to those seen in central Europe. Crown density was satisfactory for the spruces; Scots pine proved difficult to assess because of its naturally light crown and some stands with low density showed evidence of attack by fungi or insects. The survey, while reassuring, is more important as a basis from which changes can be assessed at resurvey, the first of which will be done in 1985. A full report of the 1984 survey will be published.⁽¹⁾

W. O. BINNS

Advisory work

Tree plantings on refuse land fill continue to cause problems. The direct planting of large container stock into anaerobic compact covers, without cultivation or grass control, is wasteful and neglects the effects of the buried wastes and the measures known to improve growth, such as cultivation, drainage and weed control.

Christmas trees are being widely grown on agricultural and waste land as short-term cash crops. The main problems encountered are weed competition and nitrogen deficiency; potassium is occasionally deficient too. Growth of Norway spruce and some other conifers now being used as Christmas trees can be satisfactory on soils with a pH of between 4.5 and 7.5. Even where some free CaCO₃ is present in the surface layers Norway spruce transplants seem to grow well, provided weed control and nutrient supply are adequate. A moisture retentive sandy-loam to clay-loam rooting medium seems important, being better than coarser or heavier textures which either store insufficient moisture or lead to physical problems.

D. F. FOURT

⁽¹⁾Forestry Commission Research and Development Paper 142 *Forest health and air pollution—1984 survey*, published in August 1985.

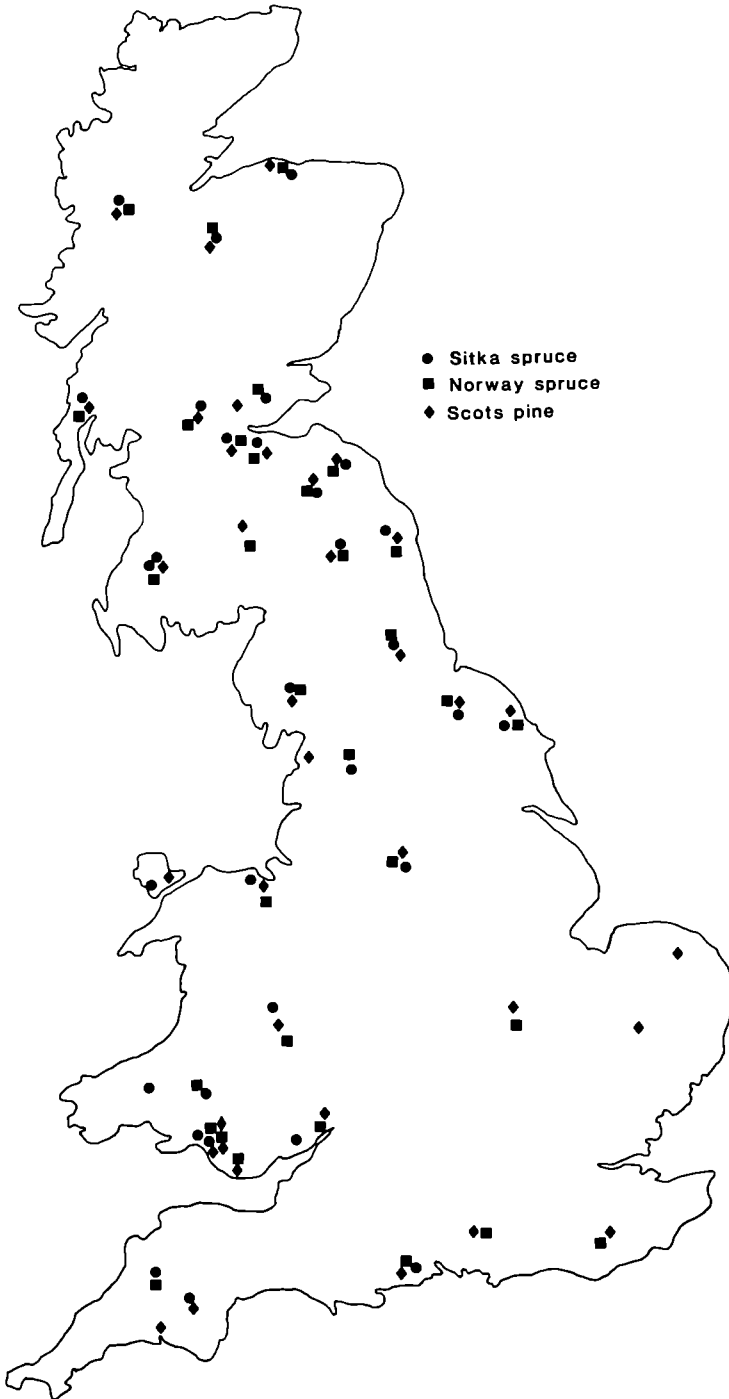


Figure 2. Location of assessment plots for the 1984 survey of forest health.

There were a large number of enquiries on acid rain and forestry, leading to numerous lectures and talks. At the time of the press conference to release the results of the forest health survey (see above) media interest was unprecedented for forestry affairs. Research and Development Paper 134 *Acid rain and forestry* was used extensively in answering enquiries.

W. O. BINNS

SITE STUDIES (NORTH)

Classification and improvement of upland soils

Clay soils

The experimental work on a peaty gley soil at Kershope Forest (Cumbria) (*Report* 1981, p. 28; 1982, p. 19; 1983, p. 24; 1984, p. 25) has continued. Three of the four hydrology plots were felled during 1983; Table 8 shows the main hydrological results.

Table 8 Water balance of four 2 ha plots. Crop: Sitka spruce, top height 18–22 m
Units: mm equivalent depth of water

Year	Mean of three plots felled during 1983			Control plot (not felled)	
	Rainfall P	Drain discharge R	P-R	Drain discharge Rc	P-Rc
1981	1403	692	711	—	—
1982	1568	769	799	710	858
1983	1278	622	656	462	816
1984	1259	837	422	433	826

The drain discharge (runoff) from the three plots was greater in 1984, the first full year after felling, than in previous years in spite of the lower rainfall, the effect of which is seen in the results for the control plot. Comparison with the control plot suggests that if felling had not taken place the drain discharge from the three plots would have been about 480 mm in 1984. Felling has therefore increased runoff by about 360 mm. The difference P-R for the felled plots was surprisingly high (422 mm). Since leakages are considered unimportant, most of this loss is ascribed to evaporation of rain intercepted by the thick layer of lop and top.

Detailed observations of the depth of the water table and of soil moisture potential have been made to measure the effects of the ditches which were installed in 1965–68. Table 9 gives an example of comparisons of water table depths for the ditch spacing treatments before and after clear felling nine of the 18 drainage plots.

In this and similar comparisons the apparent trend of increasing depth to water table with decreasing ditch spacing is small and usually not statistically significant, implying that it is not necessarily real. This suggests that we should not expect ditches at 10 or 20 m spacing to provide deeper rooting

Table 9 Period mean depths to water table (cm) for ditch spacing treatments and separately for 'fell' (F) or 'not fell' (N) treatments

Data set	Spacing				Felling		
	10 m	20 m	40 m	lsd‡	F	N	lsd‡
1. Weeks 43-50 of 1981 (before felling)	45.3	43.0	37.0	9.0	43.3	40.2	7.4
2. Weeks 43-51 of 1984 (after felling)	50.8	47.5	40.0	9.6	42.5	49.6	7.8
3. Difference (2-1)	5.5	4.4	3.0	3.3	-0.8	9.4	2.7*

‡Least significant difference between treatment means ($p < 0.05$).

*The difference between F and N treatments in this row of the table is significant at $p < 0.001$.

or greater stability of the stand than ditches at 40 m spacing, even when combined with 37 years of tree growth. This conclusion is of course restricted in application to similar upland clayey gley soils with slow hydraulic conductivity.

The results under 'Felling' provide a useful illustration of the interpretation of experimental results, particularly those involving soil measurements. Subtracting 1984 values from 1981 values removes the inherent site variability and provides a more precise measure of the effect of the felling treatment. The third row of results shows that the water table in the felled half is 10.2 cm shallower than in the not-felled half, by comparison with what it was in 1981, and this difference is significant ($p < 0.001$). An equivalent approach to the analysis of the effects of the drainage treatments would require data on water levels to have been collected before ditches were dug. Although some data were collected then, they were insufficient for adequate comparisons with recent results. Although the experiment has failed to demonstrate a worthwhile response in water table depth to increased drainage intensity, the potential benefits from increasing the stability of stands on these windthrow-hazardous sites are so great that they justify continued interest in research on drainage.

D. G. PYATT

GENETICS

Testing

Pollinations

Good flowering in the Sitka spruce clone banks at Ledmore (Tayside) and Wauchope (Borders) permitted further crosses, using a pollen mixture as the tester, or factorial mating designs using clones of proven high general-combining-ability for rate of growth. Within the next 2 years it is expected that all the clones forming the three Sitka spruce base breeding populations will be under test.

In Lodgepole pine a single-pair mating programme amongst trees of Alaskan origin was completed at Wareham, Dorset. This was the largest single pollination programme ever undertaken by the Branch; 890 crosses and 17 000 isolations were made and 57 000 flowers were involved.

The majority of larch grafts over 5 years of age flowered well and 320 crosses involving 19 000 flowers were made. These crosses included a small experiment comparing the effects of dry and rehydrated pollen on seed yields. An average increase of between one and two seeds per cone from rehydrated pollen was not statistically significant.

Forest progeny tests

The first random specific-crosses between Sitka spruce clones selected for high general-combining-ability were planted in replicated tests on up to five sites. Sixty-three specific-crosses were planted with the aim of identifying genetically superior combinations which can then be re-created by controlled pollinations for later bulk vegetative propagation by rooted cuttings and also to provide a source of F_1 selections for future breeding work. Normal 8-tree family plots were used at four of the sites but 7×7 tree plots were planted at Arecleoch (Dumfries and Galloway) for demonstration purposes and also to permit higher selection intensities to be used in the future when selecting F_1 individuals for further breeding work. In addition, polycross families of a further 72 untested Sitka spruce candidate trees were planted in replicated tests on three sites. The number of Sitka spruce candidate trees with families in tests is now 1394. The intra-provenance crossing programme adopted for Lodgepole pine continued with 123 QCI origin \times QCI origin single-pair matings. In addition 28 open-pollinated families from some of the same trees were planted in replicated tests on three sites. Open-pollinated families of 26 Douglas fir trees growing on Glentanar Estate (Grampian) were also planted in replicated tests on three sites.

Assessments of height, diameter and form continued for Sitka spruce, Lodgepole pine, Scots pine and larch. The oldest fully replicated Sitka spruce progeny test was measured for 15th year diameter, and the first 6th year assessment for height, diameter, basal bow and straightness of a Lodgepole pine inter-provenance cross (Alaska \times Long Beach, Washington) was completed. Sixth to 8th-year height was assessed on 64 Sitka spruce half-sib families of which five were found to be genetically superior for vigour (15 per cent above the standard imported controls).

Sixth year assessment of 13 Sitka spruce clones crossed with a White spruce pollen mixture and replicated at three sites suggests great potential for the hybrid. The mean of the hybrid families for height exceeded the Sitka spruce \times 'orchard quality' pollen cross by 20 per cent at Fort Augustus, Grampian Region, and 14 per cent at Wark in north-east England, but showed no benefit at Torrridge, Devon.

Pollen testing

Studies on the viability and handling of European larch pollen were carried out on several clones. The optimal procedure to ensure high viability was to maintain twigs in a moist condition during pollen collection, to air dry the pollen at room temperature, and to bottle and freezer store the pollen at -20°C as soon as the moisture content fell to 12 per cent. Drying in a

desiccator over silica gel or at slightly raised temperature in an oven caused a rapid and drastic reduction in viability. Freezer stored pollen maintained excellent viability for at least 10 months, and when removed from storage for use its viability is unimpaired by large temperature variations or transit operations so long as exposure is avoided by storage in closed containers; after removal from freezer storage, viability is maintained in closed bottles at room temperature for at least a few days.

Seed production

Seed stands and seed orchards

A further 14 stands totalling 234 ha were registered as seed sources; registration was refused to five others. Six of the newly registered stands were privately owned.

The first part of a 6.5 ha Corsican pine orchard based on tested clones was planted at Kinver (West Midlands). An additional 5.6 ha Lodgepole pine seedling orchard, based on random specific-pair matings between selected trees of Queen Charlotte Islands origin, was established at Otterford (Somerset).

The national registers of seed stands and orchards have been completely revised as a consequence of the recent Forestry Commission reorganisation which resulted in extensive changes to Conservancy and Forest District boundaries and to compartment numbers. The editing task was rendered relatively easy by having the basic information stored in the Branch's computerised database.

Biochemical variation

Studies on the biochemical resistance of Sitka spruce to the decay fungus *Heterobasidion annosum* have continued in collaboration with Pathology Branch with sampling and analysis of a series of trees which had become naturally infected from neighbouring artificially inoculated stumps. The progress of the fungal decay column through the roots and up the stems is being studied in association with the xylem oleoresin composition. Variation in resin biochemistry over the surface of stem discs is being investigated in relation to zones of infection.

In conjunction with Silviculture Branch (North), biochemical characterisation of Sitka spruce families used in vegetative propagation has shown that large differences in a number of terpene characteristics exist between families, giving ample opportunities for using certain families as chemical markers in commercial improved mixtures.

In a study of the susceptibility of Scots pine to *Peridermium pini* in East Anglia in collaboration with Pathology Branch, no evidence was found for a simple relationship between infection intensity and the concentrations of any of the terpenoid components of the shoot cortical oleoresin.

Database

Following considerable development work over recent years, in which two contrasting database management systems were investigated, it has become clear that the needs of the Branch can be satisfied by maintaining a variety of simple files on the Edinburgh Regional Computing Centre's mainframe computer or on local microcomputers. The use of a number of file handling

and sorting routines provides reference lists of all necessary information and data. The extra benefits of the type of specialised interactive searching routines offered by database management systems are small compared with their considerable running costs.

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

PHYSIOLOGY

Flower induction

The occurrence of seed cones in the upper crowns of large trees makes the cones inaccessible for artificial pollination and collection. In a study of Sitka spruce grafts over 90 per cent of the seed cones were found on the upper half of the crown, though pollen cones were more broadly distributed. The possibility of improving accessibility by decapitating trees was examined in an experiment at the Wauchope (Borders) clone bank. Grafts with 10 branch whorls were decapitated by sawing through the stem above the sixth whorl, girdled, and given a stem injection of gibberellin A_{4/7} just above the ninth whorl. In spite of the removal of the normal flowering zone the decapitated trees had only 24 per cent fewer seed cones than the intact trees. The trees had thus adapted to decapitation and seed cones were produced on the lower branches. Counts of cones on whorl six support this observation as there were on average 12 cones on whorl six on intact trees, whereas there was a significant ($p < 0.01$) 5-fold increase to 60 cones following decapitation. This pruning method is thus an effective orchard management technique, and together with inductive treatments can produce abundant pollen and seed cones which are accessible for treatment and collection. (See Plate 1.)

J. J. PHILIPSON

Vegetative propagation

Micropropagation

Vitrification commonly occurs in Sitka spruce cultures (*Report* 1984, p. 31). It can be induced by submerging the cultures either in liquid medium or in sterile distilled water on solid medium. The condition occurs in the absence of plant growth regulators and results in morphological, anatomical and physiological changes and enhanced growth and development.

Established cultures on solid MS medium without plant growth regulators were submerged in sterile distilled water for 0, 14, 28, 42 or 56 days. Only the untreated control did not produce vitrified new growth. Apical extension was promoted in all treatments and the maximum shoot meristem production occurred after 56 days submergence (Figure 3). Reversion to normal growth (after the water was removed) occurred more rapidly after prolonged submergence than after short submergence. The survival and normal development after subculture of shoots and buds formed during treatment, whether vitrified or reverted, demonstrated that the induction of vitrification is a technique that can be used for the proliferation of Sitka spruce shoots *in vitro*. Rooting of the micropropagules still remains a problem. Trials have demonstrated that although rooting levels of up to 40 per cent can be achieved under mist, the shoots are liable to damage and death in the

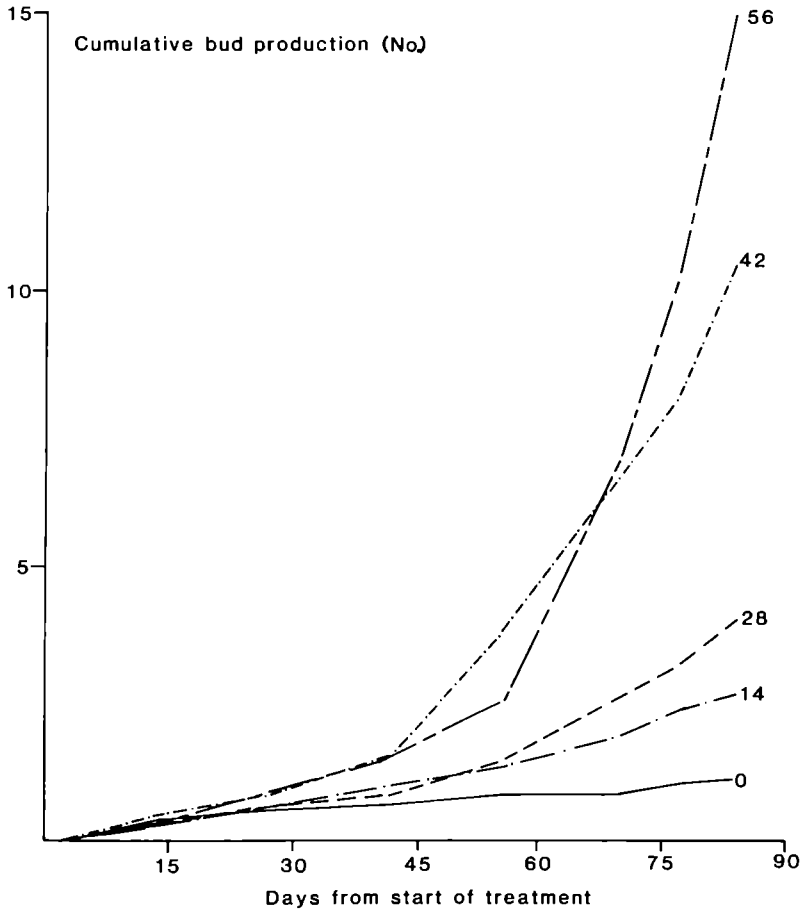


Figure 3. Cumulative bud production from Sitka spruce cultures submerged for 0, 14, 28, 42 and 56 days.

relatively harsh environment of a mist house where temperature and humidity fluctuate widely. The benefits of more stable conditions of a growth room are currently being explored.

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 fifth time in March 1985. Attempts to establish the grafted material *in vitro* have so far proved unsuccessful.

A. JOHN

Mycorrhizas

Sitka spruce seedlings were grown in containers for 7 weeks after germination, and then inoculated with one of nine different mycorrhizal fungi or a water control treatment. Three months after inoculation, mycorrhizal establishment

varied from a complete lack of mycorrhizas in the controls and in some fungal treatments, to total colonisation of short roots in the *Thelephora terrestris* treatment. 2500 seedlings were planted at each of two sites: on a new planting site at Shin Forest (Highland), and on a restocking site at Kielder (Northumberland). There were no growth differences at outplanting, but one of the treatments at Shin had stimulated height growth by 18 per cent at the end of the growing season. No such growth enhancement occurred at Kielder.

The experiment (*Report* 1984, p. 32), in which nursery seedbeds were inoculated with either *T. terrestris* or *Laccaria proxima*, was assessed in the autumn. No growth responses were detected, and examination of roots showed that the inoculated fungi had failed to compete with naturally occurring mycorrhizal fungi in these unfumigated plots. Nursery trials are continuing this year with the aim of investigating mycorrhizal establishment in fumigated and unfumigated soil.

C. WALKER

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

Reduced growth and bent top of Sitka spruce

Reduced growth of Sitka spruce has occurred in recent years over some 9000 ha in the South Wales coalfield area, especially in thicket and early pole-stage crops in the highest and most exposed areas. Annual height growth of affected stands is typically reduced to 20 cm or less, and eventually the leading shoots of some trees grow at an angle to the vertical. Characteristic thinning of the crown, dieback of branches and the production of epicormic shoots show some similarity with the forest decline recently reported from Germany, but the conspicuous yellowing of Norway spruce needles seen in Germany does not occur.

The main aim of the investigation is to provide basic information on the responses of Sitka spruce to combinations of stresses. Stresses which could occur in the affected area are frost, winter waterlogging, summer drought, defoliation by the Green spruce aphid, exposure, atmospheric pollution and possibly toxicity from heavy metals. Twenty sites have been selected covering a range of growth rates. The investigation is mainly at the descriptive stage with measurements of climatic variables, atmospheric concentration of sulphur dioxide, soil water potential, water table depth, rooting depth, tree growth, leaf chemistry and aphid populations. Experimental work has so far been confined to spraying selected trees on each site to control the aphids, and to the exposure of potted Sitka spruce plants on towers at tree-top height to test the effects of the aerial environment on plant health and growth.

M.P.COUTTS, A. J. LOW, D. G. PYATT, W. O. BINNS, C. I. CARTER

PATHOLOGY

Advisory services

Southern England and Wales

During the year the manual system of record keeping and enquiry processing was converted to a computerised system using a relational database. This has greatly aided the clerical aspects of advisory work and also allowed faster and more accurate retrieval of data.

Browning of 1983 shoots of Grand fir probably associated with winter cold was reported from central Wales but, in contrast to the situation in north-west England and Scotland (see below), no other species were found to have been affected. Also in Wales, severe frosts in early May damaged newly flushed beech shoots and injured the lower stems of 8-year-old Douglas fir and 6-year-old Noble fir.

The hot, dry summer produced drought damage similar to that in 1983 with Leyland cypress 'Stapehill 20', Western red cedar, Giant sequoia, Norway maple, yew and Tulip tree all affected. Also during the summer months many cases of *Phytophthora* root-killing on sizeable trees were reported including *P. cinnamomi* on yew, *P. citricola* on yew and *Robinia* × *hillieri* (our first record on *Robinia* species), and *P. cryptogea* on Lawson cypress and yew. A mixed consignment of transplants from Holland in November showed symptoms of severe *Phytophthora* damage and *P. cryptogea* was subsequently isolated from samples of beech and Sweet chestnut. The powdery mildew *Microsphaera platani*, recorded for the first time in 1983 (*Report* 1984, p. 33), was again observed on London plane in central London but was rather less severe.

The bacterium *Erwinia amylovora* was isolated from fresh, small bark lesions at the base of stems of 10 to 15-year-old Whitebeam in August. This is our first confirmed case of direct bark infection by this bacterium and it is probable that entry was via the lenticels (Lewis and Goodman, 1965). Such infections had been suspected before (*Report* 1979, p. 32) but clear evidence has been lacking. The fungus *Sphaeropsis sapinea* (= *Diplodia pinea*), commonly found as a saprophyte, was identified on dying shoots of an Austrian pine in Hampshire. This is only our second record of this fungus acting as a probable pathogen, the first being in 1951. No damage equivalent to that recently reported from the Netherlands (van Dam and de Kam, 1984) has been observed.

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

Scotland and northern England

The most frequently recorded form of injury was an unusual type of foliage browning and shoot dieback which affected a wide range of conifers during the winter 1983/84. This was the subject of a major investigation and is reported separately.

Extremes of climate and misuse of chemicals were, as in previous years, common causes of injury. Enquiries concerning the latter included two cases of injury to pine following aerial fertilisation of plantations with urea. In 1984, frosts in mid-May caused widespread and spectacular damage to newly-

flushed beech and other hardwoods in southern Scotland and northern England. Following an extremely dry spring and summer in parts of northern Britain, a number of cases of drought damage were recorded, most notably dieback of hedgerow beech in the Dumfries area. Drought was implicated in several cases of browning in Norway spruce. The symptoms closely resembled the disorder known as top-dying but, unusually, developed in late summer. A more classical case of top-dying was of interest as it occurred on the relatively uncommon Serbian spruce.

Among agents, the most frequently recorded were the root pathogens *Heterobasidion annosum*, *Armillaria* spp. and *Meripilus giganteus*. The last was involved in several cases where advice on decay in amenity hardwoods was sought. An unusual case of foliage injury to Common silver fir was found to be caused by the rust *Pucciniastrum epilobii*. We are grateful to Mr. A. P. Bennell (Royal Botanic Garden, Edinburgh) for this identification which provides the first British record of the rust on Common silver fir.

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

Resin top caused by *Peridermium pini*

In recent years this stem rust has increased significantly in the older Scots pine in Thetford Forest (Report 1984, p. 34), and a need has been recognised for more information on the likely course of the disease in the remaining areas of pre-1940 Scots pine in the main block of the forest. To this end a detailed analysis was conducted during 1984 on c. 100 freshly felled trees on each of five sites. A summary of data from this study is shown in Table 10.

Table 10 *Peridermium pini* infection in five plots of 50 to 60-year-old Scots pine in Thetford Forest

	Number
Trees analysed	510
Dead trees	40
Live trees	470
Trees free from infection	260
Trees with trunk lesions below timber height (7 cm diameter)	140
Trees with trunk lesions below timber height and with crown symptoms	61
Trees with trunk lesions below timber height and showing healthy crowns	79

Trees killed by the disease are routinely removed during thinning and it was not surprising to find that the number of dead trees in the plots was closely related to the amount of time that had elapsed since the last thinning. A total of 1444 separate rust infections was recorded on the 470 live trees. There was strong evidence that the lesions were clustered on certain trees leaving a much higher percentage of live trees without disease (55 per cent) than would have occurred had the lesions been randomly distributed. From consideration of all available evidence it seems likely that a significant proportion of trees possess appreciable disease resistance.

Thirty-one per cent of the live trees had lesions on the main trunk below timber height and of these just under half possessed dead tops or current

crown symptoms as a result of cambial girdling and xylem dysfunction (Plate 6). The rate of cambial girdling was found to average 4.3 cm/year and from this it was possible to produce a prognosis for the 79 trees with trunk lesions but no crown symptoms. Thus it was calculated that 37 would have died or suffered crown dieback within 4 years, 60 within 8 years and all 79 within 12 years. It was concluded that two thirds of the old Scots pine in the main block of Thetford Forest could be given a useful life expectancy of at least 12 years.

J. N. GIBBS, B. J. W. GREIG, I. T. HICKMAN

Dutch elm disease

Elm regeneration

The survival of English elm suckers has been monitored in a series of plots in southern England since 1977 (*Report* 1979, p. 31; 1980, p. 33; 1981, p. 33 and 1982, p. 25). Cumulative losses through Dutch elm disease have increased from 8.7 per cent to 17.6 per cent during this period. The oldest trees in the plots are now 12 years old and several are over 10 m tall with a diameter at breast height (1.3 m) of around 20 cm. In a second series of plots in which the regeneration has been thinned out to give well-spaced trees, the disease has increased from 2.2 per cent in 1980 to 17.4 per cent in 1984. In 1983 and 1984 all the new infections were caused by the aggressive strain of *Ceratocystis ulmi* and none by the non-aggressive strain.

Trial of Trichoderma on artificially inoculated elm

In 1983 a small experiment was carried out to test *Trichoderma* as a curative and protective treatment for Dutch elm disease. 'Binab T' pellets were applied to 15-year-old English elm and Huntingdon elm in mid-March for the protective treatment and mid-July for the curative treatment. At the end of June, small wounds on two branches on each tree were inoculated with a spore suspension of *C. ulmi*. By September 1983 the mean percentage of crown showing symptoms was 78 per cent on the English elm and 27 per cent on Huntingdon elm. By September 1984 the figures were 93 per cent and 33 per cent respectively. No significant difference was found between the untreated control trees and those receiving *Trichoderma*. Work on the evaluation of *Trichoderma* on elms subject to natural infection by *C. ulmi* is being conducted by the University of Salford. The Forestry Commission is involved in this work with some experiments in southern England.

B. J. W. GREIG

Foliage browning and shoot death in Sitka spruce and other conifers during winter 1983-84

Severe foliage browning and shoot death was observed on Sitka spruce, Norway spruce, Scots pine, Lodgepole pine, Douglas fir and Grand fir during spring and early summer 1984 but it was most serious on Sitka spruce. The gross appearance of damage varied between species due to differences in morphology and to differences in the length of time damaged needles were retained, but detailed examination showed an essentially similar pattern of symptoms on all species.

Damage consisted primarily of shoot death which occurred during the 1983-84 dormant season; there was no evidence of significant previous injury. Dieback was not confined to the 1983 shoots but frequently extended into older internodes resulting in the death of substantial second order branches. The dead shoots were distributed on affected trees in a characteristic manner being concentrated in a zone of variable extent between the upper few whorls of the tree, which remained healthy in all but extreme cases, and the lower one-half to three-quarters of the crown which also escaped injury. There was a marked variation in the severity of damage sustained by adjacent trees and even in the most severely damaged crops a few individuals remained virtually unscathed.

In Sitka spruce, the species most commonly affected, the severity of damage increased both with elevation and crop age and was most severe in crops more than 45 years old at elevations greater than about 250 m. By contrast damage was rare and insignificant in crops less than 20 years old or below about 200 m. Damage to pine occurred at scattered locations throughout Scotland and northern England but on spruce significant damage appeared virtually to be restricted to western forests from Cumbria to Sutherland, although it was widespread within that area. Slight damage occurred in the east but at much higher elevations than in the west. Minor damage occurred in crops which probably total several thousand hectares whereas serious damage was much more restricted and occurred only at scattered locations involving a few hundred hectares.

Although the symptoms shown by affected spruce bore some resemblance to those attributed to 'acid rain' in Germany (Binns and Redfern, 1983), they differed in important respects. Most notably, damage in Britain occurred during a single dormant season and was not associated with the striking magnesium deficiency symptoms characteristic of the German syndrome. The evidence strongly suggests that damage on all species was caused by certain weather phenomena during the 1983-84 winter; particularly alternating periods of mild and cold weather accompanied by strong winds. This conclusion receives some support from the occurrence of similar damage on some of the species in previous winters. However, since the precise mechanism of damage remains unknown the possibility has to be considered that trees were predisposed to climatic injury by other environmental factors.

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

REFERENCES

- Binns, W. O. and Redfern, D. B. (1983). *Acid rain and forest decline in W. Germany*. Forestry Commission Research and Development Paper 131.
- Lewis, S. and Goodman, R. N. (1965). Mode of penetration and movement of fireblight bacteria in apple leaf and stem tissue. *Phytopathology* 55, 719-723.
- van Dam, B. C. and de Kam, M. (1984). *Sphaeropsis sapinea* (= *Diplodia pinea*), cause of dieback of top shoots with *Pinus* in the Netherlands. *Nederlands Bosbouw tijdschrift* 56, 173-177.

ENTOMOLOGY

The Great spruce bark beetle, *Dendroctonus micans*

A further intensive survey was carried out in 1984. Numbers of infested sub-compartments increased by 16 per cent to 1573 but infested trees (all species combined) dropped by 37 per cent to 21 833. The decrease in infested trees was probably attributable to sanitation felling. In contrast to the sharp decline in numbers of infested Norway spruce the totals for Sitka spruce rose by 12.5 per cent reflecting a wider survey but possibly confirming the greater susceptibility of this species demonstrated in research studies. Sanitation felling connected with the survey was not carried out in 1984 and control efforts were concentrated on the predatory beetle *Rhizophagus grandis* (Plate 2).

H. F. EVANS, C. J. KING, D. WAINHOUSE, R. M. BROWN, R. S. HOWELL*

Mass rearing of *R. grandis* began in early 1984. By October a total of 35 500 adult beetles had been produced. Of these 32 000 were released into *D. micans* infested spruce forests in England and Wales at 948 sites of which 401 were Forestry Commission owned and 547 were private. The main problems encountered during the rearing programme were the variable viability of *D. micans* adult females and the incidence of the entomopathogenic fungus *Beauveria bassiana* which is the principal factor in the 30 per cent mortality of *R. grandis* between the prepupal and adult stages. Six forest sites where *R. grandis* had been released were surveyed during late 1984 and *R. grandis* was recovered from five of these. This gives encouragement that the predator is establishing under British conditions.

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

The Pine beauty moth, *Panolis flammea*

In 1984 population monitoring by pheromone traps showed a sharp drop in catches in most blocks. However, larval and subsequently pupal numbers were high for the first time since the outbreaks of 1976 to 1980. Consequently large scale monitoring using pheromone traps has been discontinued and an investigation to improve the method initiated. In one area with known high populations control measures were deliberately not taken in order to check assumptions previously used for control decisions. Here about 50 ha died following complete defoliation. This confirmed that pupal counts of about 15/m² and associated egg numbers represent high risks. A further 150 ha were killed on a private estate. Extensive pupal surveys in autumn 1984 indicated the potential need for control measures on 5500 ha (5000 ha FC, 500 ha private woodlands) in 1985. This will be confirmed by egg counts before spraying. These areas, in Highland Region, are virtually all on peat soils over Moine schists, contrasting with low populations on peats over Old Red Sandstone in the same region.

Investigation of the possible effects of spraying the organophosphorus insecticide, fenitrothion, on bird populations in upland forests continued. This was sponsored by the Ministry of Agriculture, Fisheries and Food under the auspices of the Pesticides Safety Precautions Scheme. An area of 142 ha

*Statistics and Computing (South) Branch

in the Elchies block of Craigellachie Forest (Grampian) was sprayed using 300 g a. i. at a volume of 1 litre/ha. Research at this site has now been completed and a report will be published during the coming year.

J. T. STOAKLEY

Life table studies continued at two sites. Populations continued to increase at Shin Forest (Highland) where 2283 eggs were recorded per tree, with severe defoliation later in the season (68 per cent of current foliage). Assessments over a range of egg densities in surrounding areas established a 'critical' number of more than 1400 eggs per tree that resulted in unacceptable damage (>50 per cent foliage loss). About 33 per cent of the study plot, together with some 30 ha of trees in the near vicinity, were killed. In autumn 1984 the pupal count was 300/m² but declined to 108/m² following attack by the fungus *Isaria farinosa*. At Craigellachie Forest (Grampian) populations showed moderate increases over the previous low levels. The autumn pupal count was 2.5/m². Parasitism of pupae was 26 per cent in the study plot and up to 75 per cent in adjacent areas.

D. A. BARBOUR, J. T. STOAKLEY

Experiments at Elchies block of Craigellachie continued. More eggs were laid on trees in deep peat areas than in iron-pan areas. Larval mortality on trees on both soil types was higher in thinned and thinned-fertilised plots than in control and fertilised plots. In addition, trees with the greatest height to girth ratios tended to have most eggs laid on them. Populations were three times greater than in the preceding year. In laboratory studies female moths laid more eggs on Skeena River and South Coastal provenances of Lodgepole pine than on Alaskan and North Coastal provenances, even when offered no choice. Pre-reproductive delay was inversely related to the suitability of the host for larval growth and development. A delay in mating resulted in both reduced fecundity and fertility. Female moths lived longest on those hosts on which they laid most eggs. Larvae grew faster at higher temperatures and had higher growth rates on Southern Interior, Central Interior and South Coastal provenances of Lodgepole pine than on Alaskan and North Coastal provenances. Growth rates were intermediate on Scots pine but larval survival was poorer.

S. R. LEATHER, J. T. STOAKLEY

Populations from Scots pine forests in southern England and Scots and Lodgepole pine forests in Scotland were sampled using pheromone traps and the moths used in a study of isoenzyme polymorphism. Polymorphism of the malate dehydrogenase locus provided evidence of genetic differences between northern and southern populations of the moth. No significant differences were found between populations from Scots pine and Lodgepole pine.

D. WAINHOUSE, M. R. JUKES

The Pine looper moth, *Bupalus piniaria*

Following record high numbers of pupae in January 1984 egg counts were carried out at Tentsmuir Forest (Fife) and Roseisle (Moray) in July with 4000 eggs per tree being set as the criterion for insecticidal control. This was

exceeded over large areas of Tentsmuir Forest but not at Roseisle. On 16 August, 1100 ha of Tentsmuir main block were sprayed with diflubenzuron (Dimilin®) at 67.5 g a.i. in 2 litres diesel oil per hectare using a helicopter fitted with Micron X1 rotary atomisers. Excellent control was achieved, resulting in a reduction of about 99 per cent in pupal numbers compared with the previous winter. Only 47 pupae were found in the sprayed area and all were either dead or parasitised, effectively resulting in no survivals following spraying.

J. T. STOAKLEY, S. G. HERITAGE, H. F. EVANS, D. A. BARBOUR

Pupal surveys were carried out in 39 areas. Counts declined sharply at Culbin (Moray), Roseisle (Moray) and Montreathmont (Angus). Tentsmuir (Fife) recorded a highest compartment mean (HCM) of 22.4/m² in an outlying block left unsprayed. HCMs were 12.0 at Cannock (Staffs), 11.2 at Swynnerton (Staffs) and 9.6 at Sherwood IV (Notts), maintaining previous high levels. Sherwood II at 7.6, Sherwood III at 14.8 and Laughton (Lincs) at 4.8 all showed threefold increases, reaching their highest ever levels while Elveden (Norfolk) with 5.2 returned the highest Thetford count since 1957.

R. M. BROWN, D. A. BARBOUR

The Green spruce aphid, *Elatobium abietinum*

Differences in susceptibility to the Green spruce aphid of provenances of Sitka spruce appear to be related to the length of their growing season. Phenological differences of less than 2 weeks occur at bud burst time. Norway spruce, probably the aphid's original host, has a more protracted period between bud-burst and needle extension. In 1984, from 23rd May to 11th July, analysis of the old needles showed that amino acid concentrations declined significantly as buds developed. The northern provenances of Sitka spruce and other provenances subject to dry summer conditions tend to have only a short growth period. At bud setting time high concentrations of foliar amino acids coupled with favourable temperatures could make such trees more vulnerable to early winter attack with consequent depletion of reserves in the needles. The outbreak that occurred in the winter 1979/80 on the provenance experiment at Rhondda has had a lasting impact on growth of the northern provenances, whereas the more southerly provenances quickly recovered.

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

The European pine sawfly, *Neodiprion sertifer*

Following comprehensive research by the NERC Institute of Virology at Oxford, Tate and Lyle Research and Development* marketed, for the first time in 1984, a stabilised formulation of the nuclear polyhedrosis virus of *Neodiprion sertifer* produced from infected larvae collected in the field. This product, called Virox, is specific to *N. sertifer* and was used successfully to control heavy infestations of the sawfly in 3000 ha of young Lodgepole pine plantations under Forestry Commission and private management in the north of Scotland. Ultra low volume application, shortly after egg hatch in late May, was mostly from the air using 1 litre of Virox, water and Actipron

*Now Microbial Resources Ltd.

(self emulsifying oil) mix per hectare. Following surveys of numbers of egg clutches in early spring a further programme of aerial application on 2700 ha is planned for 1985.

H. F. EVANS, J. T. STOAKLEY, S. G. HERITAGE

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

Experiments to test alternatives to gamma HCH for protection of young transplants were concluded. These showed that in general the pyrethroid insecticides permethrin and cypermethrin are as effective as gamma HCH and less phytotoxic.

First year results from a two year survey of attack by *Hylastes* spp. on Sitka spruce transplants in upland restocking sites showed, on the whole, levels of damage which confirm the need for effective protection against this insect.

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

Advisory services

Browning of beech foliage by *Rhynchaenus fagi* was widespread during June in southern England, particularly in the New Forest. The defoliation of oak by *Tortrix viridana* was slight in the south but damage was reported from Norfolk, the Forest of Dean, Gloucestershire, Worcestershire and Yorkshire.

Various pests affected the quality of nursery stock, the most serious being cutworm larvae (*Agrotis* spp.).

Forestry Commission plant health inspectors found *Ips typographus* on two occasions under Norway spruce bark in dunnage from Europe. The scolytids *Dendroctonus brevicomis* and *Pityogenes plagiatus* were found for the first time in Britain on timber from Canada.

The frequent requests for information on the control of *Euproctis chrysoorrhoea* reflect the high populations of this insect still present on urban trees in the London area.

The total number of enquiries received at Alice Holt was 364 of which 154 were Forestry Commission and 210 private, while 72 were received at NRS made up of 42 Forestry Commission and 30 private.

T. G. WINTER

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

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

Studies are in progress to determine, within a wide range of spruce species, secondary compounds correlated with susceptibility to attack by the Green spruce aphid. A steam distillation process has been developed to extract the leaf oil component (volatile chemicals) from foliage samples for detailed analysis and bio-assay. A gas chromatograph (Hewlett Packard 5880A) has been fitted with a capillary column system and the first traces (chromatograms) show that the more resistant the tree is to aphid attack, the more complex is the mixture of secondary compounds. The Green spruce aphid will not infest certain species in a mixed spruce stand, suggesting that a

volatile component is involved in the plant-insect relationship. Passing the vapour of the secondary component extracts from *Picea smithiana*, a resistant spruce, over aphids confined in 'Pyrex' tubes caused distress and death, but not when the extracts were from susceptible spruces; other resistant species remain to be tested.

J. P. WRIGHT, C. I. CARTER, J. F. A. NICHOLS

WILDLIFE

Management of deer, squirrels and other mammals

A major review of red deer research over the past 8 years is nearing completion. A wide range of performance (0-85 per cent yearlings pregnant) is exhibited in forest populations with some records of twins and calf pregnancies from the highest performance areas. A high proportion of grasses in the diet, compared with heather, influences nutrition and increases fertility.

A review of the current distribution in status of feral Sika deer in Britain has been completed. In most Scottish populations range extension poses a threat to commercial forestry and, due to hybridisation with red deer, may affect the genetic conservation of native red deer.

The study of roe deer performance now covers 15 forests ranging from Dartmoor in Devon to Achnashellach in north Scotland. It has been found that 4-6 years' data are required to give a picture of the local variation in growth and reproductive performance.

Air sampling was undertaken to determine the levels of phosphine that a ranger might be exposed to when gassing rabbit burrows with Phostoxin. A total of 233 samples were taken at seven forests and none of these suggested that exposure was likely to be unsafe. The effectiveness of Mag discs (a metal phosphide similar to Phostoxin) was investigated. Eight hundred burrow entrances were treated and only eight were reopened by rabbits. Spontaneous combustion on a minor scale was experienced on a number of occasions.

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

Birds

Field studies have continued to look at the ways in which tawny owl and goshawk are adapting to second generation forests in the uplands. The population of goshawks under study had its best year so far. Mortality was again low amongst breeding adults and a policy of leaving nesting areas undisturbed resulted in an average of nearly three young leaving each nesting area. Significant differences in tawny owl reproduction were recorded between Kielder (Northumberland) and Glenbranter (Argyll) from 64 breeding attempts in nest boxes. In Kielder, incubation started earlier, larger clutches were laid and fledged broods were almost twice as large. The effect of the availability of the main prey, the field vole, is being tested against these differences (comparing two methods) to establish the changes in relative abundance of small mammals. These are mainly being monitored on restocked areas which are assumed to provide the main field vole habitat.

S. J. PETTY

Damage

Simulated bark stripping on Sitka spruce and Lodgepole pine has shown a difference in response of the two species. Increased proportions of bark removed raise the probability of death of Lodgepole pine particularly on the smaller diameter trees when the tree snaps off at the wound. The Sitka spruce that died were all in the smaller diameter classes and had not snapped off; some of these deaths could have been due to suppression. Resin flow from the wounds on the larger Lodgepole pine partly occluded the wounds irrespective of the area of bark removed. Resin flow from Sitka spruce was negligible.

Roe deer browsing on restocked Sitka spruce areas at Kielder (Northumberland) has shown that within 4 years the protection provided by a fence has allowed Sitka to outgrow the leader damage height, at present taken at 1.5 m. The mean height of trees in comparable unfenced areas is only 0.25 m. This has been estimated to have delayed establishment from 5 to 10 years on different sites. In contrast, at Inverliever Forest (Argyll) where there are similar proportions of leader damage to Sitka spruce, differences in height growth between fenced and unfenced areas after 3 years are negligible. This is probably due to the availability of a greater amount of alternative food. This does not prevent initial damage to leaders but it appears to reduce continued browsing of side shoots emerging from the current leader, a feature which has important bearing on the resulting height growth.

The practicalities of determining whether or not fencing is required on areas where restocking damage levels are not yet available is being developed. This involves protecting a sample of trees with individual tree guards and comparing protected and unprotected trees annually.

A workshop on deer damage in upland forests has reviewed the overall situation and indicated that future priorities should expand the work in determining significance of damage to individual trees and the final crop, relate damage levels to deer densities on different site types and establish methods of wide-scale, large area damage surveys to complement the nearest neighbour method.

L. A. TEE, P. R. RATCLIFFE

Chemical and mechanical repellants

Temporary fencing for roe deer browsing protection for up to 5 or 6 years is provided by lightweight netting supported on high tensile spring steel line wires and untreated stakes. Two types of netting are available: a light gauge two-ply hexagonal mesh which can be left *in situ* to disintegrate or a lightweight welded mesh which can be dismantled and re-used. Trials of alternative rabbit fencing materials have continued: a field trial of the high tensile polypropylene mesh netting proved unsuccessful and it has been replaced with a heavier mesh for further trials. A solar panel for charging the battery power of an electric fence is being tested: the electric current failed, however, to prevent squirrels from climbing the fence.

The chemical repellants Arcotal, Arbinol and Bio Rep Horse Tails were tested inconclusively against roe deer browsing. A paint-on jelly type repellant had a limited trial but this suggested that it may be useful against grey squirrel bark stripping.

Individual tree protection concentrated on developing protection for motorway tree plantings against bark stripping by field voles. On unprotected trees fresh damage can be found throughout the year but the peak occurs between December and February. Development of high tensile polypropylene mesh netting for tree guards against cattle and hares continued.

H. W. PEPPER, L. A. TEE, B. A. MAYLE

FIELD SURVEYS

Surveys

Full crop assessment and mapping surveys were carried out on 60 000 ha with a further 2500 ha of surveys of disposal subjects. Site surveys were completed on 8000 ha. Field Surveys staff were also used to carry out a survey of signs of air pollution damage to conifers, the results of which are reported on page 24.

Growing stock database and production forecasts

Implementation of the new Forest District management structure led to the renumbering of many compartments and changes to the boundaries of administrative areas which in turn resulted in considerable work in amending the Subcompartment database. Use of the database for answering enquiries and providing information for special projects continues to increase. Such projects ranged from providing details of a stratified random sample of compartments for assessment in the Forest Health Survey to production forecasts for South Scotland Conservancy to examine the effect of changes in cutting regime assumptions on future yield.

Remote sensing developments

Following some success in forest classification from LANDSAT (multi spectral scanner) imagery on flat terrain, work on upland areas followed during the year. Problems of terrain shadow led to some inaccuracy but the main source of error was related to the similar spectral response of heather moorland and conifer species, notably pine. An evaluation of SPOT simulated data was carried out in anticipation of the forthcoming French satellite remote sensing system with the level of resolution proving to have application in general woodland monitoring. The Forestry Commission has been closely involved during the year with a Department of the Environment funded project on satellite monitoring of woodland carried out by the National Remote Sensing Centre at Farnborough. Extensive use of LANDSAT thematic mapper data is being employed and the spatial and spectral resolution of this system seems well suited to the study.

J. DEWAR, A. J. A. BETTS

CENSUS OF WOODLANDS AND TREES

Work during the period has been mainly concerned with the preparation and publication of the remaining County Reports. At the end of the year the Reports for the four remaining counties in north-east England, and all the Welsh counties, were still unpublished but their publication was planned for May 1985. Other work involved dealing with numerous and varied enquiries for data and also with the preparation of the main Report which will cover methodology and results in rather greater detail than have been published to date.

Fieldwork has been undertaken by the Census Section as subcontractors to Hunting Technical Services Ltd. who are carrying out a project on monitoring landscape change for the Department of the Environment and the Countryside Commission. This involves field teams assessing features such as current land use and the nature of boundaries on the sampling strips which were previously used for the assessment of non-woodland trees in the 1979-82 Census of Woodlands and Trees. Work started in September 1984 and continued, when practicable, during the winter. Completion is expected in autumn 1985.

G. M. L. LOCKE

MENSURATION

Work progressed during the year included growth modelling (reported separately on pp. 51-53), the preparation of 2.0 m and 2.4 m spacing line thinning yield tables for the major coniferous species and a number of individual projects covering measurement procedures and growth and yield studies. Advice on tree and stand measurement and other aspects of forest mensuration continues to absorb a significant part of the Section's activities. The tariff and assortment forecasting services were widely used by field staff. 355 tariffs each with an individual assortment forecast and 52 non-standard assortment forecasts were processed. Tariffing seminars were held in all conservancies to update field staff and to improve understanding of measurement procedures.

A major investigation into the conventional methods of sawlog measurement was completed during the year under review. More than 1000 sawlogs of Scots and Corsican pine were measured at Thetford Forest (Norfolk and Suffolk). Analysis of the data confirmed the extreme variability of taper rates between individual logs. The investigation revealed that neither the top diameter nor mid diameter methods of sawlog measurement give totally unbiased estimates of volume. However there was no firm evidence that more complex methods would justify the additional costs of measurement.

A study of the effect of dry deposition of sulphur, as assessed by the Warren Spring Laboratory, on rates of growth of Scots pine, Norway spruce and Sitka spruce using permanent sample plots provided no evidence of any significant trends upwards or downwards over the past 30 years.

A comparison of selective and systematic respacing of Sitka spruce in a 17-year-old experiment showed that selective respacing resulted in some gains in volume production, basal area production and mean diameter, but the differences were not statistically significant. However selective respacing did result in increased mean height and gave some gains in tree quality.

A study of volume and dry matter production in Sweet chestnut coppice covering a range of sites, ages and stocking densities showed that a good relationship exists between total volume or dry matter production and mean diameter at breast height of a coppice stand. This relationship can be used to eliminate time consuming and thus expensive measurements of production in the field.

Work on revised field procedures for controlling the volume marked in thinnings was completed and a new publication *Thinning control* (Forestry Commission Booklet 54), containing sections on yield class assessment, thinning practice and the field procedures for controlling a thinning, was prepared.

T. J. D. ROLLINSON

WOOD UTILISATION

Timber quality of British sawn softwood

Studies to determine the effect of initial planting distance on the yield of structural timber obtainable from stands of Sitka spruce form part of a joint research programme and are undertaken at the Princes Risborough Laboratory of the Building Research Establishment. Sample logs were collected from a further three sites bringing the total number of battens cut and examined to well over 2000. The project is more fully described in Part II of this Report.

British larch

Another part of the joint FC/BRE programme has involved the collection of sample logs from 21 stands of larch. The stress grading machine settings subsequently obtained help the species compete more effectively in the softwood structural market. In terms of machine grading performance, no distinction could be made between battens cut from logs of European, Japanese or Hybrid larch origin.

Transmission/telecommunication poles

BS 1990: Part 1 *Specification for softwood poles* was published and extends the range of permitted species to Norway and Sitka spruce. Long life is a prerequisite for poles and preservation to achieve full sapwood infusion and retention is essential. Spruce is known to be more difficult to treat by conventional pressure methods, but a joint Forestry Commission/Electricity Council programme of research has shown that sap displacement techniques can give satisfactory results. FC Forest Record 128 *The production of poles for electricity supply and telecommunication* gives further details.

R. G. HANDS

WORK STUDY

METHOD STUDY

Forest management

Method studies were continued into a wide variety of silvicultural operations. A trial with the Famo T5M line transplant lifter was extended into a nursery handling system for use with this machine. Trials were carried out with a variety of transplant packaging materials. Further progress was made with the modified heavy duty Dondi drainage equipment; the hydrostatic drive now under development for the motive unit promises to improve the performance of the Dondi markedly. Trial results with the TTS 35 H disc scarifier (Plate 4) are very encouraging with good clearance of brash, and suitable ground preparation, at least on the drier sites, and outputs are good. Notable amongst various projects on aerial fertilising was that on the Decca Flagman guidance system which begins to show its potential value to the field manager as a means of controlling helicopter flying performance. A further advance in chemical weeding was made with the refinement and redesign of the already well received drench gun. An evaluation of all terrain vehicles began with early trials clearly demonstrating the superiority of 4-wheel all terrain cycles compared with the 3-wheelers currently used. Short comparative trials of the Bambi and Big Dipper fire fighting helibuckets were carried out and the Big Dipper showed up favourably. Trials with a fixed wing Turbo Agcat for both water and foam bombing showed the potential of this aircraft given reasonable landing facilities. An evaluation of a hydraulic hoist, the Hydroladda, indicated potential for this machine both in seed collection and the management of seed orchards.

Harvesting and marketing

The regular monitoring of new chain saws and ancillary equipment has continued; two chain saws were added to the Forestry Commission approved list, namely the light but relatively powerful Husqvarna 154 SG and the heavier-duty Stihl 038. The Treejack double lever breaking bar and the Fiskars 19450 breaking bar were tested and recommended for FC use. The favourable performances of an OSA 260/706 clear felling harvester and Gremo SK 35 thinnings harvester fitted with automatic stump treatment device led to the decisions to purchase one of each of these machines for operational use. The Bruun Two thinnings harvester was very impressive except for the quality of snedding which was poor. A comprehensive survey of practices in timber measurement is under way. Trials were carried out to assess the potential of small rough-terrain front end loaders as low cost secondary handling machines in cable crane harvesting operations. The Manitou Maniscopic MT 422 appeared a particularly good prospect. Further development work was carried out to apply organised shortwood felling methods in thinning and a report is in preparation. The draft of the final report on roadside facilities for harvesting has been completed: this is also intended for publication. This year saw the introduction of organised shortwood working at Thetford.



Plate 1. Drilling a small hole in the stem of a Sitka spruce graft. Injection of a mixture of gibberellins will stimulate pollen production and female flowering in the following year. (E2104)



Plate 2. Adult of *Rhizophagus grandis*, a predatory beetle imported and being reared and released as a specific biological control agent against the Great spruce bark beetle *Dendroctonus micans*. (A10808)



Plate 3. Forest health and air pollution—1984 survey. A 44-year-old stand of Norway spruce in Alice Holt Forest, Hampshire; one of the permanent plots used in the survey. (CN197)

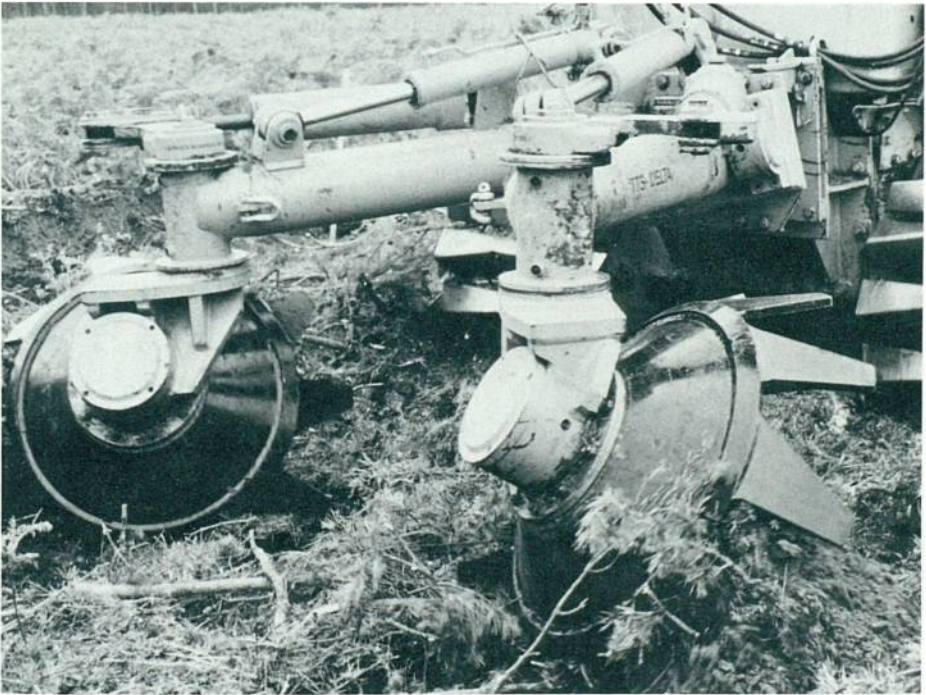


Plate 4. The TTS Delta 35 H disc scarifier being used for ground preparation on a restocking site. (A10806)



Plate 5. Automatic weather station at a height of 673 m in the Kirkton catchment of Balquhiddy (Strathyre Forest, Central Region). (Institute of Hydrology)

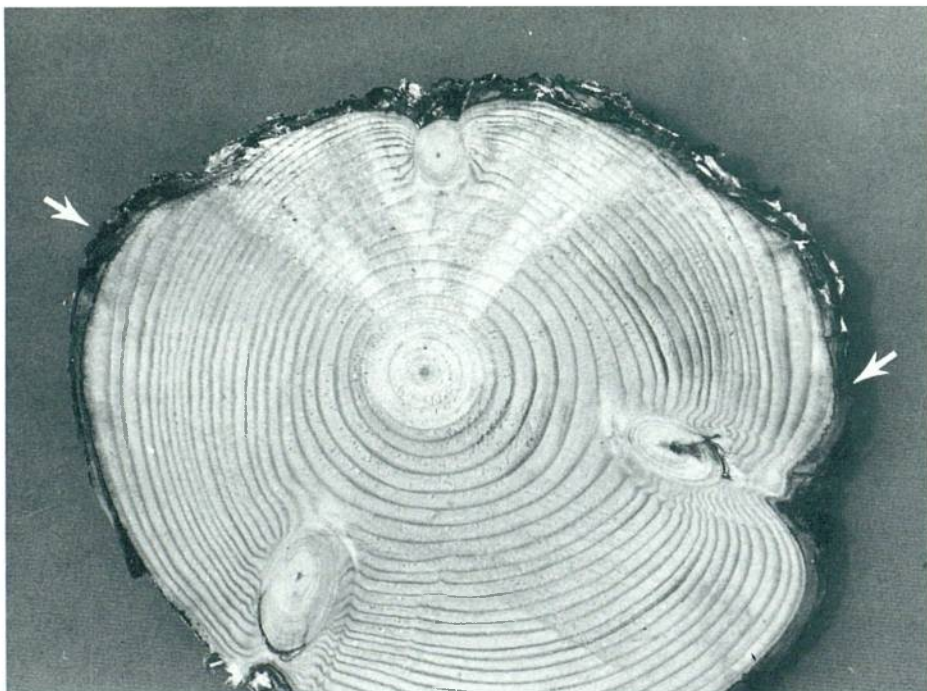


Plate 6. Developing *Peridermium* lesion on the upper stem of a 50-year-old Scots pine. Much of the affected tissue is heavily soaked with resin. The arrows mark the points of most recent death to cambium. By determining the age of the lesion the average rate of cambial killing can be calculated. (A10807)

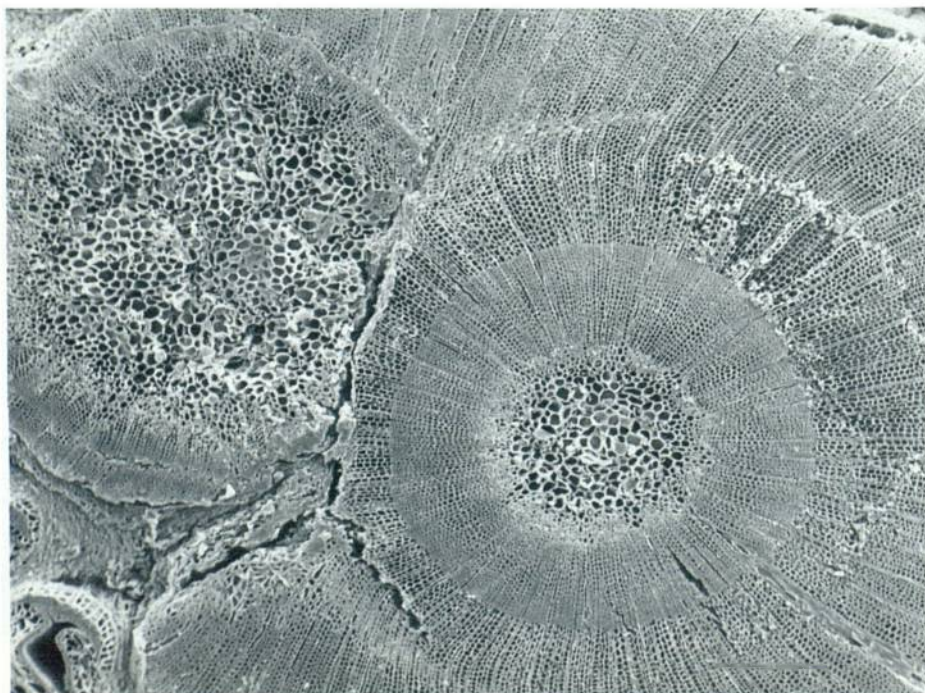


Plate 7. Scanning electron micrograph, taken on a Jeol 35R scanning electron microscope, showing the development of a union in a Sitka spruce graft. In this 6-week-old graft, early callus formation has been followed by xylem differentiation from the cambium of both components. Here, the contribution from the active rootstock predominates, partially enveloping the scion (left). (I. Weatherhead)

Work measurement

Substantial resources were again committed to work measurement and output guides were produced for the weedwiper, the drench gun, extraction by Volvo 861 forwarder, lifting transplants with the Famo T5M, shortwood contour felling, extraction of shortwood from contour felling by Timbermaster and FC Igland cable crane, and provisional output guides were prepared for the OSA and Gremo harvesters and the Bruun 678P processor. The major project to produce end product times for organised shortwood is nearing completion.

Safety

Close liaison with the Safety Officer continues to ensure safe working practices. Assistance has been given in the revision and drafting of Forestry Safety Council Guides.

Communication of results

In addition to 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 HGTAC/FC Technical Notes.

A. J. G. HUGHES

INSTRUMENTATION

A prototype hot-air dryer has been coupled to the vibrating dewinger in the Seed Extractory; 500 litres of seed can now be dewinged and dried in one operation in less than half the time taken previously. A metric vernier girth band jig was made and girth bands which measure tree diameter direct to the nearest 0.1 mm are now in production. A dispenser which remotely places and breaks open sachets of highly toxic fumigant in rabbit burrows has been successfully field tested; both the effectiveness and safety of the operation have been improved. An improved oxygen analyser has been made which runs for longer periods and at lower temperature than its predecessor; associated glass-epoxy encapsulated microcathodes are being produced in quantity by a specialist firm. Electrical specifications were drawn up on behalf of Work Study Branch for their helicopter foam fire fighting system; these have been passed by the Civil Aviation Authority. Electrical specifications were also drawn up and a system installed in Engineering Division's prototype mobile workshop. Considerable effort is currently being channelled into the open-topped chamber project; prototypes of filters, fans and duct work have been commissioned ready for trial, the electrical power installation sub-contracted and the computer based data capture and control equipment is well in hand.

R. CARNELL

STATISTICS AND COMPUTING

Statistics

Alice Holt

From the results of annual surveys in 1982-4 and using the BLOBMAP program (see Computing below) the outbreak of *Dendroctonus micans* has been extensively mapped and analysed. Within the limits of the data, the probable course of the outbreak was traced from the earliest occurrence (in 1973). This helped in establishing a strategy for the release of the specific predator *Rhizophagus grandis*.

It was found that the data from the national survey of the health of Scots pine and Norway and Sitka spruce, designed in the form of a 2³ factorial experiment with factors elevation, rainfall and sulphur deposition, were better treated by multiple regression. Major differences in health between geographic regions were detected but no significant damaging effect of sulphur, the only pollutant for which countrywide data are available, was found.

Some progress has been made in the analysis of the results of strength tests of 4 m battens from the unthinned spacing plots at Brechfa (Dyfed) and Clocaenog (Clwyd). It has been shown that the mathematical form of the effect of spacing (a logistic curve) is similar at the two sites. The main differences between the sites can be represented by a single parameter determining both the relative loss of strength and the spacing at which the rate of loss of strength with increasing spacing reaches a maximum. This spacing was 1.17 m at Brechfa and 1.73 m at Clocaenog. This interim result emphasises the importance of extending the analysis to the available material from other sites.

Interactive programs were written to fit linear functional relationships by Bartlett's method for the case when the error variance of both the y and the x variates are unknown.

Aerial fertiliser distribution patterns were examined to estimate the amplitude of the waves resulting from different flight-line spacings. The optimum spacing taking into account operational costs was found to be 12 m.

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

Northern Research Station

An experiment investigating the interaction between wind turbulence and the forest canopy required the use of time series techniques, in particular spectral analysis, to describe the frequency composition of wind over the surface.

Some work has been done to provide a parsimonious description of a covariance matrix by assuming that the variables on which it is based are determined by linear growth curves with random rates of increase and starting values. The methods required are essentially those of Grizzle and Allen (1969).

I. M. S. WHITE

Modelling

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

Alice Holt

A simulation model of dynamic response of a tree to an externally applied force has been developed in order to aid the Division's effort on the problem of windthrow. The structure of the model has been determined by the descriptive work of Coutts (1983) on the components of anchorage. The differential equations of the model are solved numerically. The sensitivity of the model to different aspects of root/soil-plate geometry are now being investigated.

Simple models have been developed to aid the study of optimal mixes of species used in planting programmes when the different tree species are subject to epidemic risks dependent on their total planted area. The gross simplification of these models, of what is an extremely complex strategic decision making process, makes such work very exploratory. However even the simplest of the models suggests that optimal planting strategies are related in a discontinuous way with the parameters of the model.

Work has continued on the fitting of families of growth curves to mortality and growth data from sample plots with the aim of consolidating these relationships into a coherent framework.

The methods developed for building 'tree times' synthetically from time studies of shortwood harvesting were used to compare time estimates based on measurement of end products with the usual whole-tree measurement method. It is hoped that after further testing the most precise method will be chosen for regular use.

K. RENNOLLS, I. D. MOBBS

Computing

Alice Holt

A number of measures have been taken to increase the security of both the computing equipment and the data held on it.

The Sheffield University screen editor was installed and it is now possible to use its full facilities on most of our VDUs. The Culham magnetic tape archiving system ARCAID was installed to enable more convenient archiving and retrieval of files. Late in the year a Hewlett-Packard 7475A graph-plotter and the Culham GHOST 80 graph-plotting system were purchased. The 4.04B version of GENSTAT was brought into use and this has enabled the Calcomp 1012 plotter to be used for GENSTAT output.

With the aid of temporary staff the long job of mounting the backlog of literature references for Pathology Branch was finished and the editing process is progressing well.

Further developments in the RAPPORT database system have been made in particular for deer catch records and the analysis of conifer seed-test results. The main advance, however, has been in the establishment of a Pathology enquiries database system which allows telephone enquiries to be logged as they are made and subsequently followed through the advisory system.

The whole system for managing the Subcompartment database in-house has now been written and is ready for parallel running against the original system held at the University Computing Centre (UCC), London. Unfortunately considerable extra work became necessary to cope with a change in the UCC operating system despite the willing help they gave.

Work in liaison with G. Marshall on the MAPLE map-digitising system produced an agreed level of documentation and a sandwich student is helping to meet a more satisfactory standard aimed at allowing future development.

In collaboration with Site Studies (South) Branch a system to monitor air pollution at a remote site was designed and the software written to allow automatic data collection, reduction and transmission to the Prime computer.

Further developments were made in the program BLOMAP to enable a variety of symbols of variable size and colour to be drawn on a map of any chosen part of the United Kingdom defined by selected boundaries. The program has been used on several projects.

G. J. HALL, R. C. BOSWELL, B. J. SMYTH, A. J. PEACE, R. M. A. GILL

Northern Research Station

Despite being incomplete the Experiment Register database has provided useful answers to occasional queries. At present, knowledge of the database and its management are both necessary to make cost-effective searches. A facility was added to translate between the numeric codes for features and their corresponding text. Experiment names were clarified when these had become confused among long-standing records, and notes of these clarifications were organised on a computer file. A master list of all experiments not yet in the database was compiled and a form-filling pack was produced to assist those who prepare the information for machine operators to enter.

Software was developed within the NOTICE package on the mainframe to plot locations cheaply, by their grid references, on outline maps of Scotland or Great Britain. This has several applications and has effectively detected incorrect grid references in database records.

Before card-readers are withdrawn from service, over 3000 assessment datasets now stored on punched cards have to be read in to mainframe archive. These numerically indexed datasets date back over 10 years and occasionally contribute old data to new analyses. The task has been started and unwanted datasets are simultaneously being weeded out and scrapped.

Other developments have included exchange of electronic mail with American addresses, access to Edinburgh University's online library catalogue, tests of session level communications with the HQ VAX computer, and a survey of computing interests followed by tuition to develop staff skills at the Northern Research Station.

As plans develop within Silviculture (North) Branch to install a microcomputer which will monitor polyhouse sensors and control environments, liaison has been maintained with this Branch and with other organisations which might contribute relevant experience.

Two Apricot microcomputers with hard discs were purchased. Software was obtained to enable two Sirius microcomputers to be used as medium-resolution graphics terminals and spreadsheet software was bought for one of them.

A micro HELP system was written and installed on three different makes of machine. This reminds occasional operators how to use the system and helps them to learn some of the features of UCSD-p. Three short courses of instruction on this operating system were also given.

Micro programs have been developed for Genetics Branch to allocate seed and pollen and keep updated stock records, also to cost graft production. For Physiology Branch a program to digitise root lengths was largely rewritten and for Silviculture (North) Branch there were modifications to a program which summarises windflow parameters. Mr J. N. R. Jeffers of the Institute of Terrestrial Ecology kindly provided a Basic program for cross-impact modelling derived from Kane (1972). This was rewritten in Pascal.

Two Epson HX-20 portable microcomputers were tried as data encoders when some Genetics Branch field experiments were being assessed. Apart from doubts about their robustness they did not compete successfully with the map-form record sheet which is in standard use for progeny trials and is well adapted to small line plots and frequent changes of identifier information. However, trials of the HX-20s in easier conditions assessing poly-house experiments were more successful and will be continued.

R. W. BLACKBURN, K. P. DONNELLY

REFERENCES

- Coutts, M. P. (1983). Root architecture and tree stability. *Plant and Soil* **71**, 171-188.
 Grizzle, J. D. and Allen, D. M. (1969). Analysis of growth and dose response curves. *Biometrics* **25**(2), 357-381.
 Kane, J. (1972). A primer for a New Cross-Impact Language—KSIM. *Technological Forecasting and Social Change* **4**, 129-142.

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

Modelling forest growth

Work on this project has continued along some of the lines suggested in *Report* 1984 (pp. 53-55) though progress has not been as fast as had been hoped owing to staff shortages and competing priorities. The inter-tree competition model has been extended to include a measure of local stocking in addition to the apical dominance factors of the previous model. This model, termed GFD (for 'Generalised Ford and Diggle'), therefore has two components: one which might be thought of as corresponding to crown competition for light and the other based upon a circular domain of influence, possibly analogous to a root-competition effect. GFD provided a significant improvement of the fit to the growth trajectories of larger trees. It has five parameters, in general, but for our trial data two of these turn out as being redundant so that they may be regarded as constants. An alternative empirical 3-parameter model termed IFM (for 'Influence Function Model') has also been developed and both models provide an adequate description of the trial growth data.

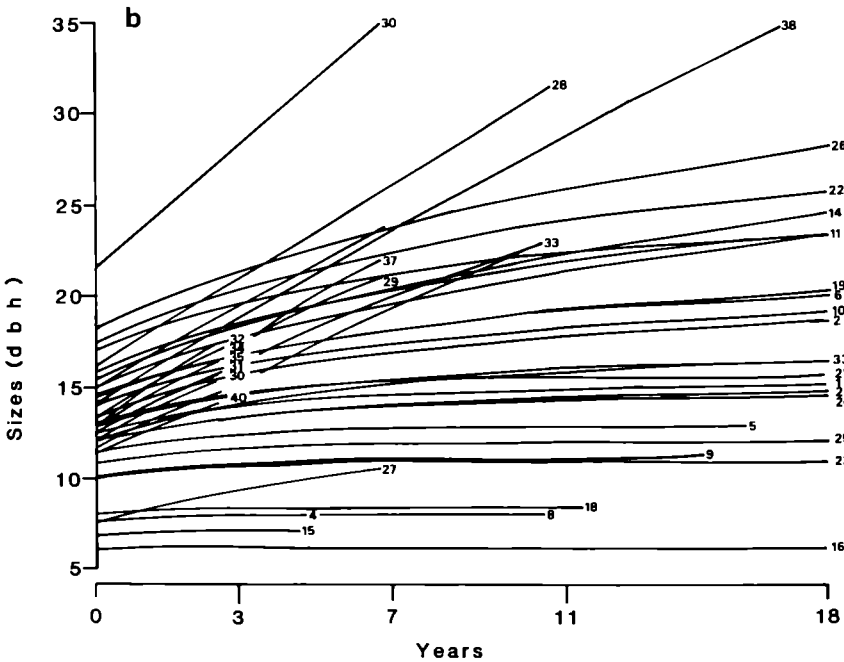
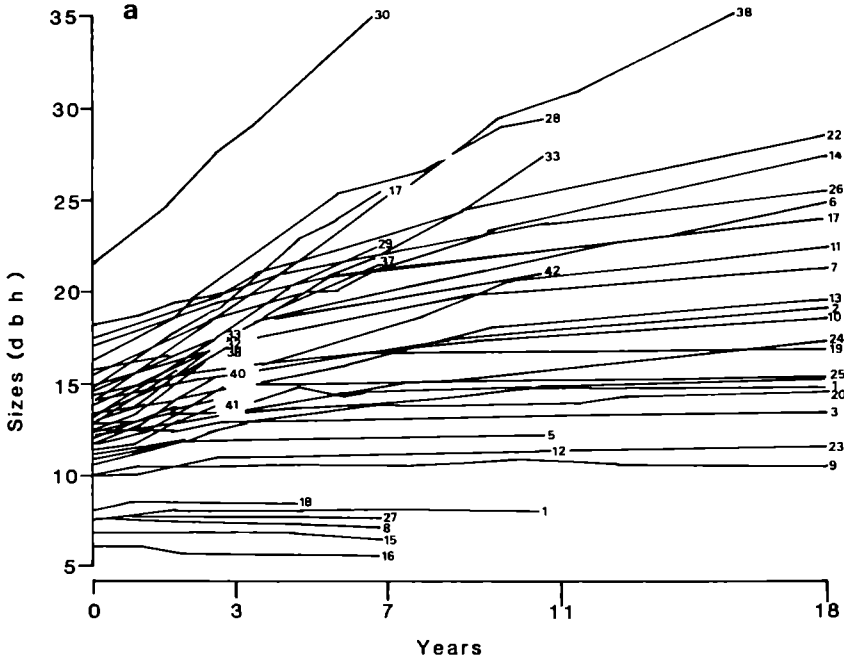


Figure 4 (a) Diameter growth data for two plots from the Dyfi thinning experiment.
 (b) The predicted growth paths using the fitted IFPM with the GFD competition submodel.

Figure 4 shows the GFD fit obtained for a mix of data from sample plots having heavy thinning and no-thinning. From a mensurational point of view the model clearly provides a good basis for interpolation and possibly extrapolation. However further work is needed on improving the physiological appropriateness of the dynamics of the nutrient related state variables of the canopy and litter layers.

The individual tree growth model (IFPM) is driven by dbh variables, this being appropriate to both available data and the probable management usage of the model. However work has progressed on introducing individual tree total height into the model. Following an initiation of heights, using an empirical diameter-height relationship, these are incremented using an auto-regressive model dependent upon previous heights and diameters. These increments are then scaled to ensure that the stand top height evolves in accordance with established height-age growth relationships, which in this case have been described using a family of Chapman-Richard functions. Thus IFPM is capable, with suitable approximations and assumptions, of being used from data consisting of a diameter distribution (possibly with a spatial distribution) and the usual mensurational site index estimate (i.e. Yield Class).

K. RENNOLLS, T. J. D. ROLLINSON

COMMUNICATIONS

Towards the end of the year a review of the Branch was undertaken with the aim of improving the service to researchers, field staff and private growers and owners. Archival functions in the Library and in Photography Section were disengaged from the day to day activities, and proposals were drawn up for a more efficient dissemination of technical publications within the Commission and in the private sector.

Acquisitions and loans in the Library both continued to increase at an annual rate of around 10 per cent. The DIALOG online information service, which is available in the Library, was of particular value, providing access to a large number of databases in forestry and related subjects.

The following technical publications were published during the year ending 31 March 1985.

Report

Report on forest research 1984 (£6.80)

Census Reports

The remaining 42 of the total of 65 national, Conservancy and county reports on the Census of Woodlands and Trees 1979-82 were issued (£3 each report).

Book

Decorative trees for country, town and garden, by A. F. Mitchell and J. Jobling (£9.95)

Bulletins

- 61 Technology transfer in forestry, edited by G. H. Moeller and D. T. Seal (£6.50)
- 62 Silviculture of broadleaved woodland, by J. Evans (£9.50)

Booklets

- 26 Mid diameter sawlog tables, 2nd edition (£2.25)
- 31 Top diameter sawlog tables, reprint (£1.35)
- 39 Forest mensuration handbook, reprint with minor amendments (£6.00)

Forest Records

- 126 Oak wilt, by J. N. Gibbs (90p)
- 127 Fertiliser experiments in established conifer stands, by R. McIntosh (£1.75)
- 128 The production of poles for electricity supply and telecommunications, by J. R. Aaron and J. S. Oakley (£1.00)

Leaflets

- 71 Ploughing of forest soils, by D. A. Thompson (£1.70)
- 83 Coppice, by R. E. Crowther and J. Evans (£1.75)
- 84 Guide to upland restocking practice, edited by A. J. Low (£2.25)

Arboricultural Leaflet

- 1 The external signs of decay in trees, by C. W. T. Young, 2nd edition as revised by D. Lonsdale (£1.00)

Research and Development Papers

- 134 Acid rain and forestry, by W. O. Binns (£1.00)
- 137 Mammal/bird/damage questionnaire 1983 (£5.50)

Miscellaneous

- Forest research, 5th edition.
- A list of trees and shrubs at Westonbirt Arboretum, by J. E. J. White (£1.50)
- Forestry Commission catalogue of publications 1985

Arboriculture Research Notes

This series is issued by the DoE Arboricultural Advisory and Information Service.

- 54/84/SILS Control of epicormic shoots on amenity trees, by D. Patch, M. P. Coutts and J. Evans
- 55/84/ENT The knopper gall, by M. R. Jukes
- 56/84/SEED Dormant tree seeds and their pre(sowing) treatment, by P. G. Gosling
- 57/84/EXT The brown-tail moth, by P. H. Sterling (CFI)
- 58/85/PATH Phytophthora root disease, by R. G. Strouts

Research Information Notes

- 84/84/SILN Scandinavian scarifiers and their potential for site preparation in British forestry, by P. M. Tabbush
- 85/84/ENTO The knopper gall, by M. R. Jukes
- 86/84/PHYS Timing of root development in Sitka spruce, by M. P. Coutts
- 87/84/WILD Animal incident investigation—abnormalities or deaths, by H. W. Pepper
- 88/84/WILD Birds of prethicket restocked plantations in north Wales. Report of joint RSPB/FC study 1983, by F. A. Currie
- 89/84/SILN Phosphate fertilisers in upland forestry—types, application rates and placement methods, by R. McIntosh
- 90/84/SILN Vegetative propagation of conifers using stem cuttings. I. Sitka spruce, by W. L. Mason
- 91/84/SILN Vegetative propagation of conifers using stem cuttings. II. Hybrid larch, by W. L. Mason
- 92/84/SILN Vegetative propagation of conifers using stem cuttings. III. Commercial conifers other than Sitka spruce and Hybrid larch, by W. L. Mason
- 93/84/FS 'MAPLE'—The Forestry Commission map digitising system, by A. I. D. Horne
- 94/84/FS The Forestry Commission subcompartment database I. Description of data held, by A. I. D. Horne and M. Whitlock
- 95/84/FS The Forestry Commission subcompartment database II. Background and current application, by A. I. D. Horne
- 96/84/SILN The use of tatter flags for exposure assessment in upland forestry, by B. R. Reynard and A. J. Low

B. G. HIBBERD

OTHER HEADQUARTERS DIVISIONS**PLANNING AND ECONOMICS****Forest Investment Appraisal Package (FIAP)**

In the Forestry Commission investment decisions are appraised using discounted cash flow techniques. A computer package, FIAP, has been written to do the calculations necessary for the economic appraisal of forest investment decisions. Figure 5 shows the structure of the package. The planting models describe the pattern of expenditure cash flows on a particular site over a rotation. The miscellaneous parameters define the calculation more precisely. Using the package allows the forest manager to carry out appraisals suited to his particular situation and to consider a wide range of possible options quickly and easily.

FIAP

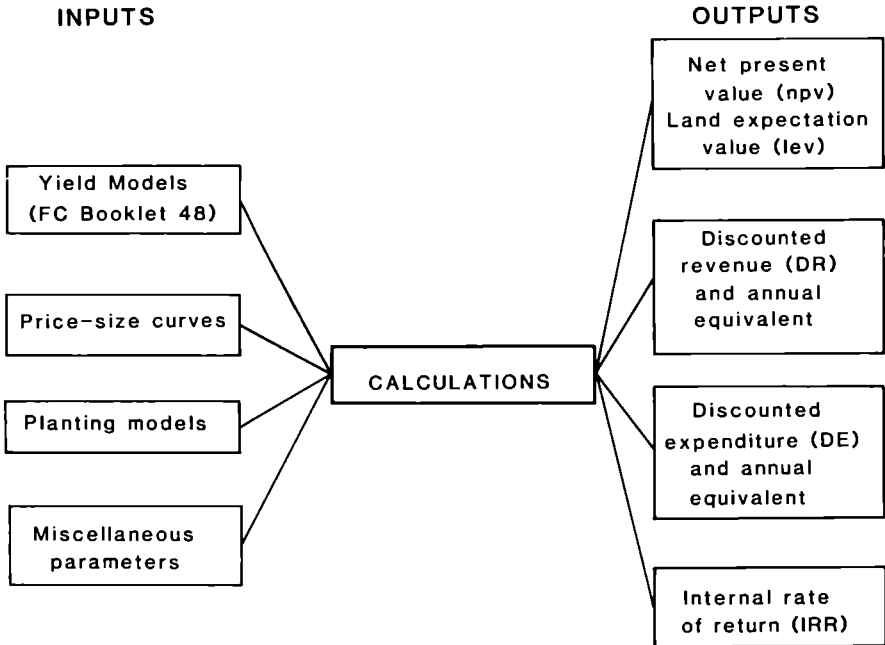


Figure 5. Structure of the forest investment appraisal package.

Price size curves

Last year's *Report* (1984, p. 57) noted that analyses had been made of standing sale prices in relation to species, distance from markets, as well as tree size. These detailed data were available for only a limited range of years. A general concern in appraisal and valuation is the shape of the long run relationship between price and tree size. Multiple regression analysis has been applied to average standing sale prices dating from 1957 in order to estimate a long run relationship between timber value and tree size. Allowance has been made both for the changing level and shape of the relationships over time and for differences between the English, Scottish and Welsh data. Some adjustment has been made in the lowest size categories in order to reduce errors arising from an inherent bias in the data. The long run price size curve is used for valuing stands in appraisal work and is expected to be adopted for the next quinquennial review.

D. S. GRUNDY

PART II

Work done for the Forestry Commission by Other Agencies

SILVICULTURE

Factors influencing accelerated growth of young trees in plastic tube shelters

by E. RENDLE

Horticulture Department, Wye College, Kent

The experiment established in May 1983 comparing the growth of young trees in the field, in shelters and in a glasshouse was continued through two growing seasons until November 1984. The effects of an extended light regime and the application of hormone (GA_3) were tested. All trees were well watered and kept free of weed competition. By the end of the second growing season all sheltered trees had grown out of their tubes, those under continuous illumination achieving a greater increase in height. Trees in the glasshouse grew considerably, some reaching over 3 m; those in constant light retained their leaves and grew throughout the winter.

There was no significant difference between the mean dry weights of field grown trees, with or without shelters, but the trees raised in the glasshouse maintained their weight advantage. The effect of the shelter or hormone treatments is not on the overall production of dry matter but on the way it is distributed within the plant. The proportion of total dry weight allocated to the stem is increased both by shelters and hormone but in the shelters this is associated with a decrease in the root fraction. Such differences are reflected in the stem/root ratio of sheltered trees (mean 2.75) compared with unsheltered (mean 1.37).

A computer data-logging system was used to monitor the physical environment within the shelter in terms of temperature, humidity and radiation. During hot weather both temperature and humidity are higher within the shelter than out in the field. Light levels are reduced during the middle of a sunny day but similar at other times. In late winter air temperature within the shelter rises above that outside during daytime, but may drop below ambient readings at night. Humidity is generally higher inside the tube. An examination of CO_2 concentrations at three heights within the shelters has shown that levels are higher at 30 cm than at 60 or 90 cm, the latter being the lowest recorded. When the soil surface within the tube was covered, the concentration of CO_2 at all heights was depressed, suggesting that the soil is a significant source of CO_2 within a shelter. The study of CO_2 levels will be continued in more detail.

Herbicide evaluation for forestry uses

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

*Agriculture and Food Research Council, Long Ashton Research Station,
Weed Research Division, Begbroke Hill, Yarnton, Oxford*

Weed control in seedbeds

Earlier (*Report 1984*, p. 60) we reported that dressing conifer seed with the herbicides diphenamid and napropamide controlled weeds in the seedbed and also stimulated crop growth of Sitka spruce and Lodgepole pine. Unfortunately, the stimulation did not recur in a subsequent experiment on Sitka spruce. The reasons for this disappointing result are not understood. However it is hoped to continue seed treatment studies as part of another programme with agricultural crops. Recent commercial developments in seed treatment technology are of interest and should enable chemicals to be applied much more evenly and accurately in future.

Weed control in transplant lines and young plantations

A limited number of new herbicides and formulations have been screened. The grass-killing herbicide haloxyfop (DOW 453) continues to show promise for selective use in coniferous or broadleaved crops. Treatment with sethoxydim in autumn controlled *Calamagrostis epigejos* and an application of 1 kg a.i./ha of FBC 32197 in July had useful effects against *Molinia caerulea*. Neither herbicide adversely affected any crop species.

A new oil soluble formulation of glyphosate prepared by reacting glyphosate acid with the cationic surfactant Ethomeen S12 is much more active than 'Roundup' against *Rhododendron ponticum* and *Calluna vulgaris* (heather). However this extra activity against weeds is achieved at the expense of reduced selectivity.

The most interesting result from experiments concluded in 1984 was from a trial with pot-grown *Rhododendron ponticum*. This investigated the use of adjuvants with medium volume and very low volume controlled drop applications of glyphosate and hexazinone. An extract from the results is given in Table 11. For all treatments, application of the same dose in more concentrated form (i.e. with the addition of less water) through a controlled droplet applicator significantly increased the activity of both herbicides.

Table 11 Weight of living leaf and current season's shoot growth after 12 months, as percentage of control

	Glyphosate (3 kg a.i./ha)		Hexazinone (3 kg a.i./ha)	
	Spray volume			
	250 l/ha	25 l/ha	250 l/ha	25 l/ha
No adjuvant	70	58	45	20
1.7% Ethylan D252	85	37	34	0
1.7% Ethylan D252 + 1.7% Agral (Mixture B)	54	28	67	0

Additives also improved phytotoxicity, effects with hexazinone being particularly marked. In the experiment, Ethylan D252 on its own was as effective as the mixture with Agral, 'Mixture B'. This was apparently because the surfactants in formulated glyphosate and hexazinone kept the Ethylan D252 in suspension. Ethylan D252 without water-soluble surfactants forms an unstable emulsion which is impracticable to use.

REFERENCES

- Turner, D. J. and Tabbush, P. M. (1985). Studies with alternative glyphosate formulations. *Proceedings of the British Crop Protection Council Symposium 'Application and Biology'* (BCPC Monograph 28), 135-145.
- Clipsham, I. D. (1985). Effects of application method and adjuvants on glyphosate and hexazinone phytotoxicity to *Rhododendron ponticum*. Tests of agrochemicals and cultivars 6. *Annals of Applied Biology* 106 (Supplement), 98-99.

The response of the tree stem and crown to wind loading and artificial loading

by P. BLACKBURN

Department of Forestry, University of Aberdeen

Further comparison of theoretically predicted and actual stem deflection curves involved 10 Sitka spruce trees in a tree-pulling experiment at Moffat Forest (Dumfries and Galloway) (*Report* 1984, p. 61). The soil was a peaty gley and the movement of the root plate was monitored. Following soil breakage two samples were released and re-pulled and, although the maximum resistance and the deflection at this point were unaltered, the initial force per unit deflection was halved. The theoretical stem bending curves gave good approximations to the actual curves until soil breakage occurred.

The critical windspeeds to cause uprooting were calculated using measured wind profiles and assuming static loading of the crown. Values obtained greatly exceeded the windspeeds recorded during a gale which caused damage. Recalculation using measured damping ratios and assuming that the gust frequency coincided with the tree frequency to cause resonance reduced the values to within the range of the maximum recorded gust. Displacements of three sample trees, estimated from accelerometer data, were compared with simultaneous windspeed recordings. Perfect resonance was not observed but very large oscillations were observed to build up over a period of two to three cycles. It appears that calculation of static forces is not a reliable basis for predicting critical wind speeds although it may be useful for comparative purposes.

Theoretical stability calculations for unthinned plantations at spacings of 2.0 m, 2.4 m and 3.0 m showed that for static loading the increase in the resistance to uprooting or breakage as a result of increasing mean tree size outweighed the greater drag force on the crown. Whether greater stability occurs in practice will depend on whether or not this increased resistance outweighs the effect of possible changes in damping ratios and of increased wind loading due to deeper canopy penetration.

SITE STUDIES

Effects of afforestation on water resources

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

Institute of Hydrology, Crowmarsh Gifford, Wallingford, Oxon

Effects on quantity

The emphasis has been on detailed checking of streamflow structure ratings and on methods of areal precipitation estimation prior to analysis of the accumulating data from the Kirkton (forested) and Monachyle (heather/grass) catchments at Balquhiddy during the year (Plate 5). Planning for the start of the clear felling operation in the Kirkton catchment in 1986 is well in hand.

In the physical process studies the major field programme on snow interception in forest canopies is nearing completion. Analyses of a number of storms have shown interception losses ranging between 40 and 69 per cent of total precipitation, figures considerably in excess of those expected from equivalent rainfall events. Results from the tree thinning experiment indicate that interception losses from rainfall before and after thinning are equal, within the experimental error. Detailed analysis suggests that the increased roughness of and wind penetration through the thinned canopy increases evaporation rates during rainfall to the point where this offsets the reduction in canopy storage. Future studies proposed include the measurement of the interception characteristics of larch using the gamma-ray attenuation technique and the application of simple soil moisture deficit modelling techniques to determine the effects of afforestation on low flow events.

Effects on quality

75 per cent of the Llanbrynmair Moor (Powys) experimental catchment has now been afforested and increases relative to the control catchment are appearing in both organic and inorganic nitrogen concentrations in the streamflow and in sediment losses, the latter arising mainly from access road erosion. Clear felling in the Hafren Forest (Powys) study will start in July 1985.

Nitrogen transformations in a forest soil and their influence on tree growth

by R. M. REES and J. W. PARSONS

Departments of Forestry and Soil Science, University of Aberdeen

This report summarises the results obtained at the end of a 3 year study.

Tree growth, litter fall and litter decomposition were measured in a 39-year-old stand of Sitka spruce near Aberdeen. A split plot experiment was used to examine the effect of nitrogen addition (200 kg ha⁻¹ N as (NH₄)₂SO₄) and carbon addition (1000 kg ha⁻¹ starch) in the main plots and trenching in the subplots. Weight loss from litter bags was 24 per cent in the carbon treated plots and 22 per cent in the nitrogen treated plots and in the controls, there being no significant difference between these treatments. Nitrogen availability and the total nitrogen concentration were highest in the

litter of the nitrogen treated plots throughout the course of the experiment. Small amounts of nitrogen were immobilised in the control plots during the first 8 weeks of the experiment. A 3.5 per cent increase from the total amount initially present was observed. This rose to 7.1 per cent and 9.7 per cent respectively in the carbon and nitrogen treated plots. Rates of CO₂ production measured in the field were found to be highest in the carbon treated plots.

Litter fall was seasonal with peaks in June and October. Greatest amounts of litter fell in the control plots (3410 kg ha⁻¹ y) although the needle litter in those plots also had the lowest nitrogen concentration (ranging from 0.75 to 1.14 per cent). Unexpectedly, trenching (the exclusion of live roots from a small plot of soil) slightly decreased the rate of litter decomposition. It also increased the moisture content, the availability of nitrogen, and amount of soluble organic nitrogen in the litter. Probably as a result of an adequate nitrogen status at the beginning of the experiment, little increase in tree growth was observed in response to added nitrogen.

GENETICS

Variation and inheritance of wood properties of Sitka spruce

by P. E. WOOD

Department of Plant Sciences, University of Oxford

In a pilot study in Clocaenog Forest (Clwyd), a 'Pilodyn' wood-density tester was used and the results were examined alongside those obtained from X-ray densitometry. The test with a 'Pilodyn' involves releasing a spring-loaded blunt pin into the wood (after removing a small area of bark) and measuring the depth of penetration. The test is simple, quick and non-destructive. There was a high correlation coefficient ($r = 0.92$) between pin-penetration and mean tree-density, measured over 20 individual trees by X-ray densitometry. It was therefore decided that the 'Pilodyn' would be used as a screening tool for large numbers of families in the progeny tests and from the results a smaller number of families would be selected for densitometry.

Fifteen-year-old families growing on two other sites were subsequently studied, at Tywi Forest (Dyfed) and Bennan Forest (Dumfries). On each site, 46 families were tested with the 'Pilodyn' (including 3 controls), and of these about 25 families were selected for densitometry. Cores 8 mm in diameter taken at breast height were used for the densitometry. The innermost rings were excluded from the results, since it was found in the pilot study that the high density of the juvenile core distorts predictions of the mean density of a whole mature tree. The correlations between pin-penetration and mean density, at the family-mean level, were 0.70 (Tywi) and 0.67 (Bennan). Differences between trees accounted for the greatest proportion of the variance, but family differences were highly significant and the mean family densities ranged from 0.41 to 0.51 g cm⁻³ at Tywi, and 0.37 to 0.46 g cm⁻³ at Bennan.

A smaller study has also been made of tracheid length and cross-sectional dimensions. The results are broadly similar to those of other studies (for example Dinwoodie, 1963) and family differences are small.

REFERENCE

Dinwoodie, J. M. (1963). Variation in tracheid length in *Picea sitchensis*. *DSIR Forest Products Research Special Report* 16. HMSO, London. 56 pp.

Investigation of the early failure of Sitka spruce grafts

by I. WEATHERHEAD and J. R. BARNETT

Plant Science Laboratories, University of Reading

Present investigations aim to distinguish the numerous possible factors involved in graft-failure so that parameters or conditions shown to have important effects on scion rejection can be removed or ameliorated. The factors involved may be divided into three main groups: those which are imposed by the grafting technique or procedure; those which are inherent in the species (genetic, physiological and biochemical characters) and within the clones grafted; and lastly, the post-grafting environment within polythene-skinned grafting houses.

Differences in the grafting success of scions from different Sitka spruce clones suggest a degree of genetic incompatibility. Certain clones may simply be better at withstanding conditions of water-stress, or it may be that a genetically-mediated positive rejection mechanism is involved. Physiological studies of the factors involved in failure, both before and after grafting, have shown water-stress within the scion to be of primary importance. This problem is currently being investigated with particular reference to the treatment of secondary scions immediately following collection from grafts 10–18 years old, and to the effect of storage upon water relations and tissue activity.

The development of cells at the graft union, as revealed by scanning and transmission electron microscopy (Plate 7), shows a sequence in successful grafts from the initial resin production by both rootstock and scion, through a phase of callus production, to the differentiation of primary-type xylem elements. It is possible that graft-incompatibility is caused by some chemical recognition process. Gas liquid chromatography is being used to determine if there are quantitative differences in resin monoterpene composition between successful and unsuccessful grafted Sitka spruce clones.

PHYSIOLOGY

Changes associated with ageing in Sitka spruce

by M. J. STEELE

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The age of the parent tree from which cuttings are taken can influence their ability to root. Generally there is a decrease in this ability with increasing age (Gardner, 1929; Black, 1972). To characterise further the changes occurring with tree age in apical whorl shoots (*Report* 1983, p. 61; *Report* 1982, p. 65) a rooting study of cuttings taken from trees aged 1, 4, 6, 11, 16, 21, 35 and 39 years was initiated in March 1984 and assessed over a period of 16 weeks. More than 95 per cent of the cuttings taken from trees aged 1

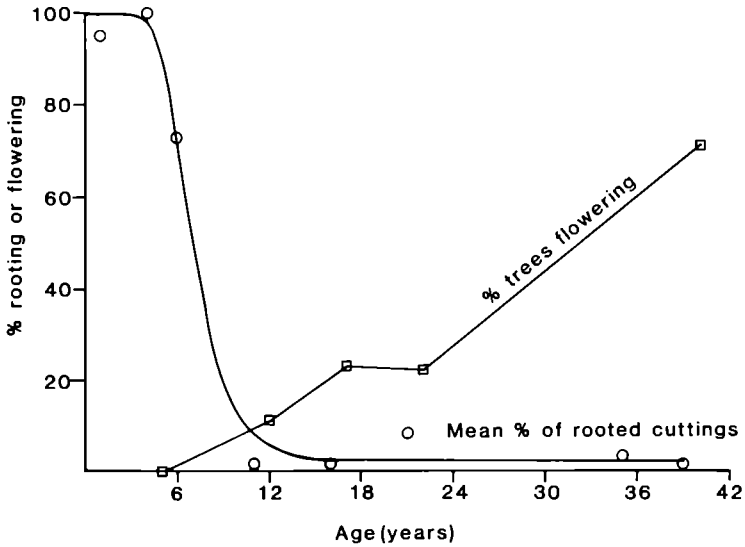


Figure 6. The decrease in the ability of cuttings to root and the increase in flowering with age for Sitka spruce.

and 4 years, and 73 per cent of those from 6-year-old trees had rooted by this time. But for those taken from 11-year-old trees the response was less than 2 per cent.

The relationship of rooting ability of cuttings with age (Figure 6) can be described using a modified Gompertz function and is similar to the other changes already characterised (*Report 1984*, p. 65). But more significantly it serves to illustrate the problem of attempting to use vegetative means of propagation to exploit the reliable prediction of later performance which for Sitka spruce can only be recognised at 8 to 10 years from seed (Gill, 1983). Using the relationship found in this study, the ability of apical whorl cuttings to root decreases from about 40 to 15 per cent between these 2 years. Although the proportion of cuttings which rooted would probably have been greater for cuttings taken from lower positions in the crown (Grace, 1939; Roberts and Moeller, 1978), much higher levels of rootings, with negligible plagiotropism, are required for economic mass propagation (Gill, 1983).

In August of 1984, which was an exceptional year for flowering, five of the plantations from which the cuttings were taken were sampled for numbers of individuals producing female flowers. This simple assessment shows an apparent increase in the number of flowering individuals with age (Figure 6), with only 11 per cent of the trees producing flowers by the age of 12.

The results further highlight the problem that, at the age at which future potential can be recognised, Sitka spruce is too old for vegetative propagation yet too young for sexual reproduction. In an attempt to overcome this seemingly intractable problem a number of different approaches are being considered. Currently, the regenerative capacity of explants from the shoots that have sprouted from newly felled trees aged 8 and 13 years are being examined since the *in vitro* propagation of explants taken from stump sprouts of Coast redwood more than 50 years old has been achieved (Boulay, 1979).

REFERENCES

- Black, K. (1972). The influence of shoot origin on the rooting of Douglas fir stem cuttings. *Proceedings of the International Plant Propagators Society* 22, 142-157.
- Boulay, M. (1979). Multiplication et clonage rapide du *Sequoia sempervirens* par la culture *in vitro*. In Micropropagation d'arbres forestiers. *AFOCEL, Etudes et Recherches* 12, 49-55.
- Gardner, F. E. (1929). The relationship between tree age and the rooting of cuttings. *Proceedings of the American Society for Horticultural Science* 26, 101-104.
- Gill, J. G. S. (1983). Comparisons of production costs and genetic benefits of transplants and rooted cuttings of *Picea sitchensis*. *Forestry* 56, 61-73.
- Grace, N. H. (1939). Vegetative propagation of conifers. I. Rooting of cuttings taken from the upper and lower regions of a Norway spruce tree. *Canadian Journal of Research* 17, 178-180.
- Roberts, A. N. and Moeller, F. W. (1978). Phasic development and physiological conditioning in the rooting of Douglas fir shoots. *Proceedings of the International Plant Propagators Society* 28, 32-39.

Immunoassay of endogenous hormones in Sitka spruce during cone induction

by A. CROZIER and T. E. BELL

Department of Botany, University of Glasgow

Changes in the levels of endogenous plant growth regulators which occur during the cone-induction phase have been investigated. Shoots were collected weekly from 28 April to 7 September 1982 from mature 14 years-grafted ramets of Sitka spruce. Tissue excised from the flowering zone in mid-crown was placed in liquid N₂ and subsequently stored at -20°C prior to analysis. Five gram samples of tissue, together with a [2,3-³H] gibberellin A₉ (GA₉) internal standard, were extracted with methanol and the extracts purified by polyvinylpyrrolidone chromatography and ion exchange chromatography on a DEAE cellulose support. The extract was then methylated with diazomethane and subjected to reversed phase high performance liquid chromatography (HPLC). Successive HPLC fractions were collected and aliquots tested with a radioimmunoassay for GA₁ and an enzyme-linked immunoassay for indole-3-acetic acid (IAA).

The GA₁ immunoassay exhibits cross reactivities with structurally-related GAs such as GA₃ GA₄ GA₅ GA₇ GA₈ GA₉ and GA₂₀. It thus provides a convenient method for assessing the levels of the biologically-important C₁₉-GAs. A GA₁-like peak was the major component in the Sitka spruce extracts and traces of GA₉ were also detected. The level of GA₁ fluctuated from 50 to 10⁴ picomoles g⁻¹ during the course of the late spring and summer while IAA was present at c. 10⁴ picomoles g⁻¹ and varied only slightly. Variations in GA₁ and IAA content were random in pattern and as a consequence it is not possible to associate them with either stem elongation, bud scale development or foliar and sporophyll differentiation. The hormone contents of new and old shoots from potted grafts subjected to hot-dry and cool-wet conditions were also examined. Once again there were no obvious correlations between subsequent cone production and the amount of IAA and GA₁ present.

Analyses carried out in collaboration with Dr T. Yokota, University of Tokyo, have established the presence of the steroidal growth regulators castasterone and typhasterol in *Picea* extracts. It will now be possible to test the effect of these substances on cone-induction in Sitka spruce.

Measurement of soil shear strength

by D. L. O. SMITH

Scottish Institute of Agricultural Engineering, Bush Estate, Penicuik

The shear strength of forest soil is being investigated as part of a study on the mechanics of windthrow. The apparatus, shown schematically in Figure 7, was designed at the Scottish Institute of Agricultural Engineering to measure the *in situ* shear strength of the interface between the soil-root ball and the root-free soil below mature trees. The method involves trenching around a tree stump to below the rooting depth and then measuring the torque required to rotate the root ball relative to the underlying soil. A mean shear strength of 13 (± 0.5) kPa was obtained for the soil below the stumps of five 34-year-old Sitka spruce growing in the peat of a peaty gley.

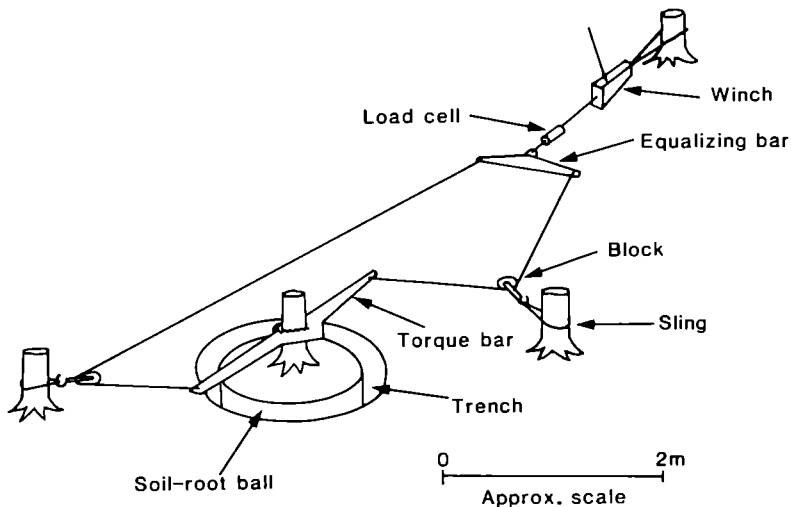


Figure 7. Apparatus for measuring soil shear strength.

Root strength in relation to windblow

by G. J. LEWIS

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

This project seeks to evaluate the mechanical properties of the following anchorage components of the root system of Sitka spruce: first, large diameter main lateral roots in bending on the leeward side of the tree and in torsion at points perpendicular to the direction of turning moment, and secondly, small diameter woody roots in tension on the windward side of the trees.

The work so far has concentrated mainly on the tensile properties of small diameter woody roots. Forestry Commission tree pulling experiments have shown this component to be the main resistance to uprooting when the applied turning moment is at a maximum (*Report 1984, p. 29*). The root

material has been collected from Beddgelert Forest (Gwynedd) and tested in tension with the root ends set in plastic tubes with dental grade plaster of Paris (Kaffer-D).

Over 700 individual tensile tests on small diameter woody roots have been carried out. The relationship between ultimate tensile stress and root cross section area (CSA) is approximately linear at least to a CSA below bark of 6 mm² (Figure 8). Further information is being obtained on roots of larger diameters. Investigations are also in progress on the variation in root tensile strength with distance from the tree stem, and the relationship between rootwood and stemwood strength properties in a set of 9-year-old Sitka spruce clones. Preliminary work has also been carried out in the study of the mechanical properties in bending of larger diameter roots.

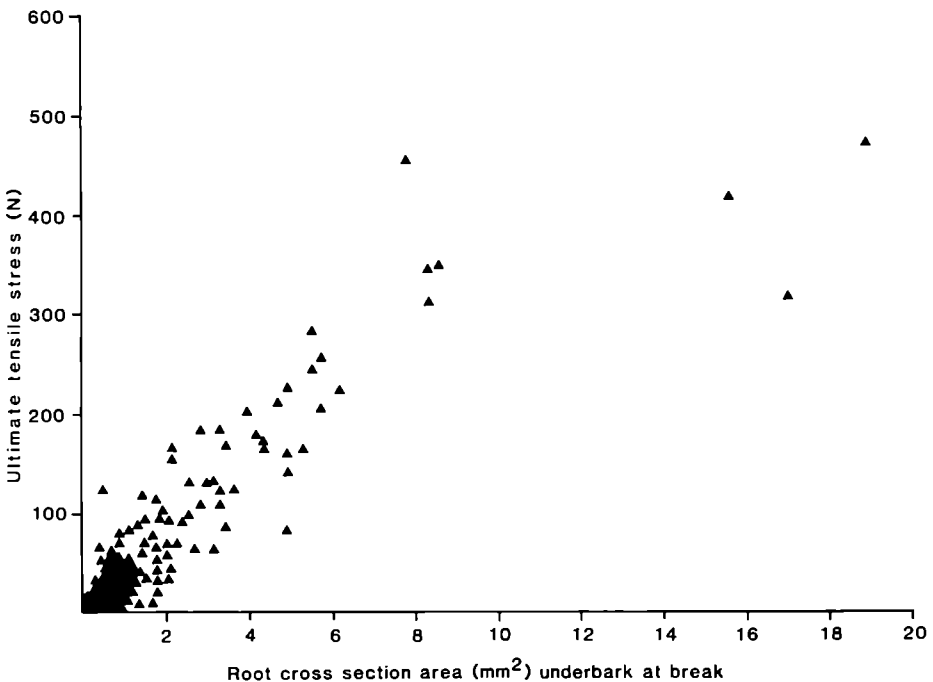


Figure 8. Tensile strength of Sitka spruce roots.

ENTOMOLOGY

Effects of the European pine sawfly on Lodgepole pine

by R. BRITTON

Department of Forestry and Natural Resources, University of Edinburgh

The following report represents the abstract from a recently completed Ph.D. thesis, the research for which was partly funded through a travel grant awarded by the Forestry Commission.

Outbreaks of the European pine sawfly, *Neodiprion sertifer* (Geoff.), are a common occurrence in young forest crops of Lodgepole pine. Damage in Britain has so far been largely restricted to plantations in the pre-canopy closure stage and due to the feeding behaviour of the pest, whereby only mature needles are consumed, crops survive these attacks and experience only a temporary loss of growth.

This study had two major aims. First, to investigate the physiological and nutritional processes at work in damaged trees and, second, to attempt an economic analysis of growth impact in young crops. Little attention has been given in the past to studying the growth impact of damage by this defoliator but developments in the biological control of this pest have led to an environmentally acceptable method of preventing outbreaks and, hence, the need to justify expenditure on such operations.

Field study plots were established at Shin Forest (Highland) which included an exclusion treatment, based on insecticide spraying, to compare growth of undamaged trees with various defoliation treatments, both natural and artificial. Modified regressions of total leaf area : sapwood basal area were developed so that defoliation could be defined quantitatively in terms of projected foliage surface area. Maximum sawfly defoliation caused an average loss of 20 per cent of the total foliage area over 2 years in a southern interior provenance of Lodgepole pine. Reductions in stem volume increment and height growth were greater, at 32 per cent and 31 per cent respectively, in 1983, the year of greatest defoliation, than in the first year of the study (1982).

Inorganic and organic nutritional studies revealed that this type of damage can result in varying effects on the remaining foliage, which appear to be very dependent on the stage of the outbreak and climatic factors. Major below-ground effects of severe sawfly damage were demonstrated in potted seedlings, where up to 50 per cent reductions in root dry weight were shown.

A survey of the incidence of *N. sertifer* confirmed that outbreaks are largely restricted to crops not exceeding 7 or 8 years of age. Height increment data were used to show that an outbreak can result in a total loss of 0.8 m growth over a six year period. Economic calculations showed that this represented a loss in revenue which exceeded the current costs of controlling an outbreak using biological control methods.

The study also includes reviews of the literature pertaining to both insect and host species, together with an overall review of quantitative and qualitative defoliation studies.

WOOD UTILISATION

Joint research programme on British-grown timber

by T. HARDING

*Princes Risborough Laboratory, Building Research Establishment,
Department of the Environment*

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

Timber from three more Forestry Commission spacing experiments has been studied. The influence of stocking density, resulting from planting distance

and thinning, on stem form and structural wood yields has been examined in a comparison of adjacent stands of Sitka spruce from Fernworthy Forest, Dartmoor. Structural wood yield from a closely planted (1.4 m spacing), lightly thinned crop was significantly higher, at 84 per cent of the sawnwood out-turn, than that from a wider planted (2.7 m spacing), unthinned but marginally younger stand, with a 52 per cent yield.

Differences in structural wood yields could be attributed to differences between the stands in stem form and size and number of branches, factors affected by planting distance and the opportunity offered by thinning for the selection of final crop trees.

Effect of wood characteristics on machine grading of Sitka spruce

Work has been initiated to determine the contribution of different growth features and their interaction on the performance of sawn Sitka spruce when machine graded. To date, effort has centred on developing measuring techniques to record growth features from battens and using them to start the collection of information on knots, grain alignment, cross-sectional growth details, wood density and machine stress grading stiffness, for a database for a computer model. Initial data have been collected for some 130 Sitka spruce battens and preliminary analysis has commenced.

Conversion of British-grown timber

A measuring survey has been carried out to assess the sawing accuracy being achieved in British mills using bandsaws and reducer bandsaws to produce structural timber, with a view to optimising the dimensional accuracy of British structural softwood. So far 12 sawmills have been examined and the dimensional variation within and between pieces determined, as well as the overall variation. The results have been compared with those published overseas and also with data from a parcel of overseas timber measured at Princes Risborough Laboratory. Indications are that the sawing accuracy of imported material (using bandsaws and reducer bandsaws) is markedly better than that being obtained in British mills. In continuation of this work the sources of inaccuracy will be identified in order to offer advice for improvement.

APPENDIX I

Publications by Forestry Commission Staff

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

AARON, J. R. and OAKLEY, J. S. (1985). *The production of poles for electricity supply and telecommunications*. Forestry Commission Forest Record 128.

Describes the level of demand and the process by which poles are accepted for use in this market. Refers to the newly published British Standard 1990 (Part 1) which extends the range of species accepted. Records the acceptance of British grown Norway and Sitka spruce which, if correctly selected and preserved, can meet the exacting levels of performance demanded.

ANDERSON, M. (1985). The impact of whole tree harvesting in British forestry. *Quarterly Journal of Forestry* 79, 33-40.

Interest in harvesting tree crowns as well as stems decreased with the recent depression in prices but may return as soon as smallwood prices rise. In upland areas all above ground parts of poorly grown and average Sitka spruce crops could be harvested, particularly on slopes. This could increase biomass yield by 25 to 30 per cent, but the phosphorus drain would also increase at least 4 and possibly 25 times. Since many upland sites are P-deficient this cost must be counted. Accelerated leaching, changes in decomposition, phosphorus fixation and waterlogging are other possible consequences.

BAILEY, J., YEOMAN, E. and WHITE, J. (1984). *Educational resources leaflet*. Westonbirt Arboretum.

Locally produced guide for teachers giving details of facilities available. Three coloured illustrations (one suitable as a poster) and an access map (in colour).

BALDWIN, E. (1985). Leyland cypress trials in the southern uplands. *Scottish Forestry* 39 (1), 3-7.

Between 1959 and 1972 nine plots of Leyland cypress were planted on a range of sites, all exposed or severely exposed and mainly on peat soils. Survival was generally good where protected against deer. Growth at 6 years averaged about 1m; at the end of 1982 all plots of Leyland cypress were shorter than adjacent Sitka spruce or Lodgepole pine.

BARBOUR, D. A. (1985). Patterns of population fluctuation in the Pine looper moth *Bupalus piniaria* L. in Britain. In *Site characteristics and population dynamics of Lepidopteran and Hymenopteran forest pests*, eds. Bevan, D. and Stoakley, J. T. Forestry Commission Research and Development Paper 135, 8-20.

The Pine looper *Bupalus piniaria* L. has been a sporadic pest of pine forests in Britain since 1953 and 1954, when the first outbreaks were experienced at Cannock Forest in central England and Culbin in east Scotland. Outbreaks have occurred primarily in plantations of Scots pine but areas of Corsican pine have also sometimes shown high populations. Since 1954 population monitoring has been carried out in about 50 different pine areas throughout the country by means of a winter survey of numbers of pupae in the litter.

BEVAN, D. and STOAKLEY, J. T. (eds.) (1985). *Site characteristics and population dynamics of Lepidopteran and Hymenopteran forest pests*. Forestry Commission Research and Development Paper 135.

Proceedings of a IUFRO conference at Dornoch, Scotland, September 1980. Nineteen papers (139 pp.).

BINNS, W. O. (1984). Vegetation and soils. In *Acid Rain*, Report 14, Watt Committee on Energy Ltd.

Air pollution has caused long-term vegetation changes and rainfall is currently acid in rural Britain. SO₂, NO₂, O₃ and acid rain can all contribute to plant injury, but interactions between them and with natural stresses are still poorly understood. Direct effects of acid rain *per se* on

vegetation are unlikely and mineral decomposition compensates for the loss of base cations in most soils. Ulrich has postulated a sequence of effects: growth enhancement followed by root damage and toxic accumulation of ions, ending with forest death; the hypothesis presently lacks proof. Lichen frequency allows distinction between damage from gaseous SO₂ and acid rain. A combination of pollutants, including O₃, may act directly through tree crowns to cause forest decline.

BINNS, W. O. (1984). Acid rain, farming and forestry. *Coal and Energy Quarterly* 41, 3-13.

The important primary pollutants are SO₂ and NO₂ with ozone as a secondary summer pollutant. Yields of farm crops may be reduced by pollutants but in remote areas they can respond to sulphur. Acid depositions can cause loss of bases from soils but forest decline does not seem to be initiated through the soil; it is a scattered death and decline with ozone and acid mists apparently involved, perhaps accentuated by drought and frost. Forests appear to increase acidity of fresh water in some restricted areas. There is so far no evidence of forest decline in Britain.

BINNS, W. O. (1984). *Acid rain and forestry*. Forestry Commission Research and Development Paper 134.

SO₂ pollution decreased from about 1970 and though rainfall is currently believed to be three to nine times more acid than 'natural' rain there is no evidence of direct damage to trees from acid rain *per se*. There is little evidence of damage to soils, but conifers over hard acid rocks appear to speed up the acidification of streams and lakes, leading to loss of fish. A combination of drought, frost, ozone, acid mists and SO₂ may be responsible for Central European forest decline. There is little evidence of pollution damage to forests in Britain, outside industrial areas.

BINNS, W. O. and CROWTHER, R. E. (1983). Land reclamation for trees and woods. In *Reclamation 83*, Proceedings of the International Land Reclamation Conference, Grays, Essex, 23-28. Industrial Seminars Ltd.

The establishment of trees is one way of reclaiming, landscaping and restoring ecological values of despoiled land. Such sites present many difficulties for young trees, though the input may be lower than for agriculture. Land forms leading to good drainage, the removal of compaction induced by earth-moving machinery, the right species, of the right type, well handled and planted, with good weed control are all most important. Ground cover plants must be chosen with attention to site tolerance and competitiveness. Mistakes are expensive to put right so all operations must take account of tree planting needs in a sound restoration plan.

BINNS, W. O., [DAVIS, R. D. and MUGLESTON, A. G.] (1983). Preliminary results of an experiment on the use of sewage sludge as a phosphate fertiliser in a coniferous forest. In *Processing and use of sewage sludge*, eds. L'Hermite, P. and Ott, H. Proceedings of the 3rd International Symposium, Brighton, Sussex, September 1983.

Rock phosphate was compared with two rates of sewage sludge on 30-year-old Corsican pine on an acid sandy soil in south England. The treatment supplied 50, 104 and 208 kg total P ha⁻¹ and the sludge also supplied 340 and 480 kg total N ha⁻¹. Foliar analysis after 6 months showed that the sludge treatment had significantly increased the P per cent. The N per cent was significantly increased by the higher rate of sludge. Soil analysis showed that most of the sludge had been absorbed by the litter layers.

BINNS, W. O. (1984). Weather and woodland. In *Woodlands, weather and water*, eds. Harding, D. J. L. and Fawell, J. K. Proceedings of the Institute of Biology Symposium, Edinburgh, March 1984, 1-12.

Most British forests managed primarily for wood production are growing on infertile soils in the wet and windy uplands. Forest trees must therefore be windfirm and tolerant of exposure: foresters are more constrained by wind than any other environmental feature. Growing conditions are nevertheless favourable, there is a long season with enough rain and serious droughts are rare. Mild winters can allow insect pests to build up and unseasonable frosts are common, though seldom catastrophic. Spruces are most profitable in the wetter regions and pines in the drier ones, but this basic choice is often modified for conservation and landscape values.

BLATCHFORD, O. N. (1984). The storage, classification and retrieval of research information. In *Technology transfer in forestry*, eds. Moeller, G. H. and Seal, D. T. Forestry Commission Bulletin 61, 88-91.

A review of the various systems and facilities available for handling scientific and technical information. Problems are highlighted and suggestions are made to help the forest researcher.

BRASIER, C. M. (1984). Inter-mycelial recognition systems in *Ceratocystis ulmi*: their physiological properties and ecological importance. In *The ecology and physiology of the fungal mycelium*, eds. Jennings, D. and Rayner, A. D. M. Cambridge University Press, 451-497.

Describes research on the ecology, physiology and genetics of three recognition systems operating between individual mycelia in *C. ulmi*: the vegetative incompatibility system, the sexual mating system and the sub-group fertility barriers; present epidemics, including evidence for a mechanism of antagonism between individual genotypes of *C. ulmi*, and evidence for the regulation of d-factor transmission by vegetative incompatibility.

BURDEKIN, D. A. (1984). Forestry research in Britain. *Biologist* 31 (1), 17-22.

An outline of the diversity of forestry research in Britain and current attempts to co-ordinate it. Subject areas include genetics and tree improvement, tree biology, silviculture, biotic damage, wood science and processing, environmental interactions, and the distribution, composition and properties of dry matters. The Forestry Research Co-ordination Committee will be reviewing selected areas of research.

CARTER, C. I. (1984). A preliminary list of the spiders of Cazorla. *Eos Madrid* 60, 23-26.

Three sampling methods were used to make a preliminary survey of the spider fauna of the Coto Nacional de las Sierras de Cazorla y Segura. Eighty one species, together with habitat notes, are recorded from this forest park. Twenty two species are thought to be new records for Spain.

CARTER, C. I., FOURT, D. F. [and BARTLETT, P. W.] (1984). The Lupin aphid's arrival and consequence. *Antenna* 8 (3), 129-132.

An account is given of the rapid spread of this newly arrived North American aphid species in Great Britain. The aphid's outstanding reproductive rate and association with wilting and die-back of lupins is discussed in relation to the afforestation of reclamation sites.

CARTER, C. I. and NICHOLS, J. F. A. (1985). Some resistance features of trees that influence the establishment and development of aphid colonies. *Zeitschrift für angewandte Entomologie* 99, 64-67.

Seasonal changes in soluble amino-acids of leaves and their relationship with the annual life cycle of *Periphyllus californiensis*, *Rhopalosiphum padi*, *Mindarus abietinus* and *Elatobium abietinum* is discussed. It is suggested that trees with a different phenology or containing certain secondary compounds, as well as those trees with physical barriers that can exclude aphids from feeding (such as with *Eucallipterus tiliac*), could be adopted to lessen the attacks by aphids.

CARTER, C. I. and NICHOLS, J. F. A. (1985). Host plant susceptibility and choice by conifer aphids. In *Site characteristics and population dynamics of Lepidopteran and Hymenopteran forest pests*, eds. Bevan, D. and Stoakley, J. T. Forestry Commission Research and Development Paper 135, 94-99.

Assessments of *Elatobium abietinum* infestations in Britain have shown that certain species and varieties of *Picea* are more prone to attack and support a higher aphid development rate than others. Two other kinds of aphid, also found on *Picea*, have a different grouping of species that they attack. Among the aphids that dwell on conifers it can be seen that both physical and biochemical qualities of the plant determine susceptibility and choice.

CHRISTIE, J. M. and EDWARDS, P. N. (1983). Do future establishments of permanent sample plots in Britain need to follow past practice to meet the requirements of forest management? In *Planning, performance and evaluation of growth and yield studies*, ed. Wright, H. L. CFI Occasional Paper 20, 4-9. Commonwealth Forestry Institute, Oxford.

The paper reviews the existing network of permanent sample plots and the growth models based upon them. It then discusses the advantages and disadvantages of possible alternative types of experiment and sample plots. These are still needed to improve existing growth models and construct new ones as well as to establish the effects of different treatments.

CROWTHER, R. E and EVANS, J. (1984). *Coppice*. Forestry Commission Leaflet 83.

Describes briefly the history of coppice as a silvicultural system and its present day influence. Sweet chestnut coppice is still a viable system, hazel coppice is worked in a few localities. The prospects for short rotation fuel wood coppices are discussed and other minor specialities are mentioned. Practical points over time of cutting, position and shape of cut, stocking and yield, are included.

DAVIES, R. J. (1984). The importance of weed control and the use of tree shelters for establishing broadleaved trees on grass-dominated sites in England. In *Proceedings of the ECE/FAO/ILO Seminar Techniques and machines for the rehabilitation of low productivity forest*. Turkey, May 1984.

The results of seven experiments are used to illustrate the mechanisms of weed competition and its effects. Studies of soil moisture tension and foliar nutrient content indicated that competition was primarily for moisture and nutrients reducing the survival and growth of young trees. These effects are greater on soils with poor moisture retention, or where the climate results in high soil moisture deficits. To be effective, weed control must eliminate root competition. This can be done by cultivation, herbicides or mulching; cutting weeds above ground level is ineffective. Tree shelters accelerate the height growth of young trees and protect them from mammals and herbicide drift.

EDWARDS, P. N. (1983). Portable data terminals for data collection in the field. In *Planning, performance and evaluation of growth and yield studies*, ed. Wright, H. L. CFI Occasional Paper 20, 10-14. Commonwealth Forestry Institute, Oxford.

The paper describes how data is collected manually, and how it used to be analysed manually but is now analysed by computer. The use of portable data terminals for data collection and analysis is described and the considerable advantages arising from their use are mentioned. An appendix lists the portable data terminals which are available.

[ENTWHISTLE, P. F.] and EVANS, H. F. (1984). Analysis of the natural spread of insect virus diseases in relation to pest control. In *Proceedings of the XVII International Congress of Entomology*, Hamburg, August 1984, 752.

The practical use of viruses to control pest insects relies on two main methods; firstly, dispersion in sprays, and secondly, dispersion through natural agencies. The latter is now amenable to analysis and is the subject of the paper. The pattern of primary dispersal from initially small epicentres of disease follows an indented curve of rapidly diminishing disease incidence with distance. Logarithmic transformation of the units of both disease quantity and distance reveals a linear relationship. Flattening of the primary dispersal curve precedes the development of a wave-like pattern, the secondary dispersal phase. Following this, the wave form is lost and is identified as the interference phase because of the interacting and confusing role of expanding adjacent secondary epicentres. Examples of baculovirus disease spread in populations of Lepidoptera, Hymenoptera and Coleoptera and its place as a control strategy is discussed.

EVANS, H. F. (1984). Spruce bark beetle—two years after. *Economic Forestry Group Magazine*, 11-13.

A general paper introducing the Great spruce bark beetle *Dendroctonus micans*. Biological details are given and are contrasted with the known biology of the beetle in Europe as a whole. Control measures including sanitation felling and introduction of the predator *Rhizophagus grandis* are described.

EVANS, H. F. (1984). Vigilance is vital in spruce beetle war. *Forestry & British Timber* 13 (6), 21-22.

A paper describing the history of *Dendroctonus micans* outbreaks throughout Europe and an assessment of the current status of the British outbreak. The chronology of attack in Britain is described and potential control measures discussed.

EVANS, H. F., KING, C. J. and WAINHOUSE, D. (1984). *Dendroctonus micans* in the United Kingdom. The results of two years experience in survey and controls. In *Proceedings of the EEC seminar on biological control of bark beetles*, 20-34.

The current outbreak of *Dendroctonus micans* in the United Kingdom is described. Surveys carried out in 1982 and 1983 indicated a drop in infested Norway spruce trees from 30 000 to 23 000, while numbers of infested Sitka spruce trees rose from 4800 to 5300 between years. At the same time infested sub-compartments rose from 289 to 1423 mainly resulting from a larger survey area. Aspects of the biology of *D. micans* are described and indicate that Sitka spruce may be more susceptible to attack than Norway spruce.

EVANS, J. (1983). Choice of Eucalyptus species and provenance for cold, temperate atlantic climates. In *IUFRO Colloque International sur les Eucalyptus resistants au froid*. Bordeaux, September 1983, 255-274.

Describes Eucalyptus research in Britain and Ireland. Only *E. gunnii* from central Tasmania and the Snow gums *E. debeuzevillei* and *E. niphophila*, have adequate hardiness to withstand the coldest of winters (down to -18°C) in Britain.

EVANS, J. (1984). *Silviculture of broadleaved woodland*. Forestry Commission Bulletin 62.

Silvicultural practices are described for broadleaved high forest, coppice and specialised woodland types such as farm woods, poor quality stands, upland woods and growing high quality timber. Detailed consideration is given to amenity, conservation and sporting aspects of broadleaved woodland management. Additional silvicultural notes are provided for each of the main broadleaved species.

EVANS, J. (1984). Soil and water management aspects of forestation. In *PUDOC Strategies and designs for afforestation, reforestation and tree planting*, 96-114.

Analysis of the role of tree planting to control soil erosion and modify the hydrological cycle under tropical conditions.

EVANS, J. (1984). Tree shelters—notes on their use. *Timber Grower* 93, 29-33.

Summary of recent experience with tree shelters and recommendations for their use in practice. It is stressed that shelters are not a means of reviving poor plants or ones badly handled or as a substitute for good weed control. They are an excellent aid to already good establishment practice.

EVANS, J. (1984). Measurement and prediction of site productivity changes. In *IUFRO Symposium on site and productivity of fast growing plantations*, S. Africa, 1, 441-456.

Site productivity change in successive rotations of fast growing plantations needs to be carefully monitored. Use of permanent sample plots, relocated in each successive crop, is the most certain way of detecting changes, but prediction of change still remains an inexact science, though advances in modelling ecosystem dynamics have improved knowledge of processes and the effects of various management practices.

EVANS, J. (1984). Maintaining and improving productivity of tropical and subtropical plantations. In *IUFRO Symposium on site and productivity of fast growing plantations*, S. Africa, 2, 893-905.

Overview of performance of tropical plantations and prospects for sustained productivity in the long term.

FARMER, R. A., ALEXANDER, A. and ACTON, M. (1985). Aerial fertilising: monitoring spread is vital operation. *Forestry & British Timber* 14 (4), 15-17.

The Forestry Commission fertilised 27 304 ha in 1984-5 at a cost approaching £2m. Although the future programme area will fall with the decline in new planting, application rates have been increased and fertilising will continue to represent a major establishment cost on a par with those of planting and weeding. The fertilising programme in the private sector will become of a similar magnitude.

FOURT, D. F. (1984). Preparation of mine spoil for tree colonisation or planting. In *Proceedings of the 9th Annual meeting of the Canadian Land Reclamation Association*.

Amelioration of physical constraints caused by the regrading of spoil or replaced topsoil is essential for successful growth of trees planted on disturbed land. Rooting volumes to supply 15 cm to 20 cm of reserve moisture need at least 75 cm of porous material, achieved either by loose-tipping or deep ripping of land-formed slopes by a heavy tractor pulling three winged tines. Amendments of mineral nutrients should usually be specified from foliar analysis rather than spoil assay. Nitrogen should be supplied in both replaced topsoil and by interplanted alders or legumes.

GIBBS, J. N. (1984). *Oak wilt*. Forestry Commission Forest Record 126.

Oak wilt, caused by the fungus *Ceratocystis fagacearum* (Bretz) Hunt, is only known to occur in the USA but there has long been concern that it might spread to Europe. This review has the following objectives: firstly to outline the history and biology of the disease and its means of transmission in the USA; secondly to consider whereby *C. fagacearum* might be introduced to Europe, and the steps which are being taken to prevent this; and thirdly to assess the threat to the oak population of Europe that the disease would pose if it were ever to become established here.

GIBBS, J. N., [LIESE, W. and PINON, J.] (1984). Oak wilt for Europe? *Outlook on Agriculture* 13, 203-207.

The most likely means for *Ceratocystis fagacearum* to reach Europe from North America is on wood. Veneer logs pose the most serious threat but it has been discovered that fumigation with 240 g methyl bromide/m³ for 72 hours will eliminate the fungus. Other research relevant to the regulation of the trade in veneer logs is discussed. Factors affecting the severity of oak wilt if the disease were to become established in Europe would include the resistance of the native oak species, and the effectiveness of native insects as vectors of the fungus. Recent research in this area is described.

GOSLING, P. G. (1984). Overcoming the dormancy of tree and shrub seeds. *Quarterly Journal of Forestry* 78 (3), 185-187.

The biological importance of seed dormancy is described and the characteristic features of some different types of dormancy are outlined. Standard methods for overcoming seed dormancy are discussed and some reasons for the effectiveness of dormancy breakage procedures are explained.

GOSLING, P. G. (1985). Seeds in slumber. *GC&HTJ* 197 (3), 20-21.

Popular misconceptions about seed dormancy are dispelled and this complex phenomenon is simplified in the form of a dormancy 'spectrum' illustrated by cartoons. It is stressed that for optimum results 'deeply' dormant seeds should always be pretreated before sowing and that recent research has shown how seeds exhibiting 'shallow' dormancy (under the optimum conditions used for seed testing) will always benefit from pretreatment if they are to be sown in the less than ideal conditions of the field. It is therefore a wise precaution to pretreat all seed where any level of dormancy is suspected.

GRAYSON, A. J. (1984). Evaluation of forestry research. In *Policy analyses for forestry development Proceedings*, IUFRO Division 4 Conference, Thessalonika.

Economic evaluation *ex ante* calls for certain general information that may not be readily available, together with estimates of the scale of benefit in physical terms that appears likely to be achieved. The speed and extent of application of research results compared with the position without the research under evaluation are of particular importance. Although the problem calls for no more expertise in cost/benefit analysis than is required in forestry generally, it emphasises the general lack of progress in evaluation of environmental effects.

GREGORY, S. C. (1983). The use of potato tubers in pathogenicity studies of *Armillaria* species. In *Proceedings of the Sixth International Conference on root and butt rots of forest trees*, Melbourne and Gympie, Australia, August 25-31, 1983, 148-160.

The pathogenicity to potato tubers of seven *Armillaria* isolates was tested. Isolates previously established as highly pathogenic to young conifers always infected a higher proportion of tubers than did isolates of low pathogenicity but the differences between isolates were not always

statistically significant. The technique described did not appear suitable for rapid pathogenicity screening of field isolates but it did enable some aspects of pathogenic behaviour to be observed: for example, highly pathogenic isolates tended to achieve infection via shorter lengths of attached rhizomorphs than did isolates of low pathogenicity.

GREGORY, S. C. (1984). Micro-organisms isolated from wounded stems of *Picea sitchensis*. *Transactions of the British Mycological Society* **83** (4), 683-686.

Details are given of micro-organisms isolated from unstained wood and stained wood associated with physical wounds on *Picea sitchensis* stems. The significance of these findings in relation to deterioration of the wood is discussed.

GREGORY, S. C. (1985). The use of potato tubers in pathogenicity studies of *Armillaria* isolates. *Plant Pathology* **34**, 41-48.

The pathogenicity to potato tubers of seven *Armillaria* isolates was tested. Isolates previously established as highly pathogenic to young conifers always infected a higher proportion of tubers than did isolates of low pathogenicity. However, the magnitude of the differences between isolates varied and the technique described did not appear suitable for routine pathogenicity testing. The experiments revealed differences between isolates in the length of rhizomorph that becomes attached to the host surface. This was consistently greater in isolates of high pathogenicity than in those of low pathogenicity and may be of significance to field behaviour.

GREGORY, S. C. [and WATLING, R.] (1985). Occurrence of *Armillaria borealis* in Britain. *Transactions of the British Mycological Society* **84** (1), 47-55.

A full description based on British material is given for *Armillaria borealis*, a lignicolous agaric and potential forest pathogen that has only recently been recognized as a taxonomic species. Details of the first British records are also given: it has been collected on both native deciduous trees and introduced conifers. The significance of the collections is briefly discussed in relation to the general European distribution and ecology of the species.

GREIG, B. J. W. (1984). Management of east England pine plantations affected by *Heterobasidion annosum* root rot. *European Journal of Forest Pathology* **14** (6), 392-397.

Heterobasidion annosum causes mortality and volume loss in first and second rotation pine crops. Control measures include stump treatment with *Peniophora gigantea* and stump removal on severely diseased sites.

HOLMES, G. D. (1984). Applying the results of forest research in Britain. In *Technology transfer in forestry*, eds. Moeller, G. H. and Seal, D. T. Forestry Commission Bulletin 61, 2-6.

The development and application of new techniques in forestry in Britain has been rapid and broadly successful. Reasons for this include: (1) the pressure to plant and manage forests on unfamiliar and new ground; (2) the concentration of research on defined practical problems; (3) the maintenance of close linkages between research personnel and forest managers, particularly by staff interchange; and (4) giving special attention to the form and presentation of published information, including series designed specifically for users. However, if new technology is to be rapidly introduced into future forest management, one can foresee a need for: (1) organisational changes to encourage and exploit fundamental research; (2) better methods of transferring information from researcher to manager; and (3) improved guidelines and methods for international transfer of technology.

HORNE, A. I. D. (1983). Current use of remote sensing in forest resource survey. In *Remote sensing and other methodologies in peat and terrain resource survey*. Proceedings of a symposium, Aberdeen, September 1983.

This paper deals with the requirements of forest resource survey in Britain and the present methods used to meet these needs, including use of aerial photography. Development of digital mapping and current projects aimed at assessing the potential of a wider range of remote sensing systems are discussed. The Forestry Commission has two main survey interests, the collection of national data on woodland in both public and private sectors and the continuing detailed survey of its own estate of some 1.25 million hectares. A regular national census

updates knowledge of the general extent and composition of woodlands and of non woodland trees. The detailed information required for effective management of Commission forests is updated on a 15 year cycle. Soil data are collected at time of land acquisition wherever possible.

HORNE, A. I. D. (1984). The value of Agrispine to forestry. In *Seminar on the results of Agrispine '82*. Royal Aircraft Establishment, Farnborough, October 1983.

Forestry is a long term industry with commercial rotations of conifers of 50 years or more and those for amenity broadleaves extending to as long as 300 years. The need for timely Landsat cover is thus not immediately apparent. However, where forest cover is lost either through man's action or due to natural disaster, early assessment of the extent of the change can be valuable to the forest manager. It was for this reason that the Forestry Commission wished to look at the potential of timely satellite data and so participated in the AGRISPINE project.

HORNE, A. I. D. (1984). Forest cover monitoring by remote sensing in Great Britain. In *Integrated approaches in remote sensing*, Guildford, April 1984, 99-107.

The Forestry Commission has an interest in the continuing survey of its own forest estate and in the collection of more generalised cover data for both public and privately-owned woodland throughout Great Britain. All survey requirements have been met up to now by a combination of aerial and ground survey. Use of aerial photography has posed problems of acquisition, due to weather, and through the high skilled labour input needed for interpretation. The FC are looking at the potential of other remote sensing techniques to meet their needs. It is in the field of woodland cover estimation and monitoring that satellite imagery shows the most immediate promise. The trials currently in progress to test woodland cover classifications are described. The end product is hoped to be a practical application for woodland monitoring.

HORNE, A. I. D. [CHURCHILL, P. N. and KESSLER, P. A.] (1984). A review of radar analysis of woodland. In *Earsel Conference on microwave remote sensing applied to vegetation*, Amsterdam.

With the launch of a number of satellite borne SAR's in the next decade, the need to research the potential of imaging radar to make land use determination becomes apparent. This paper reviews the woodland aspect of land use. Two major themes are studied: (1) to assess and review the ability of imaging radar to make woodland determinations and to summarise the optimum radar parameters required; (2) to review the imagery and methods used in the analysis of imaging radar data of woodland.

HORNE, A. I. D. and ROTHRIE, B. (1984). Use of optical SAR 580 data for forest and non-woodland tree survey. *Seminar on the results of the European SAR 580 radar experiment*. Italy, ISpra, May 1984.

The Forestry Commission's SAR 580 experiment used sites in different parts of Great Britain to reflect the range of woodland and topographic conditions existing in the country. The objective was to assess the potential of SAR for two district survey needs, the inventory mapping of forest crops and the census of non-woodland trees. Dual polarised X, C and L band optical radar data interpretation was compared with aerial photo interpretation, management crop maps and recent census data. Anomalies were ground checked where necessary. L-band SAR lacked the detail needed for good crop differentiation but good results were achieved with C-band and in particular with X-band where a high proportion of management boundaries were detected. The L-bands proved best for non-woodland tree detection, crown size being a limiting factor.

HOWELL, R. S. (1984). A 21st Birthday at Alice Holt. *Forestry & British Timber* 13 (12), 16.

It is 21 years since its first electronic computer was installed by the Forestry Commission's R&D Division. On the occasion of the 'Computers in Forestry' conference organised by the Institute of Chartered Foresters at Heriot-Watt University, a brief account is given of the development of computing in forest research at Alice Holt.

HOWELL, R. S. and STICKLAND, R. E. (1983). A stem analysis machine under development. In *Planning, performance and evaluation of growth and yield studies*, ed. H. L. Wright. CFI Occasional Paper 20, 61. Commonwealth Forestry Institute, Oxford.

A machine is described, the purpose of which is to allow changes in stand volume increments to be compared accurately over a number of years so that effects of insect attack, diseases, etc. can be estimated to provide a guide to management considering appropriate counter measures.

HUGHES, A. J. G. (1985). 'Snake' eases thinning chore. *Forestry & British Timber* 14 (2), 7. (see below).

HUGHES, A. J. G. (1985). The 'Snake'—a new system for timber extraction. *Timber Grower* 94, 35-36.

Describes this ingenious extraction system from Sweden.

HUGHES, A. J. G. (1985). Harvesting machinery—performance update. *Forestry & British Timber* 14 (3), 11-18

Purchase of mechanised timber harvesting units in Britain has been on a small scale but there are signs of this increasing in both the state and private sectors. The impetus has generally been the expectation of significant cost reduction but in some areas mechanisation is seen as the answer to shortages of skilled chainsaw operators.

KING, C. J. and EVANS, H. F. (1984). The rearing of *Rhizophagus grandis* and its release against *Dendroctonus micans* in the United Kingdom. In *Biological control of bark beetles*. Proceedings of a seminar organised by the EEC and the Université Libre in Brussels, 3-4 October 1984.

The paper discussed the initial control measures implemented against *Dendroctonus micans* after its discovery in the United Kingdom in 1982. The background to the decision to employ the specific predator *Rhizophagus grandis* as a means of biological control is also given. The mass rearing of *R. grandis* and its mass release into affected spruce forest is discussed. Techniques and problems of the rearing process are described.

[KOSKE, R. E. and] WALKER, C. (1984). *Gigaspora erythroa*, a new species forming arbuscular mycorrhizae. *Mycologia* 76, 250-255.

This paper describes a new species of fungus that is found commonly in sandy soils on the Atlantic coast of the USA and in the Bahamas. It is also known from a silt-loam apple orchard soil in New York State. The species forms endomycorrhizas with apple, onion, sorghum and ryegrass.

LEATHER, S. R. (1984). Factors affecting pupal survival and eclosion in the pine beauty moth, *Panolis flammea* (D&S). *Oecologia (Berlin)* 63, 75-79.

The proportion of adult *P. flammea* emerging from the overwintering pupae was markedly affected by pupation substrate, waterlogging, temperature and relative humidity. Pupae which had spent the winter in needle litter had a significantly greater survival rate than those in either soil or peat. Pupal weight loss was proportional to the length of time spent as a pupa. Female pupae lost proportionately more weight than male pupae. Pupae of both sexes lost more weight at a low relative humidity than at a high relative humidity. At low relative humidities female pupal mortality was higher than that of male pupae.

LEATHER, S. R. (1984). The effect of adult feeding on the fecundity, weight loss and survival of the pine beauty moth, *Panolis flammea* (D&S). *Oecologia (Berlin)* 65, 70-74.

Adult females fed on a saturated honey solution laid significantly more eggs than those individuals given water only or not fed at all. At 20°, the longevity of both male and female moths was significantly increased when they were supplied with a food source. In fed females, no significant weight loss occurred over the reproductive period, irrespective of the number of eggs laid or the longevity of the individual. It is concluded that adult females of *P. flammea* are likely to require an extra external food source to achieve their full reproductive potential.

LEATHER, S. R., [CARTER, N., WALTERS, K. F. A., CHROSTON, J. R., THORNBACK, N., GARDNER, S. M. and WATSON, S. J.] (1984). Epidemiology of cereal aphids on winter wheat in Norfolk, 1979-1981. *Journal of Applied Ecology* 21, 103-114.

The cereal aphid outbreaks of 1979 (*Metopolophium dirhodum*) and 1980 (*Sitobion avenae*) and their lower population levels in 1981, in Norfolk, are described. The high incidence of cereal aphid outbreaks in Norfolk is probably due to a combination of factors, including: the high hectareage devoted to cereals; the low numbers of aphid-specific and polyphagous predators present early in the season; and the dry conditions during the immigration period. It is suggested

that monitoring for *M. dirhodum* could be carried out on roses in the spring, while a forecasting scheme for *S. avenae* can only be developed when a greater understanding of its life cycle is obtained.

LEATHER, S. R. [and DIXON, A. F. G.] (1984). Aphid growth and reproductive rates. *Entomologia Experimentalis et Applicata* 35, 137–140.

Aphid size, although generally a good indicator of fecundity, is not a good indicator of aphid performance over a wide range of conditions. In general, the greater the mean relative growth rate (MRGR) of apterous morphs of *Rhopalosiphum padi* (L.), the greater their fecundity. Intrinsic rate of increase (r_m) is even more closely correlated with mean relative growth rate than fecundity. Once these criteria are quantified for a morph of a particular species of aphid over a range of conditions the morph's intrinsic rate of increase on a particular host can be estimated by a quick measure of its mean relative growth rate.

LEATHER, S. R. [and WALTERS, K. F. A.] (1984). Spring migration of cereal aphids. *Zeitschrift für angewandte Entomologie* 97, 431–437.

In those years when successful overwintering does not occur on cereal crops, the timing of colonisation and the number of alatae of the cereal aphids *Sitobion avenae* and *Metopolophium dirhodum* entering cereal crops before the end of flowering (DS 69), are related to the likelihood of an outbreak occurring. The earlier egg hatch of *Rhopalosiphum padi* occurs, the earlier alatae of this aphid are caught in suction traps. The number of eggs laid on the primary host, *Prunus padus*, is correlated with the number of emigrants (winged migrants) produced in the spring. The development of populations of *M. dirhodum* preceding the 1979 outbreak in Norwich is discussed.

LINES, R. (1984). Forestry Commission trial plantations in the Pennines. In *Ecological effects of deposited sulphur and nitrogen compounds*, ed. Beament, J. Philosophical Transactions of the Royal Society of London, Series B.

Twenty experiments including 26 species were planted between 1951 and 1957. Lead dioxide gauges set up in 1956 showed relatively high levels of SO₂. Marked improvement in growth of Sitka spruce was noted in the late 1960s as local urban pollution fell. A new set of lead dioxide gauges showed that in 1978–82 pollution had fallen by 50 per cent at these sites. Improvement in Sitka spruce growth contrasts with reduced diameter increment of Norway spruce in northern Germany over the same period.

LINES, R. (1984). *Pinus nigra* in den Pennine—Hügeln in Nordengland. *Allgemeine Forstwirtschaftschrift* 23, 593–595.

Two series of trials with *P. nigra* are described. One set of species trials compared Corsican and Austrian varieties with 24 other species under conditions of moderate pollution by SO₂. The other series comprised four provenance trials with a total of 47 seed sources. Results at 10 and 20 years are given. *Brunchorstia* dieback terminated the trials on the higher elevation, moist sites, at 20 years.

LINES, R. (1984). Man's use of birch—past and present. In *Proceedings of the Royal Society of Edinburgh* 85B, 203–213.

Man has found a diversity of uses for birch at least since Mesolithic times. In the medieval period, it was used for all kinds of domestic and agricultural purposes and it is remarkable how early its beneficial effects in silviculture were appreciated. Similarly, its amenity value has been appreciated for centuries in the rural scene and today it is employed in urban improvement too. Its importance for fuel and charcoal goes back into the distant past. Its bark is unique, with a range of end products from trinket boxes in northern Europe to large canoes in Canada. The trade in birch products is very large in eastern North America, while in Finland the plywood industry is also important. Birch will continue to play a significant role in British forestry, both as a nurse species and as the main amenity species for poor and exposed sites.

LONSDALE, D. (1984). Available treatment for tree wounds: an assessment of their value. *Arboricultural Journal* 8, 99–107.

No evidence exists by which currently available wound dressings can be recommended for long-term protection against decay. Some treatments can delay colonisation by decay fungi, perhaps to a useful degree in the case of the biocontrol agent *Trichoderma viride*. Some treatments can

prevent infection of wounds by aggressive 'fresh wound parasites'. Wound closure is enhanced by many types of treatment, particularly where thiophanate methyl is an ingredient, and is perhaps worthy of consideration in the case of moderate sized wounds.

LONSDALE, D. (1984). *The external signs of decay in trees*. Arboricultural Leaflet 1 (Second edition: revised from the original edition written by the late C. W. T. Young).

This leaflet seeks to give information enabling those responsible for trees to make a visual examination for signs of decay. In law, a tree owner is normally liable for any damage caused by branch shedding or falling of the tree. People with responsibility for trees should inspect them at regular intervals. If symptoms of ill health are detected, expert advice should be sought.

LOW, A. J. (1985). *Guide to upland restocking practice*. Forestry Commission Leaflet 84.

Restocking felled areas in upland forests form an increasing proportion of total annual planting in Britain. Problems involved often differ from those reflecting first rotation planting and the leaflet provides practical advice to managers. Successful restocking requires consideration of each part of the process from harvesting of the previous crop through site preparation, species choice, type and handling of planting stock and the actual planting operation to prevent damage by weeds, insects, fungi and mammals. Good forest design is important for amenity and conservation reasons. Management of natural regeneration may be necessary.

McINTOSH, R. (1984). *Fertiliser experiments in established conifer stands*. Forestry Commission Forest Record 127.

Results are presented from 55 fertiliser experiments in established Scots pine, Sitka spruce and Norway spruce stands in upland Britain. Application of nitrogen consistently increased basal area increment in Scots pine stands and top whorl foliar nutrient concentrations gave reliable indications of the likely degree of response. Results from the spruce experiments were more variable. Although responses to nitrogen, phosphorus and potassium were recorded, there was no consistent pattern of response. There also appeared to be an interactive effect between thinning and fertiliser in pine as opposed to an additive effect in spruce.

MASON, W. L. (1985). Clones to replace forest seedlings? *Forestry & British Timber* 14 (1), 24-26.

Reviews the development of techniques for the vegetative propagation of improved Sitka spruce. The background to current large-scale production trials is also explained.

MASON, W. L. and SALE, J. S. P. (1984). Herbicides for use on stand-over seedbeds. *Annals of Applied Biology* 105, 409-420.

Lack of effective herbicides for weed control in stand-over seedbeds is an important problem in current nursery practice. Trials of nine potential herbicides were carried out at two sites. Seven of them were more effective than the current recommendation, Diphenamid. Five herbicides have been selected for further testing.

MERCER, P. C. (1983). Callus growth and the effect of wound dressings. *Annals of Applied Biology* 103, 527-540.

Growth of callus tissue on tree wounds tended to be greater if wounds were flush, large and treated with a wound dressing, particularly one containing thiophanate methyl, if the trees were young and vigorous or had had an application of fertiliser. Growth of callus also varied with species, but in beech, at least, did not appear to be affected by season of wounding.

MERCER, P. C. (1984). The effect on beech of bark stripping by Grey squirrels. *Forestry* 57 (2), 199-203.

In 1979 a survey of beech trees in the Chiltern hills was carried out to establish the extent of damage caused to trees by grey squirrels. The frequency of attack was greatest around the age of 40 years and was concentrated on the bases of the trees. A very high proportion of the wounds (80 per cent) were not stained or decayed more than four annual rings into the tree. Callus growth was generally dependent on the age of the tree, being poor in older trees, but it also tended to be greater with bigger wounds.

MERCER, P. C. and KIRK, S. A. (1984). Biological treatments for the control of decay in tree wounds. I. Laboratory tests. *Annals of Applied Biology* **104**, 211-219.

Non-decay fungi and bacteria which had been isolated from pruning wounds of beech were examined for their ability to check the growth of decay fungi in a number of laboratory tests. Several fungi and bacteria inhibited growth although the degree of inhibition varied to some extent with the test. The most consistently antagonistic fungi were *Trichoderma* spp., especially an isolate of *T. viride*. The most antagonistic bacteria were *Bacillus* spp.

MERCER, P. C. and KIRK, S. A. (1984). Biological treatments for the control of decay in tree wounds. II. Field tests. *Annals of Applied Biology* **104**, 221-229.

Tree wounds were treated with several potential biological control agents. Of these, *Trichoderma viride* persisted the longest and was still present in most wounds after 4 years. Its establishment was aided by the addition of glycerol and, in the case of a commercial *Trichoderma* preparation on stub wounds, its persistence was enhanced by coverage with a sealant. The test organisms colonised some wounds from natural inoculum sources, especially so in the case of *Trichoderma* when wounds were treated with glycerol or PVC sheet. *Trichoderma* was the most successful biocontrol agent, reducing colonisation by decay fungi to c. 15 per cent of the control value after 4 years.

MERCER, P. C., KIRK, S. A., [GENDLE, P. and CLIFFORD, D. R.] (1983). Chemical treatments for control of decay in pruning wounds. *Annals of Applied Biology* **102**, 435-453.

Wound treatments, including sealants, fungicides and combinations of both, were evaluated for phytotoxicity and their effects on wound infection. Greatest phytotoxicity was shown by materials normally employed as timber preservatives, and the least by sealants. Microbial colonisation was not prevented by any treatment, but it was delayed by 'Santar' (sealant plus mercuric oxide) and 'Australian Arboreal' (PVA sealant plus captafol). Some treatments had a selective effect on colonisation by different fungi, and two of them ('Santar' and the sealant 'Lac Balsam') reduced colonisation by basidiomycetes while most others delayed this process. After 12 months all sealants showed some visually apparent breakdown and/or growth of fungal fruit bodies.

MITCHELL, A. F. (1985). Leaves from a tree measurer's diary. *International Dendrology Society Year Book 1984*, 85-91.

MITCHELL, A. F. and JOBLING, J. (1984). *Decorative trees for country, town and garden*. HMSO Books.

Describes the selection of both common and rare trees for particular purposes and environments. The features, merits, limitations, origin and occurrence of some 350 species and cultivars, listed in alphabetical order by scientific name in two sections—broadleaves and conifers—are included, along with colour photographs, line drawings and a colour key to aid choice of tree for types of soil, site and special uses.

[MOELLER, G. H. and] SEAL, D. T. (1984). *Technology transfer in forestry*. Forestry Commission Bulletin 61.

Proceedings of a IUFRO meeting 'Applying the results of forestry research' held at Edinburgh University, July 1983. Over 20 papers are included which outline national approaches to the transfer of technical forestry information from researcher to user, case examples and general principles. Conference recommendations are listed for both researchers and users of research results. The need to inform potential users of research results so that advances can be adopted quickly and efficiently in the field, is of paramount importance. This compilation of papers provides ideas on how this aim can be effectively accomplished, and also alerts the reader to potential pitfalls which can hinder the process of technology transfer in forestry.

[MORTON, J. B. and] WALKER, C. (1984). *Glomus diaphanum*: a new species in the Endogonaceae common in West Virginia. *Mycotaxon* **21**, 431-440.

A new species of vesicular-arbuscular mycorrhizal fungus is described which forms abundant soil-borne and intraradical spores. It is most commonly encountered in coal surface minesoils in West Virginia, but can also be found in agricultural soils.

MUHL, R. G. and HAYES, F. W. (1984). 'Contour felling'—a new extraction method. *Forestry & British Timber* 13 (5), 20-23.

The contour felling method was developed during a 3 year project to improve the efficiency of harvesting operations on mountainous terrain. The method results in brash free, orderly zones of produce which allow for easy chokering of optimum site cable crane loads. There are significant ergonomic and safety benefits to operators during the felling phase.

NEUSTEIN, S. A. and SEAL, D. T. (1984). Technology transfer: lessons of the British experience. In *Technology transfer in forestry*, eds. Moeller, G. H. and Seal, D. T. Forestry Commission Bulletin 62, 97-100.

This paper focuses on aspects of the British Forestry Commission's experience with technology transfer from which useful lessons may be drawn. Object oriented research is valueless until its fruits are applied. Shortening the period of introduction confers both economic and social benefits at the commercial and national levels. A prerequisite for wide-scale technology transfer is, firstly, a firm and specific endorsement by senior level management. This must go beyond statements of broad policy. Secondly, special staff officers must be designated to major new systems or initiatives.

PATCH, D. (1984). Kortere palen beter voor ontwikkeling van domen (tree staking). *Tuin and Landschap* (7th November), 16-17.

Current practices of staking are believed to reduce physical damage and vandalism in newly planted trees. Research and mathematical modelling suggest that some of the techniques of staking increase the ease with which a stem can be broken compared with unsupported stems. Modifications to staking practices are suggested.

PATCH, D. (1984). Safety first. *Practical Gardening* (November), 52-53.

A review of the causes of winter damage to garden trees with advice on protecting trees and effecting repairs.

PHILIPSON, J. J. (1985). The promotion of flowering in large field-grown Sitka spruce by girdling and stem injections of gibberellin A_{4/7}. *Canadian Journal of Forest Research* 15 (1), 166-170.

Mature 14-year-old grafted Sitka spruce which were field grown and 6 m tall were given stem injections of gibberellin A_{4/7} (GA_{4/7}) alone and in combination with girdling. GA_{4/7} alone produced a large and significant stimulation of the numbers of both pollen and seed cones, with means of about 200 pollen and 90 seed cones per tree, with 90 per cent of the clones flowering. The girdling treatment enhanced flowering when environmental conditions facilitated light flowering of the controls, and also increased the response to 100 mg GA_{4/7}. The stimulation of flowering was carried over into the 2nd year after treatment, but only when both girdling and GA_{4/7} had been applied together.

PHILLIPS, M. T. T. (1984). La Pine—a Lodgepole pine origin of interest. *Scottish Forestry* 38 (4), 248-250.

Describes the native habitat of a high elevation source of Lodgepole pine in Oregon and the performance of trees derived from seed collected from the area and grown on upland sites in north-eastern Scotland.

PHILLIPS, M. T. T. (1984). Small-scale seed collections can cause problems. *Forestry & British Timber* 13 (7), 26-27.

A discussion on how trees derived from seed collected from small populations may grow poorly as a result of inbreeding depression, a condition which may not become manifest until the F₂ and later generations.

PYATT, D. G. (1985). Site types in forests of Sutherland. In *Site characteristics and population dynamics of Lepidopteran and Hymenopteran forest pests*. Forestry Commission Research and Development Paper 135, 72-74.

The physical geography of the county of Sutherland is unusually diverse. It stretches from the Atlantic seaboard on the west to the North Sea coast on the east, as well as having a long coastline to the north. Towards the western side of the county lie mountains forming the northernmost part of the main watershed of north-west Scotland.

RATCLIFFE, P. R. (1984). Population dynamics of Red deer (*Cervus elaphus*) in Scottish commercial forests. *Proceedings of the Royal Society of Edinburgh* 82B, 291-302.

Describes the population dynamics of red deer in commercial forests. Simulation models indicate that high fertility and survival rates in many populations demand culling rates of c. 20-22 per cent/year in order to control numbers. In Galloway, south-west Scotland, the red deer population has increased dramatically with the expansion of commercial forestry between 1960 and 1980.

[RAYNER, A. D. M. and] WEBBER, J. F. (1984). Interspecific mycelial interactions—an overview. In *The ecology and physiology of the fungal mycelium*, eds. Jennings, D. H. and Rayner, A. D. M., 383-417. Cambridge University Press.

The value of studies of interspecific mycelial interactions in ecological, physiological and applied aspects of mycology is stressed. The need to consider such interactions in relation to the mycelial habit and ecological strategies of fungi is emphasised, and a new terminology, commensurate with this approach, is introduced. The range of types of interaction, at the gross-mycelial, hyphal and sub-hyphal levels, which can occur in culture between mycelia both of taxonomically close and widely divergent pairs of fungi, is reviewed, and what is known, or needs to be known, about the underlying mechanisms discussed.

REDFERN, D. B. (1983). Factors affecting spread of *Heterobasidion annosum* in plantations. In *Proceedings of the Sixth International Conference on root and butt rots of forest trees*, Melbourne and Gympie, Australia, August 25-31, 1983, 104-114.

Inoculation experiments were carried out to study the development of disease caused by *H. annosum* in Sitka spruce plantations growing on a range of soils in upland Britain. The soils tested varied from well drained mineral soils to poorly drained peat soils. Infection occurred to some extent on all soils but was generally most severe on mineral soils, particularly those in which rooting depth was restricted by a high water table. Soil has a direct effect on infection but factors which influence the frequency of root contacts, such as preplanting site preparation, may have a more important effect on disease spread than has hitherto been recognised.

RENNOLLS, K. and TEE, V. (1983). Estimation of the volume of a stand using a tariff procedure. In *Planning, performance and evaluation of growth and yield studies*, ed. H. L. Wright. CFI Occasional Paper 20, 91-99. Commonwealth Forestry Institute, Oxford.

Reviews previous work on tariff systems of measurement and introduces a more detailed model of the relationship between tree volume and d.b.h. than the usual volume-basal area line of Hummel (1955). The parametric estimation of this model from a 'volume-sample' and the use of the estimated parameter, together with a girth sample to estimate the total volume of the stand, are discussed. It is found that some improvement over the usual tariff estimator is possible (Hummel *et al.* (1962)). On considering if efficiency might be improved by changing the sampling fractions, it is found that the sampling fractions used in practice are remarkably close to optimum.

RENNOLLS, K., TEE, L. A., TEE, V. and MELVILLE, R. (1984). An empirical trial of a deer damage assessment method. *Forestry* 57 (1), 17-33.

This practical method of monitoring deer damage to plantations gives an estimate of the proportion of trees damaged and its standard error. It also allows the forest manager to calculate the sample size that he must use in order to obtain a target precision. An empirical trial of the method is described for a range of damage configurations which vary both in degree of clustering/regularity and intensity of damage. For all but the most clustered damage patterns the method provides estimates which are, for all practical purposes, unbiased and the standard error formula and sample size determination formula perform satisfactorily. For the most clustered damage patterns the estimates are slightly biased, but in this case the accuracy of such an estimate is well represented by the calculated standard error.

ROLLINSON, T. J. D. (1983). Biomass estimation for open-grown trees. In *Mesures des biomasses et des accroissements forestiers*, 31-36. Les colloques de l'INRA 19.

An outline method is presented for the determination of the biomass of open-grown trees using photographs and an image analysing computer. Results from a preliminary trial of the technique suggest that it should be possible to analyse and measure separately stemwood, large branchwood and small branchwood.

ROWE, J. J. (1984). Golden eagle and fox competing for Mountain hare. *Scottish Birds* 13 (3), 87-88.

Describes the competition between immature Golden eagle and fox in killing mountain hare.

ROWE, J. J. (1984). Grey squirrel (*Sciurus caroliensis*) bark stripping damage to broadleaved trees in southern Britain up to 1983. *Quarterly Journal of Forestry* 78 (4), 231-236.

Details of a damage survey carried out in private and FC woodlands in the south of England and Wales. Includes a description of the methods used and results obtained. Comments are made on the control measures used and conclusions given.

SEAL, D. T. and MILLER, K. F. (1984). What's happening about windthrow? *Forestry & British Timber* 13 (10), 24, 27.

Current Forestry Commission research programme on the improvement of plantation stability is outlined, including descriptions of recent aeromechanics research and work to increase root development on unstable soils.

STOAKLEY, J. T. (1984). The use of Dimilin against Pine looper moth, *Bupalus piniaria*, outbreaks in Scotland. In *Proceedings of the Dimilin® Forestry Seminar*, 7-8th November 1984. Dupham B. V., Weesp, Holland.

The life cycle of Pine looper and damage caused are described. Earlier outbreaks in Scots and Corsican pine were controlled using DDT and subsequently Tetrachlor-Kimphos. In 1979 a small outbreak (72 ha) on Lodgepole pine, the first on this host, was successfully controlled using Dimilin (diflubenzuron) and the same insecticide applied at ultra low volume was used, again giving good control, against an outbreak in 1100 ha of Scots pine in 1984.

TABBUSH, P. M. (1984). Scandinavian scarifiers—prospects in Britain. *Forestry & British Timber* 13 (9), 45-46.

Silvicultural aspects of site preparation for restocking are related to the effects of ploughing and scarification. The TTS-Delta disc-trencher, Bräcke patch-scarifier and Sinkkilä 2 moulder and their methods of working are described and suggestions given for suitable prime-movers.

TABBUSH, P. M. (1985). Grass weeding—why do it? *Forestry & British Timber* 14 (2), 12-13.

The evidence concerning the benefits of grass weeding Sitka spruce in the moist uplands is reviewed, and results summarised for 11 experiments in which unweeded controls were compared with handweeding or herbicidal weed control. It is concluded that competition for light is more important than competition for moisture, and that good forestry practice can virtually eliminate the need to weed in these areas.

TEE, L. A. and ROWE, J. J. (1985). An appraisal of revenue loss from conifer thinnings due to Grey squirrel (*Sciurus caroliensis*) bark stripping damage. *Quarterly Journal of Forestry* 79 (1), 27-28.

Damage by Grey squirrels to conifers over the northern part of its range has been increasing. Damage at Delamere Forest (Cheshire) was thought so serious that it would lead to loss of thinning revenue and even to premature clear felling. After detailed assessments of CP and SP the loss in revenue was calculated at 2 per cent. Damage occurred mainly in the crowns. Identifying damaged trees for removal proved difficult.

TEE, L. A., ROWE, J. J. and PEPPER, H. W. (1985). *Mammal/bird/damage questionnaire 1983*. Forestry Commission Research and Development Paper 137.

Report on presence of 45 mammals and birds and the occurrence of damage in Forestry Commission woodlands by 10 km squares.

THALLON, K. P. and HORNE, A. I. D. (1984). The use of photogrammetry and remote sensing for forestry in Great Britain. *Photogrammetric Record* II (4), 359-370.

The Forestry Commission needs information on the woodland cover of the country, both as general assessment of all ownerships for woodland census purposes and as detailed crop data on its own forest estate for management purposes. These survey requirements are outlined and the methods used for data collection are described, particular attention being given to the role

role of aerial survey. The development of a digital mapping system is also covered. Finally, the potential role of other remote sensing techniques and the trials currently in progress are discussed.

THOMPSON, D. A. (1984). The influence of shelter and weeds on early growth of Sitka spruce and Lodgepole pine. *Forestry* 57 (1), 1-16.

Different degrees of shelter from wind were achieved by using netting and were measured using tatter flags. Three treatments compared weed competition by removing no vegetation, heather (*Calluna vulgaris* L.) only or all ground vegetation respectively. Results indicate a definite relationship between material lost from tatter flags and tree dry weight at 5 years. Even the smallest increase in shelter resulted in increased growth of Sitka spruce and the beneficial effect of shelter became most apparent 4 to 5 years after planting. Tree dry weight was found to be correlated with root collar diameter and height, but not fifth year height increment. Results from weeding treatments were unclear and differed between species because bird damage interacted with weeding.

THOMPSON, D. A. (1984). *Ploughing of forest soils*. Forestry Commission Leaflet 71.

Appropriate site preparation promotes successful crop establishment by improving the rooting conditions for young trees. The long crop rotations in forestry allow soil cultivation only once every 50 years or longer. Afforestation programmes are frequently associated with difficult ground conditions; robust equipment is required and costs can be high. Ploughing prescriptions are given for specific soil groups: freely draining, impeded, and impervious. Practical considerations are discussed and a suggested ploughing procedure set out. Helpful appendices list plough types, analyse costs of ploughing, and assess the benefits which can ensue.

[TURNER, D. J. and] TABBUSH, P. M. (1984). Studies with alternative glyphosate formulations. In *BCPC Monogram* 28, 135-145.

Salts of glyphosate can be made by warming glyphosate acid with ethoxylated surfactants derived from fatty amines. One such salt made with Ethomeen S12 surfactant is oil soluble and has properties not normally associated with glyphosate, including an ability to penetrate bark. It is about as active against herbaceous species as the commercial isopropylamine salt formulation, Roundup. As with Roundup, the addition of ammonium sulphate and/or surfactants may enhance phytotoxicity. Glyphosate acid in water without surfactants is relatively non-phytotoxic. However, when Ethomeen T25 surfactant or ammonium sulphate with Ethomeen C12 is added, phytotoxicity is greatly increased, perhaps as a result of ion exchange between the acid and the cationic surfactants.

WAINHOUSE, D. and GATE, I. M. (1984). The role of the host plant in the population ecology of the Beech scale. In *Proceedings of the XVII International Congress of Entomology*, 600 (abstract only).

Within infested beech stands, intraspecific variation in susceptibility of the host and the colonising ability of the scale larvae have both been demonstrated and probably constitute the main natural regulating factors in population growth. On individual infested trees the largest mortality (80-90 per cent) occurs at the first instar or crawler stage as a result of dispersal or failure to establish on the host tree. Abiotic factors such as rainwater flow down the tree trunk appear to be relatively unimportant. Establishment success has been shown to depend on physiological and physical characteristics of the bark and the presence of bark flora.

WALKER, C. (1985). *Endogone lactiflua* forming ectomycorrhizas with *Pinus contorta*. *Transactions of the British Mycological Society* 84, 353-355.

The morphology and anatomy of an ectomycorrhiza formed between *Pinus contorta* and *Endogone lactiflua* is described. The fungus was found fruiting near the surface of pots containing Lodgepole pines and shown to be associated with mycorrhizas by mycelial connection and by use of histochemical tests. Investigations into the origin of the fungus showed that it probably was present on the trees when they were lifted from Newton Nursery (Morayshire).

WALKER, C., [READ, L. E. and SANDERS, F. E.] (1984). *Acaulospora nicolsonii*, a new endogonaceous species from Great Britain. *Transactions of the British Mycological Society* 83, 360-364.

A new species of endogonaceous fungus is described from Great Britain. Attempts to obtain the species in pure pot culture have failed. Wound healing of the type previously recorded only for *Gigaspora* species was noted on a hypha attached to a sporiferous saccule of this species.

WALKER, C. [and McNABB, H. S. Jnr.] (1984). Mycorrhizal symbionts associated with hybrid poplars from Iowa, USA. *European Journal of Forest Pathology* 14, 282-296.

Seven clones of hybrid poplar from among four sections of the genus *Populus* were potted in five soils. Two ectomycorrhizal types, an ectendomycorrhiza, and phycomycetous endomycorrhizas were found. There were indications of differences in mycotrophy among the sections of the genus *Populus*.

[WANG, G. M., STRIBLEY, D. T., TINKER, P. B. and] WALKER, C. (1985). Soil pH and vesicular-arbuscular mycorrhiza. In *Ecological interactions in the soil environment: plants, microbes and animals*, eds. Fitter, A. H., Atkinson, D., Read, D. J. and Usher, M. B. British Ecological Society special publication 4, 219-244.

Field agricultural soils adjusted to yield pH values of 4.5, 5.5, 6.5 and 7.5 were examined for the presence of vesicular-arbuscular mycorrhizal fungi. It was found that the soils differed in the active mycorrhizal fungi found, the 'fine-endophyte' being dominant at pH 4.5 whilst 'coarse endophytes' became increasingly dominant as pH increased. It was concluded that aluminium in the soil was responsible for the inhibition of coarse endophytes below pH 5.5.

[WARD, S. A.,] LEATHER, S. R. [and DIXON, A. F. G.] (1984). Temperature prediction and the timing of sex in aphids. *Oecologia (Berlin)* 62, 230-233.

The aphid life cycle contains a series of parthenogenetic, viviparous generations, followed usually by a sexual generation that produces resistant overwintering eggs. Since the decision to produce sexually-reproducing offspring ends the period of rapid growth of the clone, it should be postponed as late as is compatible with successful oviposition. The time of leaf fall determines the latest possible time of oviposition, and is itself determined mainly by daylength. The time required for the development of the final generations of aphid depends on temperature. The decision to end the sequence of parthenogenetic generations should thus depend on temperature and photoperiod. This paper calculates the optimal combination of daylength and temperature for the cueing of this decision in *Rhopalosiphum padi*. It is shown that the experimental data of Dixon and Glen (1971) are in agreement with the predictions, and that, in the field, the time of production of male *R. padi* does vary adaptively with July temperature.

WEBBER, J. F. and BRASIER, C. M. (1984). The transmission of Dutch elm disease: a study of the processes involved. In *Invertebrate-microbial interaction*, eds. Anderson, J. M., Rayner, A. D. M. and Walton, D., 271-306. Cambridge University Press.

Describes research on the sequence of fungal ecological events in the disease cycle from the time of beetle entry of diseased elm bark in autumn to breed, throughout the bark phase in winter, to the time of beetle emergence and beetle flight to feeding grooves in healthy elms in the spring and summer; provides evidence for two cycles of the fungus in Dutch elm disease; estimates numerical spore thresholds required for infection; and attempts to provide a conceptual model of disease transmission.

[WHALLEY, D. N.,] JOBLING, J. and MARSH, P. (1985). Effect of wind and salt exposure on four hybrid cypress cultivars. *Scientia Horticulturae* 25, 93-98.

Newly released x *Cupressocyparis* hybrids have been tested for their tolerance to exposed coastal conditions. Preliminary data show that the hybrids x *C. notabilis* and x *C. ovensii* were severely damaged by salt-laden winds, whilst x *C. leylandii* clones 'Rostrevor' and 'Leighton Green' were not seriously affected.

WHITE, J. E. J. (1985). *A list of trees and shrubs at Westonbirt Arboretum*. Forestry Commission.

List of 2800 entries, one for each species, variety or cultivar in Westonbirt Arboretum (a synopsis or simple listing of the full computerised catalogue containing over 13 000 taxa).

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

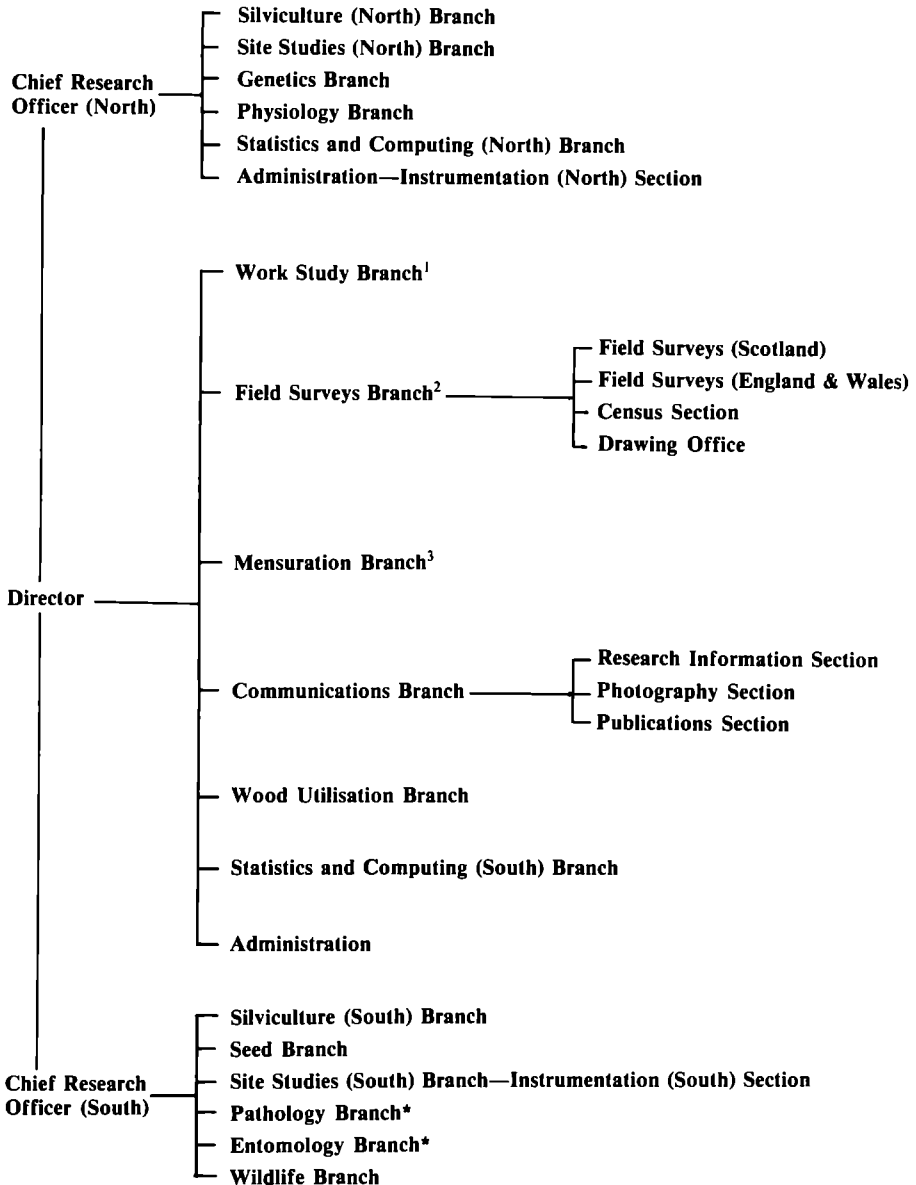
Results at 30 years are reported for a cultivation experiment on an upland heath with a podzolic ironpan soil with indurated subsoil. Differences between the six cultivation treatments in rate of height growth during the first 8-10 years were reversed in the following decade. Height differences between treatments are now small but differences in volume production between the best and poorest treatment are about 20 per cent. In the unplanted heathland the soil above the ironpan is frequently waterlogged and has low concentrations of oxygen; under the forest waterlogging does not occur and the soil is now well aerated.

WINTER, T. G. (1984). Wind assisted dispersal of *Tortrix viridana* (L.) (Lep., Tortricidae) from West Sussex. *Entomologist's Monthly Magazine* 120, 245-251.

During the period 1980 to 1982 there was a large increase in *T. viridana* defoliation of oaks in southern England. This resulted in high catches of this moth in a Rothamsted light trap adjacent to defoliated oaks in Alice Holt Forest. A similar trap at Haslemere, Surrey, 4 km from the nearest infected trees, caught few moths until 600 were trapped during one night in June. This exceptional increase was due to strong easterly winds which coincided with the peak *T. viridana* flight activity and blew large numbers of moths from West Sussex into the Haslemere area.

APPENDIX II

Research and Development Divisional Organisation



*Branches with sections at the Northern Research Station.

¹ Transferred to Private Forestry and Services Division at year end.

² On 1st March 1985 this Branch was transferred to Planning and Surveys Division as Forest Surveys Branch.

³ From 1st March 1985.

APPENDIX III

Staff Engaged in Research and Development

As at 31st March 1985

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*)
Acting Administration and Finance Officer . R. Murray (*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. E. J. Pocock, Mrs Y. K. Samuel, Miss P. J. Sparks,
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., F.I.C.For., J. Jobling, B.Sc.,
M. L. Pearce, M.I.C.For., M.I.Hort.(*Westonbirt*), M. J. Potter, B.Sc., J. S. P. Sale, M.A.,
M.I.C.For.

*Foresters:**East England Region*

P. W. W. Daborn, J. B. H. Gardiner,	<i>Centre</i>
P. D. Howard, P. Marsh, P. H. Priestley,	Alice Holt
C. W. Shanks	
M. J. Scott, R. E. Preston	Bedgebury
S. E. Malone, T. D. Cooper	Thetford

West England Region

J. E. J. White, M.I.Hort.,	Westonbirt
P. A. Gregory, M.I.Hort.	
K. F. Baker, D. G. Rogers	Exeter
M. W. Allen	Dean

ARBORICULTURE ADVISORY SERVICE (Department of the Environment)

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

SITE STUDIES BRANCH (SOUTH)

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

M. A. Anderson, B.Sc., R. Carnell, A. Willson, B.Sc., Ph.D.

Foresters: D. W. H. Durrant, B.A., D. F. Fourt, C. J. Roberts, B.A.

Laboratory: Mrs C. A. Baker, Miss S. J. Lee, Mrs D. A. Waddell, P. J. Wright, B.Sc.,
Ph.D.

INSTRUMENTATION SECTION (SOUTH)

R. Carnell, Head of Section

R. D. Butt

PATHOLOGY BRANCH (with Section at Northern Research Station)

J. N. Gibbs, M.A., Ph.D., Sc.D., Head of Branch

C. M. Brasier, B.Sc., Ph.D., D.Sc., D. Lonsdale, B.Sc., Ph.D., Ms J. F. Webber*, B.Sc.,
Ph.D.

Foresters: B. J. W. Greig, M.I.C.For., I. T. Hickman, B.Sc., D. R. Rose, R. G.
Strouts

Laboratory: Miss S. E. Chuter, B.Sc., Mrs. S. A. Kirk, Mrs T. C. Reffold

ENTOMOLOGY BRANCH (with Section at Northern Research Station)

H. F. Evans, B.Sc., D.Phil., F.R.E.S., Head of Branch

C. I. Carter, M.Sc., C.Biol., M.I.Biol., F.R.E.S., N. J. Fielding, M. R. Jukes, C.Biol.,
M.I.Biol., Miss J. F. A. Nichols, B.Sc., M.Phil., C.Biol., M.I.Biol., D. Wainhouse, M.Sc.,
Ph.D., F.R.E.S., T. G. Winter, F.R.E.S.

Foresters: R. M. Brown, M.B.E., C. J. King, A. F. Martin, B.Sc.(For.)

*Seconded from the University of Southampton

WILDLIFE BRANCH

Miss J. J. Rowe, B.Sc., Dip.Cons., C.Biol., M.I.Biol., Head of Branch

Foresters: L. A. Tee, H. W. Pepper, S. J. Petty (*Glenbranter, Strathclyde*),
P. R. Ratcliffe, B.Sc., C.Biol., M.I.Biol. (*Glenbranter, Strathclyde*)

Laboratory: Mrs B.A. Mayle

FIELD SURVEYS BRANCH‡

J. Dewar, B.Sc., M.I.C.For., Head of Branch

FIELD SURVEY SECTION

H. W. Bell, B.Sc., (*Culloden*), A. J. A. Betts, B.Sc., M.Sc.

Foresters stationed at Alice Holt:

N. Fearis, B.Sc., M. D. Whitlock

Foresters stationed throughout England and Wales:

R. P. Davis, N. C. Day, A. C. Dover, N.D.F., M.I.C.For., D. Goodbody, D. Hammond,
G. W. Munford, C. Olsson, J. L. Read, H. Roberts

Foresters stationed throughout Scotland:

J. Boluski, N. Bousfield, S. A. D. Brown, B.Sc.(For.), J. Davidson, B.A., M.W. Davies,
R. Evans, J. D. Findlay, H. Gillen, P. Hutchinson, N.D.F., I. R. McNicol, C. J. Ross,
H. Schneider, J. J. Spittal, J. Straiton, G. Taylor, J. A. Walmsley

MENSURATION SECTION‡

T. J. D. Rollinson, B.Sc., M.I.C.For.

Miss J. M. Gay, B.Sc.

Forester: E. J. Fletcher

CENSUS SECTION

G. M. L. Locke, B.Sc. (*Edinburgh*)

Forester: J. C. Proudfoot

DRAWING OFFICE (*Edinburgh*)

K. F. Ball

D. B. Armstrong, R. H. Beck, G. D. Bull, G. M. Challis, K. R. Fergus, J. Gibson,
B. Hearse, J. C. Henderson, Miss E. McKeen, Mrs E. Mann, Mrs L. E. Marshall,
Miss S. Murchison, S. Nicol, A. Pearson, Miss V. M. Stuppel, R. Venables

WOOD UTILISATION BRANCH

R. G. Hands*, B.Sc., M.I.C.For.

WORK STUDY BRANCH

A. J. G. Hughes, B.Sc., M.I.C.For., Head of Branch

St J. G. D. Bland-Flagg, M.M.S., P. E. Cliffe, R. A. Farmer, B.A., Ph.D., M.I.C.For.

Field Teams:

North Scotland

R. G. Muhl, (Leader),
A. Corson, B.Sc., M.I.C.For., M. T. Hoban,
F. W. Jackson, Mrs J. C. C. Scott, B.Sc.

Centre

Smithton, Inverness
and Stirling

Borders

A. C. Alexander, B.Sc. (Leader),
M. Acton, J. D. Neil, W. M. Jones

Ae, Dumfries

‡See Appendix II, page 87.

*Stationed at Princes Risborough Laboratory.

Eastern England	R. Leslie, M.A., M.I.C.For. (Leader), P. B. Lane, A. H. C. Solowo-Coker	Thetford
Southern England	C. J. Cloy, B.Sc., M.I.C.For. (Leader), T. P. Edge, B.Sc.	Brockenhurst
Wales	A. C. Thompson, B.Sc., M.I.C.For. (Leader), C. D. Ford, B.S. Hicks, D. H. Jones, W. J. Parkin, B.Sc., C. J. Pearce	Brecon and Dyfi
<i>Special Duties:</i>	J. A. Drummond, B.Sc.	Ae, Dumfries

STATISTICS AND COMPUTING BRANCH (SOUTH)

R. S. Howell, Head of Branch
 R. C. Boswell, B.Sc., M.I.S., G. J. Hall, B.Sc., B.A., Miss L. M. Halsall, B.Sc., Miss T. J. Houston, B.Sc., I. D. Mobbs, M.I.S., A. J. Peace, B.Sc., K. Rennolls, B.Sc., M.Sc., M.I.C.For., Miss B. J. Smyth, B.Sc.

COMMUNICATIONS BRANCH

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

RESEARCH INFORMATION SECTION

B. G. Hibberd, M.I.C.For., Head of Section
 Miss S. J. Miles, B.A. (Librarian)

PHOTOGRAPHY SECTION

I. A. Anderson, F.I.I.P., Head of Section
 G. L. Gate, Miss M. Trusler

PUBLICATIONS SECTION

E. J. Parker, Ph.D., C. Biol., M.I.Biol., M.I.C.For., Head of Section
 J. Williams (Graphics Officer)

ADMINISTRATIVE STAFF

HEO: R. Murray (*Accounts*)
 EOs: Mrs K. A. Fielding (*Estabs.*), Miss J. R. Lacey (*Accounts*), M. G. Wheeler (*Office Services*)

*Other HQ Staff*ENGINEERING DIVISION (*Alice Holt*)

J. G. Mair, B.Sc.(Eng.), A.I.R.T.E.

FOREST MANAGEMENT DIVISION (*Alice Holt*)

Seed Store/Extractory: T. A. Waddell

STAFF AT NORTHERN RESEARCH STATION

SILVICULTURE BRANCH (NORTH)

A. J. Low, B.Sc., M.Sc.F., Ph.D., M.I.C.For., Head of Branch		
R. Lines, B.Sc., F.I.C.For., W. L. Mason, B.A., B.Sc., M.I.C.For., K. F. Miller, B.Sc., M.I.C.For., P. M. Tabbush, B.Sc., M.I.C.For., C. M. A. Taylor, B.Sc., M.I.C.For.		
<i>Foresters:</i>		<i>Centre</i>
Special Projects	B. R. Reynard, J. B. McNeill	Northern Research Station
<i>North Scotland Region</i>	J. C. Keenleyside	Newton, Grampian
North Scotland Area	W. G. Paterson, N.M. Proctor, B.Sc., R. J. Wallace, B.Sc.	Lairg, Highland
North East Scotland Area	A. A. Green, G. R. Menzies	Newton
North West Scotland Area	D. S. Coutts, D. R. Tracy	Fort Augustus, Highland
<i>Central Scotland Region</i>	J. D. McNeill	Northern Research Station
East Scotland Area	A. H. Reid, C. D. Rider, B.Sc.	Perth, Tayside
South East Scotland Area	M. K. Hollingsworth, J. G. Whyatt	Northern Research Station
West Scotland Area	A. B. Lewis, S. Stables, B.Sc.	Kilmun, by Dunoon, Strathclyde
<i>Borders and North England Region</i>	E. Baldwin	Mabie, Dumfries and Galloway
Borders Area	P. W. Gough, J. Stannard	Kielder, by Hexham, Northumberland
South West Scotland Area	F. S. Smith, P. Harrison	Mabie
North East England Area	R. E. J. Howes, A. L. Sharpe	Wykeham, Scarborough, North Yorkshire
<i>Wales Region</i>	N. P. Danby, S. J. Corcoran, E. R. Robson	Brecon, Powys

SITE STUDIES BRANCH (NORTH)

D. G. Pyatt, B.Sc., Ph.D., Head of Branch
A. R. Anderson, D. Ray, B.Sc.

GENETICS BRANCH

R. Faulkner, B.Sc., M.I.C.For., Head of Branch
A. M. Fletcher, B.Sc., Ph.D., A.I.W.Sc., M.I.C.For., G. I. Forrest, B.Sc., M.Sc., Ph.D.,
S. J. Lee, B.Sc., M.I.C.For., C. J. A. Samuel, B.Sc., Ph.D.

Foresters: W. Brown, R. B. Collins, I. J. M. Dawson (Westonbirt), C. J. E. Fleming (Newton), M. T. T. Phillips (Newton), R. E. Stuart, G. C. Webb (Westonbirt)

Laboratory: Miss C. M. M. Baldwin

PHYSIOLOGY BRANCH

M. P. Coutts, B.Sc., Ph.D., M.I.C.For., Head of Branch
A. John, B.Sc., Ph.D., J. J. Philipson, B.A., Ph.D., C. Walker, B.A., Ph.D.
Laboratory: Miss M. Brown, K. Clifford, B.A., Miss D. Denovan, C. McEvoy,
Miss G. Peaston

PATHOLOGY SECTION (of Branch at Alice Holt)

D. B. Redfern, B.Sc., Ph.D., Head of Section
S. C. Gregory, M.A., Ph.D.
Forester: J. E. Pratt
Laboratory: Miss G. A. MacAskill

ENTOMOLOGY SECTION (of Branch at Alice Holt)

J. T. Stoakley, M.A., M.Sc., D.I.C., F.I.C.For., Head of Section
 D. A. Barbour, B.Sc., Ph.D., F.R.E.S., S. G. Heritage, M.I.Biol.,
 S. R. Leather, B.Sc., Ph.D., C. Biol., M.I.Biol., F.R.E.S.

STATISTICS AND COMPUTING BRANCH (NORTH)

D. H. Stewart, B.Sc., C.Biol., M.I.Biol., F.I.S., Head of Branch
 R.W. Blackburn, B.Sc., K. P. Donnelly, B.Sc., M.Sc., Ph.D.,
 I. M. S. White, B.Sc., M.Sc.

ADMINISTRATIVE STAFF

HEO: J. McA.Smith
 EO: I. Macleod

INSTRUMENTATION SECTION (NORTH)

D. J. Brooks, Head of Section

STAFF AT HEADQUARTERS

PLANNING AND ECONOMICS DIVISION

D. S. Grundy, M.A., M.Phil.
 Mrs. W. C. G. Harper, B.Sc., M.I.C.For.,
 Ms D. Mitlin, B.A. (Econ.), R. Q. Oakes, B.A., Mrs. J. Thompson, M.I.S.

STAFF CHANGES

Transfers in: M. W. Allen (Forester) from South West England Conservancy to Silviculture South, Dean. W. Brown (Chief Forester) from East Scotland Conservancy to Genetics, Northern Research Station. J. N. Charles (Forest Officer II) from North East England Conservancy to Work Study, Thetford. A. Corson (Forester) from South Scotland Conservancy to Work Study, Inverness. J. Dewar (Principal Forest Officer) from South Scotland Conservancy to Field Surveys, Alice Holt. B. G. Hibberd (Principal Forest Officer) from North East England Conservancy to Communications, Alice Holt. W. M. Jones (Forester) from West Scotland Conservancy to Work Study, Ae. J. D. McNeill (Chief Forester) from Silviculture North, Kielder to Silviculture North, Northern Research Station. M. J. Potter (Forest Officer II) from North Scotland Conservancy to Silviculture South, Alice Holt. P. H. Priestley (Head Forester) from North West England Conservancy to Silviculture South, Alice Holt. D. G. Rogers (Forester) from North Wales Conservancy to Silviculture South, Exeter. C. J. Ross (Forester) from North West England Conservancy to Field Surveys, Ae. Mrs J. C. C. Scott (Forest Officer II) from East England Conservancy to Work Study, Inverness. A. L. Sharpe (Head Forester) from secondment in Nepal to Silviculture North, Wykeham. S. Stables (Forester) from East Scotland Conservancy to Silviculture North, Kilmun. D. R. Tracy (Forester) from North Scotland Conservancy to Silviculture North, Fort Augustus.

New appointments: R. W. Blackburn (Higher Scientific Officer) Statistics and Computing North, Northern Research Station. Miss T. J. Houston (Assistant Scientific Officer) Statistics and Computing South, Alice Holt. Miss S. J. Lee (Assistant Scientific Officer) Site Studies South, Alice Holt. Miss P. J. Sparks (Assistant Scientific Officer) Seeds, Alice Holt. J. P. Wright (Scientific Officer) Site Studies South, Alice Holt.

Transfers out: B. G. Allison (Forester) from Work Study, Inverness to East Scotland Conservancy. N. J. Best (Forester) from Site Studies South, Alice Holt to South West England Conservancy. D. J. Collins (Forester) from Field Surveys, Culloden to East Scotland Conservancy. B. F. Edwards (Head Forester) from Silviculture South (Agency) to Information Branch, Headquarters. D. Elgy (Head Forester) from Silviculture South, Alice Holt to South West England Conservancy. J. G. S. Gill (Forest Officer I) from Genetics, Northern Research Station to North Scotland Conservancy. F. W. Hayes (Head Forester) from Work Study, Stirling to West Scotland Conservancy. A. I. D. Horne (Forest Officer I) from Field Surveys, Alice Holt to East England Conservancy. D. J. Lyons (Forester) from Silviculture South, Exeter to South West England Conservancy. N. MacKell (Head Forester) from Silviculture North, Fort Augustus to North Scotland Conservancy. R. McIntosh (Forest Officer I) from Silviculture North, Northern Research Station to North East England Conservancy. J. D. McNeill (Head Forester) from Silviculture North, Kielder to Silviculture North, Northern Research Station. A. C. Miller (Head Forester) from Field Surveys, Chester to North West England Conservancy. P. G. Risby (Forester) from Silviculture South, Alice Holt to West Scotland Conservancy. J. B. Spencer (Forester) from Work Study, Ae to North East England Conservancy. M. R. T. Spengel (Forester) from Field Surveys, Lochgilphead to South Scotland Conservancy. R. E. Warn (Forester) from Silviculture South, Dean to South West England Conservancy.

Promotions: A. J. A. Betts (Field Surveys, Alice Holt) to Forest Officer I. I. J. Cotterill (Statistics and Computing South) to Senior Data Processor. N. J. Fielding (Entomology, Alice Holt) to Scientific Officer. G. I. Forrest (Genetics, Northern Research Station) to Principal Scientific Officer. Miss J. M. Gay (Field Surveys, Alice Holt) to Higher Scientific Officer. S. G. Heritage (Entomology, Northern Research Station) to Higher Scientific Officer. Mrs. B. A. Mayle (Wildlife, Alice Holt) to Scientific Officer. E. J. Parker (Publications, Alice Holt) to Senior Scientific Officer. C. M. A. Taylor (Silviculture North, Northern Research Station) to Forest Officer I. M. D. Whitlock (Field Surveys, Alice Holt) to Head Forester (Career Specialist). A. Willson (Site Studies South, Alice Holt) to Senior Scientific Officer.

Resignations: R. M. A. Gill (Higher Scientific Officer) Computing and Statistics South, Alice Holt. M. W. Harold (Assistant Scientific Officer) Site Studies South, Alice Holt. Miss K. A. Spriggs (Assistant Scientific Officer) Seeds, Alice Holt.

Retirements: O. N. Blatchford (Principal Forest Officer) Communications, Alice Holt. A. E. Coates (Head Forester) Computing and Statistics South, Alice Holt, A. E. Crofts (Forester) Silviculture North, Kilmun. K. A. S. Gabriel (Head Forester) Silviculture North, Wykeham. C. McLean (Chief Forester) Genetics, Northern Research Station. A. F. Mitchell (Forest Officer I) Silviculture South, Alice Holt. G. Pringle (Chief Forester) Silviculture North, Betws-y-Coed. K. P. Thallon (Principal Forest Officer) Field Surveys, Alice Holt.

Death: J. R. Price (Principal) Administration and Finance Officer, Alice Holt.

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GLOSSARY

*Latin names of trees cited by common name in this Report***Broadleaves**

Alder, Common	<i>Alnus glutinosa</i>
Grey	<i>A. incana</i>
Beech	<i>Fagus sylvatica</i>
Cherry, Bird	<i>Prunus padus</i>
Wild	<i>P. avium</i>
Chestnut, Sweet	<i>Castanea sativa</i>
Elm, English	<i>Ulmus procera</i>
Huntingdon	<i>U. hollandica</i> 'Vegeta'
Lime, Common	<i>Tilia</i> × <i>europaea</i>
Mulberry	<i>Morus nigra</i>
Oak, Pedunculate	<i>Quercus robur</i> (<i>Q. pedunculata</i>)
Sessile	<i>Q. petraea</i> (<i>Q. sessiliflora</i>)
Plane, London	<i>Platanus</i> × <i>hispanica</i>
Sycamore	<i>Acer pseudoplatanus</i>
Tulip tree	<i>Liriodendron tulipifera</i>
Whitebeam	<i>Sorbus aria</i>

Conifers

Cedar, Western Red	<i>Thuja plicata</i>
Cypress, Lawson	<i>Chamaecyparis lawsoniana</i>
Fir, Common Silver	<i>Abies alba</i>
Douglas	<i>Pseudotsuga menziesii</i> (<i>P. taxifolia</i>)
Grand	<i>Abies grandis</i>
Noble	<i>A. procera</i> (<i>A. nobilis</i>)
Red	<i>A. magnifica</i>
Larch, European	<i>Larix decidua</i> (<i>L. europaea</i>)
Hybrid	<i>L. × eurolepis</i>
Japanese	<i>L. kaempferi</i> (<i>L. leptolepis</i>)
Pine, Austrian	<i>Pinus nigra</i> var. <i>nigra</i>
Corsican	<i>P. nigra</i> var. <i>maritima</i>
Lodgepole	<i>P. contorta</i>
Scots	<i>P. sylvestris</i>
Redwood, Coast	<i>Sequoia sempervirens</i>
Spruce, Norway (Christmas tree)	<i>Picea abies</i>
Serbian	<i>P. omorika</i>
Sitka	<i>P. sitchensis</i>
White	<i>P. glauca</i>
Yew	<i>Taxus baccata</i>

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