FORESTRY COMMISSION

REPORT ON FOREST RESEARCH FOR THE YEAR ENDING MARCH, 1949

LONDON: HIS MAJESTY'S STATIONERY OFFICE
1950

PRICE 1s. 9d. NET

FORESTRY COMMISSION PUBLICATIONS

GENERAL REPORTS

ANNUAL REPORT FOR THE YEAR ENDED 30TH SEPTEMBER, 1948. (H.C.171.) 1s. 3d. (1s. 5d.)

REPORT BY THE COMMISSIONERS ON POST-WAR FOREST POLICY, 1943. (Cmd. 6447.) 2s. 0d. (2s. 2d.)

SUPPLEMENTARY REPORT, 1944 (PRIVATE WOODLANDS). (Cmd. 6500.) 2d. (3d.)

REPORT OF THE NEW FOREST COMMITTEE, 1947. (Cmd. 7245.) 3s. 6d. (3s. 8d.)

EMPIRE FORESTS AND THE WAR—STATISTICS PREPARED FOR THE FIFTH BRITISH EMPIRE FORESTRY CONFERENCE, 1947. 1s. 0d. (1s. 2d.)

PROCEEDINGS OF THE FIFTH BRITISH EMPIRE FORESTRY CONFERENCE, 1947. 10s. 0d. (10s. 4d.)

SUMMARY REPORT OF THE FIFTH BRITISH EMPIRE FORESTRY CONFERENCE, 1947. 1s. 0d. (1s. 1d.)

BULLETINS

No. 8. BRITISH BARK BEETLES. AUGUST, 1926. 3s. 6d. (3s. 8d.)

No. 13. STUDIES ON TREE ROOTS. AUGUST, 1932. 3s. 6d. (3s. 8d.)

No. 14. FORESTRY PRACTICE—A SUMMARY OF METHODS OF ESTABLISHING FOREST NURSERIES AND PLANTATIONS WITH ADVICE ON OTHER FORESTRY QUESTIONS FOR OWNERS, AGENTS AND FORESTERS. (Revised 1946.) 2s. 0d. (2s. 2d.)

No. 15. STUDIES OF CERTAIN SCOTTISH MOORLANDS IN RELATION TO TREE GROWTH. May, 1933. (Revised 1947.) 2s. 6d. (2s. 8d.)

No. 16. STUDIES ON THE PINE SHOOT MOTH. JULY, 1936. 1s. 0d. (1s. 2d.)

No. 17. THE CULTIVATION OF THE CRICKET BAT WILLOW. JULY, 1936. 2s. 0d. (2s. 2d.)

No. 18. SPRING FROSTS. JULY, 1937. (Revised 1946.) 2s. 6d. (2s. 8d.)

NATIONAL FOREST PARK GUIDES
(Fully illustrated)

ARGYLL.	1s. 6d. (1s. 8d.)
FOREST OF DEAN.	2s. 0d. (2s. 2d.)
GLEN MORE.	2s. 0d. (2s. 2d.)
HARDKNOTT.	2s. 0d. (2s. 2d.)
SNOWDONIA.	2s. 6d. (2s. 9d.)

Prices in brackets include postage

The priced items on this page and inside back cover are obtainable from

H.M. STATIONERY OFFICE

York House, Kingsway, London, W.C.2; 429 Oxford Street, London, W.1 (Post Orders: P.O. Box 569, S.E.1); 13a Castle Street, Edinburgh, 2; 39 King Street, Manchester, 2; 2 Edmund Street, Birmingham, 3; 1 St. Andrew's Crescent, Cardiff; Tower Lane, Bristol, 1; 80 Chichester Street, Belfast; or through any bookseller

The Forest Research Station, Alice Holt Lodge, near Farnham, Surrey

FORESTRY COMMISSION

REPORT ON FOREST RESEARCH FOR THE YEAR ENDING MARCH, 1949

LONDON: HIS MAJESTY'S STATIONERY OFFICE
1950

CONTENTS

PART I: WORK CARRIED OUT BY FORESTRY COMMISSION STAFF

PART II: COMMITTEE ON NUTRITION PROBLEMS IN FOREST NURSERIES *by* Dr. E. M. Crowther, *Rothamsted Experimental Station*

PART III: RESEARCH UNDERTAKEN FOR THE FORESTRY COMMISSION BY WORKERS ATTACHED TO UNIVERSITIES AND OTHER INSTITUTIONS

Part I. Work carried out by Forestry Commission Staff

INTRODUCTION

By JAMES MACDONALD
Director of Research and Education

Staff

During the year ended 31st March, 1949, the writer became Director of Research and Education in place of Mr. W. H. Guillebaud, who succeeded Mr. Gosling as Deputy Director General. Forest research in Great Britain to-day is very largely Mr. Guillebaud's own creation, for he built up from small beginnings the organisation which we now possess, and during his long period of office, as Chief Research Officer and Director of Research, exercised a profound influence on the trend of silvicultural development.

Other changes during the year included the resignation of Mr. I. J. Leadbeater, District Officer, who received another appointment, and the recruitment to the staff of Mr. J. D. Matthews, District Officer, who will work on Genetics.

The sudden death of Dr. M. C. Rayner is much regretted. Her long association with forestry produced most valuable results and was, all through, a rich source of ideas. It is fortunate that Dr. I. Levisohn is available to carry on the work which Dr. Rayner initiated.

Forest Research Station—Alice Holt

The installing of mains electricity into Alice Holt Lodge was nearing completion at the end of the year under review, while the building is now completely centrally heated and provided with domestic hot water as a result of work carried out during the summer of 1948.

The neglect of the grounds during the war is gradually being made good, and greenhouses and out-buildings are being repaired and adapted to meet the needs of the Station. The former cucumber house has been fitted up for propagation, with electrical bottom-heat, and the fig-house is being used for experiments in grafting. It is proposed to instal a refrigeration chamber in one of the outhouses.

Office and laboratory accommodation is being used to the limit and it has been necessary, already, to obtain and adapt two sectional wooden huts for extra office accommodation. Although some space will be set free by the winding-up of the Census of Woodlands, there is no doubt that proposals for extending Alice Holt Lodge will require to be seriously considered in the not too distant future.

The Year's Work

The work which is going on falls into two main classes :

(a) Work carried out directly by Research Officers of the Forestry Commission. (Part I of this Report.)
(b) Work on special problems carried out by Universities and other Institutions with the help of grants from the Forestry Fund. (Part III.)

These two types of activity should be kept quite distinct, with one exception, the work on nutrition problems in forest nurseries, in which the Commission's Research Officers co-operate with Dr. E. M. Crowther of Rothamsted and his staff, under the guidance of the Committee which is presided over by Professor F. T. Brooks. (Part II.)

Part I, which deals with the activities of the Commission's Research Officers, is composed of a number of sections, each on a different subject, and each contributed by an officer who has been intimately concerned with the subject under review. Most of the principal sections of our work are dealt with but there are two omissions ; one is the establishment of hardwoods, and the other is the afforestation of upland *Calluna* soils. The extensive experimental work which has been done on this type of land is now being assesssed and summarised with a view to publication, and it is hoped that this will be made ready for the printers some time next year. The omission of sections on these subjects gives room for fuller reports on some subjects which are not usually so fully treated.

The following are brief summaries of reports which are given more fully in the subsequent sections :

(a) STUDIES OF GROWTH

In addition to the remeasurement of 26 existing sample plots, 102 new plots were established between 1st April, 1948, and 31st March, 1949, bringing the total up to 387. Work started on the preparation of volume tables for all the more important conifers and hardwoods in Great Britain. It is hoped that these tables will be published in 1950. Methods for estimating the volume and increment of the timber still standing in Great Britain were devised by the Mensuration Section and used in the Census of Woodlands. The estimates for Scotland have been prepared, and will be published with those for England, which will be available in a few months. A revised yield table for Japanese larch has gone to press and one for Sitka spruce is being made ready for publication. Several minor investigations were undertaken, some twenty enquiries were dealt with and, in the absence of a qualified statistician, the Mensuration Section also advised on the design of silvicultural experiments and undertook their statistical analysis.

(b) PATHOLOGY

The work of the Pathologist followed the usual lines and dealt with a large number of problems. One recent development is the appearance on sycamore in the north-east of London of a disease caused by an, as yet, unidentified fungus. This fungus can cause rapid death of the tree, but it is not known how serious it will prove to be.

Botrytis caused considerable damage on a large number of conifers, the dull, damp summer proving favourable for the spreading of this fungus, and it was particularly severe in some heathland nurseries. Further work is required on its control.

Injury following the drought of 1947 became evident in some cases during the summer of 1948. Records of damage to plantations of Japanese larch and Norway spruce have been obtained.

Work has continued on the investigation of die-back of Scots pine on calcareous soils, of Corsican pine, and of groups of Sitka spruce and Norway spruce. An additional survey of Douglas fir in connection with *Phaeocryptopus gäumannii* has been carried out, while spraying with different compounds has been continued in order to find an effective means of controlling *Keithia thujina* in the nursery.

The Pathologist continued his work on poplars throughout the year.

(c) ENTOMOLOGY

Like the Pathologist, the Entomologist has had to deal with a large number of problems during the year and, again like the Pathologist, he has been handicapped by the lack of assistance. To keep watch on our plantations in all parts of Great Britain is too much for one man to attempt, either in entomology or pathology.

The infestation of the bark beetle *Ips sexdentatus* attacking conifers in South Wales appears to have died down, while *Ips typographus* does not yet seem to have become established in the forests in this country. Among the other bark beetles, interest has centred on *Myelophilus minor*, formerly restricted to north-eastern Scotland, which has now established itself in the south of England.

Work has continued on the control of Cockchafer (*Melolontha* and allied species) in the nurseries, and tests, so far inconclusive, have been made with modern insecticides as a means of controlling the Pine Weevil (*Hylobius*).

Some attention has been paid to sawflies. The attack by a small sawfly, *Anoplonyx* on hybrid larch, near Dunkeld, Perthshire, appears to have died out. Larvae of the Large Larch Sawfly (*Pristiphora*) were found last year at Radnor Forest, and a survey is being carried out to ascertain the present distribution of this species, which is a major pest.

(d) GENETICS

Progress in genetics is dealt with under three main heads, namely the study of variation, propagation work and breeding.

Variation in leaf size and shape has been studied in beech, and variation in branch form in larch. Stem form and crown width in Scots pine at Thetford have been broadly correlated with latitude, and individuals which are resistant to damage by late frost and possibly to *Neomyzaphis* insect attack have been found among Sitka spruce. Forms of *Pinus contorta* have also been studied.

The assessment of form in provenance trials was undertaken by two methods, one visual and the other consisting largely of measurements. Spring grafting under glass was carried out on two broadleaved and eight coniferous species, using four main grafting methods. The most useful grafts were the Veneer Side and Whip-and-tongue grafts, and ash, beech, larch, *Cupressus macrocarpa* and Douglas fir responded well.

Spring grafting in young plantations was commenced on two broadleaved and three coniferous species.

Breeding work has been restricted to collection of information and study of technique. The species *Pinus banksiana* and *P. contorta* were crossed reciprocally.

(e) ECOLOGY

Ecological work in the past year has been centred on beech. A comprehensive study of the ecology of British beech is being pursued along three branches. The first aims at giving a broad view of the variety of conditions, natural and man-made, under which beech is growing both within its natural range and farther afield. The second involves the compilation of more detailed information about the growth of beech, and site characteristics in beechwoods chosen to represent these varied conditions. Particular attention has been given to woods about the origin of which reliable information exists. The third method of approach is specially concerned with very young beech crops, planted or natural, and aims at illuminating the main ecological factors which affect survival, height growth and straightness of stem. All the data so far collected have been from the south and east of England ; but it is proposed

to devote the summer of 1949 to the midland and northern counties, where beech, although not indigenous, is in some localities growing extensively and well.

(f) TREATMENT OF SEED

The need for a quick and accurate method of determining the germination capacity of seed has led to a programme of work on staining methods with various chemicals, of which the most promising is tetrazolium bromide.

The standard practice of seed soaking, prior to sowing, together with earlier work on this subject, has been brought under review. So far, it appears that soaking before sowing gives no great benefit, except in Sitka spruce.

(g) NURSERY WORK

A large programme of experimental work has been carried out in connection with the work of the Committee on Nutrition Problems in Forest Nurseries and, in addition, various other work has been handled, most of which has been a continuation of projects started in former years.

In the North, sterilisation of nursery soils by steam or by formalin and other chemicals was the main subject of study, while in the South, various projects were dealt with, including seed-bed covering media, watering and shading of seedbeds, weed control by selective weedkillers, composts and vegetative propagation.

(h) AFFORESTATION OF PEAT

Apart from an extension of planting into the difficult country of Caithness and Sutherland, there has been little new work on peat, and this project, which has been going on for so long and which has given some remarkable results, has reached a stage when it is necessary to stop and review past developments before deciding the next line of advance. It would, however, appear that the main problems have now passed from the establishment stage to that of maintenance. The report on our work on peat, which is now under way, will give an opportunity for a survey of the whole field.

(i) LOWLAND HEATHS

At Wareham Forest, the outstanding feature has been the success of broom in promoting the growth of Sitka spruce and other species.

(j) PROVENANCE STUDIES

A report on some of the trials of various origins of different species brings out various interesting points. At Thetford, for example, Scots pine from the more northerly region appears to have the best form while vigour is associated mainly with plants originating from north-central Europe.

STUDIES OF GROWTH

By F. C. HUMMEL
Mensuration Officer

Establishment and Remeasurement of Sample Plots

In addition to the remeasurement of 26 existing sample plots, 102 new permanent sample plots were established during the year. Twenty of the new plots are in England, 38 in Scotland and 44 in Wales, where there are but few older plots. Japanese larch takes pride of place with 31 new plots, although

in importance this species ranks lower than some of the others ; but several causes combine to swell the number of new plots in Japanese larch. Six of the plots were established in the spacing experiments at Rheola and Crychan in South Wales, where plantings have been carried out at four-foot, six-foot and eight-foot spacings respectively. The majority of these spacing experiments will be assessed by a simpler procedure, but as the above two series were particularly suitable they were turned into permanent sample plots. At both places height growth was slightly better at the four-foot spacing than at eight-foot, while girth, as might be expected, showed an opposite trend.

PERMANENT SAMPLE PLOTS

SUMMARY OF ESTABLISHMENTS AND REMEASUREMENTS, 1/4/48 to 31/3/49

	England	*Scotland*	*Wales*	*Total*
Plots in being 1st April, 1948 ..	148	118	19	285
Plots established 1/4/48 to 31/3/49 ..	20	38	44	102
Plots written off	*Nil*	*Nil*	*Nil*	*Nil*
Plots in being 31/3/49 ..	168	156	63	387
Plots remeasured 1/4/48 to 31/3/49 ..	9	14	—	23
Miscellaneous Plots established 1/4/48 to 31/3/49	—	18	1	19

Most of the other twelve Japanese larch sample plots in Wales were established at the request of the Director for Wales, on sites where Sitka spruce has failed rather unexpectedly, but Japanese larch is showing some promise ; More detailed information on its rate of growth in this locality is therefore urgently required. At Drumtochty, in East Scotland, advantage was taken of the rare opportunity of having a large area all of one age and covering a considerable range in elevation. A complete series of all five recognised thinning grades (B, C, D, E and L.C.) was established at an elevation of 720 feet and single D grade plots were established at 600 feet and 940 feet. This larch was planted in 1935. Height growth in 1948 was as follows :

600 feet	29½ feet top height
720 feet	22½ feet top height
940 feet	13½ feet top height

A series of three plots at Brechfa in South Wales (B, D, E grades) was established because with a top height of 35 feet at twelve years they probably represent the fastest rate of growth of which Japanese larch is capable in Great Britain, and it is desired to find out up to what age Japanese larch can maintain this rapid rate of increment. The other plots of Japanese larch are mostly single plots selected as being more or less representative of the areas in which they are situated.

The fifteen new Sitka spruce plots consist of a series of four plots (B, C, D, L.C. grades) on Croydon Hill, Brendon Forest, in Somerset, and the others are single plots covering a wide range of site conditions and rates of growth. At one extreme, there is the plot at Bettws y Coed, Gwydyr Forest, which, at twenty-five years, has a top height of 72 feet, and has produced a total volume of 6,044 cubic feet per acre, of which 2,628 cubic feet have been removed in thinnings. At the other extreme, there is the high elevation plot at Dartmoor, which on an exposed site, at 1,400 feet, has a top height of 31½ feet, and has produced in twenty-three years a volume of 2,406 cubic feet per acre, of which 491 cubic feet have been cut out. This, however, is by no means the slowest rate of growth for Sitka spruce, but no areas of poorer quality

have as yet reached the stage at which they have a measurable volume of standing timber.

Of the fourteen new Douglas fir plots, four (B, C, D, L.C. grades) constitute a series near Bettws y Coed in North Wales in a moderately slow-growing stand which is typical of the area. Another series of three plots (B, C, D grades) was established at Brechfa in South Wales. The other seven are single plots in areas where there is a fair amount of Douglas fir. Scots pine and European larch are represented with only four and three plots, respectively, because these old favourites are comparatively well represented in plots that had been established previously. The remaining new plots were distributed over a great variety of coniferous and broadleaved species, about the growth of which we know very little and must get to know more. The fastest growth of any plot established during the year was shown by the grey alder at Drummond Hill, East Scotland, which at fifteen years had reached a height of 48 feet. The plot of *Pinus monticola* on Colonel Balfour's estate at Dawyck in Peebles-shire is of special interest, because at twenty-six years it has produced a volume of 3,200 cubic feet, which is considerably more than first quality Scots pine. There can be little doubt that these five-needled pines would have a considerable future in this country if blister rust could be avoided.

The great majority of the new plots are in Forestry Commission plantations, but a few where nothing comparable was to be found on Commission land were established on private estates, to the owners of which grateful acknowledgment is made for their kind co-operation.

Sample Plot Procedure

The record number of new establishments of sample plots was made possible by the various modifications in sample plot procedure that had been introduced during the previous year. During the current year only minor modifications in field technique were introduced, but work continued on several more important problems to which no ultimate solution has yet been found. One concerns the methods of measurement in plots of broadleaved species, for which the existing procedure, which is mainly adapted to conifers, is not entirely suitable. Another problem of long standing is the question of measuring standing sample trees in old stands. Thanks to the Swedish sectional ladders, and some exceptionally competent tree climbers among the new recruits to the Sample Plot Parties, it was possible this year to measure standing sample trees in plots where this would previously have been considered impossible, but climbing these tall trees is necessarily slow, laborious, and at times not altogether safe. The possibility of using an optical instrument for obtaining diameter measurements high up a tree, without having to climb it, has therefore received further attention. The prototype of a range-finder with an eight-inch base, which was constructed for surveying purposes, has been made available through the courtesy of the Director-General, Ordnance Survey. Preliminary trials with this instrument have proved very successful. At a range of forty-four yards (forty meters), diameters can be determined to the nearest tenth of an inch. The instrument is comparatively light, weighing only a few pounds, and it has the great advantage over the type of dendrometer that has been used in the past, that it measures both range and diameter. Further trials with this instrument are in progress.

A simplified code of sample plot procedure was evolved, which is termed the "Bedgebury Procedure" after the forest plots at Bedgebury where it was first put into practice. It is intended to become the standard procedure in the numerous silvicultural experiments which reach the size where some records of volume and increment are desirable, but where the detail required in permanent sample plots is unnecessary.

Volume Tables

The estimation of volume in the Census of Woodlands necessitated the preparation, in a relatively short time, of general volume tables for all the more common species of conifers and hardwoods. For the conifers, material was readily available from our permanent sample plot records, and preliminary volume tables were prepared for Scots pine, Corsican pine, European larch, Japanese larch, Douglas fir, Norway spruce and Sitka spruce. Each of these tables was based on about 1,000 trees. The main deficiency of these tables lies in the fact that as most of our permanent sample plots are still young, there was very little material with which to support the higher ranges of girth and height in the tables. Before issuing these tables for publication, this deficiency will be overcome by utilising, in addition to the permanent sample plot records, the large amount of measurements available from war-time fellings in 1914-18 and 1939-45 which it was not possible to incorporate in the preliminary tables in time to be of use in the Census of Woodlands. The data for Scots pine have now been finally summarised. There were 2,500 trees from England and a similar number from Scotland. It was gratifying to find that the agreement between the two sets of figures was extremely close, so that there can be no doubt that for a given breast-height girth and height the average volume per tree is the same in England as in Scotland. The two sets of figures are therefore being combined for the compilation of a single table.

The preliminary tables were prepared graphically, but the final tables will be calculated mathematically. A trial of various formulae has narrowed the choice to one of the following two :

1. $V = G^2H + kH^3$
2. $V = G^2H + kG^3$

where V = Volume
G = Breast-height girth
H = Total height of tree and
k = is a constant

Both these formulae, which are derived from suggestions by Dr. D. J. Finney and Mr. G. M. Hammersley of Oxford University, appear to fit the data on which they have been tried, and they are now being tested on further material before a final choice is made.

Work has also started on extracting from the permanent sample plot records the data required for producing assortment tables, i.e. tables which, in addition to giving the total volume of a tree for a given breast-height girth, show what proportion of this volume is over six inches and nine inches top diameter. It is fortunate that it has been customary in our permanent sample plots to measure trees in ten-foot lengths instead of in one length only, because without the information on taper derived from these sectional measurements, it would not be possible to prepare assortment tables. The interesting fact has emerged that for a given breast-high girth the percentage of timber over six inches or nine inches diameter does not vary greatly with height.

There was far less material from which to prepare hardwood volume tables. It was therefore necessary to send out a party to measure what trees they could in timber yards and felling areas all over the country. Their work was greatly helped by the ready co-operation of the great majority of saw millers, timber merchants and landowners whom they had to contact. Tables for oak, beech and birch have been prepared and will be issued shortly. In view of the limited material on which they are based, and owing to the inaccuracies that result from having to estimate breast height on felled trees, the degree of accuracy achieved by these tables cannot be very great, and they must be considered as provisional.

Thinning Yields

During the year, data were received in respect of 360 tenth-acre plots, from 139 compartments, which were established in order to obtain information on the thinning volumes that may be expected in different types of stands and at different ages. An analysis of the first 242 plots revealed that the average thinning volume per acre, for all species combined, works out at about 200 cubic feet (excluding pulpwood). A preliminary examination of pulpwood volumes suggests that, for trees up to a height of about 60 feet, pulpwood averages about 0.2 cubic foot per tree in most species. All these figures must be considered as extremely tentative, but if the present flow of tenth-acre plot data continues, it should be possible to provide much more reliable estimates on these and other points by next year.

At the request of some Conservators of Forests, various methods of obtaining an estimate of the standing crop in these tenth-acre plots were tried, and it was found that the best method was to select three to five thinnings with breast-height girths equal to, or at least near, the mean breast-height girth of the crop, and to multiply the average volume of these trees by the number of trees in the plot. When the thinnings are all too small to provide trees of the right girth (either in or near the plot), a reasonably satisfactory estimate (which, however, tends to be low) may be obtained by taking the three largest thinnings available, and applying the formula :—

$$\text{Volume of crop} = \frac{\text{Volume of three largest thinnings} \times \text{basal area of crop}}{\text{Basal area of three largest thinnings}}$$

The Increment of Broadleaved Species in Great Britain

In 1947 and 1948, some 1,500 stems of the more important broadleaved species were analysed by a Special Duty Party. The examination of these analyses during the current year has revealed the following main points of interest :—

(1) Elm appears to reach an average volume per tree of 75 cubic feet at one hundred years ; beech and sycamore at that age were found to have average volumes of 50 cubic feet ; oak and ash about 35 cubic feet.

(2) Differences between species in the rate of growth start at an early age, with the result that the periodic annual increment per cent at any given age above thirty years is practically the same in oak, beech, ash, elm and sycamore ; although these species differ considerably from one another in the actual rate of growth in terms of cubic feet per annum.

(3) There appears to be no dropping off in the current annual increment in any of these species before 150 to 170 years, and there are even some trees which show no dropping off at 190 years. This, however, does not take into account that in old trees the increment may be offset by decay, and that the increment of a stand drops off earlier than the increment of individual trees, owing to the gradual reduction in the number of stems.

(4) The fastest records of growth for oak and ash come from East England, and for elm and beech from the South. In all broadleaved species the average rate of growth in Scotland appears to be definitely less than in England. A forest record setting out these results in greater detail is being prepared for publication.

The Determination of Volume and Increment in the Census of Woodlands

In connection with the Census of Woodlands it was necessary to devise methods for estimating volume and increment. The methods were decided upon in co-operation with the Chief Census Officer and subsequently modified slightly in the light of an extensive field trial in the county of Roxburgh, and

of valuable suggestions by Dr. Yates at Rothamsted and Dr. Finney of Oxford University, to whom the original draft procedure was sent for criticism. In connection with the volume sampling for this survey, Dr. Finney and Mr. H. Palca specially investigated "The elimination of bias due to edge effects in forest sampling." (They are publishing a paper with this title in *Forestry*.) The help received from these mathematicians is gratefully acknowledged.

The methods finally adopted for estimating volume and increment are briefly as follows : Sampling is stratified by county, species and age class, but the actual stands to be sampled, and the exact positions of sampling plots in them, are selected strictly at random on the basis of one-tenth acre circular plot for every 200 acres of forest. Along the edges of stands, semi-circular plots are used. They secure the practical advantage of having all plots of a uniform size without incurring the risk of introducing a serious bias. Within each tenth-acre plot, the standing volume is estimated by counting the stems and determining, by means of volume tables, the volumes of ten to twenty randomly selected standing sample trees, which are girthed and measured for height. Except in the youngest age classes, increment is obtained by applying an average figure for increment per cent to the volume in each species and age class. These increments per cent are calculated from yield tables for species for which they are available, or to which yield tables of other species are known to apply. In the case of oak and other broadleaved species for which there are no British yield tables and few other records of growth, increment per cent figures have been calculated from the stem analyses referred to in the previous paragraph. In the youngest age classes, where increment per cent figures are very variable and misleading, direct estimates of increment are obtained from the differences in average volume per acre between successive ages, as revealed by the tenth-acre sampling plots. By the end of March, 1949, the estimates of volume and increment for Scotland had been prepared. Those for England and Wales will be available in another few months.

The Movement of Tree Classes

A note on the Movement of Tree Classes which was prepared for publication in *Forestry* embodies the results of an investigation, the object of which was to find out how dominants, co-dominants, sub-dominants, and suppressed trees are represented in pure, even-aged crops at different ages and under different thinning treatments, and to what extent individual trees tend to maintain or change their relative position in the canopy during the life of a stand. The results of the investigation, which was based on data from our permanent sample plots, were what was expected. There is a general downward trend in tree classes : dominants tend to become co-dominant, and co-dominants tend to become sub-dominant or suppressed. A crop, in later life, thus consists almost entirely of trees which were originally dominant. This points to the importance of encouraging, by judicious thinnings, at an early age, the best shaped dominants at the expense of the less desirable ones, and, as a corollary, the very low survival value of the co-dominants and the sub-dominants suggests that, in marking early thinnings, it is not worth while to spend too much time in choosing between the individuals of these lower classes, although it may be important on silvicultural and economic grounds to prescribe the approximate number of trees in these lower classes to be removed in any one thinning.

Other Work

The Mensuration Section has given what help it could with the design and statistical analysis of nursery and other silvicultural experiments. Thirty-three nursery experiments, some of them with complicated factorial layouts,

were analysed, and in order to facilitate the design of future experiments, a study was made of the variability of seedlings. It was found that on an average the variation coefficient for the number of seedlings is usually approximately 20 per cent, for mean height about 15 per cent, and for weeding times 25 per cent or more.

A considerable amount of time was also spent in dealing with enquiries, both from inside the Forestry Commission and from other sources.

PATHOLOGY

By T. R. PEACE
Pathologist

The work is grouped according to the tree genus concerned, with a general heading "Conifers" to cover diseases attacking a large number of coniferous genera. Miscellaneous matters are dealt with at the end of the section.

Conifers

BOTRYTIS

The summer was abnormally dull and damp, and the fungus *Botrytis*, which is usually of little importance except on nursery plants of *Sequoia gigantea*, became a serious pest on a large number of conifers. It was particularly noticeable on cypresses (*Cupressus macrocarpa* and *Chamaecyparis lawsonia*), on Sitka spruce and on Douglas fir, but it also attacked Norway spruce and other conifers ; several severe attacks were noted in heathland nurseries. Numerous enquiries about the disease were received during the summer and autumn. During the winter, resting sclerotia (small black bodies) of the fungus were found on diseased plants and even on the grass in the rides in infested nurseries. In the early spring an enquiry was received as to the possibility of recovery or the redevelopment of disease on badly affected Sitka spruce seedlings. Normally, given a dry spring and an average summer, there is no need to fear this disease, but the presence of so many sclerotia may mean that the disease will reappear in quantity this season, even if the weather is not entirely to its liking. In sheltered situation the fungus has remained active throughout the winter, and dying Douglas fir shoots with active *Botrytis* on them were collected during mid-March as well as earlier. This disease is certainly worthy of further study, particularly with reference to spray control. It is probable that for this purpose suitable conditions for infection could be produced even during a dry summer by shading and heavy watering.

DROUGHT INJURY

Injury following the drought of 1947 did not become really evident till the summer of 1948. Several instances were recorded where Japanese larch planted in grass had succumbed, but in most instances the collapse of this species took place rapidly. At Apethorpe (Rockingham Forest) and on a private estate on a similar heavy clay near Bourne in Lincolnshire, Norway spruce were examined which seemed to be dying as a result of damage to their finer roots during the 1947 drought. In both places there was distinct evidence that the damage was worst where the spruce were mixed with hardwoods, particularly ash, which suggested that ash may be a more efficient water absorber than spruce. Unfortunately, it has not been possible to find time to do the root excavations that would be necessary to give more definite evidence on this trouble.

FUME DAMAGE

Opportunity was taken of a visit to Fort William to examine the damage to trees in Nevis and Leanachan Forests believed to be caused by the fluorine fumes from the aluminium works. Typical material was collected, and a series of water colour paintings have been made by Mrs. Lewis (Laboratory Assistant) for future reference.

Pine

PINE ON CALCAREOUS SOILS

Field data have been collected on the distribution of the dying of Scots pine on the Oolitic limestone at Allerston Forest, in Yorkshire. The detailed survey has failed so far to give any clear correlation between the distribution of the disease and the depth of soil over the limestone. Although the symptoms closely resemble those associated with the *Fomes* dieback of pine in East Anglia, careful examination of a large number of trees has confirmed that *Fomes* is not a primary agent at Allerston, nor does it commonly occur even in a secondary capacity.

The strip of mixed Scots pine/Corsican pine/Beech at Friston Forest, which is on the South Downs chalk, was reassessed and marked for thinning. So far there is no evidence that any of the different methods of thinning has had any effect on the progress of the disease, which in any case is not very rapid. However, the disease has made some progress and is still almost entirely confined to Scots pine.

CRONARTIUM RIBICOLA

Arrangements have been made to import, in the summer, grafting scions of strains of five-needled pines resistant to *Cronartium ribicola*, the white pine blister rust, from the United States. Some difficulty has been experienced in getting stocks on which to graft them, and they will be of comparatively little value unless they can eventually be propagated by cuttings reasonably easily, or unless they breed true as regards resistance.

DIEBACK OF CORSICAN PINE

In Allerston Forest a preliminary survey has been made of the dieback of Corsican pine that occurs there and also at Glentress, Slaley, and other forests. This survey has so far failed to correlate the dieback with any topographical or soil factor, but has confirmed, on the ground of entirely unrelated distribution, that it has no connection with the dying of Scots pine mentioned above. In any case the symptoms are different. The Scots pine die slowly, but generally, as a result of root failure. The trouble with the Corsican pine is much more localized, parts of the tree remaining healthy, while others die, and quite vigorous recovery shoots are often made just below affected portions ; in severe cases, and especially with originally weak trees, death does eventually occur. This trouble has in the past been attributed to *Brunchorstia destruens*. More recently in England (Day), and on the Continent (Van Vloten and Boudru), frost has been given the primary role, and *Brunchorstia* placed in a secondary position. The disease seems to have a tendency to occur at the higher elevations, in areas of moderate or high rainfall, where it is possible that the cambium would remain active too late in the autumn. Useful records on the progress of the disease on numbered trees are being kept by the forester at Slaley. It is hoped during 1949 to complete the survey of this disease in Allerston Forest. During the winter a detailed report was received from the North-West England Conservancy on a very serious outbreak of this trouble at Thornthwaite. The figures suggest that it is the worst case of this kind so far recorded on Corsican pine.

Spruce

DYING OF GROUPS OF SITKA SPRUCE

During the summer, plans were made of a number of groups of diseased Sitka spruce at Thirlmere in Cumberland, in the Forest of Dean, at Dunster in Somerset, and at Longleat in Wiltshire. These plots will be used to study the progress of the disease. In collaboration with Mr. W. R. Day, a more detailed study was made on uprooted trees in the Forest of Dean. In this connection a small Trewhella Monkey Jack has proved invaluable for uprooting small trees for root studies. Mr. Day's isolations were not successful, so that we are still quite uncertain about the real cause of these dying groups. The first recorded instance of this trouble was at Llantrisant Forest, South Wales, where groups of Sitka spruce, Corsican pine and Japanese larch were dying, and where the fungus *Phytophthora* was isolated. Elsewhere the disease seems confined to Sitka spruce, and occurs on such a wide range of sites that it is difficult to believe that any particular soil or site factor is responsible. The plots will be subject to repetitive study during 1949, and a further visit for detailed work with Mr. Day is being arranged.

DYING OF NORWAY SPRUCE AT COMLONGON ESTATE, DUMFRIES

Plots have been laid out on this estate to study the progress of this unexplained disease, which so far has not been found elsewhere, though two much less devastating outbreaks with somewhat similar symptoms are being kept under observation. Excavation of roots suggests that the trouble is not due, as had originally been supposed, to the failure of the fine roots. If this is ruled out, the symptoms would suggest a fungal pathogen attacking the foliage and possibly the twigs of the tree. No fungal fructifications are present, however, and repeated isolations have failed to produce anything more than a mixture of saprophytic fungi. Further observations will be made during 1949.

CRACKING OF SPRUCE

Visits were paid to several areas where spiral cracks have appeared in conifers, mainly Sitka and Norway spruces, but also in Douglas fir, and in one case apparently in larch. In nearly every case affected trees tend to be above average size and to lie near plantation margins. The detailed examination of material is being done by Mr. W. R. Day at Oxford, and preliminary examination suggests that the damage was caused during the cold winter of 1946-47, rather than by the hot summer of 1947. In Pitfichie Forest (East Scotland) all the affected trees that could be located have been marked by the District Officer. These will be used for periodic studies of the healing of the cracked stems and on the entry of decay into them.

Douglas Fir

PHAEOCRYPTOPUS GAUMANNII

A second annual assessment was made of this disease on 176 numbered trees in Wales and the West of England. A report was prepared summarizing the data collected in 1947 and 1948. In this, it is concluded that there is definite evidence that the fungus is a damaging parasite on Douglas fir. Its effect on needle colour and needle-shedding is, however, curiously inconsistent. While a tree with rich deep green foliage is likely to be free or nearly free from the fungus, many trees making perfectly normal growth, and with foliage only the slightest degree "off colour", may be found quite heavily infected. This being so, it is difficult to evaluate the significance of the fungus as regards the cultivation of Douglas fir in this country.

Larch

CANKERS ON JAPANESE LARCH

Cankers on Japanese larch have followed brashing at Coed y Brenin and Radnor Forest in Wales, and at Allerston in Yorkshire. An experiment has been set up at Coed y Brenin to test the effect of three methods of brashing (stick, billhook and saw) at four different times of year. This experiment has only recently been completed, and there is nothing to report as yet.

Thuja

KEITHIA THUJINA

Spraying experiments were carried out with proprietary sulphur and copper-containing sprays in four nurseries : in two, on transplants, and in two others on rising one-year seedlings. The disease had hardly appeared on the latter by the end of the season, so naturally the spraying had no effect; but on the transplants a lime sulphur preparation had a very marked effect, whereas a colloidal sulphur preparation and a copper-containing spray gave no control. Further spraying experiments will be carried out during 1949.

Thuja plicata has been successfully sown at four isolated nurseries where this genus had not previously been grown. It is hoped that these stocks will keep free from the disease, and prove the value of isolated uninfected nurseries for raising this species. The disease had not appeared at any of them by the end of the season, but the real test will be in 1949, as it is during the second year that the disease usually becomes serious. A short report on these experiments has been prepared.

Poplar

POPLAR TRIALS

During the year silvicultural work on poplars was handed over to Silviculturist, South, but the varietal trials were continued. Some further planting was carried out at the Hockham (near Thetford in Norfolk), Auchencastle (Dumfries-shire) and Dyfnant (Montgomery) trial areas, and the first plots were planted in a fourth area at Hallyburton in East Scotland. A further site has been selected at Urray, north-east of Inverness, and a new site is being sought in the west of England.

A fairly suitable area for the Populetum, which is to contain three plants of all the clones in our possession, whether of timber value or not, was found in the New Forest, and planting was started. The permanent stool bed on the Lodge Pond site at Alice Holt was started this year, but it will be necessary to retain the beds at Bedgebury (Kent) and Fen Row (near Rendlesham, Suffolk) for a year or two more, until the Alice Holt bed becomes established. The nursery stocks are now in four nurseries, as well as on part of the Lodge Pond site. Eventually, providing the fertility of Fen Row nursery can be restored (and a manuring programme has been started with that end in view) it should be possible to use only Fen Row and part of Kennington nursery for this purpose.

A small varietal planting was made on an area at Harling (near Thetford, Norfolk) where the existing poplar crop is in general doing badly and is cankered, probably by *Dothichiza*. The plots at Yardley were beaten up, but the vacant plots are being reserved for any varieties that we may procure which are considered suitable for such heavy soil and coppice competition.

Arrangements were completed for the distribution of cuttings of the four selected varieties within the Forestry Commission, to nurserymen and to private landowners. The area of the stool bed at Fen Row established for this purpose was more than doubled.

I paid a visit to Italy in connection with the second meeting of the International Poplar Commission. A most interesting tour had been arranged, which included visits to factories using poplar, as well as to poplar plantations. The discussions were of less value, but the contacts made should prove very useful. A full report has been submitted.

A good deal of time has been spent on advisory work on poplar planting, and on visits to estates and forests where poplar has been planted, in order to acquire additional information on the most suitable varieties for different sites in different parts of the country. Our knowledge of this matter, particularly as regards the wetter parts of the country, is still very meagre.

A comprehensive exhibit on poplar and its uses, with particular reference to its possibilities for farms, was prepared for the agricultural shows. It attracted a fair amount of interest, but did not lead to as many enquiries as had been expected.

POPLAR CANKER

The area at Alice Holt planted with cankered sets was further extended, and a number of varieties for trial were interplanted between the cankered rows. The idea is that these will be subject to heavy natural infection. If necessary this will be supplemented by artificial infection. Among the clones received and collected this winter are supposedly resistant strains of *P. eugenii* and *P. trichocarpa*, normally canker-susceptible varieties.

Elm

ELM DISEASE

The new method of survey, started in 1947, was repeated and slightly extended. It now includes 1,837 trees, 22% of which showed active symptoms of the disease. This is an increase on last year, and is attributed to the build up of the beetle population during the hot summer of 1947. A number of the areas surveyed prior to 1947 were also revisited, and some of these showed the same marked increase. It is believed that this is only temporary, and that the disease will assume normal proportions next season.

Inoculations to test resistance were resumed on some of the clones remaining from our work on disease resistance before the war. As a result three more clones have been abandoned because of their susceptibility. The remainder are being propagated by grafting. The latest Dutch selection, Bea Schwarz, said to be resistant to *Ceratostomella* and *Nectria*, has been imported for trial.

Spraying experiments with D.D.T. and B.H.C. were carried out on street trees at Folkestone and were designed to prevent the beetles infecting the trees. The results, especially with D.D.T., were encouraging, but it is realized that control by spraying can only have a very limited application. Experiments on a larger scale, with D.D.T., are being planned for 1949, and will be carried out at Aldenham (Hertfordshire) as well as at Folkestone.

Chestnut

ENDOTHIA PARASITICA

The presence of *Endothia parasitica* on a wide scale on chestnut in Italy is causing concern, and opportunity was taken of my visit to the Poplar Conference there, to see something of its ravages and to meet the persons working on it. Arrangements were made to get *Castanea*, from a number of different origins in this country, tested in Italy for resistance to the disease. Unfortunately, owing to the wet cold summer, the production of good chestnut seed in this country was very poor, and none was sent abroad for testing. However, plants from several origins were sent to Italy, and grafting scions, also from

different places, were sent to America to be tested for resistance. We may thus get some information on the general level and possible variations in the susceptibility of our native *Castanea* to the disease. Two lots of seed of resistant chestnuts have been received from America and successfully raised. They will eventually be tried to see how they behave under natural conditions in this country.

Very good tempera paintings of the symptoms of the disease were received from Italy, and a booklet containing reproductions of these is in course of preparation.

PHYTOPHTHORA

Several reports have come in of what appears to be Ink Disease caused by the fungus *Phytophthora*. The only case visited, at Parkhurst Forest, Isle of Wight, was quite typical, but time has not allowed any extended work. There appeared to be a definite association between the disease and poor, if not definitely bad, drainage.

Beech

CANKER AND BARK DIEBACK

Several cases of bark dieback in beech have been noted during the year. The fungus *Nectria* seems to be associated with this type of injury, but it is suspected that the real cause is more fundamental. No further work has been possible on the canker of young beech at Westbury and Denge Forests.

Willow

The provisions of the Watermark Disease Order applicable to Essex have now been extended to Suffolk and to parts of Hertfordshire and Middlesex. Inspections, arranged by the Essex authorities, have already been extended to the first two of these counties.

Considerable discussion has taken place on the advisability of further extension of the Order, and also on the possibility of requiring set beds to be certified disease free. These matters are still under consideration.

Sycamore

WANSTEAD PARK DISEASE

A curious disease of sycamore in Wanstead Park, Essex, was brought to notice by a local naturalist, Mr. Waller. In its investigation, which is still only in the early stages, I have received great assistance from Mr. P. H. Gregory of Rothamsted, as well as from Mr. Waller himself. It closely resembles a disease of plane, recorded in America, and due to a fungus *Endoconidiophora*, except that at Wanstead there is an extraordinarily profuse production of brown-black spores. The fungus appears to travel up and down the tree—we do not yet know how it enters—staining the wood as it goes. Wherever the staining touches the periphery, the cambium and then the inner bark die, and the spores are produced in chains from a stroma pushing off the outer bark, and producing black spore-covered lesions on the tree. Death of the tree is usually, but not always, rapid. The fungus has not yet been identified, and, apart from one chance record from a garden a mile away in Leytonstone, it is not known whether the fungus extends beyond the immediate neighbourhood of the Park. The Park authorities have agreed to fell and burn all the affected trees. It is hoped shortly to appoint a temporary surveyor, so that we can discover how far the disease extends. If the distribution is still limited, more stringent measures may have to be taken in an attempt to eradicate it.

Miscellaneous

QUARANTINE

A good deal of time has been spent on discussion of the revision of the Orders governing the import of forest trees into this country. As a result it was finally decided to delete *Ulmus* from the prohibited list, to include *Castanea* in view of the presence of chestnut blight in Italy, and to make the import of poplars a matter of licence, so that control can be exercised over the varieties imported. The continued importation of chestnuts for eating purposes remains a serious gap in our defences against the disease, especially as tests have proved that a certain number do retain their capacity to germinate, despite Italian statements that their viability was destroyed by water steeping treatment. It must be admitted, however, that the water treatment may have a valuable effect, merely by washing off the spores.

LECTURES

Lectures on Forest Pathology have been given to a course at Cirencester organized by the Royal Forestry Society of England and Wales, and at the Forester Training Schools at Parkend, Benmore, Glentress and Lynford. Lectures on poplar were given to landowners and timber merchants' courses at Northerwood House, and at the British Association meeting at Brighton. A general lecture on forestry with special reference to diseases and pests was given at the Plant Protection Ltd. Research Station at Fernihurst, Sussex.

AGRICULTURAL SHOW EXHIBITS

It was considered that the exhibit at the agricultural shows, while adequate, was too "amateur". A rather more ambitious exhibit on poplars and on general forest pathology is now in course of preparation.

PHOTOGRAPHS

Mounting of the pathological and poplar photograph collection is now nearly completed. It includes about 1,200 prints.

CARD INDEX

About half the forest pathology card index has been sorted and revised. The remainder will be done during the winter of 1949-50. This index continues to be of great value, especially in answering enquiries.

ENTOMOLOGY

By H. S. HANSON
Entomologist

Bark Beetle Infestations

IPS SEXDENTATUS

The infestations of *Ips sexdentatus* Boern. which occurred in several coniferous areas in South Wales during 1947, died out, and no fresh infestations were reported during 1948. Investigations revealed that the resident predator population played an important part in terminating the infestations. *Hypophloeus fraxini* Kug., a non-indigenous species belonging to the family *Tenebrionidae*, was one of the most efficient predators, and was numerous in each area examined. This species has for many years arrived in considerable numbers in the bark of *Ips*-infested maritime pit props imported from France,

and has long been established as a breeding species in South Wales and in several localities in the South of England. Another useful predatory beetle, *Aulonium ruficorne* Ul., family *Colydiidae*, is present in several localities, and probably became established in the same way.

During 1948, arrangements were made for the collection of bark beetle predators in French forests for importation to this country, and Professor Hubault undertook to organize and supervise this work. Several hundred adult specimens and numerous larvae have been received. The collections include both the above species, also *Platysoma oblongum* F., family *Histeridae*, another important enemy of bark beetles.

IPS TYPOGRAPHUS

Although considerable numbers of these beetles were distributed to various parts of the country in the bark of the earlier shipments of spruce logs imported from Germany during recent years, no report has yet been received of this species having become established in the forest. Nevertheless, it seems probable that *Ips typographus* may have succeeded in breeding in the bark of spruce timber in country sawmill yards, and may still be present in some localities. A few hibernating specimens were found in the bark of spruce logs in a timber yard in South Wales in February, 1949. Numerous specimens of the parasite *Ipocoelius seitneri* Ruschka, (*Hym. Pteromalid.*), received from Germany in 1948, were liberated in Rheola Forest, South Wales.

MYELOPHILUS MINOR

Formerly, the distribution of this species in Britain was confined to pine areas in Scotland, particularly in the north-east and northern counties. During the last few years *M. minor* has been found breeding in several localities in Hampshire and Dorset. The first record was in Dorset in 1942. Since then it has been found breeding in Wilverley Enclosure in the New Forest, and in the bark of pine timber in a sawmill yard in that locality. The most recent record is from Mr. G. D. Rouse, who reports "a fairly extensive infestation" in scorched Corsican pine poles in the burnt area at Warcham Forest in the spring of 1949.

As *Myelophilus minor* became established in Dorset at least four years before imported pine logs began to arrive from Germany, the infestation cannot be attributed to that source. On the other hand, it is known that extensive outbreaks of bark beetles occurred in devastated forest areas along the coastal belts in France during the early stages of the war. It seems probable, therefore, that some of these bark beetles, including *M. minor*, may have been blown across the Channel and got established in pine areas along the south coast.

Myelophilus minor is potentially a more dangerous pest than *M. piniperda*, because the former can successfully attack trees which are in a condition slightly too vigorous for the breeding purposes of the latter, and because it can more successfully utilize thin-barked material for breeding purposes when necessary.

The popular opinion that *M. minor* prefers to breed in thin bark, and that it confines its attention to this type of material, has its origin in the fact that in the north of Scotland, and in Sweden, *M. piniperda* begins to breed earlier in the season than *M. minor*, and, in districts where *M. piniperda* is numerous, the thick bark becomes congested with the egg-galleries of this species before *M. minor* begins to breed. In these circumstances the latter is compelled to utilize the thin-barked material. This type of material tends to dry out rapidly, and this causes a high rate of mortality. This has led to the belief that *M. minor* is incapable of building up a large population.

The large-scale trap-stem experiments carried out during the bark-beetle investigation showed quite conclusively that *M. minor*, like *M. piniperda*, definitely prefers thick bark for breeding purposes. In any locality where *M. minor* was abundant and *M. piniperda* was relatively scarce, the former selected thick bark for its egg-galleries in preference to thin bark ; and the thick bark of trap-stems was utilized by *M. minor* to its maximum capacity to ground level, while the thin bark of these trap-stems was only lightly infested.

M. minor will readily breed in the bark of Corsican pine and maritime pine, and egg-galleries were recently found in the bark of maritime pine pit props from France at a colliery in South Wales. In fact, the first infestation recorded in Dorset was in the bark of maritime pine, and the present infestation at Wareham is in the bark of Corsican pine. When the egg-galleries are formed in thick bark, the surface of the timber is not excavated, as is the case when the beetles breed in thin-barked material. Consequently there is no permanent record left on the surface of the timber when thick bark infested with *M. minor* is removed.

Slightly scorched trees around the edge of burnt areas provide exceptionally favourable breeding facilities for *M. minor*, and these trees should in all cases receive special attention. If any of the trees are utilized for breeding purposes they should be felled and peeled to destroy the broods, before the latter can complete their development. Felling and thinning operations provide unique opportunities for destroying bark beetle broods, and constitute the best method of preventing outbreaks.

Chafer Control Investigation

The investigation into the control of chafers in forest nurseries, begun in 1947, was continued on a larger scale during 1948, and attention was chiefly directed to nurseries heavily infested with the cockchafer (*Melolontha* and allied species).

A summary of the work is given below under the headings "Chemical Control" and "Natural Control". Under the latter heading are included observations made on the biological, ecological, cultural and mechanical control aspects of the problem.

As the investigation develops, it becomes increasingly evident that, associated with chemical control methods, there are risks of causing repercussions which may create problems infinitely more complex than the initial problem of insect control. On the other hand, it seems probable that a suitable combination of natural control methods may provide a relatively simple solution to chafer, and other soil insect, control problems in forest nurseries.

CHEMICAL CONTROL

Large scale experiments in the prevention of damage by cockchafer larvae, using a dusting compound containing the gamma isomer of benzene hexachloride (B.H.C.), were carried out at Rhinefield Nursery, in the New Forest, during the seasons 1947 and 1948. A preliminary experiment to test the effects of this substance on seed germination and root development in seedbeds, was also carried out at Rhinefield during 1948. A detailed assessment of the above experiment was made at the end of 1948.

The application of B.H.C. for the protection of transplants gave excellent results, particularly the root dusting method of application.

On the other hand, heavy application of B.H.C. in seedbeds of Japanese larch produced complete mortality of the plants, and lighter applications produced varying degrees of mortality according to method of application.

It is known that a very high percentage of benzene hexachloride is recoverable from the soil up to two years after application, but it is not known how

long the substance persists and remains toxic. There is, therefore, a possibility that repeated applications of this substance for the protection of the roots of transplants, might result in an accumulation in the soil sufficient to render a nursery unsuitable for seedbeds. This subject will be investigated in collaboration with the Silviculturists. Further experiments have been laid down to test the effects of B.H.C. on several species in seedbeds, and with lined out plants. In these experiments, decreasing strengths of application have been used with the object of ascertaining the minimum effective rate of application for the protection of the roots of transplants, and the maximum safe rate of application in seedbeds. These experiments are also designed to test the effects of the limestone "filler" in the absence of B.H.C.

One seedbed experiment without further application of either B.H.C. or "filler" has been laid down on the site previously occupied by the 1947-1948 experiments, in which heavy applications of B.H.C. were used for the protection of the roots of transplants. The object of this experiment is to ascertain whether the soil still contains enough B.H.C. to cause toxic effects on the germination of seeds, and development of seedlings. The untreated controls in the previous experiment are included and will provide controls for the present experiment.

NATURAL CONTROL

All nurseries in the South of England reported to be heavily infested with *Melolontha* have been visited during the year, and much useful information has been collected.

REASONS WHY HEAVY INFESTATIONS OCCUR

In every case where heavy infestations of cockchafers occur in the areas visited, the nursery was either closely surrounded by woods of broadleaved trees, or had large areas of broadleaved trees in the immediate vicinity, and beech hedges either in the nursery or around the edges.

In the adult stage cockchafers feed on the foliage of broadleaved trees, and it seems probable that the presence of a liberal supply of suitable food in close proximity with exceptionally favourable sites for egg-laying, is one reason why certain nurseries are so heavily infested. There is also reason to believe that the smaller the area of the nursery in relation to the mass of surrounding food supply, the heavier the infestation is likely to be ; as in the case of Bere, and Stockley and Rhinefield nurseries in the New Forest.

In certain cases, where adjacent blocks of broadleaved trees have been cleared during recent years, nurseries which were formerly heavily infested with *Melolontha* are now relatively lightly infested.

PARASITIC AND PREDATORY INSECTS

The Dipterous parasite *Dexia rustica* F., of the family *Tachinidae*, plays a very important part in the control of *Melolontha* in some localities. A total of over 15,000 chafer larvae were collected from various localities and examined to ascertain the distribution and prevalence of the parasite population. Of 5,000 living larvae collected from Bere Nursery, 2,365 or 47.3% were found to be parasitised by *Dexia* ; and of 2,117 larvae collected from the Hemsted Nursery, Bedgebury Forest, 758 or 35.8 per cent were parasitised. This relatively high percentage of parasitism at Hemsted in 1948 is remarkable in view of the fact that Dr. M. Walker recorded that the parasite could not be found at Hemsted nursery during the 1937 and 1938 chafer infestation.

During the season 1948, the parasitised chafer larvae from Bere contained an average of 2.43 parasite larvae, while those from Hemsted contained an average of 2.21. Parasitism by *Dexia* reaches its maximum late in the autumn, and as unparasitised larvae tend to leave the upper layer of soil and descend

to their winter quarters rather earlier than the parasitised larvae, it seems likely that the collection and destruction of chafer larvae in late autumn may, in some cases, result in the destruction of the greater part of the parasite population and actually hinder the work of control, if a large proportion of the unparasitised larvae escape destruction. At that time of the year the cockchafers, which will produce the next generation, are lying in pupal cells, normally at a considerable depth in the soil, and therefore escape destruction by normal digging operations. Consequently a depleted parasite population may result in an abnormally severe chafer infestation in subsequent seasons.

The parasitised chafer larvae are finally destroyed by the parasite larvae towards the end of May, or during the month of June. The maggot-like parasite larvae emerge from the remains of the host larvae and form puparia in the soil, and the flies begin to emerge towards the end of June. The parasite *Dexia* does not as a rule begin breeding until the end of July, but continues to do so during August and September.

July is the best time to concentrate on the destruction of chafer larvae in forest nurseries, as at that time there is little risk of destroying parasite larvae.

Although *Dexia rustica* F. is generally regarded as the most abundant parasite of *Melolontha*, another species, *Dexia vacua* Fall., occurs in some localities ; and, although considered to be local in distribution, this species has been recorded from areas in the South of England, in Wales, and as far north as Sutherland.

In the adult stage both species feed on the flowers of certain umbelliferous plants, and it seems probable that the presence or absence of suitable food plants in the vicinity of any particular nursery will largely determine the abundance of the parasites in that area. If it is necessary for the parasites to disperse over wide areas to find suitable food plants, this will doubtless have an adverse effect on the percentage of parasitism. Conversely, an abundant supply of suitable food plants for the adult insects, in the vicinity of the nursery, would tend to deter dispersal and probably cause a concentration of parasites.

It also seems probable that a technique may be devised for facilitating the emergence of the adult flies, and the more effective distribution of their progeny. These and other aspects of the chafer control problem are receiving attention.

Predatory ground beetles and their larvae also destroy large numbers of very young chafer larvae, and play a very important part in helping to reduce chafer infestations during the early stages of development.

Insecticides for the Control of Pine Weevils

Preliminary tests with modern insecticides for the control of the Pine Weevil, *Hylobius abietis*, were not conclusive. The weevils showed a high degree of resistance to D.D.T. Better results were obtained with B.H.C., but E.605 gave the best results. As this substance is highly toxic to mammals and birds, further tests are necessary to find the minimum lethal dosage for weevils, and a suitable method of application for general use in the forest.

Some difficulty was encountered in making assessments of results, because of a high rate of natural mortality among old weevils in the controls. Further experiments will be carried out with young weevils of a known age during the season 1949.

Parasites of Pissodes Weevils

The following species of Hymenopterous parasites were bred from weevils of the genus *Pissodes* :

A few specimens of *Ephialtes laticeps* Ratz. (*Ichneumonid*) were reared from *Pinus contorta* cones infested with *Pissodea validirostris* Gyll. received from Roseisle, Morayshire.

A large number of *Ephialtes terebrans* Ratz. (*Ichneumonid*) were reared from Corsican pine infested with *Pissodes notatus* F. received from Pembrey, South Wales.

Numerous specimens of the parasite *Calyptus mucronatus* Thoms. (*Braconid*) were also reared from Corsican pine material infested with *Pissodes notatus* collected in Alice Holt Forest. This specimen was previously reared from *P. notatus* material collected in the New Forest.

It seems probable that certain prolific species of parasites might with advantage be transferred from localities where they are numerous, for establishment in *Pissodes*-infested areas where these parasites are known to be absent.

Parasites of the Spruce Longicorn Beetle

The following species of *Ichneumonid* parasites were reared from the bark of Norway spruce, infested with Spruce Longicorn Beetle, *Molorchus minor* L., collected in Alice Holt Forest:

Helcostizus albator Thunb.
Ischnocerus rusticus Geoff. (= *filicornis* Kriech).
Deuteroxorides albitarsus Grav.

Megastigmus from Imported Tree Seeds

A few specimens of the Chalcid fly *Megastigmus suspectus* Borries emerged from the seed of *Abies nordmanniana* imported from Denmark. This species has previously been recorded (McNeill, 1946) from the seeds of *A. grandis*, from Orton, Morayshire, seed year 1944. The latter was the first known record of *M. suspectus* in Britain.

Sawfly Infestations

LARCH SAWFLY INFESTATION AT DUNKELD

A small larch sawfly which defoliated large plantations of hybrid larch at Craig Vinean Forest, near Dunkeld, and on the Atholl Estates in Perthshire, was identified as *Anoplonyx duplex* Lep. (=*Platycampus duplex*, Lep.), family *Tenthredinidae*.

A species of Hymenopterous parasite, reared from cocoons of the sawfly, was identified as *Aptesis brachypterus* Grav. (=*Microcryptus brachypterus* Grav.) *Ichneumonid*. This is a very efficient parasite capable of building up a very large population by attacking the sawfly larvae after the latter have spun cocoons. It seems likely that this parasite was largely responsible for preventing a repetition of the large scale infestation, as reports from the local forest officers state that the sawfly infestation was very slight in 1948.

THE LARGE LARCH SAWFLY AT RADNOR FOREST

A few larvae of the Large Larch Sawfly, *Pristiphora* (= *Lygaeonematus*) *erichsonii*, Hartig., were found on European larch at Radnor Forest during the late summer of 1948. This insect is capable of causing great destruction. A survey of larch areas will be carried out during 1949 to ascertain the present distribution of this species.

SAWFLIES ON SPRUCE

Small infestations of two species of spruce sawflies have recently been reported from several localities in the south of England. These species are *Pristiphora abietina* Christ. and *P. hercyniae* Ht. A small infestation of the former occurred on a private estate in Bedfordshire during 1948. Both these species are pests of considerable importance in Europe.

SAWFLIES ON PINE

In addition to numerous small infestations in other parts of the country, two extensive infestations of *Neodiprion sertifer* Geoff. = *Lophyrus rufus* Ratz. occurred during 1948 at Langdale Forest and Broxa Moor (Allerston Forest) in Yorkshire, and on Beacon Fell in Lancashire.

In a large batch of material received from the Yorkshire infestation, the majority of the larvae were found to be infested with a polyhedral disease. This infested material was sent to the Agricultural Research Council's Virus Research Unit, at the Molteno Institute, Cambridge. The presence of the disease has been confirmed, and it has since been successfully transmitted to healthy larvae. Some of the diseased material was forwarded to Canada for establishment in sawfly infested areas.

From a large batch of material received from the Beacon Fell infestation, the following *Ichneumonid* parasites were reared in considerable numbers : *Torocampus eques* Htg. (=*Mesoleius eques* Htg.) and *Exenterus abrutorius* Thnbg. (=*E. cingulatorius* Hlgr.). Both the above species are parasites of the larvae ; it is probable that a cocoon parasite may also be present.

Lepidopterous Pests on Coniferous Trees

EVETRIA PURDEYI ON CORSICAN PINE AT BAWTRY AND LAUGHTON FORESTS

The decrease in density of the infestation of *Evetria purdeyi* Durr. reported in 1947, was maintained during 1948. From a large batch of infested material collected at Bawtrey, the following Hymenopterous parasites have been reared :

Pteromalidae :
Habrocyterus eucerus Ratz.
Eutelus sp.

Eulophidae :
Tetrastichus seticollis Thoms. (Species new to Britain).

Braconidae :
Eubadizon extensor L.
Apanteles sp.

Ichneumonidae :
Hemiteles areator Panz.
Hemiteles sp.
Ephialtes sagax Htg.
Itoplectis maculator Fabr.
I. alternans Grav.
I. alternans Grav. var. *kolthoffi* Auriv.

In some cases only single specimens were reared but some species of parasites were fairly numerous.

All the above species are parasitic on several other insects. Some are common parasites of the Pine Shoot Moth, *Evetria buoliana* Schiff. It seems probable that in the aggregate these and other resident parasites will ultimately control this new pest.

PEST ON SITKA SPRUCE AT HOPE FOREST

Dingy Bell, *Eucosma diniana* Guen. (*pinicolana* Zett) (=*Zeiraphera diniana* Gn.).

This moth is grey with three oblique dark brown bands on the fore wings, and has a wing-span of half to three-quarters of an inch (12 to 18 mm.). It is a pest on Sitka spruce at Hope Forest in Derbyshire, and is probably widely distributed. In Europe it is a pest on larch, but as yet it has not been recorded as a pest of larch in this country.

On beginning to feed in the spring, the tiny larvae attack the base of developing shoots of Sitka spruce. The injured shoots wilt and the needles turn reddish brown as if damaged by frost. The larva spins a silken tube within the tassel-like tuft, and feeds on the wilting needles until after its second moult ; it then transfers its attention to green foliage, on which it subsequently feeds. It pupates in a web spun among damaged needles, and the moth emerges in August and September.

The following species of Hymenopterous parasites have been reared from material received from Hope Forest, Derbyshire.

Pteromalidae :

Habrocytus eucerus Ratz.

Eulophidae :

Cirrospilus pictus Nees.

Braconidae :

Meteorus pallidipes Wesmael.
Oncophanes minutus Wesmael.
Apanteles. sp.

Ichneumonidae :

Itoplectis alternans Grav. var *kolthoffi* Auriv.
Omorgus borealis Zett.

PEST ON SITKA SPRUCE AT WAREHAM NURSERY

Grey Red-barred Twist, *Eulia politana* Haw. (*lepidana* H-S.) (=*Argyrotaenia pinatubana* Kearf).

This moth caused damage to Sitka spruce transplants in the nursery at Wareham during the season 1948. It is silver grey with red bars across the fore wings, and has a wing-span of about half to five-eighths of an inch (12-16 mm.).

The normal food of the larvae is reputed to be *Myrica*, *Erica*, *Centaurea*, etc., and its normal distribution is mainly heathland. This insect affords a good example of how species, which have hitherto been regarded as of no economic importance, may become pests on exotic coniferous trees.

In the nursery at Wareham, the larvae of this insect caused damage by destroying the leading shoots of Sitka spruce, thus causing bushy growth and multiple leaders. Fortunately there is a strong resident parasite population in the locality, and more than half the specimens collected were parasitised by an *Ichneumonid* parasite *Phytodietus geniculatus* Thoms.

In addition to the above species, several other potential pests of Sitka spruce are being studied. Special attention is being devoted to the Green Spruce Aphis, *Neomyzaphis abietina* Walker, and another species of aphid, the precise identity of which has not yet been determined.

Export of Beneficial Insects

As a by-product of the chafer investigation, 6,000 *Melolontha* larvae, parasitised by the *Tachinid* fly *Dexia*, have been sent by air to other countries for the control of allied species of white grubs. 2,000 of these parasitised larvae were supplied to the United States Bureau of Entomology ; for these we have received payment of 500 American dollars. 4,000 parasitised larvae have been sent to Mauritius on behalf of the Commonwealth Bureau of Biological Control.

Commonwealth Entomological Conference

The Entomologist attended the meetings of the Commonwealth Entomological Conference, held in London during July, 1948.

Consultative and Advisory Work

During the year, 94 applications have been received for identification of specimens, or for advice on entomological matters. Of these, 46 were from members of the Forestry Commission staff, and 48 from private estates, timber merchants, or municipal authorities.

Visits were paid to numerous Commission areas and nurseries in connection with insect pests. Several visits were also made to ports in South Wales to examine cargoes of imported pit props.

Reports were written on two meetings with local representatives of the National Coal Board, and the Board of Trade, in connection with the control of bark beetles in imported pit props and at colliery dumps.

Reports were also written prescribing treatment for insect control in large burnt areas at Wareham Forest, Ferndown Forest and Ashley Heath, Ringwood, and on damage to seedlings in Bramshill nursery.

GENETICS

By J. D. MATTHEWS
Geneticist

The general procedure in forest genetical research is as follows :

(1) The species to be studied are chosen and the characters desired from all points of view are listed.

(2) The variations found within each species are studied, and those which have the greatest number of desirable characters are marked down.

(3) Individuals are selected from the desirable strains and breeding work is based upon them.

The end of March marked the completion of six months of work, during which progress was made in Stages 1 and 2, particular attention being paid to beech, European larch, Scots pine and Sitka spruce.

The Study of Variation

Beech

Prominent among the characters desired in beech are superior height and diameter growth, a straight main axis without fluting or forking in the lower and middle sections, good crown and branch form, and improved timber quality.

Beech has been studied in the Forest of Dean, in the Cotswolds and at the Crawley portion of Micheldever Forest, Hampshire, a very striking variation being found at the last-named forest in a young beech-larch mixture on a rather frosty chalk downland site. At one extreme were trees with rather narrow leaves, short and sharply ascending branches, and very straight persistent leaders. These individuals were making very fast growth and were well above the frost zone. At the other extreme were trees with rather wider leaves, longer and more spreading branches, no persistent leader and poor coarse form. These latter individuals appeared to have been regularly frosted. Other examples of the same type are now being followed up.

European Larch

The desirable characters for larch include superior diameter and height growth, good stem and crown form and, a most important consideration, resistance to die-back.

Variation in larch has been studied in the provenance trial at Clashindarroch, Aberdeenshire, at Drummond Hill, Perthshire, and also at Savernake, Wiltshire. Branch form has proved of value in the identification of certain provenances.

Scots Pine

External characters which desirable Scots pine phenotypes should possess are superior diameter and height growth, straight stems with low rough-bark formation, crowns which are narrow to intermediate in width, with branches which are light and few in number. Scots pine has been studied at Croxton Park, Thetford, Norfolk, and at Bedgebury, Kent.

Sitka Spruce

The widespread nature of damage by the insect *Neomyzaphis abietina* has brought an additional factor into the selection of Sitka spruce, superior growth and form, hardiness to late frosts, and resistance to *Neomyzaphis* attack being among the criteria used. Individuals have been found in the Forest of Dean (Churchill Inclosure), the Thetford area (Croxton Park) and Coed y Brenin (North Wales), which appear to be able to throw off attack by the aphis. These trees have leaves with very blunt and shouldered apices, and a very heavy construction. The leaf section is flat, the twigs are quite glabrous, and the individuals of this type can often be picked out in a plantation by virtue of their dense compact crowns, dense and flattened leaf arrangement, bluish leaf colouration and, where *Neomyzaphis* attack is prevalent, by a sharp contrast in the intensity of infestation. It is too early to state whether or not this particular type of tree is resistant to *Neomyzaphis* attack ; and the possibility of these trees being of hybrid origin must also be followed up. The example found at Coed y Brenin is, however, later in flushing than typical Sitka spruce, and is thriving well in a very frosty locality.

Other Species

The differentiation of *Pinus contorta* into coastal and mountain forms was studied at Beddgelert and at Clocaenog, North Wales. The provenance trials at Clocaenog contain a good range of origins, including the "shore pine" strains with dense, compact and rounded crowns, and dark green foliage, and the "lodgepole pine" strains, with more open, conical and narrow crowns, grey green foliage and very good form.

Individual Trees

Records of interesting, and possibly valuable, individual trees of all species are being kept, these being based upon our own observation or on information received from those interested.

Nursery Trials

Seed of over twenty beech provenances collected by the ecologist was available for sowing this spring, and a small intensive nursery trial has been laid down. Assessments of height growth will be made, and botanical features will be studied later in the season.

The Assessment of Form in Provenance Trials

Provenance trials are valuable subjects for the study of variation, and may later become sources of breeding material. Two methods for the assessment of form are being tested, the first in the North and the second in the South.

(1) Each factor considered to be of importance is being measured, e.g., total height, girth, bends in the stem, spread and depth of crown, angle, size

and number of branches, thickness of bark, etc. This is a slow process, but the results obtained are precise, and small differences can be brought out very clearly.

(2) Measurement of height and girth is used to obtain an indication of vigour, while assessments of form are made on a visual scoring system. A factor such as stem form is divided into three classes (good, moderate and poor) each of which is defined and given simple numerical values. This method has proved speedy and practical, but the weight given to each factor is as yet arbitrary, and much depends on the knowledge of the observer.

It is probable that the visual method will be of value in bringing out major distinctions between large numbers of provenances ; while measurements will be required to bring out fine distinctions and a clear picture of variations within a provenance.

Propagation Work

Spring Grafting under Glass

Grafting is used for the following purposes :

(1) To enable material suitable for breeding purposes to be brought from all over the country to one central place.

(2) To provide material for comparative trials designed to assess the genetical quality of individual élite trees.

(3) To encourage early flowering and to enable artificial pollination to be carried out near to ground level.

(4) To provide material for the formation of seed orchards.

This spring four general grafting methods (Veneer Side, Lateral Puncture or Slit, Whip-and-tongue, and Cleft) were tried out on two broadleaved and eight coniferous species, with the objects of determining the most suitable grafts for spring work, and of evolving a standard procedure for the collection of material suitable for breeding purposes. The glasshouse used was unheated, and the average temperatures for the months of March, April and May ranged between 55° and 60° F. A small part of the interior of the house was put under extra glass and set aside for bedding half of the completed grafts in a mixture of Bedford sand and peat. Before grafting, the house was sprayed with a 1 per cent formalin solution, as a precaution against Graft Disease (*Chalaropsis thielavoides*). A total of 135 grafts were completed, each one being recorded and studied individually ; the species concerned were : beech, ash, Corsican pine, Scots pine, Norway spruce, Sitka spruce, *Cupressus macrocarpa*.

The following results have emerged from this assessment :

THE STOCKS

Well rooted and sturdy one-plus-one transplants, up to fifteen inches high and about the diameter of a pencil at two to three inches from soil level, appear to be the most suitable for the majority of the species studied.

The stocks should be potted into four-and-a-half- to five-inch pots in late October or early November, and placed in ash beds protected by lath or similar cover. The move to the glasshouse should be made in February, and the time of grafting depends on the progress made in the house. The stocks must be moving vigorously when grafted, and the speed at which they can be brought on can be greatly increased by the use of heat in the glasshouse.

THE SCIONS

Scion material was derived from three main sources :

(1) Material collected locally in January, and stored in cool moist conditions for over forty days before use.

(2) Material collected locally and grafted on the same day. The one year old wood was divided to make top, middle, and basal scions.

(3) Material collected in Scotland and sent by rail packed in cool moist conditions.

The material came from all parts of the crowns of the parent trees, and the scions used were mainly of one year wood, three to four inches long and derived from vigorous leading shoots or second order branches. The results obtained indicate that this type of scion can be used quite successfully.

THE GRAFTING METHODS

The two most successful methods were the veneer side graft, and the whip-and-tongue graft. When the equivalent of sap-drawer branches are left to keep the stock in good health, the cleft graft can also be used to good effect. Less success was obtained with the lateral puncture or slit graft. Ash, beech, larch, *Cupressus macrocarpa* and Douglas fir responded well to spring grafting under glass, while the pines and spruces proved more difficult, the principal factor involved appearing to be the film of resin which formed at the union of stock and scion. Improved technique should do much to overcome this problem.

Spring Grafting in Young Plantations

This work was commenced at the end of the period under review, the stocks being up to ten years old, and the species, oak, beech, larch, Norway spruce and Douglas fir. Standard top working methods have been used.

Breeding

At present efforts are being directed towards the study of the techniques of breeding and the collection of information for future work.

Phenology

General observations are being made on a number of species, with particular reference to the dates and period of flowering and the degree of protandry or protogyny exhibited by these species. Records are being kept at Bedgebury National Pinetum, Alice Holt, and in the Forest of Dean.

Controlled Pollination

Pinus banksiana and *Pinus contorta* were chosen for experimental controlled pollination work at Alice Holt. The two species were crossed reciprocally under glass, and in the nursery, using both fresh and stored pollen. Female flowers of *P. banksiana* were also pollinated at four distinct stages of development. A long-term scheme for controlled pollination in the Bedgebury Forest Plots has been drawn up, in order that advantage may be taken of the great number of species available there.

Visits

A great deal of valuable help and guidance has been received at the research stations and other organizations which have been visited during the past six months. Advice on glasshouse design and operation was received at the John Innes Horticultural Institution and at Reading University. Walnut propagation was studied at the East Malling Research Stations and the propagation of softwood and hardwood cuttings at both the Royal Botanic Garden, Edinburgh, and at the Gardens of the Royal Horticultural Society, Wisley. Messrs. Hilliers of Winchester kindly gave advice on conifer grafting.

FOREST ECOLOGY

By J. M. B. BROWN
Ecologist

Forest ecological work in the past year has been directed towards a comprehensive investigation of the ecology of British beech woods. This object is being approached along three main lines :

(a) By a survey of the natural behaviour and methods of treatment of beech in different regions of Britain.
(b) By recording in more detail the growth of beech crops on representative sites in all the main beech growing areas.
(c) By study of the ecology of young beech crops in different circumstances.

The extensive survey (a) is designed to reveal the variety of condition in which British beech is growing ; to show in particular, how different methods of treatment are related to the natural distribution of the tree, to factors of climate and soil, and to traditional methods of land use and markets, and to indicate how far such differences of treatment should influence the deductions made from the assessments of representative crops. These assessments (b) aim at giving factual expression to the variety of conditions in which beech crops have been growing, and the manner in which the species responds to them. The detailed records from representative sites (b), supplemented and balanced by information collected during the extensive survey (a), will form the foundation on which a reasoned account of the ecology of cultivated beech can be worked up. The third line of approach (c) faces different problems and requires different methods. Briefly, the purpose of such work is to recognise, if possible to isolate, and then to measure, the critical ecological factors affecting the survival, growth and stem form of young beech crops.

Work to Date

This has comprised :

(1) A review and tabulation of the data collected in beech woods during a survey of war fellings.
(2) Plans for a comprehensive survey of beech in Britain in 1949/50.
(3) Discussions with certain owners, or their agents, of beech woods in south-east England and the Chilterns, and preparatory contact with other estates.
(4) Full records of some mature beech woods.
(5) Visits to numerous young beech crops in various parts of south and east England, mostly in Thetford Chase and Sussex. The influence of shade, frost and soil conditions has been studied in a preliminary way.

Results

Data collected from war-time fellings provided general indications of the performance of beech in different parts of England, and a good deal of detailed information about the Chilterns beech. Outside the Chilterns, beech sites recorded were very sparsely distributed over England and Wales : in particular, the Cotswold Hills (Jurassic limestone) and the South Downs (chalk) were very meagrely represented. Only five beech crops were recorded in Scotland. These gaps in the records have been filled in, to a small extent only, by the data recently collected ; and the main object of the investigation now undertaken is the extension of the survey to all parts of Britain where natural or planted beech occurs. In this work a more detailed description is made of the site, particularly of the soil ; and in the records of the crop, more

attention is paid, on the one hand, to diameter growth and, on the other hand, to such factors as provenance, past history and treatment. In the Chiltern records, a major defect is the lack of information about the origin and treatment of the crops, and the previous use of the land. Every effort is now being made to obtain and use all available information on these points. The data so far obtained point to a rather slower growth of beech in the Chilterns than on the South Downs, or the Cotswolds. There are three possible causes of this :

(a) The Chiltern beech may be genetically inferior in respect of height growth. Such intrinsic inferiority would be perpetuated by the ruling system of natural regeneration : in effect, the selection method of felling must have amounted, on many estates, to a selection of the weakest trees for reproduction.
(b) The method of silviculture (selection forest) may perhaps, by allowing too much shade over the young crop, have a slight depressing effect on growth in height and diameter.
(c) The soils of the Chilterns may be less suited to the production of first quality beech than the soils of the Cotswolds or South Downs.

Exceptionally good crops of beech have been recorded in the Chilterns, and more may be discovered on further exploration. Within the Chiltern beech area, the soils vary widely. True rendzina soils, which are not very common, produce some very good, as well as some rather poor, crops. In general, the true clay-with-flints of the escarpment and western part of the dip slopes carries better beech than the brick-earth (Pliocene) and Eocene deposits in the east and south-east, but there are only scanty data from these latter formations.

Outside these southern counties, where beech occurs naturally and often plentifully, there are planted crops of beech in every part of Britain. Wales and western Scotland have but little to show ; in many other districts, crops of beech are scattered and small. Preliminary investigations show that, on suitable soils in the English Midlands, in Yorkshire, and possibly in eastern Scotland, beech can be grown that is little inferior to beech on good sites in the South. War fellings have made great inroads into beech crops throughout the country ; but it is believed that there is still scope for a thorough extension of the very tentative survey made during the war in the North and Midlands of England and in Scotland. The first indications are that, in each of the regions where beech has long been grown, some particular silvicultural treatment has become habitual. It is desirable that the modes of application and the effects of these standard treatments and of any important modifications should be fully studied.

Site Factors and the Growth of Beech

Within the range of beech in Britain, it seems that soil is of more importance than climate or topography. In exposed western areas, wind is probably the limiting factor in the growth of beech ; but beech does not occur there to any great extent, and elsewhere the tree shows itself to be wind-firm and tolerant of considerable exposure. In coastal districts, however, salt-laden winds may cause scorching of beech foliage. In the south of England, elevation appears to count for little : good quality crops have been seen at 800 feet on the Chiltern escarpment. Data are insufficient for appraisal of the importance of elevation in more mountainous regions. The best beech crops seen have stood in valleys where, probably, the greater depth of soil is no less important than the shelter in improving the environmental conditions. Aspect, too, needs closer examination in relation to beech growth. On the European continent, south-east is said to be most favourable. It is unlikely that south-east, or any other aspect, is best in all circumstances in Britain. On shallow chalk soils in the

drier parts of the country, south and south-west aspects appear to aggravate the danger from summer drought.

The most significant soil factors appear to be the four discussed below, but these are closely interwoven and, in the present state of knowledge, it is impossible to evaluate them separately :

(1) Depth.
(2) Texture.
(3) The drainage profile.
(4) Carbonate content, or base status.

(1) *Depth* must be recorded in conjunction with the nature of the limiting layer. Where this is partially weathered chalk, or hard limestone, beech roots extensively and deeply in the many vertical and horizontal channels which percolating rain-water slowly dissolves between the blocks of solid limestone. These channels become loosely filled with mineral soil, and furnish the deeper roots of the beech with a rich source of minerals and moisture. The optimum, or minimum, depth is also dependent on the texture, and probably on the degree of base saturation of the soil : eighteen inches of sand, especially leached sand, are certainly much less satisfactory than eighteen inches of rich loam. Data from sandy soils are still too scanty to give much indication of the reaction of beech. On fertile calcareous loam over chalk in the Chilterns, the distribution of beech roots indicated that eighteen inches was more than adequate for full development, while twelve inches, or less, was restrictive.

(2) *Texture* influences the minimum depth required in the way indicated. Texture also affects the drainage profile and base status. Any mineral soil will grow beech ; but during the vegetative period great demands are made on the soil water, while defective drainage affects growth and vigour. Consequently, sands, which are often excessively drained, and stiff clays, where drainage is commonly impeded, are generally unsatisfactory.

(3) *The drainage profile* is a troublesome factor to describe and measure. Further, both the season and the vagaries of the weather may profoundly influence the soil environment. For these reasons, no single set of observations in the field, even if amplified by determinations of soil-water content, can give a full account of the environment of the roots of a growing tree. Nevertheless, the importance of this factor has been shown for several tree species, and much can be learnt from accurate observation of the fresh profile. Accordingly, an attempt has been made to identify a series of types of drainage profile, so that different sites may be compared in respect of this, and so that eventually the growth of beech (and of other kinds of tree) may be related to it.

(4) *Base status.* Except on dolomitic limestone, the exchangeable calcium content is a good index of the base status of a soil. Measurement of this value is important on the more acid soils. Soils with a high pH value may be assumed to have a good base status : only when the pH is much below 6 is there need to estimate exchangeable calcium. Loam clay soils of low pH may still hold good reserves of bases, while acid sands are nearly always deficient. Besides this, the maintenance of soil fertility under crops of beech has, in some cases, been shown to depend on the base status of the soil. Beech mobilises the soil calcium and opens up the deeper layers ; so that, by removal in the crop and dissolution down the profile, soils not naturally rich in calcium become depleted. Even soils derived from calcareous parent materials may, in British conditions (except, perhaps, in the dry and warm east and south-east counties) become leached to a considerable depth under continuous crops of beech. The effects of this washing out of calcium carbonate may be seen on the chalk of Hampshire and the Chiltern Hills. It is very desirable that more information should be obtained about this aspect of beech ecology. It may be presumed that the intensity of leaching is affected by many factors, such as

rainfall, altitude, aspect, exposure to prevailing winds which scatter the fallen leaves, and by the composition of the crop, silvicultural treatment, and the method of regeneration.

The data obtained from many young beech crops, natural and planted, have taught the lesson that, however valuable shelter may be during the early growth of beech, excessive or prolonged shade is detrimental to height growth and form. Neglect of cleaning and thinning due to the war has resulted in many beech plantations suffering from competition for light and root-space, with associated nurse trees. In the Chilterns selection forest, too, the same phenomenon is almost ubiquitous. The natural seedlings which appear after every seed year, especially where single trees have been cut out, show the influence of this competition sooner or later. Satisfactory means of measuring light-intensity, or soil water, were not available in 1948, and no detailed studies have so far been made. Observations on many sites suggested that young beech trees respond best when full light from overhead is tempered by some side shade, which will shield from frost and wind, stimulate height growth, discountenance low side branches, and foster good conditions at the soil surface. Shade and root competition are admittedly by no means the only factors affecting the growth, vigour and form of young beech crops on the various sites where they are found. But the practice of planting beech with, or under, a nurse tree is widespread, and so the effects of competition merit the closest attention. The same applies equally to all naturally regenerated beech.

There is little doubt that the influence of these and, where desired, other ecological factors, could be studied most satisfactorily in a series of defined areas, where regular observations and assessments might be made over a period of years. It is hoped that a number of such plots can be set out and described within the next twelve months. The great variety of conditions asks for a large number of plots : the time needed for adequate recording of each counsels moderation. A satisfactory compromise might be made by restricting the detailed recording to one major beech district, e.g., the South Downs. It must be emphasised that all ecology is dynamic : the changes, and the forces bringing them about, can only be fully assessed when the site is under continuous observation for a period, and when certain of the crucial factors are subject to some measure of control.

Forest Ecological Reserves

At the British Association meeting in 1938, the Chairman of the Forestry Commission made an offer which got a good response from ecologists. He affirmed that the Forestry Commission would be prepared to set aside certain of their areas for the study of ecological succession, or the investigation of problems of plant or animal ecology. It was intended to stimulate interest especially in unplanted areas, where invasion by trees might be looked for. A good beginning was made in 1939, but the war caused a suspension of work when few definite promises of co-operation had been received by the committee appointed to administer the scheme. Early in 1946, however, this committee, under the chairmanship of Sir William Wright Smith, set to work again, and many applications for reserves were received, mainly from the botany departments of the Universities.

In July, 1948, the Ecologist succeeded Mr. J. A. B. Macdonald as secretary to the committee, whose chairman is now Dr. H. Godwin. A schedule, prepared for the committee's last meeting in January, 1949, showed eight departments actively engaged in chosen reserves and fourteen others making plans, or waiting for more favourable conditions before launching out. Interesting and valuable records have already been made in these forest areas : Gwydyr ; Cwm Einion (Merioneth) ; Wyre ; Sherwood ; Thetford ; Bramshill ; Forest of Dean (High Meadow woods) ; New Forest.

THE TREATMENT OF SEED

By G. D. HOLMES
Assistant Silviculturist

Germination Tests

Due to the importance of having an accurate and rapid method of assessing seed germinative capacity, a programme of experiments was undertaken during 1948 designed particularly to assess the reliability and accuracy of chemical vital-staining methods.

The procedure has been to develop a standard technique for staining and preserving seed under test, and to attempt to correlate the results obtained with germination in a standard laboratory germinator, and in the field.

A number of chemical compounds have been tested, including indigo carmine, sodium biselenite, and 2-, 3-, 5-triphenyl tetrazolium chloride, and tetrazolium bromide. Of these compounds tetrazolium bromide was selected as being the most suitable, due both to the clarity of the embryo staining and to its non-toxic nature.

A satisfactory standard test procedure has been developed, and a classification of stained embryos on the basis of the area stained and density of staining has been worked out. A method of permanent preservation of embryos has also been evolved.

A large number of tests, both of a routine and experimental nature, has been carried out on Sitka spruce, Japanese larch, Scots pine, Corsican pine, *Abies concolor*, *Picea omorika*, beech and lime. Over 130 tests have been made in all.

The staining is done under strictly controlled conditions, and large numbers of tests, carried out on separate samples from the same seed consignment, give closely similar results. A variation between samples of more than 5% can be regarded as unusually high.

The tetrazolium "germination" value is invariably an over-estimate of actual germination. Data is insufficient as yet to allow definite conclusions and calculation of conversion factors, but from the information available the relationship seems a fairly consistent one.

A large experiment is now in progress with tetrazolium bromide to provide the necessary data for determination of the precise correlation between the various embryo-staining categories, germination under standard laboratory conditions, and germination over a wide range of field conditions.

Seed Treatment

(1) SEED SOAKING

Experiments at Kennington Nursery, Oxford, over two seasons, using Sitka and Norway spruce, Scots pine, and European larch as test species, show no evidence to support the practice of seed soaking prior to sowing, with the one important exception of Sitka spruce. Sitka spruce shows a significant increase in final germination after six days' soaking, which gave 44% germination as compared with 26% for unsoaked seed.

The rate of germination of Sitka spruce is increased by soaking, with which 90% of germinable seed germinated in 47 days, compared with 60% in the case of unsoaked seed. A slight increase in rate of germination was also obtained with Norway spruce. In Scots pine and European larch, germination is slightly reduced by soaking, particularly for long periods.

The smallness of the effects obtained from soaking was suspected from the results of a similar experiment in 1947.

Artificial watering of seedbeds showed no effect on germination, and only very slight and inconclusive effects on seedling growth.

(2) ACID TREATMENT OF SEED

The promising results recently obtained in Denmark in the stimulation of the rate and total germination of coniferous seed by acid treatment prior to sowing, suggested experiments to test this on seed of Corsican pine, Norway spruce, Sitka spruce and European larch.

Acid solutions ranging from pH 2.5 to 7.0 were used, for different soaking periods from 24 to 144 hours.

Results were disappointing. Soaking seed in acid solutions with a pH value of 2.5 has a very considerable reducing effect on the percentage of seeds germinated. Soaking in weak acid solutions (pH 4.5 to 5.5) slightly increases germination in European larch and Sitka spruce. Some stimulation of the rate of the germination occurs, but this is small in comparison with fertility differences.

Notwithstanding these slight increases in the speed of germination, the final effect of acid treatment at the end of the first season is, if anything, detrimental.

Seed storage

An experiment is now nearing completion which compares the influence of duration of low-temperature moist storage, and low-temperature dry storage, on the rate and capacity of germination of a number of species.

EXPERIMENTAL WORK IN THE NURSERY

By M. V. EDWARDS and G. D. HOLMES
Assistant Silviculturists

A. Partial Soil Sterilization

The work here described was concerned with partial soil sterilization and soil acidification in long-established nurseries; with organic and inorganic forms of manuring in both new heathland and in established nurseries, and with various other subsidiary projects. Except where otherwise stated, all results apply to one-year-old Sitka spruce sown by standard methods.

I. Steam and Formalin and Manuring

A comparison of steam and formalin sterilization and various manurial dressings was carried out in continuation of the work of previous years. Steam was highly effective in reducing the time taken in weeding, by 60 per cent at Newton (Moray), and by 97 per cent at Benmore (Argyll), though at Fleet (Kirkcudbright) it was less effective, and there it is suspected that some extraneous cause made the steaming incomplete.

Its effect on height growth at Kennington (near Oxford), Newton and Benmore was very good, the increases in mean height being 0.8 in. (80%), 0.4 in. (25%) and 0.3 in. (20%) respectively. The increase in usable one-year seedlings was 21 thousands per pound of seed (50%) at Newton and 23 thousands (70%) at Benmore.

Formalin was less effective than steam as a weed-killer, but it reduced weeding times by an amount varying from 20 per cent to 70 per cent, and it was generally more effective than steam in increasing height growth and in the number of usable plants produced this year in Scotland.

However, at South Laggan (Inverness-shire) and Widehaugh (Northumberland) both sterilizers were ineffective, and so was the effect of a nitrochalk top-dressing during the summer. Phosphate and potash were effective, and it is thought that at these two centres, which have not been heavily cropped with conifers lately (the site of the South Laggan experiment in particular was pasture three years back), there is little need for sterilization or nitrogen, but that probably phosphate is the limiting factor.

The chief effect of farmyard manure was to reduce the number of seedlings and increase weed growth, the latter probably causing the reduction in seedlings. Even sterilization after manuring is not entirely effective in reducing the weeds. The beneficial effects of farmyard manure are usually seen in the second year.

The nitrochalk top dressing was astonishingly effective at Newton, as was the case in other experiments there where nitrogen was used. Its effect was unexpectedly greater with sterilizers than without them. The same result was noted at Kennington, with ammonium sulphate top-dressing.

Phosphate and potash (a combined dressing) had little effect in unsterilized soil, or with farmyard manure on sterilized soil, but elsewhere it was effective.

II. Methods of Steaming

The standard Hoddesdon pipe system was compared with the metal hood or bottomless box placed over the loosened soil surface, and the harrow with hollow tines, by which steam is injected into the soil without digging the pipes in. Various lengths of time of steaming were used with each method. The experiment produced no significant results, though the hood and harrow methods were surprisingly efficient in view of the fact that they are often considered obsolete, and at Newton both were more effective as weed-killers than the standard pipes.

At Tair Onen (South Wales) a "road burner" as sterilizer worked very effectively as a weed-killer, and absence of weeds resulted in increased production of seedlings. A six-minute application was more effective than shorter times, so that still longer periods might be even better. It was as successful as formalin in increasing height growth.

An experiment at Tulliallan (Fife), with sterilization in January and March on both wet and dry soils, showed no differences between treatments ; but weather conditions were bad, and the experiment is being repeated this season in modified form.

It is obvious from these and previous experiments on details of steaming technique that, while they show an advantage in steaming as compared with no sterilization, uncontrolled variations between treatments, such as variations in boiler pressure, differences in the length of pipe from the boiler to the plot being treated, etc., vitiate the comparisons which are desired. These points have been the subject of experiment in 1949.

III. Formaldehyde, Benzene Hexachloride and Carbon Bisulphide

Five different strengths of formalin solution and three levels each of a compound containing B.H.C. and carbon bisulphide, were tested in seven nurseries in Scotland.

FORMALIN

One-tenth of a gallon of formalin per square yard, derived from horticultural practice and tested in previous years, was confirmed as the best rate of application, and gave significantly greater height growth *and* weed control than untreated plots at Newton, the Royal Botanic Garden, Edinburgh, and Fleet ; and greater height growth at Tulliallan, where weedings were not recorded. It was also effective on height growth, but not on weed control, at Benmore and effective, in less measure, at Inchnacardoch (Inverness-shire). It had no result at Mabie (Dumfries).

The optimum dilution was in $2\frac{1}{2}$ gallons of water at Newton, Tulliallan and the Royal Botanic Garden, and $1\frac{1}{4}$ gallons at Inchnacardoch, Benmore and Fleet ; $\frac{3}{4}$ gallon was less effective, but there was little difference between any of the rates.

In most cases, as usual, formalin slightly reduced the *total* number of seedlings, through increasing the *usable* number, but there was a notable

exception at Newton, where the effect of formalin was outstandingly good in all respects.

B.H.C. COMPOUND, AT 0.8, 1.6, AND 3.2 OUNCES PER SQUARE YARD

This compound, which contains B.H.C., had little effect on height growth, the only significant result being a reduction with the highest level of application at the Royal Botanic Garden. Total numbers were significantly reduced at Tulliallan, Benmore and Fleet, but at Inchnacardoch a slight increase in both total and usable numbers was recorded with increasing doses. Weed growth was increased in almost every case, significantly at Inchnacardoch, Newton and the Royal Botanic Garden, which may perhaps be attributed to the effect of B.H.C., which is recorded as beneficial to some agricultural crops. In view of its beneficial effect on lined-out conifers, recorded in England, further trials might be made.

CARBON BISULPHIDE, AT $1\frac{1}{2}$, 3, AND 6 OUNCES PER SQUARE YARD

Carbon bisulphide had no effect on height growth, but it reduced numbers significantly at almost all centres, though results were erratic and not corresponding to increasing levels of application. Weed growth was almost everywhere increased, significantly at Inchnacardoch, Newton and the Royal Botanic Garden.

Carbon bisulphide was also used at Tair Onen and Kennington with very similar results.

These results are difficult to reconcile with American work, but there, doses of an ounce per square foot or more are used, and the need for sealing the soil surface and other precautions to prevent evaporation are emphasized. Further trials are necessary before carbon bisulphide can be rejected as useless.

B. Acidification

In view of recent evidence that many nurseries have been overlimed in the past, the effect of sulphuric acid, ammonium sulphate, and sulphur at three levels of application was tried out in five Scottish nurseries selected as being likely to be too alkaline for the optimum production of conifer seedlings. Sulphuric acid was used at Kennington and Tair Onen.

Acidification had markedly beneficial results, increasing the mean height at Newton by 0.8 inch, at Barcaldine and Montreathmont by 0.3 inch, at the Royal Botanic Garden and Tulliallan by 0.25 inch, and at Kennington by 0.20 inch. The optimum treatment, however, varied, and there was no correlation between the effect of the acidifiers and the soil pH before their use.

Ammonium sulphate was the most effective at Newton and Tulliallan, the highest level of sulphur at the Royal Botanic Garden and Montreathmont, and sulphuric acid at Barcaldine. The effects of sulphur were in order of its level of application, except at Barcaldine.

Soil sterilization in the same experiment (steam at Newton and Tulliallan, formalin elsewhere) gave more marked effects than the acidifiers, but whereas at Barcaldine there was a marked positive correlation between the effect of sterilization and the effect of the acidifiers (in this case the effects of the higher sulphur levels were small or deleterious), at the other nurseries there were signs of negative correlation between sterilization and acidifiers. The very heavy dose of ammonium sulphate proved less beneficial than other acidifiers in most cases (except at Newton), and interactions between it and both sterilization and fertilizers suggest that it combined an overdose of nitrogen with a beneficial acidification.

It is unlikely that the effect of the sulphur will have been fully realized in one season, and the experiment is being continued with both resowing and lining out for a second season. Results so far can only be regarded as incomplete.

C. Manuring

I. Placement of Fertilizers

An experiment on placement of fertilizers below the seed, as is done in agricultural practice, was carried out on the recommendation of Dr. Stewart of the Macaulay Institute for Soil Research. This necessitated a return to drill sowing, now generally given up in Scotland, and a selection of combinations of drilled fertilizers was used, placed by hand methods, though in the event of success a machine would be employed.

Normal and double densities of seed were used, on the assumption that putting the fertilizer in the right place might enable more plants to be raised in a given area ; and the experiment was carried out, in established nurseries, on sterilized ground.

Sowing at double density naturally produced more seedlings per unit area, and in all cases reduced the yield per pound of seed. This reduction was correlated with the number produced with normal density sowing, apparently irrespective of method of fertilizer application, but the number of seedlings is also inversely correlated with height growth, and sacrifice of numbers is inevitable as the size of seedlings increases.

Broadcasting produced a higher yield of seedlings per pound of seed ; and the decrease in yield caused by increased density was less in broadcast treatments, though it must be noted that this applies to total numbers of seedlings at one year of age only.

Among the various placement combinations, the higher levels of fertilizer application gave better results as a rule than the half levels, and all were strikingly better than unmanured controls ; but between the various combinations of drilling and broadcasting, no conclusions can yet be drawn. The experiment is being kept to grow on for a second year, and a new one on similar lines has been started.

II. Organic and Inorganic Manures in Heathland and Established Nurseries

Both raw hopwaste and bracken hopwaste compost were tried in comparison with farmyard manure and artificials, in three heathland and two established nurseries in Scotland. The compost was unfortunately only 5 per cent bracken ; and 5 lbs. per square yard gave practically identical results with 10 lbs. of raw hops of about equivalent manurial analysis value. Farmyard manure from a notably rich supply gave the greatest increase in height growth at Devilla and Achray Heathland nursery, but the poor manure used at Inchnacardoch Heathland nursery was slightly less effective than the hopwaste and compost. As usual the organic manures had little effect in the established nurseries. Of the artificials, again as usual, the greatest effect was given by phosphate, but nitrogen gave a very great increase in height at Newton. These results were obtained with a standard N, P, K application in all nurseries ; but now that several years' results are becoming available for each of several nurseries, it will soon be possible to study the results over a period of years, and possibly alter the rates of application to suit individual soils.

III. Fertilizers in General

In most experiments, treatments under trial were carried out both in the presence of a standard N, P, K dressing and without it. In general the results of previous years were confirmed : that fertilizers by themselves in old nurseries have but a small beneficial effect, whereas this effect is much increased along with sterilization. It is probable that the same effect is true of acidification. Moreover, in the absence of any weed-killing treatment, the fertilizers increase the growth of weeds as well as seedlings, whereas with sterilization or acidification the weed growth is reduced and seedling growth accelerated, both by

the fertilizer and by lack of weed competition. There is evidence, however, that the beneficial effects of sterilizers are not by any means solely due to removal of weed competition.

D. Seedbed Investigations

I. Seedbed Covering Media

The value of a number of hardwood and coniferous sawdust grades and mixtures, as seedbed covers, was compared in Alice Holt Nursery with standard 2,L. Bedford sand and nursery soil.

Germination and growth differs greatly with the type of cover ; and the response of different species to any one treatment varies a good deal, as will be seen from the following summary and conclusions :

SITKA SPRUCE : Coarse sand, and conifer sawdust plus sand (in 50% mixture by volume), were superior to all other covers used. Hardwood sawdust or nursery soil covers were definitely harmful, both in depressing germination and decreasing survival of germinated seed.

NORWAY SPRUCE : No advantage was obtained by using coarse sand, the germination and survival with sand and nursery soil being exactly similar. This was most unexpected, as the soil at Alice Holt has a fairly high silt fraction, and is prone to surface "caking".

Hardwood sawdust plus sand has proved to be the best cover, while pure conifer sawdust and the conifer sawdust-sand mixture were almost as good.

It is of interest to note that the poor results with Bedford sand in Norway spruce were largely due to the decrease in seedling numbers throughout the season after completion of germination. The favourable results obtained with sand and sawdust mixtures would appear to act in reducing moisture and temperature extremes.

SCOTS PINE : All media had similar effects, with the exception of hardwood sawdust and nursery soil, which were both markedly superior to the others. Coniferous sawdust plus sand was appreciably better than coarse sand alone.

In all three species, the effect of the sawdust/sand mixtures was very small on the germination rate, but may be quite considerable on net germination, that is : the number of standing seedlings at the end of the season.

The above observations are all tentative, and no general prescription can be made without further experiment over a range of seasonal conditions.

II. Watering of Seedbeds

A series of experiments has been undertaken at Wareham and Kennington, to estimate the effect of watering on composted and uncomposted seedbeds of Sitka spruce during their first season.

As the results will be affected greatly by seasonal variations, the experiments are being repeated over four growing seasons.

After two years, the data obtained from a range of sites is very similar, and shows that, generally, watering alone had no effect on height growth ; but that addition of compost without watering greatly increased height growth and production of usable seedlings. Regular watering applied to *composted* beds produced a very much more pronounced effect than watering *uncomposted* beds.

Watering benefits vary a little from soil to soil, but the general story remains the same. In a season such as 1948, with a fairly evenly distributed rainfall, compost effects greatly outweighed watering effects.

The definite trend towards increased response to compost application with increased moisture, is borne out by the 1947 data when the drier season resulted in a much decreased compost response, and a more clearly demarcated watering effect, on the composted sections.

III. Shading of Seedbeds

An investigation was made in 1947 and 1948 to determine the advantages of shading coniferous seedlings, with standard lath shelters, against excessive sun heat during the growing season.

Two sheltering treatments were applied, continuous lath cover over the beds from the date of sowing and periodic cover when the screen temperature attained 70° F. for two consecutive days.

Shading effects were very similar in the particularly hot dry season of 1947, and the milder and moist season of 1948. With the notable exception of Sitka spruce, shading did not increase growth or production of one year seedlings.

European larch, Douglas fir, and *Thuja plicata* were not affected at all ; although there was a slight reduction in the yield of usable seedlings of Douglas fir when the beds were continuously shaded.

Sitka spruce showed a marked response to shade. With April sowings in 1948, an increase in yield of usable seedlings of 50% was obtained with periodic lath shelter. Continuous shelter on the other hand was harmful, and the seedling yield amounted to only one-half of that obtained from completely unshaded beds. This reduction of yield by continuous shelter was very considerable, and a little surprising, and was not noticeable during the hot summer of 1947.

IV. Weed Control

SELECTIVE WEED-KILLERS IN CONIFER SEEDBEDS

Preliminary trials were completed during 1948, using a range of compounds, in liquid form, applied to seedbeds as a fine spray in controlled volume and concentration.

The toxicity of the compounds used, to common nursery weeds, was known ; and the 1948 experiments were designed to detect any injurious effects on tree species. Three species were tested, Douglas fir, Japanese larch, and Corsican pine.

Out of eleven chemicals used, the following four emerged as relatively harmless to the growth of the three species tested :

Ethyl phenyl carbamate at 0.5%.
Sodium methyl chlor-phenoxy acetic acid (a growth regulating substance).
Two aromatic petroleum products.

The results are of considerable interest, as both the petroleum products are known to be almost certain death to *Poa annua*, *Chenopodium* species, and *Arrhenatherum*, and severely injurious to spurrey and chickweed, all of which can be serious nursery weeds.

Experiments on Sitka spruce, European larch, and Scots and Austrian pine, have enabled the isolation of an additional promising compound for more intensive trials.

Further experiments are now under way, with special emphasis on oils and petroleum by-products as selective herbicides.

E. Composting and Trials of Compost

The long-term composting and fertility demonstration at Wareham Heathland nursery was continued.

The nursery sections under an organic composting regime have now been worked since 1943. Seedling yields per pound of seed in the compost demonstration sections were, in most species, well below the high average shown by this nursery over the past five years. The low yields can be attributed to the combined effects of drought in May, damping-off in June, and a severe attack of *Botrytis* in late summer.

This nursery, as yet, shows no signs of declining fertility, but the slow invasion of weeds, particularly *Poa annua*, is making itself felt ; and weeding costs for 1948 were approximately 66% higher than for 1947. Only part of this increase may be attributed to the wetter season. It may well be the case that the economic life of a heathland nursery of this type is limited by the number of years for which weed growth can be kept at bay, rather than by declining fertility.

As in previous years, C5/0 (Composted hopwaste with no added nitrogen) and C5/10 (25% hopwaste, 75% chaffed bracken) gave the best results in growth and seedling production. There is little difference between the effectiveness of these two composts. Under normal circumstances C5/10 is more economic. Two out of the twelve demonstration sections were rested during 1948, and green cropped with a mixture of Italian rye grass, oats and vetches. After digging in, the sections were mulched with four to six inches of bracken until spring.

Compost trials on a woodland soil in Bagley Wood Nursery, Oxford, during 1948, yielded interesting results. Similar composts prepared under cover and in the open were found to have precisely similar effects on the growth and outturn of one year Sitka spruce seedlings. This result must be accepted with reserve, as the summer of 1947, when the composts were prepared, was relatively dry. The composts used consisted of chaffed straw, or chaffed bracken, pure or in mixture with ride trimmings. Hopwaste was used as an activator in all cases. All composts greatly increased the yield of usable seedlings at one year. The addition of superphosphate, at 6 cwt. per acre, considerably enhances the compost effect on this soil type. Chaffed straw 75% + 25% hopwaste and ride trimmings, and chaffed straw 75% + 25% hopwaste without ride trimmings, were the most successful on this soil.

Careful costing records of all composting operations, including cost of materials or cutting, haulage, heaping and maintenance, were kept during 1947 and 1948. Average costs, based on the weight, of material remaining at the end of the composting process, are given below :

Compost	*Cost per ton, final compost*
1. Straw 75% Hopwaste 25%	£3 10 0
2. Bracken 75% Hopwaste 25%	£4 2 0
3. Ride trimmings 60% Straw 20% Hopwaste 20%	£3 14 6
4. Ride trimmings 60% Bracken 20% Hopwaste 20%	£6 0 0
5. Straw 50% Bracken 25% Hopwaste 25%	£4 7 5
6. Bracken 50% Straw 25% Hopwaste 25%	£4 7 6

No costings are given for hopwaste composted pure. This material now has its greatest value as an activating agent for other materials.

The high cost of No. 4 is due to the considerable shrinkage and loss of weight during the composting process.

F. Miscellaneous Projects

I. Vegetative Propagation

An experiment was laid down to determine the most favourable combination of controllable factors necessary for the outside propagation of Sitka spruce and Weymouth pine cuttings. The immediate object was to raise clonal stocks of late-flushing spruce, and a suspected rust-resistant Weymouth pine.

Cuttings were inserted in August, 1948. Interim survival counts show acid peat in 33⅓% admixture with coarse Bedford sand to be the most suitable rooting medium in both species.

There are no exceptional hormone responses, the greatest survival being in untreated cuttings or cuttings treated with the lowest hormone concentration (500 parts per million indole-acetic acid, applied in talc).

Weymouth pine is a species unsuitable for vegetative propagation in the open. The low survival rate (20%) in the open, under the most favourable combination of treatments, is due to the large leaf area and succulent shoot. The only solution will be to obtain rapid rooting by the use of more intensive conditions, bottom heat, and high atmospheric humidity to prevent drying out. Sitka spruce is a species which can be propagated in the open, given lath shade to prevent undue sun heat.

Trials were also made under cold frame conditions, with summer cuttings of Sitka spruce *Cupresso-cyparis* and *Cupresso-cyparis leylandii*. Cuttings of both species show high survival rates, with commencement of rooting in April, 1949.

II. Grass Leys

Experiments are being continued to study the effect of grass ley, and straw mulching, as a means of promoting and maintaining a state of fertility suitable for raising forest tree species, particularly conifers.

These investigations were commenced in 1946 and 1947, and no conclusions on fertility effects can yet be made.

III. Soil Heating

A trial of electric soil heating by low-tension bare wire in frames, and using John Innes potting compost, was repeated at Glentress but, owing to insufficient supervision, was a failure. Soil heating will inevitably imply soil watering, and must be under the control of a resident forester who can supervise it twice daily. In this case such attention was not available, and the heated beds dried up.

IV. Soil Inoculation

A trial of soil inoculation with *Rhizopogon* sporophores, arranged by the late Dr. Rayner, in combination with raw hopwaste and artificials and both Sitka spruce and Scots pine, has shown little result in the first year at Roseisle, Morayshire, but is being continued.

An experiment on "virgin" soil was carried out to discover if soil mycelia producing haustoria were present, and to study the rate of decomposition of cellulose cones. Samples have periodically been sent to Dr. Levisohn, whose report is awaited.

V. Lining-out Extensions

Parallel extensions, in established and heathland nurseries, of certain 1947 experiments, indicate that in general those seedlings which obtained an advantage in the first season retain an advantage the next year.

VI. Experimental Technique

The fundamental problem of experimental layout and statistical analysis was continually under review during the year, and trials with different intensities of sampling were made. It is hoped that improvements will be made which will materially increase the reliability of experimental results.

AFFORESTATION OF PEAT

By J. A. B. MACDONALD
Silviculturist, North

There is a certain glamour about any attempt to reclaim desert, which finds expression in letters to the Press from people to whom our extensive peatclad wastes are a challenge. It may come as a revelation to these people, that of the total area planted by the Forestry Commission in Scotland to date, some 35 per cent is on one type of peat or another ; furthermore almost the same proportion of some 1,100 forestry experiments laid down in Scotland and Northern England by the Commission's Research Branch is concerned with peatlands, often of the poorest types. For the first time a complete survey of each one of the Commission's 330 peatland experiments has been carried out, and a schedule prepared as a basis for the bulletin on the Planting of Peatlands which it is hoped to publish shortly. These experiments extend from Borgie Forest in the centre of the north coast of Scotland, through western forests in Ross, Inverness and Argyll, to Galloway and the Borders, and there are others in North Wales.

This survey entailed an examination of each experiment in the field and the scheduling of :

(1) *Results to date* based upon the latest assessment and the present appearance of the plots.
(2) *The Projects* written up under twelve subject groups into which the individual trials fall.
(3) *The International Decimal Subject Classification* as adopted by Commonwealth Forestry Bureau and the Forestry Commission library.
(4) *The Objects* of the individual experiment.
(5) *Each Treatment* involved.
(6) *The Layout* classified into :
    (a) Satisfactory and capable of analysis if required.
    (b) Replicated, but design not first-class.
    (c) Not replicated, or insufficiently replicated, including trial plantations, demonstrations, etc., where the question of layout does not arise.
(7) *The Tree Species* employed as indicators.
(8) *The Peat/Vegetation types* involved, of which there are ten in all, grouped for convenience into three main classes :
    (a) *Calluna/Scirpus*,
    (b) *Calluna/Molinia/Eriophorum*,
    (c) *Molinia* to *Juncus*.

(9) *An estimated value of results obtained to date* classified as :

(a) Definite and important,
(b) Definite but not of first importance,
(c) Inconclusive, or
(d) None obtained.

Site Preparation and Planting

Taking, in turn, the twelve groups into which the experiments fall, the first, covering site preparation and planting, contains over a hundred separate trials. Several of these began as early as 1924, with comparisons of direct planting methods. General failure of those methods led to numerous comparisons of direct planting with turfing. The latter treatment resulted in great improvement in growth and survival on difficult peat types. Six experiments dealing with turves and drains, and no less than fifteen with draining intensity, show at least how difficult it is to dissociate the effect of draining from that of turfing. They also indicate that better results follow upon deeper and closer draining, although drainage intensity experiments are notoriously difficult to lay down satisfactorily. An attempt to assess the value of draining and turfing in advance of planting, involved several experiments, and clearly demonstrated that there is no advantage in turfing and draining even one year in advance.

A number of experiments were concerned with the type of turf and show markedly different results according to site. Heavy turves appear to do better on well-drained *Molinia* sites than on the poor *Scirpus* peats, where the shallow form of planting turf is better and a group of shallow turves is better than a single one. Experiments dealing with the origin and placing of turves showed no advantage when plants were inserted on peat brought up from well below the surface, and one test suggests that the normal method of inverting the turf, vegetation downwards, is justified. Four trials deal specifically with the method of planting on turves. It was in these that the simple side-notch method generally adopted in Scotland was discovered to be as good as, and cheaper than, other methods. Nine miscellaneous turfing experiments were inconclusive in result, while six others testing pot-grown plants, later inserted into turves, and plants raised on turves in a turf nursery (Sir John Stirling Maxwell's system), proved too expensive for general adoption.

Ploughing was the natural outcome of the turfing experiments, many of which were actually designed with a view to later mechanisation. The first ploughing trial was at Glen Righ Forest in 1928, and it has been followed by sixteen others. In 1946 the Lon Mor bog in Inverness-shire was successfully single-furrow ploughed by means of a tractor with extra wide tracks and a Cuthbertson draining plough. Results of the planting there have been most encouraging.

The Tough-peat Knoll Project

A type of *Scirpus/Calluna*-clad peat of a very tough nature, often found on morainic knolls, has been treated as a separate project. This type was agreed, at a Divisional Officers' Conference in Scotland in the middle thirties, to present the most difficult problem in the pre-war years. The trials compare five methods of preparation and planting, of which the simplest and, so far as result was concerned, least satisfactory, was direct notching and the best, generally speaking, a complete mock ploughing (done with a spade).

Species

Besides twenty-six experiments actually established to compare the behaviour of different species, it was possible to obtain relevant information from about sixty additional trials. Altogether some fifty individual species

have been tried on the peat types ; among the pines, lodgepole pine (*Pinus contorta*) is outstanding, but this species itself is most variable, and its coastal type is far superior to inland types on poor and exposed situations. Among the larches, hybrid larch is outstanding, and has definitely established its claim as one of the principal pioneer species on the poorest types of peat. Spruces, with the exception of *Picea omorika*, have been disappointing on the poorest types, although Sitka spruce is the best species on *Molinia* and better types. From a few trials, *Tsuga heterophylla* and Nootka cypress seem worthy of more attention, but white spruce, *Thuja plicata*, and all hardwoods, including birch, rowan and alder, have proved more or less useless as initial species on the difficult types. A much wider range of species do quite well on the better peats.

Mixtures of Species

Thirty-seven experiments, whether primarily designed to do so or not, contain intimate mixtures of species. In the majority of these, and chiefly on the poorer peats, lodgepole pine has been employed to nurse Sitka spruce. At the stage now reached when the oldest mixture is only about twenty years old, the success of lodgepole pine in mixture with spruce is obvious. Japanese larch is better than Scots pine in mixture with Sitka spruce on very poor peat at Achnashellach, but at Kielder this larch is disappointing in the same mixture. It will be a number of years yet before the other mixtures provide much information.

Age and Type

Between 1922 and 1934, some twenty experiments were concerned with trials of plants of different ages and types, from one year seedlings to two-plus-two transplants. Experiments were concerned mainly with spruces, and all the plants had been raised in the normal way in established nurseries. Under poorest conditions transplants did better than seedlings. On the better types two-year seedlings did as well as transplants in several trials, but failed in one case.

Between 1937 and 1940, four experiments were laid down to test types of plants produced by various special or salvage treatments in ordinary nurseries ; among which were seedlings which had been undercut or wrenched in their third year. These suffered heavier losses in the field than did the normal transplant controls. Transplants lined-out one inch apart in the nursery did just as well in the field as those lined-out at two inches apart, while dense bedding-out had an adverse effect on growth and survival in one field experiment, but not in another. The possibilities of closer lining-out call for further investigation in view of present high labour costs.

In twelve experiments, of fairly recent origin, new types of plants raised in heathland nurseries, or in established nurseries on ground which had been partially sterilized, are being compared with standard planting stock. The earliest of these contained no plants from sterilised soils ; however, the superiority of the heathland or woodland nursery-raised transplants stands out very clearly over normal nursery transplants.

Manuring

There are over one hundred individual trials within the manuring project, the oldest dating from 1925 ; fifty, or about half, are situated at Inchnacardoch. For technical advice the Commission are indebted to Dr. A. B. Stewart of the Macaulay Institute for Soil Research. Despite the number of separate experiments the results can be summarised briefly : an initial application of phosphate is essential on the poorest peat types ; without it spruces and larches fail completely and even pines do badly. These results had been so convincingly

demonstrated twenty years ago, that since then phosphate dressing has been adopted universally on these poorest types in experiments ; also to a great extent in ordinary plantations. On the poorest types, lack of phosphate has often resulted in the complete failure of the plot or area concerned. On the *Molinia* types, however, phosphate dressing may make for a small initial improvement in growth, but this difference most certainly does not justify the expense. Between these extremes, types exist on which one initial dressing makes all the difference between reasonably successful growth and almost complete failure. One-and-a-half ounces per plant of a high grade basic slag, or of ground mineral phosphate, is a satisfactory dressing, and application on the surface around the plant just after planting appears to be quite satisfactory, besides being a great deal cheaper than application under the turf before planting.

A certain amount of top dressing has been done with phosphatic manures, especially to the spruces on the poorest types, where they invariably check even after a good start induced by initial phosphate manuring. On these poor types a reapplication appears to be necessary after about three years. Two and even three such top dressings have been effective in the experiments ; the check period is reduced if the spruce is mixed with pine.

Applications of lime and nitrogen in various forms have proved either useless or harmful, but minor beneficial effects have been secured through manuring with magnesium and potash. Dressings of compost and of peat soil from actively growing plantations were quite effective, but the bulk required rather rules out such dressings in practice. Several complete fertilizer mixtures have been tried, but here again only the phosphate content seems to have been effective. In no case has any significant benefit been obtained in the field as a result of applications of manure in the nursery prior to planting out.

Trial Plantations

Numbered among the peat experiments, there are twenty-four trial plantations in which the outcome of intensive experiments are tested under field conditions. Three of the most interesting are at Inchnacardoch Forest on poor *Scirpus* types of hill peat, and two of them employ the Anderson group method of spacing. A notable set of trial plantations at Borgie was destroyed by fire after becoming well established. Some of the latest trial plantations have been planted on single furrow, tractor-ploughed peat, and have made a good start. Many of the trial plantations stand out well on poor moorland, previously considered unplantable, and provide the best indications of the progress made in moorland afforestation up to the time of their establishment. In addition to the trial plantations just mentioned, there are, within the so-called high-elevation project, almost twenty additional trial plantations on peat. The most interesting is on a shoulder of Cairn Gorm in Queen's Forest. Within it lodgepole pine is the only species which shows much promise. In this high and exposed site, group planting has not been a success ; it appears to provide less mutual shelter than an ordinary spacing of single plants.

Miscellaneous Experiments

These include small trials laid down to investigate such things as cultivation prior to planting, shelter, weeding, bedding-out and mulching. Among these the most striking experiment is the shelter belt at Lon Mor, Inverness-shire, where the outstanding tree is a coastal type of lodgepole pine which has completely outgrown Scots and mountain pines as well as inland races of lodgepole pine.

In the salvage experiments, an attempt was made to stimulate spruces which had been directly planted on poor peat types, and had checked severely,

by lifting them bodily, together with a small area of the peat on which they were merely existing, and placing this turf on top of the natural ground surface. This generally proved fatal in the absence of phosphate, and was only moderately successful where phosphate was applied. That such plants could recover if placed in optimum conditions, was proved by taking several back to the nursery where they soon recovered. Altogether fifteen experiments are included in this group.

The earliest of the twelve registered trials of direct sowings was made at Inchnacardoch in 1927. Since the war the project has been taken up again, and phosphate-dressed Scots pine sowings seem most promising. Spruces are less successful because of their small size during the first winter, when frost-lift is a serious danger. Sowings of birch, alder and rowan, tried in 1932 at Beddgelert Forest, North Wales, were complete failures.

A new development in peat afforestation research began during the year, when the Department of Agriculture for Scotland offered certain areas in Caithness and Sutherland to the Commission for experimental planting. Most of the areas are on peat, but two or three in Caithness are on good mineral soil, although in very exposed sites near the sea. In these cases the establishment of shelter is the main problem. Two small areas of very poor *Scirpus* peat at Strathy in North Sutherland, and one exposed site on better soil types at Skiall in North Caithness, have been single-furrow drain-ploughed ; the Strathy area has been planted up with various species in a matrix of coastal lodgepole pine, and the better area at Skiall with various species in a matrix of Sitka spruce. In both instances the matrix species was considered, from past experience, the best known for the site, and the secondary species all worth trying in a pioneer plantation of this sort. These plantations are to be followed up in the next two years by repetitions, in order to test the species in different seasons. Finally, specific points requiring investigation will be the subjects of intensive experiments.

In addition to the trial plantations just described, there are, in the list of new field experiments, a certain number of trials which have been laid down on peat. These include experiments connected with natural regeneration, direct sowing, position of planting on ploughed ground, height and diameter of planting stock in relation to survival in the field, age and type, field extensions of nursery experiments, and a trial of late-flushing Norway spruce.

An important and somewhat disquieting development in peatland afforestation, which requires investigation, concerns primarily the Border forests. As is well known, great areas of the Border lands are covered with *Molinia* peat, which is of no great depth on the slopes but frequently over three feet deep on more level sites. Commission plantations on these lands have for the past twenty years been established by planting on turves. Originally the turves were obtained from shallow drains opened mainly for that purpose, but the channels did act as drains when necessary, and quickly removed excess surface water from the scene. In recent years the turves have been provided by ploughing.

Now the trees—mainly spruces—are growing up, and their roots are generally very superficial. Already many of these roots have crossed the shallow turf-drains, and as a result water movement in some of the channels is held up and slight flooding or bogging already appears. The problem is whether to clear and deepen the old turf-drains, and in so doing sever the roots of adjacent trees, with the risk of some windthrow, now ; or to avoid drain cleaning and chance a rise in the water table locally, followed by possible die-back of all but the most superficial roots, consequent loss of growth, and the haunting fear of extensive windthrow in the future. A survey of the conditions is about to begin.

PLANTING EXPERIMENTS ON LOWLAND HEATHS

By M. NIMMO
Assistant Silviculturist

The problems peculiar to lowland *Calluna* heathland have been under investigation for many years at Wareham Forest, Dorset. The soils are leached sands of the Bagshot beds.

Broom as a Nurse for Conifers

Of the several points of interest this year the most striking is the outstanding success of broom as a nurse crop for establishing exacting species which have previously failed, even when given successive doses of phosphate.

The first experiment on these lines at Wareham was carried out in 1938 with *Abies nobilis*, Sitka spruce, *Thuja plicata* and *Tsuga heterophylla*, which were introduced into an existing broom crop, then four years old and approximately six feet high. The trees were each given two ounces of basic slag at the time of planting.

Despite the fact that the broom has now practically died out, all four conifer species continue to grow well and, at the end of 1948, the *Abies nobilis* averaged 3½ feet with 6-inch shoots, the spruce, 7 feet with 13-inch shoots, the *Thuja*, 7 feet with 9-inch shoots, and the *Tsuga*, 6 feet with 11-inch shoots. It is remarkable that such good growth (for Wareham) should continue after the death of most of the broom.

In order to give a longer period of association with living broom, experiments were laid down at Wareham in 1945, 1946, 1948 and 1949, in which the trees were planted at the same time as the broom was sown.

The results of these experiments are most promising, as is shown by the following comparative figures, taken after the 1948 growth was completed :

	BROOM + PHOSPHATE		PHOSPHATE ALONE	
	Mean Height (inches)	*Mean Shoot (inches)*	*Mean Height (inches)*	*Mean Shoot (inches)*
Sitka spruce, planted 1945	40.6	6.1	22.5	1.1
Norway „ „ „	28.4	7.3	14.3	.9
Douglas fir „ „	46.6	6.3	29.1	1.1
Tsuga heterophylla „	36.2	6.9	20.2	1.3

It is interesting to note that, quite apart from tree growth, the broom changes the heath vegetation. *Calluna*, *Molinia*, *Erica* and *Agrostis* all double the height of their flowering shoots, while species such as bramble and willow-herb make their appearance.

Before leaving the subject of the effect of broom there is one other observation worth noting. In 1942, a few units of a 1938 direct sowing of Corsican pine were intersown with broom when the pine were approximately 3½ feet high ; an assessment in June, 1948, gave the following result :

	CORSICAN PINE		
	Average Height (feet)	*Average Shoot (inches)*	*Diameter (inches) (1 ft. above ground)*
Pure	11	16.0	3.3
With Broom	12.6	18.0	4.0

Other Leguminous Nurses

In Experiment 89, planted in 1948 and dealing with a comparison of various nurse crops for raising Sitka spruce, a very good result was obtained from a direct sowing of *Robinia* on prepared patches to which compost had been added. Many seedlings were twelve to twenty inches high at the end of the first year. This tree is being tried in the hope that it will continue the "leguminous effect" for a longer period than broom, and perhaps thereby ensure that the nursed species reach canopy stage without checking.

Robinia might be quite a good tree on these poor sands, and a small-scale trial is being made both with transplants and direct sowings.

Two other leguminous species which are being tried, on a small scale, are the tree lupin (*Lupinus arboreus*) and bladder senna (*Colutea arborescens*). Both of these are more or less naturalised, and frequently colonise new road works and railway cuttings on the Bagshot beds.

Mountain Pine as a Nurse

In 1932 an experiment was laid down to test the Danish method of raising Sitka spruce in a matrix of mountain pine (*Pinus mugo*).

For over ten years little benefit from the pine nurse was visible, but now with the closing of the pine canopy, the spruce is at last showing greater response ; in the pine the Sitka averages 33.7 inches high, with 2.1 inch shoots and good-coloured foliage ; in the pure plot the foliage is yellow, the average height only 17.6 inches and the average shoot only half an inch. While with broom the nursing effect develops rapidly, pine nurses only show good results when they begin to control the heather.

Mulching and Hoeing

During the past two years the use of an auto-scythe for ride clearing at Wareham has given us a lot of cut heather, and this material has been tried with marked success as a surface mulch for checked spruces and Lawson cypress. Even after only one growing season the change is most obvious both as regards colour of foliage and growth of shoots.

Rather similar results have been obtained by hoeing or screefing ; the suppression or removal of heather is the common factor. Probably neither of these treatments can be applied economically on any scale and they have, to some extent, been superseded by ploughing.

Season of Planting

A small-scale trial of season of planting of Corsican pine, covering the period from October to March, and repeated for three years, was completed in 1947, and the summarized figures give interesting results.

The best survival figure is for November planting (mean 82 per cent), with February almost as good with 78 per cent. The worst is March (40 per cent), while the first half of October also seems unsatisfactory and gives only 58 per cent survival.

Direct Sowing on Compost

At Ovens Hill, Wareham Forest (Expt. 38, Forest Year 1939), there is now an interesting comparison between a normal conservancy planting of Corsican pine, one-plus-one transplants on single furrow ploughing, and a direct sowing of the same species on prepared patches to which compost was added. The direct sowings now average 68.0 inches high, with shoots of 9.5 inches, while the normal planting averages 24.1 inches high with 6.6 inch shoots. As regards survival, there were no blank patches in the direct sowings, but approximately 25 per cent of the planted stock failed.

Nursery Extensions

Plants of Scots and Corsican pines raised with compost in heathland nurseries continue to make excellent growth in Experiments 50, 1940, and 68 and 69, 1944, in Wareham Forest and are superior, both in survival rate and in growth, to both seedlings or transplants from arable type nurseries.

PROVENANCE STUDIES

By R. F. WOOD
Silviculturist, South

Provenance trials of various species have increased in importance since the commencement of the study of the genetics of forest trees. Many of the trials are now approaching the stage when variations in form are most apparent, and methods of recording these are being studied. Information on yield and volume increment has not so far been obtained from most experiments, but the thinning stage is approaching in a number of them.

Only the more important observations arising out of the year's studies are here mentioned. As provenance of European larch has received special study with a view to publication, no attempt has been made to cover that investigation fully.

Provenance of Larches

A practical matter that has received considerable attention is the method of assessing larch provenance experiments. It is desired to devise a means of defining, recording, and, where possible, measuring, the various characteristics of European, Japanese and hybrid larches grown from different lots of seed. Trials were made of methods of measuring the branch size and form, attack by canker and the straightness of main stems, in addition to the normal height, girth, and current shoot-length measurements carried out in the past. A preliminary note was submitted, the question has been discussed with the Geneticist, and a revised method of assessment is now under practical trial. It is expected that the method will be adaptable to other species.

Recently these experiments have been assessed one hundred per cent, at least as regards height, and the labour could be very greatly reduced by sampling. An example of this is afforded by a recent assessment of Experiment 1, Clashindarroch Forest, planted in Forest Year 1931.

This experiment is laid out in the form of Anderson's Group System, and is a trial of larch from two Continental and two Scottish origins, raised in six nurseries, with both seedlings and transplants used in the forest. Each group is expected to furnish only one or two main-crop trees, and in this assessment only the two trees of largest girth per group (to give an approximation to top height) were assessed. Mean heights, survival and incidence of canker will be worked out in due course.

A re-examination of the data for the 1936 assessment of the same experiment at Drummond Hill, which had been done on a hundred per cent basis, showed that assessment of the largest tree per group only would have given the same relative result as measurement of all the trees in each group.

European Larch

THE INTERNATIONAL LARCH PROVENANCE EXPERIMENT, FOREST YEAR 1946

This experiment is replicated at Savernake, Mortimer, Walcot, Wyre and Haugh Forests in England, and at Drummond Hill in Scotland, where planting was done in 1947. Measurements of height and annual shoot were made after the completion of growth in 1948, and the form of a number of provenances was assessed in the latter part of the same year.

The first provenance in order of height growth carries the mark I. 45, and originates from the Sudeten of Bohemia at an elevation of 1,350 feet. The stem form is generally moderate and often good, the crown form is narrow and compact, and the health of the plots is good. One plot at Savernake is quite outstanding for uniformity of growth and general quality of form. (This provenance may be from the Forest Administrative District of Hrotovice, which is stated to be of Silesian origin (Obersdorf) and is famous in Czechoslovakia for the high quality of its timber.)

Provenance F. 32 from Proskua, Upper Silesia (which Münch states is not definitely of Silesian origin), follows close behind the first in vigour. This strain, which is replicated twice at all the sites except Wyre Forest, shows generally good form and had a mean height of 60.8 inches and a mean shoot of 20.8 inches in 1948. This performance is closely paralleled by Provenance I.49, from the Sudeten of Bohemia (elevation range 1,150 to 1,320 feet). The stem form of this last-named strain is moderate to good, the crown is intermediate in width and rather pyriform in shape, and the branching is delicate but rather distorted. The general impression gained at Savernake is of a healthy, vigorous and uniform crop.

The next provenance in order of vigour, F. 29, is of interest since Münch considered that much of the larch of the Harbke and surrounding estates near Helmstedt was of Sudeten provenance. This strain is well replicated at all the five sites, and is showing good growth throughout, the mean height being 56.7 inches and the mean shoot, 19.5 inches. A similarity in form between this provenance and I.45 was noted at Savernake, the crown width of F.29 being as narrow but not so compact as that of I.45, while the branching was rather similar and of small diameter. The health of the plots at Savernake is good.

Provenance I.46, which completes the first group, has a mean height of 50.8 inches and a mean shoot of 17.3 inches. The origin is again the Sudeten of Bohemia, the elevation being 2,300 feet.

Unfortunately it is not yet possible to group the worst strains in the same way, but the four lowest, in order of vigour, are all derived from various parts of the Alps. Perhaps the most interesting provenance comes from Untervaz, in the Canton of Graubunden, Switzerland (elevation 1,400-1,850 feet). The figures for mean height and mean shoot are 47.5 and 15.6 inches respectively. The stem form is moderate to good, the crowns are rather expanded and spreading, with heavy horizontal branches. The whole appearance is rather coarse and thickset, a fact noted by Engler, in 1906, when describing the Adlisberg provenance trial. The Untervaz provenance then used was, however, from a somewhat higher elevation.

Provenances B.15 and A.3 are both from the German Alps, the first being the higher levels (5,280 feet to 5,940 feet), and the second from a lower elevation (2,970 feet). The mean height of B.15 was 46.5 inches in 1948 and the mean shoot, 13.4 inches. Provenance A.3, from Hollenberg, was very similar in vigour.

The poorest strain as regards vigour of growth comes from Lötschenthal, at 4,950 feet, in the Swiss Alps. The stem form is poor, the crowns are compact, and the general impression is of a short and not too vigorous crop (mean height 43.9 inches, mean shoot 12.1 inches).

In assessing survival, great caution must be used, and it is doubtful whether any but extremely wide differences are valid, because of site variation, lack of replications of some origins, and differences in date of planting.

Japanese Larch

CLASHINDARROCH FOREST, EXPERIMENT 23, FOREST YEARS 1938-39

This experiment contains six lots of Japanese larch from Nagano prefecture, Japan, and we are fortunate in having exact descriptions of the parent trees.

The seed was received in 1937 and sown at Altonside Nursery, and the plants were put out at Clashindarroch, as one-plus-ones, in February, 1939. Five replications of plots of thirty plants each were laid down in randomised blocks with larger extensive blocks varying from 100 to 400 plants. Their heights were measured in 1947, i.e. after eight years' growth.

Failures, which were few, were beaten up in March, 1940. Survival in 1947 averaged 85%, with little difference between the provenances.

The seed from Usudo and Matsumoto has given the best results, the plants being larger than those from the Iwata seed, both at the time of planting out and in 1946. The parent trees at Usudo and Matsumoto were more vigorous, and at an age of about forty years were nearly as tall as the Iwata trees which were mature.

Details of the form of the parent trees are on record, but their progeny has not yet been assessed for these characteristics.

Norway Spruce

A final report on the trial at Kielder, which was almost entirely destroyed by fire in March, 1948, showed that Norway spruce from Scandinavia (Finland, Norway and Sweden) had made only about two-thirds of the height growth of the Central European lots (Czechoslovakia, Harz Mountains, Black Forest and Bavarian Alps), in this eleven-year-old experiment. The tallest lot of all was the Roumanian (Carpathian Mountains).

It is also of interest that in a small trial at Bedgebury (Kent) a plot from seed collected at Invergarry, Scotland, is showing considerably more vigour than lots from the Harz Mountains and the Tyrol.

Sitka Spruce

In the Kielder experiment mentioned above, Sitka spruce from Masset District, Queen Charlotte Islands, British Columbia, showed greater height growth than other lots from Skidegate, Queen Charlotte Islands ; Comex, British Columbia ; Campbell Lake, British Columbia ; Callan County and Olympic Peninsula, Washington, U.S.A. They were also better than lots from Japan and Schleswig-Holstein.

There is little difference between rates of survival and susceptibility to frost, which is not severe on this site, but those lots planted on old turves were noticeably inferior to those believed to have been planted on new turves.

At Radnor Forest a trial of four races of Sitka spruce has been assessed recently for the incidence of "stem crack". Though absence of replication enjoins great caution, it is of interest that one provenance (Coastal Mountains of Oregon, U.S.A.) contained three times more stems exhibiting crack than any other. This lot had also the greatest mean girth, and had, incidentally, the highest death-rate on establishment.

Scots Pine

The effects of seed origin in this species have been studied at Thetford in East Anglia, Bedgebury in Kent, Haldon in Devon, and Beddgelert in North Wales, as well as at Findon, Laurieston and Inchnacardoch in Scotland. Much of the most comprehensive and best replicated series of Scots pine origins is at Croxton Park, Thetford. (Experiment 18.).

This experiment is sited on land typical of the derelict arable soils of the locality, with sand and flints overlying chalky boulder clay. In the three successive planting seasons 1932, 1933 and 1934, 22 different provenance lots were planted, most being replicated three times. The unit plot is one chain square, containing 225 plants in rows of 15 each way.

During the early stages, the experiment suffered considerably from rabbit damage, and as this may have been to some extent selective, survival value as an attribute of provenance must be estimated with caution.

The provenances represented may be roughly grouped according to regions as follows :

GROUP I. HOME PROVENANCES

Key Nos.	*Origin*	*Year planted*
	(Scotland)	
1	Cawdor 57°N.	1932
19	Cawdor 57°N.	1934
7	Darnaway 57°N.	1932
9	Glen Garry 57°N.	1932
8	Glen Moriston 57°N.	1932
2	Loch Maree 58°N.	1932
	(England)	
6	England, East 52°N. ..	1932

GROUP II. MIDDLE RHINE

Key Nos.	*Origin*	*Year planted*
13	Hanau, 50°N.	1933
16	Kassel, Hesse 51°N.	1933
10	Hagenau, Bas Rhin, France 49°N.	1933
12	Wangenbourg, Bas Rhin, France 49°N.	1933

GROUP III. HUNGARY AND NORTHERN ITALY

Key Nos.	*Origin*	*Year planted*
4	Lenti, Hungary 47°N.	1932
5	Sopron, Hungary 48°N.	1932
3	Trentino, Italy 46°N.	1932

GROUP IV. SCANDINAVIA AND BALTIC STATES

Key Nos.	*Origin*	*Year planted*
11	Riga, Latvia 57°N.	1933
20	Hedmark, Norway 61°N... ..	1934
18	Valkjarvi, Finland 65°N.	1933
14	Flak, Lillesand, Norway 58°N. ..	1933
21	Lysekil, Sweden 58°N.	1934
22	Vasteras, Sweden 60°N.	1934

GROUP V. NORTH GERMAN PLAIN AND EAST PRUSSIA

Key Nos.	*Origin*	*Year planted*
17	Allenstein, East Prussia 54°N. ..	1933
15	Potsdam 52°N.	1933

Survival

Death rates at the end of the first season of growth following planting suggest the following generalisations :

(1) In seasons when a long dry period follows planting, there is a strong tendency for losses to be highest in lots originating in high-rainfall areas. This was observed in seasons 1932 and 1934.

(2) When adequate rainfall follows planting, as in 1933, losses cannot be related to the rainfall of the place of origin.

(3) It is not possible to compare the survival values of the regional groupings owing to the differences in planting seasons, but broadly speaking British provenances have been better than Hungarian and north Italian ; and "Middle Rhine" provenances better than those from the North German Plain and from Scandinavia.

Vigour

The experiment has reached the stage for brashing and a first light thinning. Measurements of height growth have been made at regular intervals ; and prior to obtaining crop measurements, these may be used as estimates of vigour.

Provenances have been ranked according to their mean annual height increment. The resulting order is discussed below.

Form

An assessment of form in the various provenances has been carried out. This was an attempt to record the characteristics generally regarded as inherent, and of importance in their effects on the value of the tree as timber. The qualities assessed were as follows :

Basal curvature of the stem : i.e. in the first five feet.

Form of the stem above five feet : degrees of straightness, ignoring obvious insect or mechanical damage.

Crown shape : symmetry of the upper crown and dominance of leader.

Width of crown : tendency to spread or remain compact.

Size of branches : in relation to diameter of stem of whorl.

Number of branches in whorl : the tendency to develop few or many branches in the whorl (the former being the desirable quality).

The method adopted was that of visual scoring into three classes 1, 2 and 3, in order of excellence for each characteristic. Plot labels were ignored to avoid "subjective" error, and three independent observers estimated each character. It was found that very consistent results were obtained, scores for individual characteristics varied little between replications, and sums of scores for plots were always close to those of their replicates, although such scores varied greatly over the series of provenances.

An attempt was made to arrive at a "quality index" for provenances, by dividing the minimum score possible by the actual score obtained, hence an ideal stand would score 1, and poorer stands proportionally less. The scores

for *stem form* were given a range of 1-3-5, to give this character more weight than other qualities which have less influence on the value of the tree. Provenances were ranked according to this "quality index". Since it appears that the value of a stand is in a sense a *product* of its vigour and its quality, it has been thought of interest to rank provenances in order of the product of their respective annual height increment and quality indexes.

Ranking according to Vigour

Ranking according to vigour is in favour of the provenances originating between 46° and 54° North latitude, namely those from eastern and central Germany, the Middle Rhine, Italy and Hungary. Of lesser vigour are the provenances between 55° and 65° North latitude including those from Scandinavia and the Baltic. At this stage the most vigorous provenance is the Forêt de Hagenau (Bas Rhin) followed by the East England. This latter is from local collection ; it is commonly believed that the pine shelter belts and hedgerows in this locality are of Scottish origin, but, unless the selective effect of a generation or two in a fresh locality are much larger than generally believed, this appears unlikely.

Ranking according to Form

Excellence of form is to a great extent a reversal of the order for vigour. It is of some interest that the best Scottish provenance, Glen Garry, is far ahead of the other Scottish lots in this respect. The chief exception to the reversed vigour ranking is the East England provenance, which lies fifth in the list in respect of form, a result of considerable importance. It is in fact the only provenance ranking in the first third of each table.

Value of Provenances in the Locality

The somewhat arbitrary effort to rank provenances in order of their "Value for Locality" places East England first and the Scottish provenance, Glen Garry, second. A very cursory examination of the experiment would almost certainly name East England the best all round provenance. Choice of the next best would depend on the objects of management, but should excellence of form be given any weight, the Glen Garry provenance must rank high.

Other Provenance Trials of Scots Pine

At Bedgebury, the Scots pine trial was largely destroyed by fire in 1942. However, the general picture has been much the same as at Thetford, though differences of form have been rather less apparent. Danish and Belgian provenances are leading in vigour among the remaining lots. The East England provenance was destroyed, but had shown good vigour.

It is of considerable interest that under high rainfall at Beddgelert, the East England provenance still compares favourably with North-west Scottish origins, which one would consider much better adapted to the conditions.

Pinus contorta

Provenance trials of this species exist at Teindland, Clashindarroch, Achnashellach and Millbuie in Scotland, and Beddgelert and Clocaenog in Wales.

Clocaenog Experiment 16 contains seven provenances of *Pinus contorta* planted during the years 1934-38 on *Calluna* heathland. The range of habitat represented extends from latitude 48° N. to 65° N. and both coastal and inland mountain forms (var. *murryana*) are represented. All provenances have grown well, and considerable differences in vigour and form are now appearing.

Vigour and Form

With the rather wide differences in planting date, measurements of height and annual growth are difficult to compare satisfactorily. It is very noticeable that vigour is expressed differently as between the coastal and inland mountain forms. The latter have the typical habit which gives var. *murrayana* the name of lodgepole pine—narrow, open crowns and straight stems. The coastal forms on the other hand have dense, compact, rounded crowns. They form a much denser canopy, and it would appear that where, as a pioneer or nurse, the suppression of heather is required, it is coastal forms that should be planted ; but where *P. contorta* is to be grown on its own merits a good type of the inland var. *murrayana* should be chosen.

The best provenance present (viewed as a timber tree) is that from east of Kamloops (1,300 to 3,450 feet elevation), Canada (50° N. 119° W.).

ARBORETA AND FOREST GARDENS

By R. F. WOOD
Silviculturist, South

While there are several collections of species at present under Research Branch management, few of these warrant the title of "arboretum", which may be confined to wide collections, usually of small groups or even individual trees, the main object being to produce specimens for interest and instruction. More attention has been paid to performance trials of species under definite conditions.

National Pinetum, Bedgebury, Kent

This is managed for a joint committee, representing the Royal Botanic Gardens, Kew, and the Forestry Commission, the Chief Research Officer being Secretary. Mr. A. W. Westall, who qualified at a Forestry Commission School, has recently been appointed Supervisor.

Few additions have been made to the large collection at Bedgebury (which comprises some 240 species) since the war. *Metasequoia glyptostroboides* has, however, been planted this spring on three sites. It appears to be slightly frost tender in the hollows at Bedgebury, but may succeed where it is protected from spring frosts.

A feature of considerable interest at Bedgebury is the natural regeneration of a number of conifers. In one group of less than half-an-acre, over twenty species may be found, including Douglas fir, Lawson cypress, *Thuja plicata*, *Abies grandis*, Sitka spruce and Norway spruce and European larch. This regeneration is being thinned in order to get small areas of different mixtures. Regeneration is also appearing under Japanese larch. Scots pine regeneration is being encouraged on an area, so far unplanted, with a view to raising a natural pioneer crop for later introduction of tender species.

A revision of labels is under way, necessitated by changes in the accepted nomenclature and by occasional errors in the identification of young plants.

Bedgebury Forest Plots

This series of quarter-acre plots was started in 1929 as a complement to the Pinetum, and is now looked after by the Supervisor. Recent work has caught up with the arrears of weeding, etc., caused by war-time labour shortage. Planting in the last two seasons has added fifteen new species to the collection, but a further thirteen plots remain to be planted before the losses of the serious fire in 1942 are made good. Seventy-eight species are now represented (including hardwoods).

Many of the earlier plots have reached the thinning stage, and, during the past year, nineteen have been thinned, or marked for thinning. Among the conifers there is a good representation of all the commoner species except Sitka spruce and *Pinus contorta*. Of the less common plantation formers, *Pinus resinosa*, *Pinus peuce*, *Cedrus atlantica* and *Sequoia wellingtonia* (*S. gigantea*) give the greatest promise. So far, hybrid larch has the greatest mean annual increment, but the indications are that it will be overtaken shortly by *Abies grandis*, Douglas fir and *Tsuga heterophylla*.

Oaks and birches seem the most promising hardwoods, red oak and *Betula lenta* being the nicest stands, but there is also a very good plot of *Nothofagus obliqua*. Many hardwoods are difficult to establish at Bedgebury because of spring frost and coppice competition.

Benmore Forest Garden, Argyll

Benmore Forest Garden originated in 1930 when some 250 acres on the hillside above the Holy Loch were laid aside for testing small blocks of as many species of forest tree as could be made available. From its inception until 1938 the Forest Garden was managed by the West Scotland Conservancy, but during the war it was decided to place it under the care of the Research Branch. There was some unavoidable neglect during the war years but, within the last year, much has been accomplished in the way of tidying up the plots, of which there are now more than 150, removing weed species, brashing, clearing paths, checking the records, tallying plots, re-identifying doubtful species, and so on. The Garden is to have its fence repaired, and to have one worker or ganger allocated to it full-time for maintenance.

The Speech House Arboretum, Forest of Dean

This small arboretum was commenced in 1910. Species were planted in small groups, but the spacing between groups was inadequate, with the result that the more successful species tend to run into their neighbours. A number of Asiatic species collected by E. H. Wilson were planted ; but these species of *Abies* and *Picea* from China proved very frost tender, and many have been lost.

Recently the collection has passed to Research Branch management, a new sheep-proof fence has been erected, and the area has been generally cleaned up. Ten new species were planted during the past season. It is intended to aim at good individual specimens rather than good plots, for which there is not enough space. This collection serves the Forester Training School at Parkend, and its maintenance is carried out by the students.

Perhaps the most interesting group is that of *Cryptomeria japonica*, but all the commoner conifers are satisfactory.

Beddgelert Forest Garden, North Wales

Growing in the exceptionally high rainfall of Snowdonia, this series of irregular plots covers twenty-five acres of stony ridges and peaty hollows. A variety of conifers has been planted, mostly between 1927 and 1932, particular attention being paid to selection of species in relation to changes in micro-topography.

As might be expected, Western North American species are outstanding on this site, and *Abies nobilis* seems to withstand the severe exposure better than most other species. *Pinus peuce* and *P. wallichiana* both show very considerable promise among the less usual species.

One object of the Beddgelert Forest Garden is to draw attention to the wide choice of species frequently open to us, provided careful attention is paid to very local changes in conditions.

THE LIBRARY AT ALICE HOLT

By G. D. KITCHINGMAN
Librarian

Book Section

The number of books in the Library, including the Lending section, the Reference section, and books on permanent loan to research officers, is now about 1,100. 125 books were added to the Lending Library during the year ; 126 books were loaned to officers outside Alice Holt, and there were 344 loans within the building. This last figure does not include numerous books borrowed for less than twenty-four hours, or consulted in the library ; these are not entered in the loan register.

Periodicals Section

A typed list of the holdings in the periodical section of the library was prepared. The number of bound volumes in this section is now 723.

Binding

129 books and volumes of periodicals were bound.

Information Files

A new feature is the beginning of a set of Information Files, numbered and classified according to the same system as is used for arranging the books on the shelves.

In these files are put typescripts, pamphlets, separates and other miscellaneous material which cannot, conveniently, be put on the shelves. All of it—before being filed—is indexed on cards in the usual way.

It would be a waste of time to try and count the number of items that have been collected in this way ; but, to date, the files fill five cabinet drawers.

Catalogue

There is a great need for a printed catalogue, at least of the books in the Lending Library. It is proposed to issue an Author catalogue as soon as all the books in this section have been reclassified under the Oxford decimal classification, and properly card-indexed. 850 have been re-catalogued to date, leaving about 250 to be dealt with.

Documentation

A start has been made with documentation work—an essential part of any special library. Documentation is the art of collecting, classifying and making readily accessible the literature available. At Alice Holt there is now a card-index containing references to books, to articles in journals, and to material filed in the Information Files. To date we have typed about 10,000 cards, and so (assuming that each reference requires on the average 4 cards—one for the Author catalogue, two for the Subject catalogue and one for the Geographical catalogue) we can say that 2,500 items of literature have been "documented". This, however, hardly keeps abreast of new and current literature ; and the important task of referencing past literature, which is fundamental to our research work, has scarcely been touched.

Visits

The Librarian attended some of the meetings of the Scientific Information Conference held by the Royal Society in London from June 21st to July 2nd,

1948. Papers and discussions on the distribution, abstracting, documentation, and dissemination of scientific research papers were particularly interesting and useful.

Library Furniture

The supply of furniture and equipment has been satisfactory except in the matter of new shelving.

PUBLICATIONS

The following papers by members of the Research Branch staff were published during the year :

Peace, T. R. The variations of Douglas fir in its native habitat. *Forestry*, Vol. 22, No. 1, pp. 45-61, 1948.

,, The second meeting of the International Poplar Commission, Italy, April, 1948. *Quarterly Journal of Forestry*, Vol. 42, No. 4, pp. 191-6, 1948.

,, Poplars in Scotland. *Scottish Forestry*, Vol. 2, Nos. 1 and 2, pp. 38-39, 1948.

Wass, J. G. The prospects of natural regeneration. *Quarterly Journal of Forestry*, Vol. 2, No. 2, pp. 107-8, 1948.

Part II. Committee on Nutrition Problems in Forest Nurseries

SUMMARY REPORT ON 1948 EXPERIMENTS

By Dr. E. M. CROWTHER

Rothamsted Experimental Station

1. Introduction

The main purposes of the investigations, which have been in progress since 1945, have been :

(a) to analyse problems of soil fertility and plant nutrition in forest nurseries, with the object of developing methods for maintaining the output of good seedlings and transplants.

(b) to see how far the proved value of certain composts on acid soils depends on the available plant-nutrients furnished by the composts, and whether there are additional benefits to be ascribed to physical and microbiological effects.

(c) to discover the cause of the common failure of Sitka spruce and other conifer seedlings on many established nurseries ; and, if possible, to find means of preventing similar failures from developing on newer nurseries, and of improving at least some of the poorer nurseries.

(d) to test plants raised in nursery experiments by their subsequent performance in forests.

(e) to develop suitable methods of manuring nurseries and forests and to improve the techniques for experimenting on these questions.

2. Conduct of Experiments

The experiments are carried out by a most intimate co-operation between the Research Branch of the Forestry Commission and some of the staff of the Chemistry Department of the Rothamsted Experimental Station. When the main lines of the programme have been approved by the Committee, the Rothamsted staff are responsible for drawing up the design of the experiments, preparing detailed working plans and transfer sheets, selecting and supplying the fertilizers, applying the treatments in all nurseries and forests in South and East England and in all forests in Wales, analysing the assessment data, and preparing the reports on individual experiments and on the season's work. Rothamsted also analyses many lots of experimental soils, plants and manures, and undertakes pot culture investigations on special problems. The Commission's staff prepare the sites and do all the cultural operations and assessments. They also apply all experimental treatments in nursery and forest experiments in North England, and in seedbed experiments in the West. All nursery experiments in South and East England were on Sitka spruce and Scots pine in 1948 and the preceding years ; the experiments in other nurseries were on Sitka spruce only. Sitka spruce generally proves more sensitive to defects of the soil, and more responsive to treatment than Scots pine. To magnify the effects of treatments, a number of the seedbed experiments were repeated on the same plots as had been used in 1947. To produce successive annual crops of one-year seedlings fit to transplant or plant in forests presents a hard target.

3. The 1948 Season

Seedling growth was particularly poor in 1948 at all nurseries except Wareham, where it was made irregular by severe windstorms in May. Sowing was generally late (towards the end of April) and this may have aggravated the bad effects of an unusually cold summer and autumn.

4. Fertilizers and Bulky Manures

The poor growing season prevented the seedlings from showing as large responses to fertilizers and composts as had been obtained in the previous years, even in the drought of 1947. As usual there were only small and irregular differences in heights of seedlings raised with compost and with fertilizers, provided adequate amounts of the major plant nutrients were supplied in the compost. Nine different kinds of bulky organic manures, including standard kinds of compost and some novel ones devised on theoretical grounds, were used at Bagley Wood, Oxford. On the average they proved inferior to a compound inorganic fertilizer and, where the fertilizer was given, there was little additional benefit from compost. A simple compost prepared from dried green bracken and superphosphate gave very good results.

There were good responses to phosphate at several nurseries with acid soils, and also to nitrogen and potassium at some of the nurseries. Responses to fertilizers and composts were generally small in established nurseries with slightly acid or neutral soils, but in one experiment at Old Kennington, Oxford, the responses were increased by previously acidifying the soil.

Several different kinds of nitrogen, phosphate and potassium fertilizers were tested, with special reference to the time of applying soluble nitrogen fertilizers, and the rate of decomposition of organic nitrogen fertilizers. For applications before sowing, slowly acting forms of organic nitrogen were generally the best, but good results were also obtained from ammonium sulphate, both in the seedbed and as top-dressings. In a large number of experiments, at thirteen nurseries, there was no evidence of any disturbance from ammonium sulphate and other soluble fertilizers applied shortly before sowing, in spite of the spell of hot dry weather which followed.

Certain combinations of nitrogen and phosphate fertilizers produced abnormally yellow plants in two Wareham experiments. The defect appeared to be associated with either organic nitrogen fertilizers in seedbeds, or late top-dressings of inorganic nitrogen fertilizers, both in the presence of superphosphate, all treatments being repeated for a second season on a very acid soil. The trouble did not occur with other phosphate fertilizers, or with ammonium sulphate given only in seedbeds.

5. Soil Acidification

Seedling growth was poor in many of the established nurseries with slightly acid or neutral soils. Treating the soil with acidifying agents in the winter or early spring of 1946/7 improved the growth of Sitka spruce seedlings in 1948 in these nurseries, and also in some with more acid soils. Acidification is one of the few treatments known to effect an improvement lasting more than one season in established nurseries. Many new experiments were started in 1948 to test alternative methods of acidifying soils. Promising results were obtained by heavy dressings of ammonium sulphate early in the winter. Some positive results were obtained from ammonium sulphate and sulphur in the year of application, though it is realized that acidification is more appropriate for land under fallow or a rotation crop than for land to be cropped at once with conifer seedlings.

6. Formalin

Formalin treatment a few weeks before sowing gave notably improved growth in 24 out of 26 tests at 9 nurseries. The effects were generally larger on the less acid soils.

7. Steaming

Steaming greatly improved seedling growth on most of a bad site in the Ringwood established nursery, though at one end of an experiment, in a long

strip, plants on unsteamed soil were as good as those on the steamed plots. No explanation was found for this irregularity. Some of the acidifying treatments proved about as effective as steaming, though it happened that they were tested on soil better than the average.

8. Rotation Crops

The residual effects of rotation crops grown in 1947, on seedlings sown in 1948, were small at Kennington Extension and depressing at Wareham, in spite of the addition of large amounts of green material and fibrous roots.

9. pH Range

If, as appears necessary, new nurseries should be on very acid soils, it will be difficult to find rotation crops which can be grown without heavy liming. Plots were laid out at Wareham, Kennington Extension, and Lynford Point (Thetford), to observe the effects of a wide range of soil reaction (artificially varied) on the growth of a variety of tree seedlings and transplants and also on some possible rotation crops. Omitting some excessively acidified soil at Wareham, it was found that ash seedlings were the only ones to fail at high degrees of acidity. Many tree species responded to light liming, but gave much poorer growth at high pH values. All the agricultural plants failed at soil acidities in which most tree species grow well. Good growth of acid-sensitive crops such as barley, sugar beet, swedes and clover may indicate that the land is unsuitable for conifer nurseries. The first-year results of these experiments are tentative and somewhat irregular, for the soils had insufficient time to settle down to approximate equilibrium both chemically and microbiologically. Later results may reveal the pH ranges in which both conifers and rotation crops may be grown satisfactorily. They may also provide scales of sensitivity to soil reaction, and show which tree seedlings can be used as indicators of soil conditions. These experiments may also reveal nutrient deficiencies or fungal attacks correlated with soil reaction.

Some rotation crops believed to succeed on acid soils were imported, as there are few such crops in British practice. Serradella and birdsfoot trefoil showed some promise, but white clover (S100) and perennial ryegrass could also be established by amounts of lime insufficient to harm sensitive conifers.

10. Watering

Additional watering of seedbeds increased heights in two of five nurseries.

11. Seed Covers

Experiments were started on several acid soils to see whether the use of calcareous seed covers would affect the growth of Sitka spruce in subsequent years. At Wareham there were significant differences between covers in the amounts of bird damage to Scots pine shortly after germination.

12. Miscellaneous Tests in Nurseries

At three nurseries, surface and subsoil were inverted before applying acidification and other treatments, to see whether it might be easier to acidify the subsoil where the surface soil had acquired too high a pH by direct or indirect liming. Sitka spruce grown with suitable manurial treatments on raw subsoils were not much smaller than those on the normal soils.

At Ringwood and Old Kennington there were no responses to several micronutrients applied in the seedbeds.

Areas resting from earlier experiments, or in reserve for future ones, were laid down to leys ; and a number of miscellaneous rotation crops were sown in observation plots.

13. Transplant Extensions

Many transplant experiments were carried out to test the growth, under uniform conditions, of seedlings which had received contrasted treatments in the seedbeds. The plants generally evened up, but the effects of a few treatments were still shown. Large tender plants obtained by watering seedbeds in the drought year 1947 gave smaller transplants than those left unwatered in 1947. On the other hand, height increases due to nitrogen fertilizers given to 1947 seedbeds in the same experiments were retained in the 1948 transplants.

Seedlings which appear "soft" do not necessarily give poor transplants. The transplants grew well where the "softness" was due to high nitrogen, but not where it was due to high soil moisture. In 1947 seedbeds there had been some dramatic responses in height to superphosphate, but in 1948 the seedlings raised with superphosphate in 1947 sometimes gave smaller transplants than those with mineral phosphate or basic slag.

14. Manuring Transplants

Transplant manuring experiments in North Yorkshire, on both a very acid moorland soil and a calcareous agricultural soil, showed large responses in height to superphosphate applied before lining-out, and to ammonium sulphate given as a top-dressing in April. Good results were also obtained from similar treatments in other nurseries, and also from top-dressing with a compound fertilizer, but there was one failure. On an unusually acid sandy soil at Sugar Hill, Wareham (with a pH around 4.0) top-dressing with ammonium sulphate checked growth in height ; other soluble nitrogen fertilizers gave good results.

15. Forest Extensions, 1947

The 1947 and 1948 assessments of forest plantings in 1947, in three forests, have been analysed. Establishment was very good for all one-plus-one plantings, and also for one-year seedling plantings at Broxa (Allerston Forest). There were about 10 per cent losses of Sitka spruce in one-year seedling plantings at Dartmoor, and 20 per cent at Decoy Heath, Wareham, the latter being a particularly poor site from which a failing stand of *Pinus contorta* had recently been removed, leaving a heavy infection of pine weevil and other pests. At Broxa, Sitka plants grew to similar heights throughout individual experiments, in spite of wide differences at the time of planting. At Dartmoor Forest, growth was more uniform, and many of the early differences persisted. Plants from experimental sowings in 1945, the first season of this work, planted out as one-plus-ones early in 1947, had grown to over 20 inches by the autumn of 1948. On the average of all available experiments, plants raised with fertilizer in the nurseries were slightly taller than those with compost in the nursery.

16. Forest Planting, 1948

The results of a single set of 1948 plantings have been analysed. One-year seedling and one-plus-one Sitka spruce and Scots pine grown in two parts of Sugar Hill Nursery, Wareham, were compared in three forests for each species. One set of plants had been raised with compost, on land repeatedly composted in previous years ; the other set were grown, with fertilizers, as the first tree crop on land cleared from *Calluna* (with a long fallow intervening before the seedbeds). There were no sharp differences in behaviour in the forests. On the whole the better growth was from the line-outs of the old nursery and the seedlings of the new nursery.

17. Forest Manuring, 1947

Experiments on fertilizers applied to Sitka spruce and Scots pine, planted as one-plus-ones in 1946/7, showed big responses to nitrogen, phosphate and potassium at Broxa and smaller responses at Dartmoor. There were also responses to nitrogen and potassium on Sitka spruce at Decoy Heath, Wareham, where phosphate was not tested in the 1947 plantings. The effects of nitrogen fertilizers were particularly marked on diameter increments. It is noteworthy that the Broxa site, in which plants grew to similar heights throughout extension experiments, should show such large responses to fertilizers applied in the forest, plants receiving N, P, K fertilizers reaching twice the height of unmanured plants. This suggests that the evening-up in the extension experiments may have been caused by some nutrient deficiency, probably nitrogen, acting as a limiting factor.

18. Continuation and Repetition of Experiments

All statements of results in this summary are based on heights in nurseries, and heights and diameters in forests. It is realized that such data are of restricted value, and that no firm conclusions should be drawn until the test trees have had several more years in the forest, and until experiments have been conducted in several years and places. In 1948, additional forest planting experiments were laid out with Sitka spruce and Scots pine at Broxa, Dartmoor and Decoy Heath, with Sitka spruce at St. Gwynno Forest, Glamorgan, and with Scots pine at King's Forest, Suffolk, a large proportion of the plantings being with first-year seedlings, both for extension and manurial experiments. The manurial experiments included different kinds of fertilizers and methods of application. As the first season's growth is generally small, a report on these experiments is postponed until the second-year assessments have been analysed.

19. Pot Culture

The pot culture experiments of 1948 were devoted to developing a technique capable of reproducing in pots some of the characteristic features of seedlings grown in the nurseries from which soil samples were collected ; and also of showing the effects of acidification and disinfecting the soil by steam and formalin. The 1948 results were seriously disturbed by uneven germination and "damping-off", but they served to bring out improvements by steam, formalin and acid.

Part III. Research undertaken for the Forestry Commission by workers attached to Universities and other Institutions

INTRODUCTION

By M. V. LAURIE
Chief Research Officer

Parts I and II of this Report deal with work that has been carried out by members of the Forestry Commission research staff, and are concerned mainly with the more technical problems of forestry. It is the policy of the Forestry Commission to leave the more fundamental aspects of forest research to universities and institutions that are better equipped to deal with them. The work reported upon here has been carried out by individuals attached to such institutions, the cost being, in most cases, wholly or partly met by grants from the Forestry Fund.

Seven brief progress reports are included dealing with the following subjects :

Research into the soil fauna of forest soils by Mr. P. W. Murphy at the Imperial Forestry Institute, Oxford. The objects of this line of research are to ascertain what insects and other small creatures exist in the soils which the Forestry Commission is dealing with, and what part they play among the numerous soil factors affecting the growth of trees. It is an almost virgin field of research, and a very extensive one, and to begin with work has been confined to devising satisfactory methods of extracting the organisms from the soil, and to sampling some undisturbed *Calluna* heathland soils in Allerston Forest, in North-east Yorkshire, with a view to determining the best sampling technique. These heathland soils were found to have large numbers of organisms in the litter and humus layers, e.g., 320 organisms in a litter sample having an air-dry weight of only 3.7 grams (one-eighth of an ounce) and 107 organisms in a humus layer sample of approximately similar size. Mites (*Acari*) predominated, mainly of the group *Orobatidae*, while *Collembola* were the second commonest group. Larger organisms such as millipedes, spiders and beetles were relatively scarce. Some difficulty has been experienced in getting the large numbers of species of mites identified. The method of extracting the insects is a modification of the Berlese Funnel technique, in which soil blocks are progressively desiccated by gentle heat from above, thereby driving the organisms out of the soil downwards into a funnel where they can be collected. The efficiency of this method in getting out all or most of the organisms in the soil still requires to be critically tested.

Towards the end of the year under review a second worker on soil fauna, Mr. Evans, has started work at Rothamsted. He is expected to investigate woodland soils more particularly. As he has only just commenced, no report is issued on his work this year.

At Oxford, Mr. P. J. Rennie is investigating the physical and chemical properties of forest soils, and is working in the same heathland areas as Mr. Murphy. It is hoped that their joint efforts will produce a composite picture of the soil conditions of parts of the Allerston area. As will be seen from his report, the work is still in the preliminary stages of finding out the best methods of determining various physical and chemical soil factors with a view to obtaining correlations between them and tree growth.

Dr. J. D. Ovington was appointed in February, 1948, to work at the Macaulay Institute, Aberdeen, on forest soils. The main subject of his investigations is the effect of the growth of tree crops on the soil during the period of canopy

formation. A range of forests, from Yorkshire to the north of Scotland, was visited, and it was decided to select the Culbin Forest area, on the north coast of Morayshire, for detailed studies. Physical analyses, chemical analyses, and bacterial and fungal counts have been made, together with measurements of tree growth on a number of quadrats in Corsican pine plantations of different ages. Water table determinations have been made in the forest and in the unplanted sand dune areas. It is too early to be able to get correlation between the various factors studied and tree growth, but the investigations give promise of very interesting results. A parallel set of investigations is also being carried out by him in Scots pine plantations in Tentsmuir Forest, Fifeshire.

At Bedford College, London, and at Wareham Forest, Dorset, Dr. Ida Levisohn is continuing the researches initiated by the late Dr. M. C. Rayner. The main lines of work are concerned with soil mycology, with particular reference to mycorrhiza and to soil fungi having deleterious effects on tree growth. Dr. Rayner's long-term nursery fertility demonstration at Sugar Hill Nursery, Wareham, based on various regimes of compost applications, was continued, and produced the usual excellent results with seedbeds and transplants of a wide range of species.

Dr. J. Rishbeth of the Botany Department, University of Cambridge, has been investigating the outbreaks of the root fungus, *Fomes annosus*, which follow upon thinning operations in pine plantations in East Anglia. The spread of this fungus, in a virulent form, from the recently cut stumps of thinnings to adjoining trees, kills the latter, and causes gaps in the crop which continue to extend from year to year. Dr. Rishbeth has been studying the conditions under which infection of the stumps takes place, and has tested various methods of preventing this infection. Painting or creosoting the freshly-cut surface of stumps was found to reduce the infection to 10 to 15% of its normal incidence. Alkaline soils were also found to be correlated with greater severity of the disease. A preliminary report on these researches has been published in *Forestry*, Vol. XXII (2).

Botanical investigations on the finer morphological differences between various races and provenances of trees, were continued by Dr. E. V. Laing of the Forestry Department, Aberdeen University. Scots pine was the main species investigated, but larches and Douglas fir were also studied. These botanical researches are likely to be of great value in genetical work, as they provide characters by which particular genotypes can be identified.

Finally, we have a report from Dr. David Lack, of the Edward Grey Institute for Field Ornithology at Oxford, on certain experiments in forest ornithology. The aim of these investigations is to determine the part played by birds in the control of forest insect pests, and to see to what extent such control can be made more effective by putting up nesting boxes in our plantations. The general lines of work to be followed are determined by a special committee under the chairmanship of Sir William Taylor, on which foresters, entomologists and ornithologists are represented. The direction of this work and the planning of the experiments are in the hands of Dr. Lack and his staff. The actual erection of the bird boxes is done by the Forestry Commission Research staff, and the detailed observations of occupation rates, etc., are arranged by Dr. Lack through local Natural History societies. The main bird-box areas in 1948 were in the Forest of Dean, and in Alice Holt Forest (East Hampshire), both in oakwoods, and at Thetford (East Anglia) in pine plantations. In 1949 the work will be extended to other areas and types of forest. So far, results have indicated that in deciduous woodland, very great increases in breeding bird population can be achieved by putting up nesting boxes. In conifers the increase is considerable though not so great. The effects of these increases on the incidence of damage by insects remain to be

determined, though it was shown that during an epidemic defoliation of oak by Winter Moth caterpillars, the proportion of caterpillars eaten by tits out of the whole was negligible, and could have had no appreciable effect. This was not unexpected, as it is believed that any controlling influence that may be exercised by increased bird populations will probably be in the periods before insect populations build up to epidemic proportions. The problem is complex, as most birds also destroy other predators and parasites of the pest insects. The work is being directed towards elucidating their ultimate effect on the population of harmful insects.

SOIL FAUNAL INVESTIGATIONS

By P. W. MURPHY
Imperial Forestry Institute, Oxford

Soil faunal investigations during the past season have been concerned principally with a rather intensive sampling of the surface layers of small heathland areas in Allerston Forest, some ten miles to the west of Scarborough in Yorkshire. A technique has been developed for the extraction of samples, involving a modified Berlese Funnel apparatus, designed to cater for large numbers of small samples. Owing to the nature of the sampling area, it has been found necessary to devise a means of obtaining these samples in a condition suitable for extraction. In addition, developmental work on other aspects has been continued during the past year. These various aspects may be conveniently considered under the following heads :

(1) Experiment No. 52 at Broxa, Allerston Forest, and ancillary sampling sites.
(2) Sampling methods.
(3) Soil and site characteristics.
(4) Extraction technique.
(5) Identification of material.
(6) Miscellaneous investigations.

1. Experiment No. 52 at Broxa, Allerston Forest, and Ancillary Sampling Sites

The major project during 1948-49 was the establishment of Experiment No. 52 at Broxa, and subsequent intensive sampling of the experimental site. The main objects of this sampling programme were as follows :

(a) To ascertain the present faunal status of undisturbed heathland comprising Experiment No. 52.
(b) To secure information on the number of samples required from a particular habitat in order to gain a statistically accurate assessment of the faunal population.
(c) To ascertain population changes on the same soil type at different stages of tree development.

Two sites (Experiment No. 10 at Broxa and No. 11 at Wykeham) in Allerston Forest were chosen for the purposes of the third object described above. For a number of reasons the data from these may not be directly comparable with those of No. 52, but at least they will indicate broad trends in population when cultivation and planting takes place. Experiment No. 52 was sampled on four occasions, involving 180 "block" samples and about 800 subsamples. In addition, the selected sites in the experimental plots at Wykeham and Broxa were sampled, the former on two, the latter on three

occasions, involving about 50 "block" samples and approximately 180 subsamples. This field work occupied 70 days (including travelling). The following table indicates the degree and time of sampling :

Field Sampling dates 1948	*Site*	*Number of "block" samples*	*Number of subsamples*
No. 1. 21st-24th June	B52	42	177
24th June	B10	5	17
27th-29th June	W11	16	57
No. 2. 13th-15th July	B52	42	179
15th July	B10	5	17
No. 2A. 1st-4th October	W11	16	69
No. 3. 23rd-27th October	B52	48	219
No. 4. 12th-16th November	B52	48	216
17th November	B10	5	19
Total		227	970

Apart from the first two samplings, the field work of this programme was achieved with remarkable success, thanks to the assistance received from Mr. Weatherall, Research Branch Forester, and the forestry staff generally ; indeed, without their help it would not have been fulfilled. Especially a word of praise for George Thompson, the writer's own assistant, who became an excellent field worker, applying himself wholeheartedly to what proved to be at times an arduous task.

2. Sampling Methods

The area occupied by Experiment No. 52 at Broxa (approximately eight and two-thirds acres) was divided into two blocks and fourteen treatment plots (as outlined in the original plan and programme of treatments). Two sample strips were selected, to lie parallel to the long axis of the experimental area, and within each a twenty-yard-square sample unit provided for each treatment plot, leaving five-yard lateral margins on either side. Thus each treatment plot had two sample units, with a total of twenty-eight for the whole experiment. For each sampling, three sample sites were selected at random within the units of each treatment plot.

All sampling methods involving the use of a cylinder or other simple means for the removal of samples, failed on this site owing to the extremely stony nature of the ground. The writer devised a technique to overcome these difficulties which, though slow and somewhat laborious, proved entirely satisfactory. Briefly this method consisted in removing a block of soil approximately five inches square from the side of a soil pit, with a closed cylinder inserted in the surface to protect the litter. This block was transported to the field laboratory, and from it soil samples were taken and a core cut for insertion in the extraction apparatus. Finally, the core was divided into two-inch sections, forming subsamples of a size suitable for extraction. With this technique, samples six inches deep were obtained without any difficulty ; and with care it was possible to take samples twelve to fifteen inches deep. There is no doubt that this area is as difficult a sampling site as will be found, and for more amenable situations a sampling cylinder which has been devised by the writer, in collaboration with Mr. Rennie, will be quite suitable for undisturbed sampling.

3. Site and Soil Characteristics

A considerable amount of information, consisting of field observations and laboratory determinations, has been collected, and tabulated for correlation with population figures. These site and soil characteristics include the following :

(a) Meteorological data.
(b) Micro-topographical features.
(c) Vegetation.
(d) Quantity and source of litter.
(e) Soil profile description.
(f) Litter and soil moistures.

In order to obtain rainfall and air and soil temperature records, a small weather station was established on the experimental site. This data should prove extremely useful for many purposes. Moisture percentages have been obtained for most of the samples, involving a total of some 950 moisture determinations (representing three to four thousand weighings). It is unfortunate that a balance of a type suitable for dealing rapidly with these routine weighings was not available.

4. Extraction Technique

A technique has been developed for the extraction of large numbers of small samples, using a modified Berlese Funnel apparatus. This apparatus is a synthesis of ideas arising out of the experience of the last eighteen months. It has now been operated for a period of nine months, and though some modifications may be necessary in the light of experience, the basic features would appear to be satisfactory. Its main advantages may be summarized as follows :

(a) Process of loading, etc., very rapid.
(b) Requires a smaller sample, which reduces population counts.
(c) Desiccating process more easily controlled and more uniform.

Eight batteries of funnels were constructed in the workshop at the Imperial Forestry Institute, and with these it was possible to extract 144 subsamples simultaneously. It was rather unfortunate that various delays and difficulties, especially in the availability of materials, compelled the writer to use these funnel sets in a partially completed condition.

5. Identification of Material

The task of counting and identification of the fauna of these samples has proceeded steadily, but a considerable amount of the material remains to be dealt with, and it will be some time before this is completed. This is slow and laborious work, especially in the early stages, owing to the taxonomic difficulties encountered, though these difficulties are diminishing as the work proceeds. It is a sorry commentary that there is only one *Acari* authority in this country at the present time who is able to undertake identifications of the *Orobatidae*, the principal group present in soils, and he is so busy that it might be two years before he is in a position to send determinations. However, Dr. Turk has kindly asked the writer to stay with him for a few days this summer, and this visit should prove of great assistance in the identification of some of this material ; but it is most unfortunate that he is unable to undertake the identification of type specimens. With *Collembola*, the other major group, the position is not quite so bad, and in any case the taxonomy of this group is much simpler. Here the writer has had considerable assistance from Dr. Gisin in Switzerland and Dr. Bagnall in this country. With the aid of these authorities, species of the following genera of *Collembola* have now been

identified : *Folsomidiella*, *Tetracanthella*, *Lepidocyrtus*, *Mesaphorura*, *Isotoma*, *Friesea*.

Results based on the material already examined would indicate the following provisional conclusions. (These remarks apply to Experiment No. 52 at Broxa only, as the material from Experiment No. 11 at Wykeham has not been examined in detail, and thus it is not yet possible to make what should prove to be an interesting comparison.)

(a) Large numbers of organisms exist in the litter and humus layers, especially in the former, with rapid falling off in both numbers and kinds in the mineral layers. This effect may be accentuated by the extraction technique.

(b) Large organisms such as millipedes, spiders and beetles are relatively scarce ; ants may be numerous on occasion, but the frequency with which colonies occur is difficult to assess.

(c) Mites tend to predominate in most samples, especially in the litter and humus layers.

(d) With litter and humus samples there is a considerable variation in population number from sample to sample. The following figures are fairly representative of the larger populations :

LITTER SAMPLE : Area $2\frac{3}{4}$ sq. inches : air dry weight = 3.7 grams (about one-eighth of an ounce).
Total organisms = 320 (*Acari* 279 ; *Collembola* 35 ; others 6).

HUMUS SAMPLE : Area $2\frac{3}{4}$ sq. inches ; depth 2 inches.
Total organisms = 107 (*Acari* 70 ; *Collembola* 32 ; others 5).

(e) The importance of extracting samples as soon as possible after removal.

6. Miscellaneous Investigations

These may be summarised as follows :

(a) Methods and technique in extraction of samples.
(b) Technique of counting and handling small organisms.
(c) Number and size of organisms in relation to sample volume.
(d) Culturing methods.

Only the first two call for comment at the present stage. Regarding (a), it will be remembered that the writer commenced this investigation with the intention of making a comparison of the flotation and funnel methods of extraction. During last year, however, the flotation method was temporarily abandoned, principally because of the difficulties encountered with samples having a high organic-matter content. From the outset the writer has been anxious to obtain precise details of the funnel method. This is especially difficult because the method is of a biological and dynamic nature, and the exact factors responsible for the enforced exodus of the population very incompletely understood. An apparatus has recently been designed and constructed (not detailed in this Report) with which it is hoped to achieve this object. The recent papers of Forsslund, Haarlov and Salt, and others, add weight to this line of thought, especially the first-named, who plainly states that he regards his funnel method as open to serious criticism, thus inferring that his very fine soil faunal survey (published 1944-45) is incomplete.

The writer is particularly glad that this question is now occupying the attention of soil faunal investigators, and that it will form an important part of the discussions of the macrobiological section of the Fourth International Congress of Soil Science, to be held in Amsterdam next year.

It seems a dangerous policy to undertake large-scale surveys using methods which, with a few exceptions, have not been critically tested. With this object in view, the writer hopes to be able to devote part of this summer's work to an examination of his extraction technique.

In regard to (b), much time has been spent in evolving a method for the rapid handling of small soil organisms, and a prototype of a mechanism for this work has been constructed. This has several good features, but some modifications will have to be made before it can become a satisfactory tool for this part of the work. In addition, a simple method has been devised for the preparation of samples prior to counting.

RESEARCH INTO THE PHYSICAL AND CHEMICAL PROPERTIES OF FOREST SOILS

By P. J. RENNIE

Imperial Forestry Institute, Oxford

Introduction

The objects of this work, which was started two years ago, are to try to determine those soil factors, both physical and chemical, which are likely to be of the most importance as affecting tree growth, and to work out suitable techniques for determining them. To start with, a moorland site in the Allerston Forest in North-east Yorkshire was selected, as giving opportunities for studying soil conditions, not only in uncultivated moorland in which trees start off very badly, but also in moorland that has been ploughed in the usual manner (single furrows fourteen to eighteen inches deep, spaced four-and-a-half to five feet apart) or cultivated in other ways, and under forest crops where the canopy is starting to close.

The work is still in the preliminary stages of working out satisfactory techniques for determining the physical and chemical characteristics of the soils under study, and there is still a considerable amount to be done. This year work was concentrated on :—

(i) Methods of determining the pore space in the soil, and the air-water distribution.

(ii) The rate of infiltration of water.

(iii) The nutrient status of the soil with particular reference to the peat layers.

An experiment was also laid down in which various surface treatments of the vegetation and soil were carried out, including ploughing, so as to provide differing conditions for the establishment of young planted trees, so that the changes in soil conditions could be studied, and later correlated with tree growth. A quantitative survey of the vegetation in the plots in this experiment was carried out, and a micro-contour survey of the surface and of the undulations of the iron-pan, was started.

In addition, soil profiles were extracted from open moorland and from six-year-old and twenty-year-old Sitka spruce plantations, and examined in detail for their chemical and physical characteristics.

The work was done partly in the field laboratory established in Allerston Forest, and partly in the Imperial Forestry Institute at Oxford.

Pore Space : Air-water Distribution Investigations

Up to June, 1948, the moisture status of the soil was determined and expressed as percentage moisture on the oven-dry (103° C.) weight of the soil.

It was evident, however, that for a satisfactory expression of the available moisture in the different horizons of the soil profile, moisture determinations should be put on a volume basis as soon as possible, and that seasonal movement of moisture should also be studied.

The sampling of soil for volumetric determinations of water and pore space presented some problems. The nature of the surface peat with its admixture of *Calluna* roots makes representative sampling difficult, and samples from this horizon reveal little about the degree of saturation. The horizons immediately beneath the peat almost invariably contain organic matter in the form of decaying tree roots, and quite high proportions of angular stones are present. Both of these factors necessitate the sieving of a very large weight of soil to obtain a representative sample. The lowest horizons (B and C), where rooting and root channels were less frequent, gave the most reproducible results. Unfortunately, the interest in these layers from the point of view of tree growth is secondary to that in the layers above the iron-pan.

A paraffin-wax immersion method to determine pore space was first tested, using a low melting point wax (50° C.) just above its melting point, and although it gave satisfactory results for the subsoil samples, it was found to be unsuitable for the peat samples and for the horizons containing varying amounts of organic matter.

A kerosene immersion method of Russell and Balcerak was then tested, and found to possess distinct advantages. A modification of the apparatus was devised so that it could be used continuously, with the minimum amount of disturbance to the kerosene, and it was found possible to expedite the impregnation period and obtain consistent and reproducible data. Even so it is only possible to deal with one or two soil profiles per day, depending on the number of clods which are examined down each profile.

Infiltration of Water

One of the immediate results of deep ploughing, with consequent rupture of the iron-pan, is probably an alteration in moisture movement. In undisturbed moorland it has been observed in the field that rainfall reaching the iron-pan horizon of the profile tends to travel over it in a more or less horizontal direction, and there is certain evidence to suggest that surface waterlogging of the moorland, which is widespread during the winter months, and which is most noticeably associated with *Eriophorum*, *Juncus* and moss-covered peat, may be due in part to a basin formation of the iron-pan.

It has also been stated that the surface peat layer may become impervious to water in its saturated condition, and indeed "run-off" from the surface is considerable after heavy rain.

It is desired to test the various horizons separately in respect of their water percolation capacity, so as to obtain quantitative data on these aspects of water movement. It was necessary to work on "undisturbed" soil samples, and special methods had to be devised for obtaining such samples, as the nature of the soil, with its high proportion of angular stones and friable matter, precluded the use of the usual types of soil-sampling tools. By following a technique described by Clarke, and using a metal cylinder as a guide, it was found possible to dissect out cylindrical blocks of soil, and to mount them in a vertically hinged cylinder to which a base plate is attached. Some difficulty was encountered in finding a convenient mounting material, and after trying various things, putty was eventually selected as having the required degree of plasticity, whilst being completely impervious to water. Hot paraffin-wax was found to be ideal for sealing the base-plate to the cylinder. The rate of percolation of water was then recorded by maintaining a constant pressure head of water on the soil surface (0.5 cm. or one-fifth of an inch of water) by means

of a constant level device, and collecting the percolating water in a graduated cylinder.

It was found that under the saturated moisture conditions of the experiment, the iron-pan horizon represents by far the least pervious zone, and constitutes a definite barrier to downward water movement.

It must be emphasised that the above technique is difficult, by virtue of the difficult nature of the material, and samples often have to be rejected owing to disintegration during the cutting procedure. The general results, however, indicate that further detailed work on the permeability, and the water-air contents of the pore space, of ploughed and unploughed moorland should be carried out.

Vegetation Control and Cultivation Experiment

The general aim of this experiment is to create varying conditions of soil working, and of vegetation control, under which the development of young planted trees can be compared, and the physical and chemical conditions of the soil can be studied. The changes in these conditions as tree crops develop and form a canopy will also be watched.

An area of typical moorland, 240 yards long by 83 yards wide, as level and uniform as possible, was selected, and divided into 42 plots. Six of these are to be kept as controls in the original untouched moorland condition. The other 36 plots constitute a factorial experiment in which three soil-working treatments (R, L, and K) are combined with three vegetation-control treatments (M, W, and O). Each of the nine combinations is split into a larger portion planted with Sitka spruce (P) and a smaller portion left unplanted. There are two complete replications of the whole, apart from the hidden factorial replications. Details of the treatments are as follows :

R :—Deep-ploughed at Forestry Commission spacing (i.e., 5 feet between furrows).

L :—Surface peat broken up by a Fordson rotary hoe to a depth of about two-and-a-half inches (6 to 7 cms.). The use of this implement for regeneration in Dutch forests led to the request for this treatment.

K :—Killing of vegetation by cutting at or just below the surface level, but with no disturbance of the bulk of the peat layer. This was effected by a small rotary hoe.

M :—A mulch of freshly-cut *Calluna*, applied at the rate of five acres cut *Calluna* per acre of moorland.

W :—Annual removal of vegetation by hand or appropriate mechanical means.

O :—No vegetation control.

The lay-out of the experiment was commenced during the latter part of 1948, and the final mulch treatment was applied in June, 1949.

Quantitative Vegetation Survey of the Experimental Site

Although the experimental site appeared superficially to be comparatively uniform, close examination showed that over small areas several distinct vegetation types occurred, of which the most important are :

(1) Dominant *Calluna.*
(2) *Eriophorum.*
(3) *Erica tetralix/Scirpus* vegetation.
(4) Bare peat patches.

A detailed survey of the experimental area was made by running parallel transects one yard apart across the width of the area (82 yards). There were 241 of these transects, and the vegetation for nine inches on either side of the transect line was recorded. The whole area was covered in this way, and vegetation maps are in course of compilation. The plan for the distribution of *Calluna*, when superimposed on the experimental plot plan, shows that *Calluna* is by no means dominant for all the plots, and that the large size of the plots is fully justified on account of this variation in the vegetation.

It is hoped that when tree response is ultimately recorded, it may be possible to obtain correlations with the initial vegetation types.

Micro-contour Survey and Pan Depth

In order to obtain the necessary data on microtopography for correlation with vegetation, and to obtain an absolute contour of the iron-pan level itself (the latter for certain plots only), a contour survey was commenced over the experimental site. Brigadier Bomford of the Department of Surveying (Oxford University) kindly provided the necessary equipment. This work has been temporarily suspended owing to the transference of the assistant who was doing it.

Mechanical Composition of Soils in the Ploughed Plots

During the deep ploughing of certain of the experimental plots, it was found that although the plough was observed to be running at a very even depth, the ridge was composed either of a leached grey soil *or* of the fawn-coloured soil from below the iron-pan. Although surface conditions were wet during ploughing, the ridge was generally composed of a friable textured sand, but on occasions the ridge came away from the plough mouldboard in a characteristic clayey fashion. Not only did this occur in the grey strips, but it was generally associated with vegetation other than *Calluna*.

In order to investigate this further, the soil colours of the ridges were recorded, and the well-defined clayey patches marked. A plan of the distribution of these colours is in course of preparation, and again correlation between the clayey patches and vegetation is being investigated.

Numerous samples were taken from the areas recorded for detailed mechanical analysis, and results are being worked out.

Peat Investigations

In order to get an estimate of the nutrient status of the moorland surface peat over the area of the experimental site, a number of samples of peat were extracted from the three main vegetation types, namely, *Calluna*, *Eriophorum* and Bare-peat/*Erica*. The samples were taken by means of an open-ended pressed-steel cylinder 10 cms. (about four inches) in diameter, after first cutting and removing the surface vegetation. Uncompressed peat samples were obtained in this way of known depth and volume, containing very little mineral contaminant. They were weighed in the moist field condition, allowed to air-dry, and then dried at 105° C. and weighed again. They were then milled to produce a fine powder.

The specific gravity (in water) was then determined which, with the moisture data, allowed an estimate to be made of the proportions of air, water and solids in the peat. Total nitrogen was estimated by a micro-chemical modification of the well-known sulphuric acid digestion method, with subsequent distillation of ammonia in a Parnas and Wagner apparatus.

Calcium, magnesium, potassium, and phosphorus are in process of estimation on aliquots of the ashed dried peat.

Soil Profile Survey

In June and July, 1948, a considerable number of profiles were extracted from the following areas :

Broxa, Experiment 52 : Moorland.
Broxa, Experiment 11 : 6-year-old Sitka spruce (with soil cultivation).
Wykeham, Experiment 6 : 20-year-old Sitka spruce (with soil cultivation).

The profiles were examined in the field laboratory, as far as facilities permitted, whilst parallel faunal investigations were in progress. On the greater number of profiles extracted the following data were obtained down the profile :

(1) Physical characteristics.
(2) Moisture status on a weight basis.
(3) A rough estimate of organic matter, by the loss on ignition method.
(4) Soil reaction (electrometric determination with glass and calomel reference electrode).
(5) Total nitrogen content.

It was soon apparent, however, that sampling on such a large scale was giving very limited information, and that it was physically impossible on a seasonal basis. In view of the desirability of being able to characterise a larger range of ecological types in terms of the physical and chemical conditions of the soil, it was decided that sampling sites should be chosen from definite ecological areas even under moorland conditions, and not randomised as hitherto.

Accordingly, some ten profiles from *Calluna* and five from *Eriophorum* areas were extracted in September and October, 1948. The physical characteristics were recorded and analytical work on them is in progress.

FOREST SOIL INVESTIGATIONS IN SCOTLAND

By Dr. J. D. OVINGTON
Macaulay Institute for Soil Research, Aberdeen

Work commenced at the Macaulay Institute on 1st February, 1948, the main subject of investigation being the effect of the growth of tree crops on the soil during the period of canopy formation.

A number of forests have been visited, including Allerston, Rannoch, Teindland, Clashindarroch, Tentsmuir, Monaughty, and Roseisle, and also the Darnaway Estate of the Earl of Moray. As a result of these visits it was decided to commence a detailed investigation at Culbin Forest on the north coast of Morayshire, and to develop suitable field techniques there which later could be applied to other areas.

An intensive survey of Culbin Forest was made. On the Culbins there is a wide range of soil conditions ranging from shingle beds, remnants of old sea beaches and river courses, to high sand dunes. Local "blowouts" have occurred and old stable horizons have been submerged by shifting sand. Corsican pine has been planted on the dunes after thatching, and Scots pine and lodgepole pine (*Pinus contorta*) on the flatter, wetter areas.

Quadrats of approximately 45 × 45 yards, showing a range of tree ages (0-20 years) and canopy development have been marked out on comparable soil sites. The soil profiles within these quadrats have been examined and sampled to a depth of four feet. Estimations of sand-grain size, pH, carbon,

loss on ignition, nitrogen, phosphate, calcium, sodium, magnesium, manganese and potassium on these samples are being completed. Preliminary investigations of the water relationships in the quadrats and across a large dune (Lady Culbin) have yielded interesting results and are being continued. On the dunes the water table was well below the sampling depth. A technique which has been developed enables the data obtained to be expressed on a volume basis instead of as a simple percentage ; it is also used for determining the physical characteristics of the soil. Preliminary investigations indicate that this method is satisfactory and may be applicable to other areas.

With the development of a humus layer on the sand, there is increased micro-biological activity. Bacterial and fungal counts have been obtained.

In addition to the sand analysis, tree measurements have been made within the quadrat areas, so that the increasing tree size and change in soil conditions can be indicated together.

At Culbin the investigation has tended for various reasons to concentrate on Corsican pine planted on the high sand dune areas.

At Tentsmuir Forest (North-east Fifeshire) a similar investigation has been initiated. Here, except along the sea shore, true sand dunes are non-existent, and the interior is relatively flat and low lying. The water table is high, and conditions are generally much wetter than on the dunes of Culbin. The range of soil conditions is not so great as at Culbin, although buried horizons have been observed. Occasional layers of sea shells are found. The area has been fixed naturally by vegetation for a longer period than the Culbins, and some visual profile development has occurred.

Low-lying quadrats, planted with Scots pine, have been marked out, trees measured, profiles described, and soil samples collected down to the water table. A similar range of tree age and size as at Culbin is found in these quadrats. The samples will be subjected to the same analysis as the Culbin samples.

In association with Mr. Oliver, Conservator for East Scotland, an experiment has been laid out to investigate the possibilities of "fixing" roads on the Culbins by establishing a close vegetational cover.

RESEARCHES IN SOIL MYCOLOGY

By Dr. IDA LEVISOHN
Bedford College, London University

Research on the maintenance of fertility in nurseries was continued. The long-term fertility experiments at Sugar Hill Nursery, Wareham Forest, Dorset, were carried on, applying Dr. Rayner's routine treatments for this nursery, namely, special cultural methods (i.e. sub-soiling, mulching), composting, and introduction of appropriate mycorrhiza-formers for the ectotrophic and endotrophic species raised.

Representatives of the whole nursery stock (first-year seedlings and one-plus-one transplants) were subjected to mycorrhizal examination, and useful data recorded as regards the time of root infection in a large number of coniferous and broadleaved species.

At Decoy, Wareham, recording and analysis of the randomized planting experiment with Norway spruce was started. The experiment is designed to test the effect of soil inoculation with *Amanita muscaria* sporophores as compared with other treatments, i.e. mulching and composting.

Among the pot-experiments carried out, a majority is concerned with a test of the growth of Scots pine and Sitka spruce in soil transported from Roseisle Nursery, Morayshire, and with an analysis of the specific soil flora from Roseisle involved in the root infection of various coniferous species.

Other pot-cultures cover a series of inoculation experiments. Growth stimulation was found to be produced by inoculating false acacia, *Robinia pseudacacia*, with specific nodule bacteria. The effect of such stimulation was analysed in more detailed experiments, using non-specific nodule bacteria and nodule extracts.

Pot-experiments to study the interrelations betweena widespread mycorrhiza-former, *Mycelium radicis nigrostrigosum*, and a root parasite, *Rhizoctonia sylvestris*, were started. So far, the results confirm the earlier observations on the interrelations between mycorrhiza-formers and pseudomycorrhiza-formers.

In the laboratory, the study of the behaviour of deleterious root fungi was continued. It was observed that certain nutritional factors are responsible for the virulence of these mycelia as reflected in the invasion of cellulosic material by the hyphae. Experiments to test this invasion effect on root tissues from coniferous seedlings, introducing mycorrhizal as well as deleterious mycelia, are in progress.

Application of ultrasonic irradiation of soil was used in a preliminary experiment with two objects in view :

(1) as a method of obtaining partial sterilisation with a minimum of disturbance of the soil character ;
(2) as a method of emulsifying certain soils in order to study their physical properties.

As regards both objects, the results of this preliminary irradiation experiment seem promising.

INVESTIGATIONS ON FOMES ANNOSUS ATTACKS IN EAST ANGLIAN PINE PLANTATIONS

By Dr. J. RISHBETH
Department of Botany, Cambridge University

In two areas visited in Thetford Forest, East Anglia, gaps in the plantations caused by the fungus *Fomes annosus* were replanted about three years ago with a variety of species, and here a number of the young trees have already died. Scots pine, Douglas fir, Lawson cypress, and beech have all been affected in this way, and it is not easy to forecast how many will eventually survive. The root systems of some of the trees killed earlier by *F. annosus* are responsible for infection in these instances.

The germination of *F. annosus* basidiospores on freshly-cut pine stumps was further investigated. It was found that, if spores on a stump surface are washed down into the tracheids, as might happen during a shower of rain, germination of the spores and the subsequent colonisation of the stump takes place, even if the surface dries out soon afterwards. In the absence of rain, spores on the stump surface will germinate, provided that the humidity remains high for a period. A large-scale experiment, in which stumps were treated in various ways immediately after felling, showed that the infection of stumps by *F. annosus* may be reduced to 10% to 15% of its normal incidence by painting or creosoting, whereas no protection is given by covering with soil.

An analysis of sites where outbreaks of the disease have occurred, shows clearly that it is more severe where the soil is alkaline. This condition arises naturally where the chalk is near the surface, and also where the soil has been limed for cultivation. This relation between soil type and severity of disease arises partly from the type of soil microflora since, in the alkaline soils, fungi antagonistic to *F. annosus* are not abundant. It has been shown that, owing to this, the number of infections which take place on living roots around stumps containing *F. annosus* is relatively great, and the rate of replacement of the parasite by other fungi in stumps is slow.

A short account of the work so far carried out in the East Anglian plantations is published in *Forestry*, Vol. XXII (2).

BOTANICAL STUDIES ON TREE RACES

By Dr. E. V. LAING
Department of Forestry, Aberdeen University

The main species studied during the past year have been larch, Scots pine and Douglas fir.

Scots Pine

From the material examined, it is possible to divide Scots pine into four morphological groups depending on needle width and thickness. These can again be sub-divided according to length of needle. A character which has proved useful in further sub-division is waviness of outline of needle, i.e. in certain cases the stomata are sunk in pronounced grooves on the leaf. Such a character can be seen in the field. In many cases, the outline of the leaf is smooth. The waviness or otherwise of the leaf outline may be taken to indicate environmental conditions, and whether a race or origin can tolerate more xerophytic conditions. A character which may be useful in the same direction is the amount of collenchyma produced in the leaf. Some origins have abundant and others have scanty collenchyma.

The colour of the current year's shoot has been found to be of some value. For instance, Scots pine of Scottish origin has in many cases greenish shoots.

Unfortunately, in many cases, cones are not yet available, from "race" plots. It is evident, however, that there are great differences not only in size of seed but in shape, and length and breadth of wing. External characters of the cone, as is well known, also vary, but it is now felt that shape of seed, and length and breadth of wing, may be more decisive in determining race.

Larches

Work has been mainly directed, in these species, to the trying out of the morphological characters already defined to determine race. It is felt now that races can be determined with a good deal of accuracy from the known characters of cone-scale form and shape of wing of seed.

Douglas Fir

It is found that Douglas fir types can be more readily defined than in any other species. Cone differences have been noted. Leaf arrangement and texture is proving very distinctive as well as hairiness or otherwise of the twig. Great variation exists in our plantations, and an attempt will be made to correlate morphological characters with the silvicultural value of the trees.

FOREST ORNITHOLOGICAL INVESTIGATIONS

By Dr. DAVID LACK
Edward Grey Institute for Field Ornithology, Oxford

The investigation of the nesting of titmice in boxes has two main objects :

(1) to establish whether and to what extent the tit population can be increased by providing nesting-boxes, with special reference to planted woodland.

(2) to determine the part played by tits in controlling insect pests in forests, with special reference to defoliating caterpillars.

A preliminary answer to the first of the above problems has already been achieved in the Forest of Dean, through the nest-box experiment started about ten years ago, and especially since the provision of boxes on a large scale from 1942 onward. The density of both tits and pied flycatchers has considerably increased, and the 1948 figures show that the density of the birds is still rising.

It was obviously desirable to extend the above work to other areas before drawing general conclusions, and particularly to areas of conifers. Accordingly, in 1948, the density of boxes in the Dean was again increased ; 150 boxes were set up in oak plantations, and 50 in adjacent conifer plantations, at Alice Holt Forest, East Hampshire ; while at Thetford, East Anglia, 100 boxes were set up in Scots pine planted in 1926, and 100 boxes in Corsican pine of the same age. Further, parallel observations were made with 200 nest-boxes set up in mixed broadleaved woodland at Wytham (Oxford) in 1947.

In 1948, it was decided to start detailed observations on these nesting-boxes with a view to establishing :

(a) the total breeding population
(b) the breeding season
(c) clutch-size
(d) nesting success

and the ways in which these four items vary from place to place and year to year. The boxes are inspected weekly, and details of the occupied boxes are entered up on Nest Record Cards. In the Forest of Dean, the work is supervised by Dr. Bruce Campbell (of the British Trust for Ornithology) and D. A. Cousins (Research Forester) ; at Alice Holt by T. R. Garnett and Charterhouse Natural History Society ; at Thetford by A. R. Bartholomew (now A. Faddy) and the Lynford Hall Forester School, and at Wytham by J. A. Gibb (Edward Grey Institute). The observations are co-ordinated by Dr. Lack (Edward Grey Institute).

In the study areas, there were 60 nests in the Dean, 69 at Alice Holt, 30 at Thetford and 80 at Wytham. Those in the broadleaved woods (Dean, Alice Holt, Wytham) were primarily great and blue tits, those at Thetford, mainly coal tits with some great tits. Full nesting data (laying time, clutch-size, nesting success) were obtained at Alice Holt, Thetford and Wytham, but unfortunately the Dean was visited only rather late in the spring, and clutch-size was missed.

In 1949, with the experience gained in 1948, full surveys are being undertaken in all four of the above areas. There has been a big increase in the tit population in the two new areas (Alice Holt and Thetford), and interesting differences have been found in the laying time and clutch-size in the two years. A further 100 boxes have been erected at Thetford, and work has been started in two new conifer areas, Gwydyr Forest (Bettws y Coed, North Wales) and Glentress Forest, the observations being organized in both cases by the Forester Training Schools.

The second object of research, which relates directly to the first, is the study of the food of the titmice, in both summer and winter. This is being undertaken by P. H. T. Hartley and Miss M. M. Betts of the Edward Grey Institute. In 1948, it was found that the titmice nesting in mixed broadleaved woodland at Wytham, fed their young primarily on defoliating caterpillars, which were very abundant that year. The breeding tit population was known from the nest-box study, and it was possible to assess the caterpillar density by two methods :

(a) By counting the number of caterpillars per hundred leaves from samples taken throughout the summer.
(b) Having first established the defaecation rate of the caterpillars, by setting out trays under the trees to measure the number of faecal pellets falling per unit area.

By comparing the tit density with the caterpillar density, and by measuring the feeding rate of the tits to their young, it was shown that, in the summer of 1948, the tits took a quite negligible proportion of the caterpillar population.

It must be stressed that the above observations relate to only one summer, and they must be repeated for several seasons for a true estimate to be obtained of the effect of tits on the caterpillar density. There is also the problem of winter food. It was found, for instance, that in January, blue and great tits in the Forest of Dean were eating many adult females of the Winter Moth, *Cheimatobia brumata*. The importance of this observation will be known only when the respective densities of the tits and the moths, and the rate of capture effected by the tits, are known, and nothing should be argued from it at present as to the usefulness or otherwise of the tits. Nevertheless, the observation is suggestive, and justifies the continuance of this work during 1949. It is hoped also that a start may be made with the food of the titmice in the planted conifer woods at Thetford Forest.

Printed in Great Britain under the authority of His Majesty's Stationery Office by Cheltenham Press Ltd., Cheltenham

(4065) Wt. 4188/1682 K20 6/50 **6/23/5**

FORESTRY COMMISSION PUBLICATIONS

(continued from Inside Front Cover)

BOOKLETS

No. 1. WOODLAND MOSSES (fully illustrated). 2s. 0d. (2s. 2d.)
No. 2. THE DEDICATION OF WOODLANDS : PRINCIPLES AND PROCEDURE. (2nd Edition.) 1s. 6d. (1s. 8d.)

FOREST OPERATIONS SERIES

No. 1. THE THINNING OF PLANTATIONS. 9d. (10d.)
No. 2. THE ESTABLISHMENT OF HARDWOODS BY SOWING OR PLANTING. 9d. (10d.)

MISCELLANEOUS

FORESTRY AS A CAREER. 3d. (4d.)
FORESTRY COMMISSION YIELD TABLES, FOR SCOTS PINE AND OTHER CONIFERS. 6d. (7d.)

LEAFLETS

Each 2d. (3d.) :

No. 2. ADELGES COOLEYI, AN INSECT PEST OF DOUGLAS FIR AND SITKA SPRUCE.
No. 3. PINE SHOOT BEETLES.
No. 4. BLACK PINE BEETLE.
No. 5. CONIFER HEART-ROT.
No. 6. HONEY FUNGUS.
No. 7. ADELGES ATTACKING SPRUCE AND OTHER CONIFERS.
No. 12. INCOME TAX AND DEATH DUTIES ON WOODLANDS.
No. 14. PHOMOPSIS DISEASE OF CONIFERS.
No. 16. LARCH CANKER.
No. 17. CHAFER BEETLES.
No. 18. TWO LEAF-CAST DISEASES OF DOUGLAS FIR.
No. 19. ELM DISEASE.
No. 20. WATERMARK DISEASE OF THE CRICKET BAT WILLOW.
No. 23. PIT PROPS.
No. 25. THE REPLANTING OF FELLED CONIFEROUS WOODLANDS IN RELATION TO INSECT PESTS.
No. 26. THE SPRUCE BARK BEETLE.
No. 27. POPLAR PLANTING.

Binders for leaflets are available 1s. (1s. 1d.)

FOREST RECORDS

No. 1. REVISED YIELD TABLES FOR JAPANESE LARCH IN GREAT BRITAIN. 6d. (7d.)
No. 2. RAISING OF ASPEN FROM SEED. 6d. (7d.)

BRITAIN'S FORESTS

FOREST OF AE (DUMFRIES-SHIRE). 6d. (7d.)
CULBIN (MORAYSHIRE). 6d. (7d.)
RHEOLA (GLAMORGAN). 6d. (7d.)

Obtainable as indicated on the inside of the front cover.

LONDON: PUBLISHED BY HIS MAJESTY'S STATIONERY OFFICE
To be purchased directly from H.M. Stationery Office at the following addresses :
York House, Kingsway, London, W.C.2 ; 13a Castle Street, Edinburgh, 2 ;
39 King Street, Manchester, 2 ; 2 Edmund Street, Birmingham, 3 ;
1 St. Andrew's Crescent, Cardiff ; Tower Lane, Bristol, 1 ;
80 Chichester Street, Belfast
OR THROUGH ANY BOOKSELLER
1950

Price 1s. 9d. net

S.O. Code No. 70—620—0—49