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Exotic Forest Trees in Great Britain

Paper prepared for the
British Commonwealth Forestry Conference
Australia and New Zealand 1957

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ERRATA

Page 5. *Second column, penultimate paragraph*:

For: "Quercus ilex" read: "Quercus cerris"

Page 25. *First column, last paragraph, fourth line from foot*:

For: "pseudofibrous" read: "fibrous"

As above but third line from foot:

For: "fibrous" read: "pseudofibrous"

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EXOTIC FOREST TREES IN GREAT BRITAIN

Paper prepared for the Seventh British Commonwealth Forestry Conference, Australia and New Zealand, 1957

Edited by
JAMES MACDONALD, R. F. WOOD,
M. V. EDWARDS, and J. R. ALDHOUS
Forestry Commission

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FOREWORD

The Sixth Commonwealth Forestry Conference, at its meeting in Canada in 1952, accepted a recommendation made by its Committee on Forest Management, Silviculture and Forest Protection which was expressed in the following words:

> 'A detailed account of the use of exotic species in the Commonwealth, based partly on information supplied to the Third British Empire Conference, was given by the late Professor R.S. Troup in his book *Exotic Forest Trees in the British Empire* (1932). Much experience has been gained since that date and it is recommended that the Standing Committee should arrange for its collection in a standardised form for presentation to the next Commonwealth Forestry Conference.'

The Standing Committee appointed a small sub-Committee, under the Chairmanship of Mr. M. V. Laurie, to give effect to this recommendation, and this sub-Committee drew up a standard form (see Appendix, page 166) for the submission of information, which they sent to each Forest Department in the British Commonwealth, pointing out that the Sixth Commonwealth Conference had resolved that the information on exotics, for which they were asking, should be presented to the Seventh Conference in Australia in 1957.

This publication is the response of Great Britain to the request of the Commonwealth Conference. Necessarily, it is a long document. The introduction of alien trees has been going on for several centuries, and the climate of the British Isles permits the cultivation of a very large number of exotics from all parts of the world, some of which have succeeded so well that they have become the staple species in British forestry. For this reason, it was thought that this report might be of general interest, and the Forestry Commission has therefore decided to make it available to the public as one of their series of Bulletins.

In preparing this report, we have followed generally the form prescribed by the Standing Committee of the Conference in dealing with the most important exotic trees in use in this country at the present day, although we have modified it slightly here and there as circumstances demanded. For trees which are used to some extent in the forest but are of minor importance, we have followed the standard form as far as it was possible to do so with the information at our disposal ; but there is, inevitably, some unevenness in the treatment of species in this class. As for the others, we have given separate notes on those exotic trees which have been tried occasionally in small plots or plantations and of which we have a record, but we are conscious that this method of procedure has led to the inclusion of some trees of no consequence at all, solely because someone has planted them on a small scale, and the exclusion of others which may actually be common in the country as ornamental trees, and the possibilities of which may be greater. We have tried to preserve an even balance and to give most space to the trees which deserve it and in this we think we have been successful. We must, however, draw attention to the account of the genus *Eucalyptus*, a genus of great horticultural and silvicultural interest, but at the same time of no forest importance here. It has been given much more space than it deserves if it is regarded as a forest tree in Great Britain, but we felt that, in view of its world-wide importance, it might be of importance to foresters in other countries to know how different species of *Eucalyptus* have behaved in conditions which are extremely difficult for them. In dealing with the awkward subject of nomenclature we have followed Rehder in his *Manual of Cultivated Trees and Shrubs*, and where this has led us to employ a botanical name not in common use, the customary name is given as well.

In compiling this report we have received help from many of our colleagues. Mr. G. G. Stewart, Mr. R. Faulkner, Mr. R. Lines and Mr. T. R. Peace have all written sections on genera and species. Mr. Peace has also provided much information on diseases and general pathology, while Dr. M. Crooke has contributed the information which is given on insect pests. Data on production and rates of growth have been provided by Dr. F. C. Hummel and on dimensions of individual specimen trees by Mr. A. F. Mitchell. Mr. J. D. Matthews has helped us by giving information about seed production and vegetative propagation, while we have depended on Mr. E. G. Richards and Mr. J. R. Aaron for assistance in preparing the sections on timber and utilisation. Others of our colleagues have also helped us in numerous ways including Mr. G. D. Kitchingman, the Librarian, who has provided literature references. Mr. H. L. Edlin has dealt with the report in its

final stages and has seen it through the press.

For permission to reproduce the diagrams in Chapter 2 we are indebted to Messrs. S. Gregory (Fig. 4), and H. L. Penman (Fig. 6) and the Meteorological Office (Figs. 1, 2, 3, 5 and 8). The Meteorological Office and Mr. E. G. Bilham have also kindly agreed to the reproduction of the data in Tables 2, 3 and 4.

FORESTRY COMMISSION,
25, Savile Row,
London, W.1.
April, 1957

Thanks are also due to the many landowners who have given facilities for the measurement and recording of their specimen trees and plantations and to those who have made available to us their own records of outstanding trees.

JAMES MACDONALD
R. F. WOOD
M. V. EDWARDS
J. R. ALDHOUS

CONTENTS

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UNITS OF MEASUREMENT

The unit of measurement used for volumes of standtimber, yields, and increments, is the Hoppus foot, which is equivalent to 1.273 true cubic feet.

Basal areas are given in square feet as measured on the Hoppus or quarter-girth system, whereby one square foot is equivalent to 1.273 square feet in true measure.

Breast height is taken as 4 feet 3 inches.

All measurements are over bark unless otherwise stated.

AUTHORSHIP OF ARTICLES

The authorship of each section of the text is indicated by initials, as follows:

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PART I

General Considerations affecting Exotic Forest Trees in Great Britain

Chapter 1

THE PLACE OF EXOTIC TREES IN BRITISH SILVICULTURE

There are few countries in the world in which exotic trees play a more important role than in Great Britain where it is now impossible to make even the shortest journey without seeing, in forest or woodland, in park or garden, a diversity of trees drawn from many different parts of the world. So familiar have many of them become, that it is hard to regard them as alien in origin; so long have they been established here and so well have they adapted themselves to the soils and the climate of this island, that they now have all the appearance of native trees. The great variety of species, growing in Great Britain, is apt to obscure the relative poverty of our native flora in trees, a poverty which is more pronounced in the conifers, of which our sole indigenous representatives are the Scots pine, the yew and the juniper. Of these, only the Scots pine is a timber tree, for the yew rarely attains size and shape suitable for conversion and the juniper is scarcely ever more than a scrubby bush. Among broadleaved trees, there is not so great a disparity between indigenous and exotic, but, even in this group, important and familiar trees such as the sycamore, the horse chestnut and the plane, as well as others of smaller consequence, have undoubtedly been introduced within historic times.

The general poverty, in species, of our native flora is, partly, due to the geographical situation of the British Isles, and, partly, the result of recent geological history. The indigenous woodland of Great Britain formed part of the Deciduous Forest of Western Europe, but, in the Highlands of Scotland, and possibly elsewhere, there were forests, dominated by the Scots pine, forming an outlier of the Northern Coniferous Forest. In Great Britain, at the very extremity of Europe, the native woodlands were lacking in certain species which occur naturally in the same types of forest on the Continent; thus, the Norway spruce was absent from the Coniferous Forest in Britain, though present elsewhere in Europe, while the beech appears to have been native only in the southern part of England, and absent from the deciduous forest, dominated by oak, in the rest of the country. The severance of Great Britain from the continent of Europe, which took place in the Atlantic period, must have prevented the migration into the country of several species which have since been introduced by man.

A country, which uses exotic timber trees may do so for several reasons or for one in particular, but in general it is impelled to this action either because its native forest is scanty, or, because its forest flora is chiefly composed of species which are not wholly suitable for its trade and industrial requirements. For both reasons, exotics are now being used in this country but it is necessary to point out that they were not introduced originally with either of those purposes in mind. The story of the introduction of exotic trees into Great Britain is a long one, going back, probably, to the beginnings of recorded history, and certainly gathering momentum from the sixteenth century onwards. Here and there, no doubt, a tree may have been deliberately introduced with a view to economic use, but most of the introductions were brought in by persons who were interested in them as subjects for cultivation in gardens and parks, for embellishment rather than for the production of timber. The great developments which took place in the sixteenth, seventeenth, eighteenth and nineteenth centuries, and which have persisted into the twentieth, were brought about by the operation of certain factors, some of

which are still at work. In the first place, Southern England, from the Middle Ages onward, has been a wealthy country and the Industrial Revolution spread wealth to other parts of Britain during the nineteenth century. This made it possible not only to finance plant-collecting expeditions, but also to provide suitable settings for the exotics, when they came in, and expert attention in their cultivation. Secondly, the enormous growth of maritime trade and the acquisition of colonies and territories all over the world, provided innumerable opportunities for the collection of seed and the introduction of plants into the mother country, opportunities which were taken advantage of fully. In the third place, Great Britain has produced a long and eminent succession of explorers and plant-collectors, the names of many of whom are familiar to all, who by their enterprise and determination brought to light the richness of the forest vegetation in many a remote and difficult region. Lastly, some credit must be allowed to the climate of this country, which, despite its vagaries, has been kind, on the whole, to alien plants.

Speaking quite generally, one may say that an exotic tree passes through three stages before it is accepted for widespread use in the forest. In the first stage, on first introduction, it is planted as a specimen tree in gardens, arboreta or parks, usually on tolerably good land and in places where skilled cultivation can be given. This testing period serves to exclude those trees which are misfits in the climate, and it sorts those remaining into trees which grow vigorously and well, and those which survive without distinguishing themselves in any way. The second stage is the trial of the more promising arboretum species and, occasionally, of some of the less promising, in small plantations or plots. This gives the opportunity of determining how a species will fare, not as a single specimen, but as a plantation and how it will stand the rougher treatment which planting as a forest tree imposes on it. Trial plots of this sort are also useful in comparing the growth in forest conditions of several species of the same genus, the differences between which may be more easily distinguished in plantation form than as arboretum trees. Many species, some long introduced, have never passed beyond the stage of trial plots. The third stage is the use of chosen species in forest plantations, almost always of limited extent, and this stage places the exotic under further test, because the selected trees often find themselves on more difficult sites than they had hitherto met with, with the result that limitations in the possible use of the tree begin to be revealed.

It has usually happened that only after these three stages have been passed, does an exotic become of widespread and general use. There are, however, certain other conditions which must be satisfied before this becomes possible, for the tree must be easy to rear in the nursery and to establish in the forest, and a regular supply of seed must be available. One can think of trees which would be used more freely if those conditions could be met.

In Great Britain, we are fortunate in having a splendid series of arboreta, almost all planted by private owners and almost all still in private possession. Although it is no longer possible for most private proprietors to maintain these collections in the ample style of fifty years ago, many of them are still in very good condition and every one of them has something to teach. It is encouraging, too, to find that this interest in arboriculture is still strong and that new collections are being formed. The Forestry Commission is sharing with the Royal Botanic Gardens, Kew, the work of maintaining the National Pinetum at Bedgebury in Kent (Forestry Commission, 1955) and it has recently acquired the celebrated arboretum of Westonbirt, on the borders of Gloucestershire and Wiltshire, which has a remarkable collection both of broadleaved and coniferous trees (Jackson, 1927). All these collections represent the vital first step in the study of exotic trees; there are many exotics still worth study at this stage, for although the exotics, which are of most importance in British forestry, are known and reasonably well understood, it is a measure of prudence to have some other trees available in reserve, in case some disease or pest puts the favourites to hazard. There is also the possibility that, for sites of special difficulty, some tree, not yet tried, may be found able to adapt itself to their conditions.

Trial plots of exotic species are found all over the country, on private estates and in the forests of the Forestry Commission, and the literature shows that many others existed in private woodlands during the last century, which have now disappeared. Larger trials, in which a number of exotic species have been set out, side by side, have also been conducted; and there are excellent examples in the Forest of Dean (Macdonald, 1931), at Bagley Wood, near Oxford, at the Royal Agricultural College, Cirencester (James, 1951) and at Crarae, in Argyll. More recently, the Forestry Commission has established sets of plots of this kind, comparing a large number of species, at Beddgelert in North Wales, at Benmore in Argyll, and elsewhere. In this sort of work, it is most important to keep adequate records, and many of the older trials on private estates have lost much of their value for this reason. By studying what is left, one can obtain much useful information, even if no written records have survived; but much is lost, and especially the knowledge, which may be quite important, of what has been tried and has failed completely. In a large organisation, such as a state forest service, it is possible to fritter away much

labour and money in conducting trials of exotics in this way and careful planning of the work is highly desirable. This is a matter to which the Forestry Commission have had to pay attention lately.

One curious feature of exotic trees in Great Britain is that very few of them have succeeded, even after several centuries, in becoming wholly naturalised, in the sense that they can maintain and extend their position by natural seeding. The outstanding example of a tree, which has so succeeded, is the sycamore (*Acer pseudoplatanus*), a native of the Continent of Europe, which was introduced probably in the early Middle Ages (Jones, 1944) and which is now spreading in most parts of the country with great vigour. For this reason, it has not been dealt with as an exotic in these pages. On the other hand, Norway spruce, which was probably brought in before the end of the sixteenth century, has never shown any sign of establishing itself naturally, regeneration being spasmodic and generally uncommon, while the European larch, which has been with us for nearly four centuries, though regenerating freely in some seasons and in some localities, has so far given little evidence of maintaining itself naturally in the country as a whole. Both these trees, therefore, long established and familiar as they are, must be regarded as exotics still, and as such, they are discussed in this work. For the purposes of this study, we have, therefore, included as exotics all those trees which are known or believed to have been introduced and which have not become naturalised, in the sense referred to. There will prove to be some anomalies, no doubt, among which the Spanish chestnut (*Castanea sativa*) is the most outstanding. We have excluded this tree, introduced probably in the very distant past, mainly because it is very well established in certain districts, although strict application of the rule just mentioned would not shut it out altogether from the list of exotics.

The use of exotic trees in forestry probably began seriously in the eighteenth century with the Norway spruce, but this is a tree about which we have surprisingly little information. At the same time, the European silver fir (*Abies alba*), was also used but here again little precise information is available. We cannot exclude the possibility that some exotic broadleaved trees were also planted at an early date, but here again we have no secure sources of knowledge. The first exotic to be used on a large scale, as a forest tree, of which we can be quite certain, is the European larch which was widely planted on their estates in Perthshire by successive Dukes of Atholl after 1750.

During the nineteenth century, European larch and Norway spruce continued to be planted and from the middle of that century onwards, Douglas fir came into general use. The last decades of the nineteenth century saw the appearance, in our woodlands, of Sitka spruce; this was used to an increasing extent during the early years of the twentieth century when it was joined, in the forest, by Japanese larch and Corsican pine. Other species, such as *Abies grandis*, *Abies nobilis*, *Thuja plicata*, and *Tsuga heterophylla*, were planted on a small scale but, in the main, the exotic conifers on which most reliance continued to be placed, were the European larch and the Norway spruce. Exotic broadleaved trees were not used except in small trial plots.

In 1919 the situation changed because, in that year, the Government of the time set up the Forestry Commission which was charged with a long term programme of forestry, involving not only restocking of existing woodlands but the afforestation of large areas of treeless land, chiefly heathland, moorland and upland pasture. It was this development which brought exotic conifers into the prominent place which they now occupy in our forests and woodlands.

In 1947, a complete census of British woodlands was undertaken (Forestry Commission, 1952) and it was possible for us to see the whole picture and to study the effect of the changes which had resulted from the national forest policy introduced almost thirty years earlier. It was found that exotic conifers by that time accounted for 61 per cent of all the coniferous high forest in the country but that exotic broadleaved trees occupied only a trivial place in the broadleaved forest. Table 1 gives details of the acreage of exotic conifers in British forests and woodlands in 1947.

EXOTIC CONIFERS IN GREAT BRITAIN: AREA AND OWNERSHIP

Table 1. Acres

Species	*Private Woodlands*	*Forestry Commission*	*Total*
Sitka spruce (*Picea sitchensis*)	25,129	141,908	167,037
Norway spruce (*Picea abies*)	47,611	85,542	133,153
European larch (*Larix decidua*)	101,758	31,145	132,903
Japanese larch (*Larix leptolepis*)	26,174	28,884	55,058
Corsican pine (*Pinus nigra* var. *calabrica*)	6,499	32,004	38,503
Douglas fir (*Pseudotsuga taxifolia*)	14,496	23,308	37,804
Hybrid larch (*Larix eurolepis*)	4,606	1,520	6,126
Pinus contorta	177	3,083	3,260
Tsuga heterophylla	170	906	1,076
Others (less than 1,000 acres each)	2,630	3,245	5,875

Sitka spruce has risen to the premier place solely because of its widespread use by the Forestry Commission; European larch, on the other hand, maintains a high position in the list chiefly because it is planted so generally by private owners. Norway spruce, Japanese larch and Douglas fir are well represented both in private and in state plantations. Corsican pine and *Pinus contorta*, and especially the latter, are much more generally planted by the Commission than by private owners.

The reasons for the increasing use of exotic conifers are well known. There is, in the first place, the general trend towards softwoods and away from the hardwoods of the broadleaved forest, the result of modern methods of utilisation, and, so far as we can see, this trend is unlikely to be reversed. That will mean an even greater use of conifers in the future. With only one native coniferous timber tree, one which cannot be used everywhere, it is inevitable that exotic conifers should be more and more employed. Secondly, several exotic conifers have shown that they are particularly well adapted to act as pioneers on some of the open land which is being afforested; Japanese larch, for example, has proved highly successful as a first crop on upland grasslands and grass heaths, while *Pinus contorta*, on the poorer peats, establishes itself quickly where many other trees fail. In the third place, our need for the greatest possible production from the land, requires us to plant high yielding species, and this need brings us back to exotic conifers. Fourthly, we have considerable areas of scrub and old coppice, some of them semi-natural, growing on sites which are marginal for broadleaved trees, or even poorer; on these sites, conversion to conifers is the only way of bringing the woodland into production and for this purpose, shade-bearing exotic conifers have proved successful. Lastly, as a result of selective felling in the past, much of our broadleaved high forest is seriously understocked. The most practical method of bringing forest like this into full production, is to enrich it by planting fast growing, shade-bearing conifers which will grow up among the hardwoods and can be harvested with them.

With broadleaved trees, the position is quite different, and the outlook is much less promising. That there will always be a market for hardwood timber of high quality, there is no reason to doubt, but for anything less than the best, markets in future may be difficult. At the present time, Great Britain, like some other countries in Western Europe, has a superfluity of inferior hardwoods, chiefly oak.

With other hardwood trees the situation is not so acute, but future developments, in other fields, may affect them also. Circumstances like these may dictate a policy of reducing the area under broadleaved forest, and confining it to the very best sites available. In the broadleaved forests of the future, it is difficult to see any important place for exotic species.

We must, therefore, expect to see a continuing high proportion of our planting carried out with exotic conifers. So far, we have used six of them—European larch, Japanese larch, Norway spruce, Sitka spruce, Corsican pine and Douglas fir—on a large scale but there are other available which have already been used in a modest way, and which may become more prominent in the future. Among these are *Abies grandis*, *Tsuga heterophylla*, *Thuja plicata* and *Chamaecyparis lawsoniana*. To some extent, these species are mutually exclusive, in the sense that a site which will suit one of them, will suit all, and we have not yet worked out any special use for them in silviculture, in the way in which a place has been found for *Pinus contorta*. It is possible that we may never succeed in this, and it may be that as one of them becomes more widely employed in planting, there will be a corresponding diminution in the area devoted to one of the others or to Douglas fir. There are some disadvantages in having too many trees at one's disposal, particularly in marketing, and care is therefore needed in the choice for planting where silvicultural requirements do not point straight to one species.

The forestry programme in Britain including as it does the afforestation of relatively large areas with exotic conifer species, often in pure blocks and stands, would seem to carry with it a great risk of serious insect damage and interference. This would appear to be increased because many non-indigenous pest species have entered with and become firmly established on the imported host trees. It is true to say, however, that these dangers have not—at least yet—become real and that, in fact, most of the crops are remarkably free from really serious insect injury. In only one instance—that of the common silver fir, *Abies alba*—has the use of an exotic tree in Britain been seriously curtailed by the incidence of insect attack.

Various insect pests are dealt with later but two important species which, on account of their general feeding habits, must be mentioned at this stage are the large pine weevil, *Hylobius abietis*, and the black pine beetles, *Hylastes* spp. Both breed most abundantly in pine areas but feed on any conifer at the time of establishment and can cause very serious damage and sometimes complete loss of the crop.

There is no evidence that exotics as a group are more or less subject to fungal and bacterial diseases than native trees but it is certainly unfortunate that a number of diseases, such as *Rhabdocline pseudotsugae* on Douglas fir, *Meria laricis* on larch and *Keithia thujina* on *Thuja*, must have been introduced

with their hosts. These and other diseases, confined to genera and species, will be considered later. Our purpose here is to cover only diseases affecting a large number of genera.

Certainly the most serious of these is *Fomes annosus*, both as a cause of death in pines, particularly Corsican and our native Scots, and as a source of butt rot in other conifers. All species of spruce and larch are highly susceptible, Douglas fir being slightly more resistant, while the status of the minor conifers is not known with any certainty. *Armillaria mellea*, an equally widely distributed, but rather less serious root fungus, also has an immensely wide host range. It is quite likely pure chance that most of the trees known to be particularly susceptible to this fungus are exotics, for instance, walnut, Japanese larch and *Picea omorika*.

Group dying of conifers, associated with *Rhizina inflata*, has been recorded in most of the principal coniferous species, with the exception of Douglas fir, but it is certainly most severe on Sitka spruce.

In the nursery, damping off occasionally affects most exotic conifers and some broadleaved trees. Grey mould, *Botrytis cinerea*, is particularly liable to attack trees with a prolonged growing season, such as *Cupressus macrocarpa*, or the *Sequoias*, probably because they continually provide the fungus with the fresh succulent tissue it requires. Species continuing growth late into the autumn and therefore liable to autumn frost injury, such as Japanese larch and Sitka spruce, are also prone to *Botrytis* attack, following frost damage. Species which fail to ripen properly, at any rate in some seasons, such as *Ailanthus* or *Catalpa*, are also liable to *Botrytis* attack on the unripened shoots. In so far as all these growth peculiarities are dependent on behaviour acquired in another climate, exotics may be regarded as more likely to be attacked by *Botrytis* than native trees.

It remains true, however, that taking a broad view, exotics present much the same disease pattern as native trees, so that their behaviour in Britain gives little support to any general condemnation of exotics on grounds of liability to disease.

During recent years much attention has been paid to questions of provenance in relation to exotic trees and much experimental work has been conducted in order to determine whether one origin of a species gives a better fit to our conditions than another. This subject has also been dealt with by Wood (1955) in his work on the forests of the Pacific coast of Western North America. Already, it has been shown that, in European larch, seed from the Alpine regions of Switzerland and the Tyrol is unsuitable for use in Great Britain as it has given rise to plantations susceptible to frost damage and subject to devastating attacks of die-back. More recent work seems to suggest that, in other species, plants of different origins may show different degrees of susceptibility to disease. This is work which may save us from gross errors, as it has done with European larch; it may give us stocks which grow slightly faster, at least in the early stages, and it may be of importance because of differences in the properties of the timber grown from seed of different origins. Most of this is long-term work and, though important, it must not be allowed too much refinement, because it will do no one any good to learn that the ideal seed source is a half-acre patch on the bank of some remote mountain stream, when it is necessary to find hundreds of pounds weight of seed for the annual planting programme. Provenance studies, as well as saving us from bad blunders, will undoubtedly add more precision to our use of exotics and may lead to an improvement in growth and performance. This, however, may be accomplished more quickly by studying what we have in the country already.

In a congeries of species such as we have in Great Britain, some native, many alien in origin, and subjected to the selective influence of nature and of silvicultural art, there are possibilities for the development of new species by hybridization and of new forms by selection. Among inter-specific hybrids we have already the notable example of the hybrid larch (*L. eurolepis*), a cross between the European and the Japanese species, which came to light in the early years of this century and which is now well established as a tree for planting. Another curious example was discovered a little later in the famous arboretum at Westonbirt, *Pinus holfordiana*, a hybrid between the Mexican *P. ayacahuite* and the Himalayan *P. griffithii*. This is a tree of some vigour and hardiness which might have value not in Great Britain only, if seed could be obtained in quantity. Then we have an inter-generic hybrid, *Cupressocyparis leylandii*, a cross between *Cupressus macrocarpa* and *Chamaecyparis nootkatensis*; this hybrid has the merits of rapid growth and of hardiness while its timber promises well. It might be used more freely if supplies of planting stock were to become available but its seed is usually sterile and we have not solved the problem of raising it vegetatively.

Among broadleaved trees, England has produced in the Lucombe oak, a hybrid between *Quercus ilex* and *Q. suber*, a tree thriving well in the southern part of the country, which has been used for ornamental purposes, though not for timber production, while another hybrid, *Platanus acerifolia*, a cross reputedly between *P. orientalis* and *P. occidentalis*, is familiar to all as the plane tree which does so much to embellish the streets and squares of London.

It is possible that many hybrids of this sort have occurred without detection already and there is no

doubt that more will appear, from time to time, in future, but fewer of them will probably escape detection, for there are likely to be more trained observers on the ground. There is also the possibility of artificial hybrids.

The improvement of our stocks of exotic conifers by careful selection, from the material already in the country, is possibly the line which will give the most enduring results. Already, a survey of seed sources is in progress in the course of which stands are classified according to their suitability for seed production and, by confining seed collections to those crops which are classified as suitable, a gradual improvement in our plantations will result. At the same time specially fine trees of numerous species have been selected in all parts of Great Britain and these will be used for breeding. It is hoped, by the use of seed orchards, to produce annually a part of our seed requirements from specially selected stocks of exotic trees but of immediate British origin. We may, therefore, look forward to an improvement in the quality and performance of our exotic trees, brought about in this way.

It has already been mentioned that scarcely any of the long introduced exotic trees has succeeded in establishing itself naturally in Great Britain but there are signs that some of those more recently introduced may behave differently, for one can now see many more attempts at regenerating themselves naturally by species such as Lawson cypress, *Thuja plicata* and *Tsuga heterophylla* than one can by older species such as European larch or even Douglas fir.

The climate in Great Britain, with generally cool summers and frequent spring frosts, is unfavourable for seed production of many exotics which are commonly planted. But one or other of the trees mentioned, which produce abundant seed crops at frequent intervals, may be able to spread unexpectedly in the new forests which we have created.

J.M.

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Chapter 2

CLIMATE OF GREAT BRITAIN

General

In Britain, the forester is fortunate in having at his disposal a long-standing body of meteorological records from numerous and well distributed stations. His only complaint is that the stations are somewhat concentrated in the industrial and the better agricultural regions, and there are insufficient records from stations situated in mountainous and sparsely inhabited country, where much afforestation is carried on. This gap has at least been partially filled by a number of special studies, and the general features of our mountain climates are becoming reasonably well known.

The authority responsible for the collection and presentation of climatological data in the United Kingdom is the Meteorological Office, which can call on some 350 stations for comprehensive observations (Bilham 1938) plus about 5,000 additional ones for rainfall. The principal sources of published information on the British climate are:—

The Book of Normals	Meteorological Office, H.M.S.O.
The Monthly Weather Report	,, ,, ,,
British Rainfall	,, ,, ,,
The Climatological Atlas of the British Isles (1952)	,, ,, ,,

In addition, two comprehensive general accounts of the British Climate should be mentioned:—

Bilham, E. G. 1938 *The Climate of the British Isles.* Macmillan, London

Manley, Gordon 1952 *Climate and the British Scene,* Collins, London

The literature is extremely large, as befits a subject matter which excites almost as much attention as any of the national sports. Here some effort will be

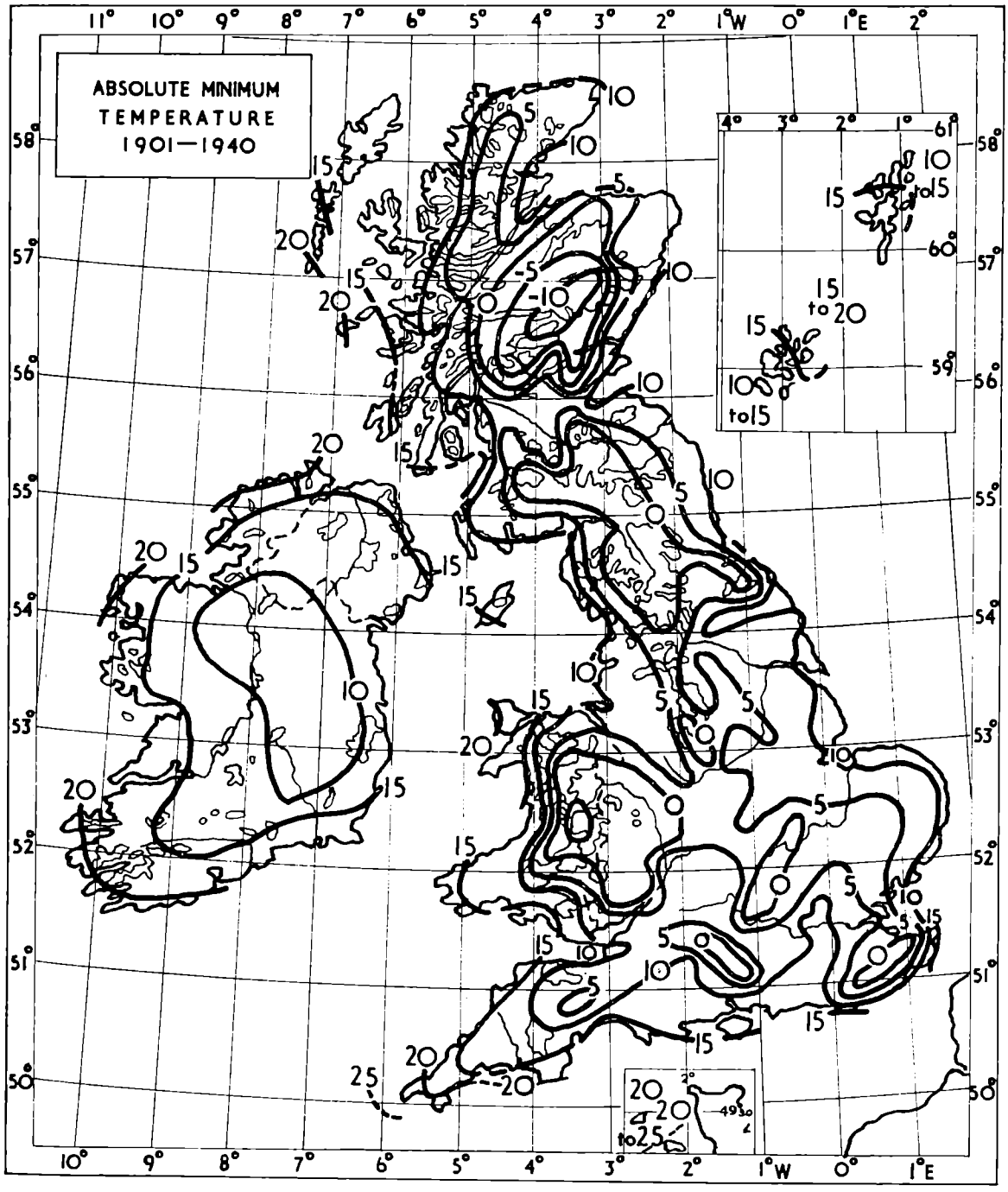

Fig. 1. Absolute Minimum Temperatures in Britain.
(Climatological Atlas)

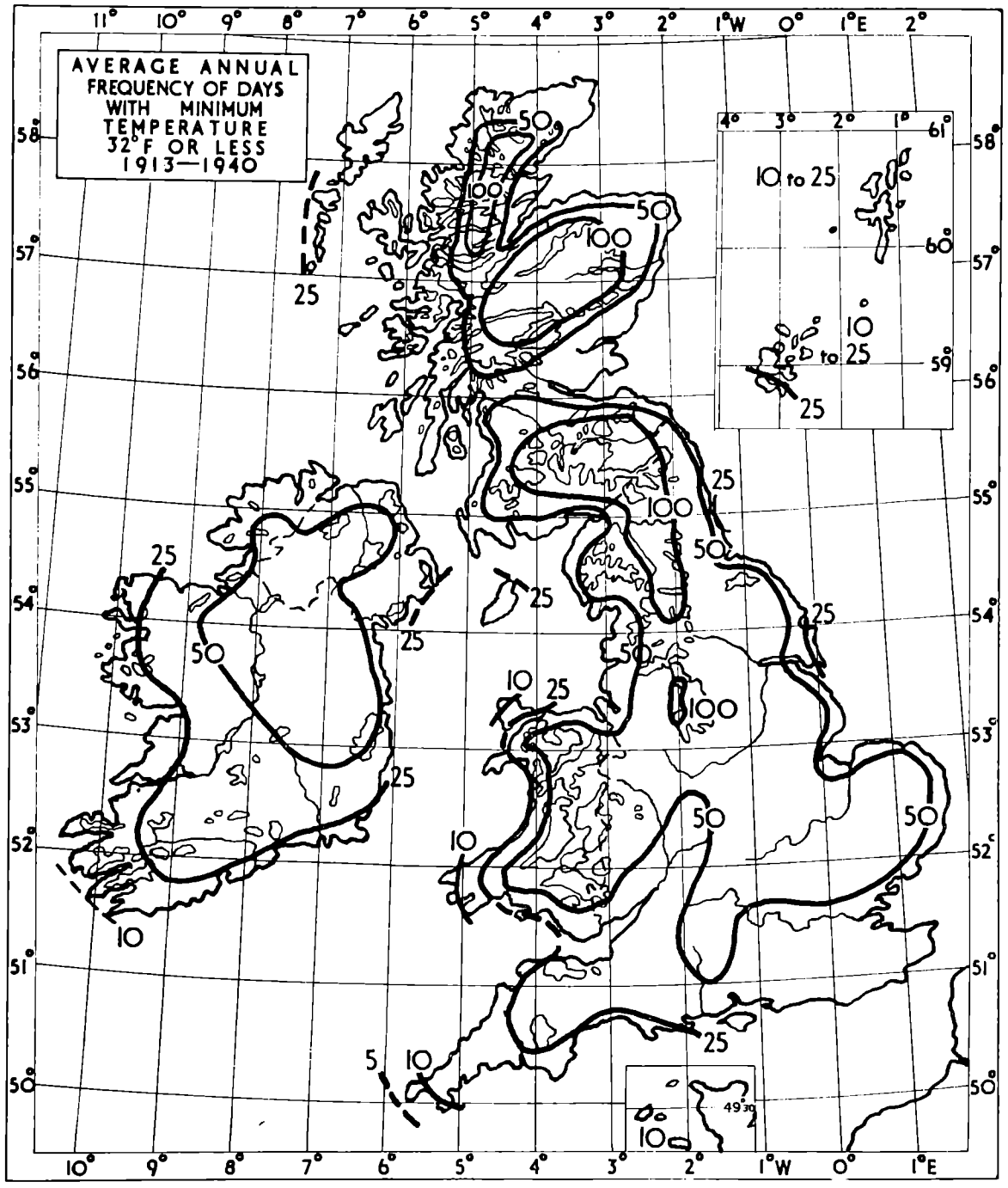

Fig. 2. Average Annual Frequency of Days with Minimum Temperature of 32°F. or less. (Climatological Atlas)

made to comment on the climatic factors which appear to be of chief importance in the cultivation of exotic trees. This is not a subject on which many definite conclusions have yet been reached and this is the less surprising since the part played by climate in the distribution of our native trees is not by any means always clear.

The mainland of Britain lies between the 50th and 59th latitudes (North). Generally speaking, the British climate owes its main features to Atlantic influences, the normal distribution of pressure bringing in westerly air streams. Also, the sea temperatures off our western sea board are affected by the warm oceanic current known as the Gulf Stream. The absence of any prominent mountains in Europe immediately to the east of us permits continental air streams to flow into the country with some ease when the general pressure system is favourable.

Hence Britain experiences (and sometimes at very short notice) changes from the usual oceanic type of climate to a more continental one. Since the annual range of temperature in a temperate continental climate is wider than in an oceanic one on the same latitude, continental air brings us colder than normal conditions during the winter half of the year and warmer than normal conditions during the summer.

The more important continental spells occur most frequently in late winter and early spring, when we sample in a modified degree the winter conditions of Central Europe, for which we are usually quite unprepared. The commoner British winter, "wet and windy", seems to leave the more lasting impression.

Illustrative meteorological data appear in Table 3, page 21.

Climatic Classification

No general agreement exists on the most suitable system of classification of climate for forestry purposes. It has long been understood that an adequate description must include the significant extreme temperatures, the amounts and distribution of the rainfall, and some measure of the summer warmth. This is the bare minimum, and other factors, such as wind velocity, may often have an overriding importance. Such information is often conveyed by simple "normals" of temperature or precipitation for months or seasons. In order to categorise climates, formulae have been used which treat such measures arithmetically in an arbitrary manner, often aiming at the best "fit" with observed disbution of vegetation. Such procedures usually meet with the difficulty that the limits of particular types of vegetation in one region are not the same as those for a related type in a neighbouring region.

A recent method which should be mentioned here is that of Gaussen (1956), in which the monthly means of temperature and precipitation are represented on the same diagram to the scale P (precipitation, mm.) = 2 T (temperature, C°). Where the temperature curve lies above that of precipitation the period is considered one of moisture deficiency (sécheresse). The International Union of Forest Research Organisations has recommended its member countries to prepare climatic maps according to this system as a trial of the method. This is in progress in Britain.

A different approach is that of Thornthwaite (1948) who attempts to link temperature and moisture requirement in one system. It is understood that his methods have proved useful in North America; in Britain however his method of calculating "potential evapotranspiration" does not appear applicable. The great attraction of Thornthwaite's approach is that his scales of temperature and moisture are intended to be related to the responses and requirements of plant growth; they are not purely arbitrary.

A convenient method of summarising data for temperature and precipitation has been devised by Kalela (1937). This is specially designed for the comparison of climates in silvicultural and provenance studies of exotics, and has been much used of recent years in Europe. The data for a number of 'type' British stations has been presented according to Kalela's method in Table 4, page 23.

Britain, for two main reasons, is a difficult country to sub-divide into meaningful climatic zones. The first and most obvious reason is that it is a small country and climatic differences are of degree rather than kind. This requires a little further comment. We have in fact very great variations in precipitation, but the distribution of rainfall throughout the year is such that at our moderate temperatures no part of the country can be considered really dry; for illustration, irrigation in agriculture is nowhere essential. The second reason is that climate in Britain is hopelessly confounded with the main physical features of the country; the older, harder rocks forming the main mountain ranges are to the west and north-west, with younger, softer deposits to the east and south-east, underlying the principal lowland areas. Since our prevailing winds are westerly and moisture-laden, rainfall is highest on western mountain regions; so also is exposure. The main climatic axis is roughly north-west to south-east, "cool/moist" to "drier/warmer" and along this direction are to be found also the main trends in soils and topography.

The interrelations between climate and the land in Britain are fully dealt with by Stamp (1949).

Very recently, Anderson and Fairbairn (1955) have made a valuable pioneer attempt at the climatic subdivision of Scotland for silvicultural purposes.

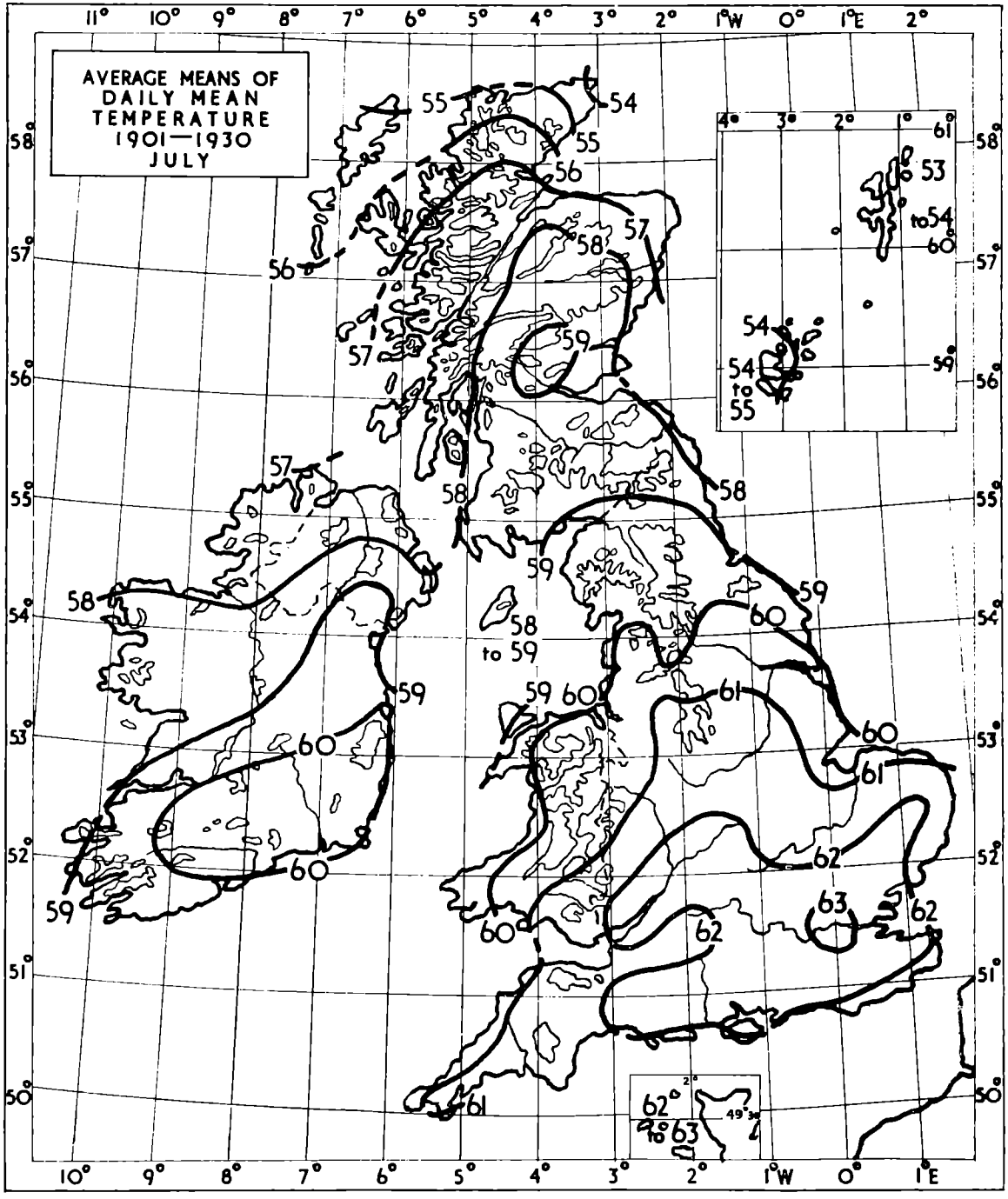

Fig. 3. Average Means of Daily Mean Temperature July.
(Climatological Atlas)

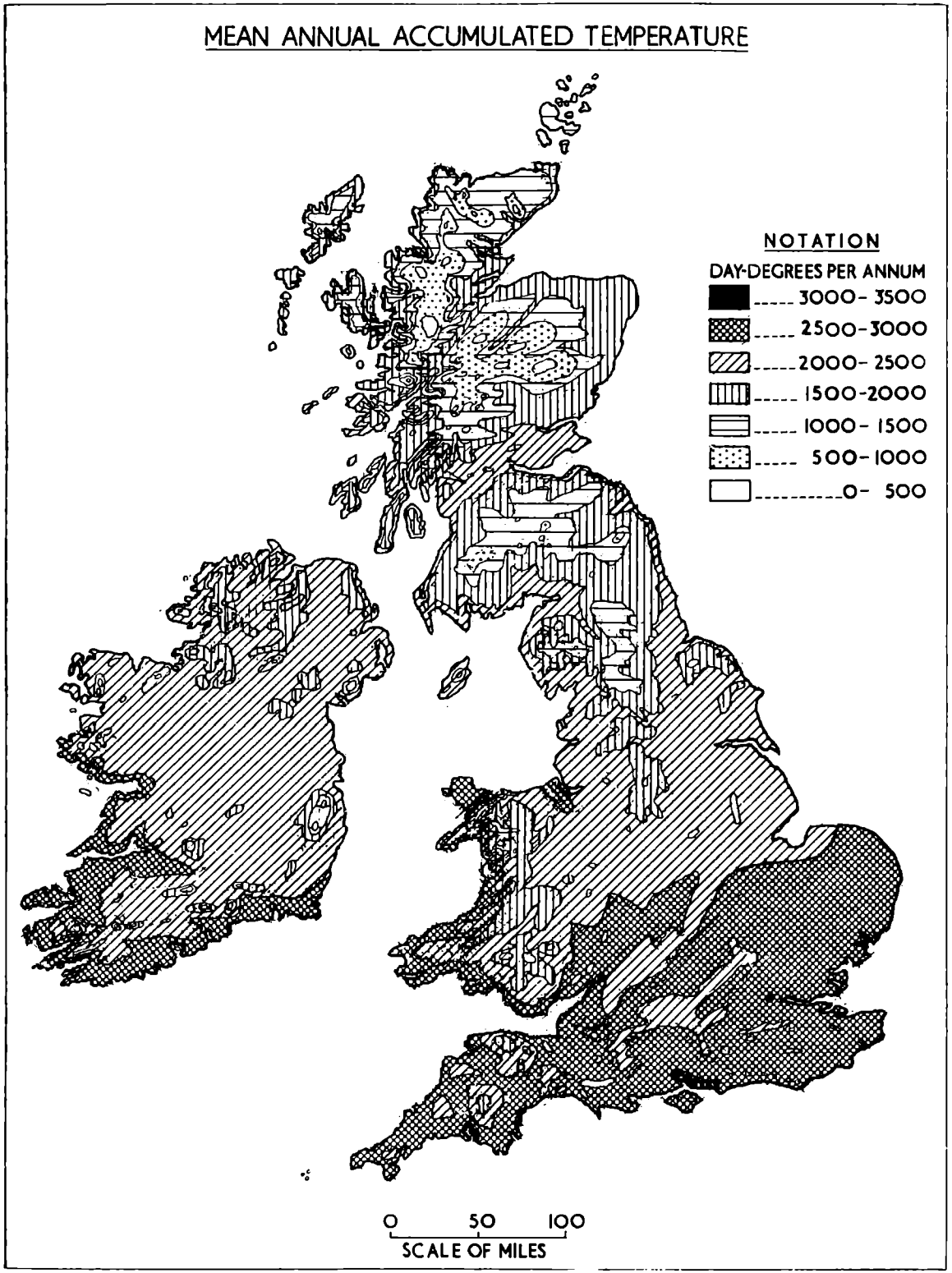

Fig. 4. Annual Value of Accumulated Temperature.
(Gregory)

They adopt the length of the growing season (which is also a measure of warmth), and the growing season rainfall, as the main variables in distinguishing climatic provinces; and they recognise the effects of altitude on temperature and exposure inside these provinces. Boundaries of the provinces are adjusted to the chief physiographic features. The geology of the provinces is described.

It seems likely that Anderson and Fairbairn's method is basically sound, though other measures of temperature and moisture must be considered. Whether it is profitable remains to be seen. There can be no doubt that we have provinces capable of definition in terms of climate, but wherever the country is mountainous, vertical zoning becomes so much more important than horizontal that the map is apt to become meaningless.

Temperature

Extremes. The range of temperature experienced is relatively small. The absolute upper limit in southern England is 100°F., while in Scotland it is perhaps 90°F. (Bilham 1938). Zero (F) temperatures are recorded in exceptional winters, and very rarely indeed temperatures below —10°F. (Bilham 1938). The mean annual range of temperatures nowhere exceeds 24°F.

Figure 1 shows the distribution of absolute minimum temperatures in Britain for the years 1901-1940. Winter favourable conditions are to be found on the coasts—particularly the west coast. This pattern is of importance for the less winter-hardy exotics, e.g. *Eucalyptus* spp., *Cupressus macrocarpa*, etc.

Winter minimum temperatures do not greatly limit the use in Britain of exotics from similar latitudes.

Unseasonable Frosts. Of greater silvicultural importance are unseasonable frosts occurring in the growing season, especially in late spring, a hazard to which almost the whole of the country is liable. Spring frosts have been studied by Day and Peace (1946), with special reference to the exceptionally severe frost of May 16th, 1935. It is scarcely possible to map the incidence of late spring frosts, though on a regional basis they occur with greater frequency and severity in inland districts than in coastal (particularly west coastal) ones. The liability of the British climate to unseasonable frosts renders the "frost-free period", a commonly-used measure of the length of the growing season, a rather misleading statistic. It is perhaps better suited to climates with a more definite march of temperature. The *Climatological Atlas* maps the average annual frequency of days with minimum temperature of 32°F. or less (Fig. 2), but the significance of this pattern for forestry in Britain is by no means clear.

Late spring frosts are sometimes severe and widespread; but more usually, while it is the general weather conditions that govern their occurrence, their severity is a matter of local topography. The collection of cold air from higher ground in poorly draining basins is the classic feature, but radiation frosts may be accentuated by the local vegetation, as when a dense grass sward insulates the ground and allows very cold conditions to develop just above its surface.

The liability to late spring frosts in a particular locality is of importance as regards the choice of species in pioneer planting, but is not usually a permanently limiting factor.

A comparatively rare but very important phenomenon is the "glazed frost" caused by rain falling with the air temperature below freezing point, trees, telegraph wires etc. becoming coated with a layer of ice. Such an occurrence in January, 1940, caused serious damage to woodlands over a considerable area of England and Wales. (Sanzen-Baker and Nimmo, 1941.) Branches may be stripped and leaders broken, or whole trees overthrown. At the worst young plantations may be devastated, but fortunately the most serious damage is seldom widespread.

Summer Warmth. Fig. 3 shows the mean July temperatures. These are sea-level isotherms and are useful only for showing the general pattern. It will be noted that mid-summer temperatures are very much a question of latitude, but there is also an appreciable tendency to build up higher temperatures inland.

A better measure of summer warmth is accumulated temperature. Gregory (1954) has used 6°C. (=42.8°F.) as a threshold value, and by subtracting this from the mean monthly temperature (if higher) and multiplying the remainder by the number of days in the month, a product in "day-degrees" is obtained. This may be summed for the year. Gregory has used the normal lapse-rate with elevation (1°F. in 300 ft. approx.) to estimate values for the principal mountain areas. His map for annual values in Britain is reproduced here. (Fig. 4). The map does not purport to show the effects of any but major differences in relief.

Summer warmth is undoubtedly a variable of importance in Britain, though its influence may not always be obvious. A number of broadleaved trees (e.g. *Fagus*, *Castanea*) stand close to their summer warmth limits in Britain, which shows most plainly in the poverty of seed production. The economic planting limit in mountainous country is rarely a matter of temperature alone, since exposure will normally prove limiting before a temperature limit can be reached.

However, the heat energy available for vegetation does fall off very rapidly with increasing elevation in our maritime climate. Manley (1952) discusses this

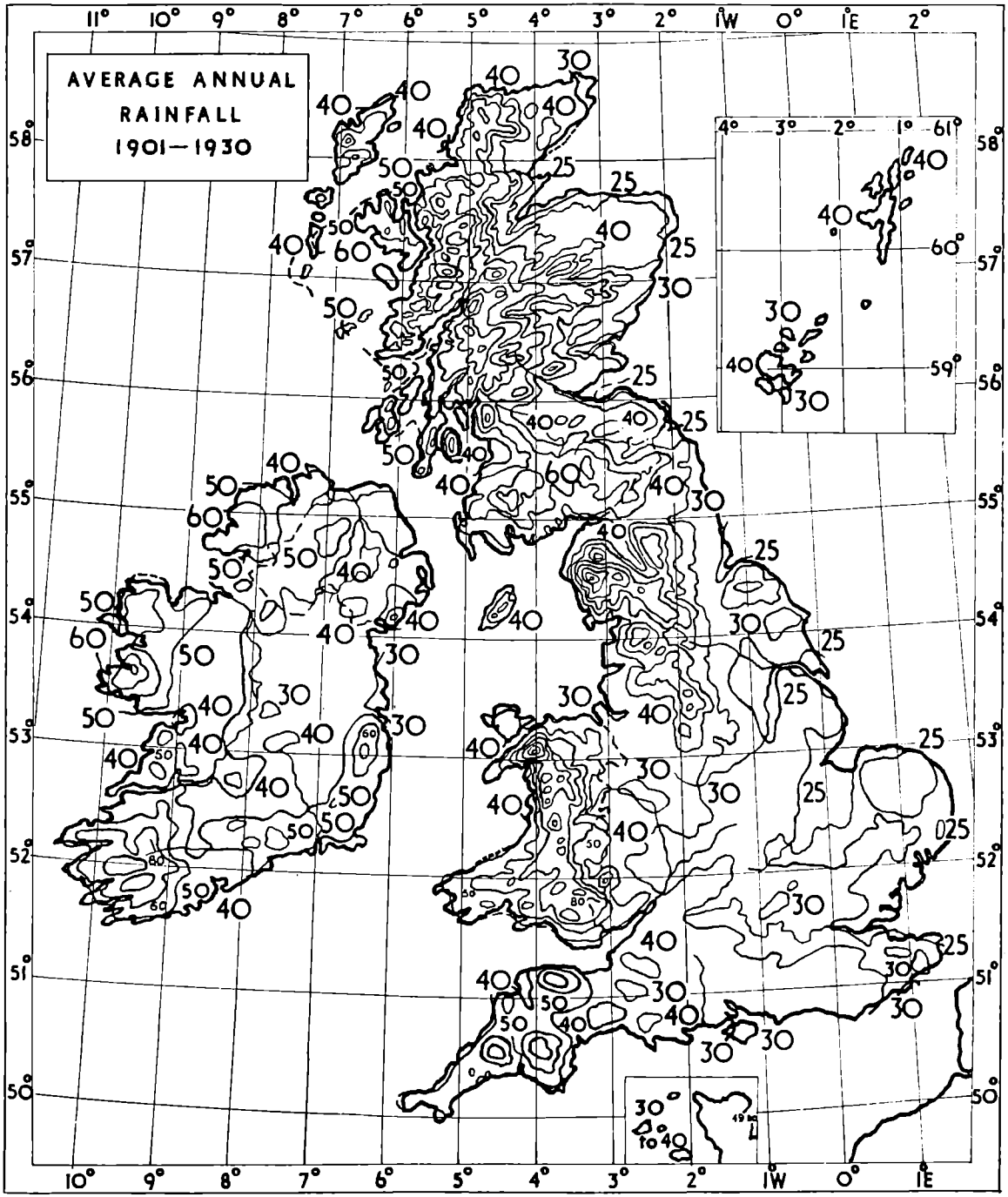

Fig. 5. Mean Annual Rainfall.

Note: From 40 inches upwards the isohyets run at 10-inch intervals to maxima exceeding 100 inches on the western hills. (Climatological Atlas)

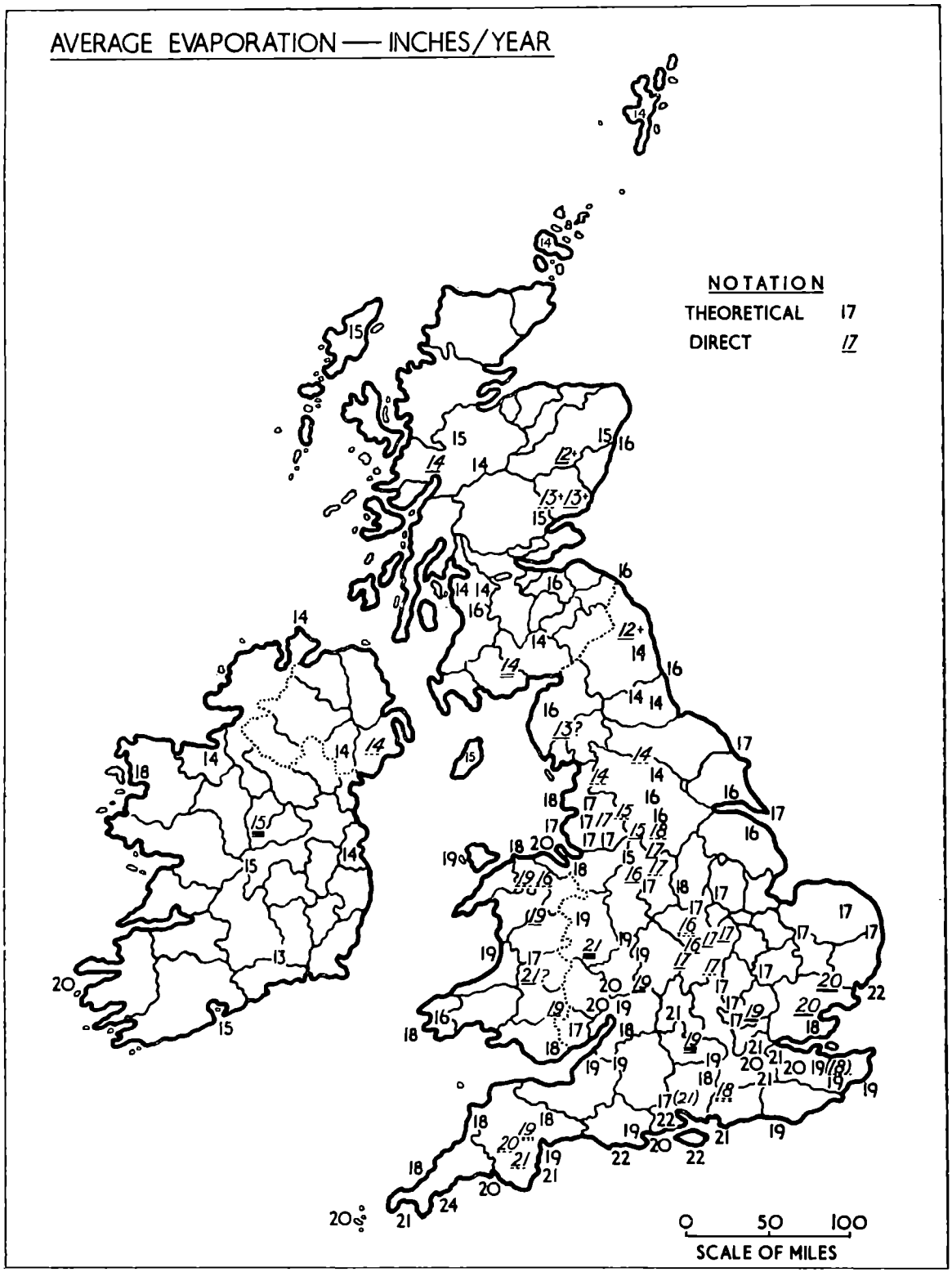

Fig. 6. Evaporation over Great Britain.
(Penman)

very fully. Regarding the *area* of the mean temperature curve over 42°F. as some indication of the heat energy available to plants in the vegetation period, he shows that this *area* is reduced to a greater degree by a given ascent in an oceanic climate than in a more continental one, assuming the normal lapse rate with altitude (approx. 1°F. in 300 ft.) to apply in both cases.

Mountain climate is also very fully discussed by Pearsall (1950). The temperature limit for tree growth in Britain is probably about 2,000 ft, at which elevation the climate may be regarded as sub-arctic. Since the temperature curve does not vary much in form with increasing altitude, but simply 'sinks', the length in days above any arbitrary value, say 42°F. (or "the growing season") is equally a measure of summer warmth.

Accumulated temperature appears a reasonably good indication of summer warmth, and has been used in the selection of sites for seed orchards, etc. (Matthews, 1955) since it can be shown that the seed-bearing of most of our important species is closely related to summer warmth. It is also highly probable that the growth of a number of our exotics is related to summer warmth, though it is not easy to disentangle this factor from other site qualities. Encouraging results have however been obtained in preliminary investigations on one important exotic, namely Corsican pine.

Rainfall, Humidity, Evaporation

Rainfall. Figure 5 shows the mean annual rainfall over Britain. The distribution requires little comment; it is very much a combination of east and west coast properties and relief. The highest average values of about 200 inches are experienced on a few western mountains in Wales, the Lake District and Scotland. At the other end of the scale averages of less than 20 inches may be found in a small area by the Thames estuary. (Bilham 1938.)

British rainfall is well distributed throughout the year. Table 2 shows the pattern on a regional basis.

It will be noted that the spring quarter is the driest (except in the North of Scotland where the summer quarter tends to be drier). The "summer half" (again except in the North of Scotland) everywhere averages over 40 per cent of the annual total, and there is a fortunate tendency for the drier, eastern side of the country to have a greater proportion of its annual rainfall in the summer than has the wetter, western, side.

The dry spring is an important feature of the British climate. It is advantageous insofar as it facilitates early nursery cultivations; but when the spring is exceptionally dry, planting losses may be considerable. The spring is also the main fire danger season in Britain.

The reasonably adequate summer rainfall has some obvious effects. Ground vegetation is usually green and fire hazard low throughout the summer, and British nurseries are not normally equipped for irrigation. Variability of rainfall is as (or more) important than the normal quantity. British rainfall is not unduly variable in annual amounts. Glasspoole (1921) has mapped the relative variability (mean deviation/mean × 100) of British annual rainfall, which for the greater part of Britain is less than 16 per cent. Gregory (1955) has made further studies on the variability of rainfall.

Shorter period variations are of course very much greater. Excessive rainfall preceding gales is a common feature of the accounts of great windblows affecting forests.

Dry periods longer than thirty days are fortunately rare in Britain.

RAINFALL OF EACH QUARTER, AND OF THE SUMMER HALF-YEAR, EXPRESSED AS A PERCENTAGE OF THE TOTAL

TABLE 2

%

	Winter (Dec., Jan., Feb.)	*Spring (Mar., Apr., May)*	*Summer (June, July, Aug.)*	*Autumn (Sept., Oct., Nov.)*	*Summer Half-Year (Apr.-Sep.) inc.*
Scotland, North	32.0	20.2	20.0	27.8	38.9
Scotland, West	29.7	19.4	22.6	28.3	42.2
Scotland, East	25.3	21.0	26.1	27.6	46.4
England, North-east	22.2	21.3	28.5	28.0	49.3
England, East	23.4	20.8	27.2	28.6	48.9
England, Midlands	25.0	21.1	26.6	27.3	47.8
England, South-east	26.4	19.7	23.9	30.0	42.9
England, North-west, and North Wales	26.2	19.4	25.5	28.9	45.5
England, South-west, and South Wales	29.5	19.3	21.8	29.4	40.7

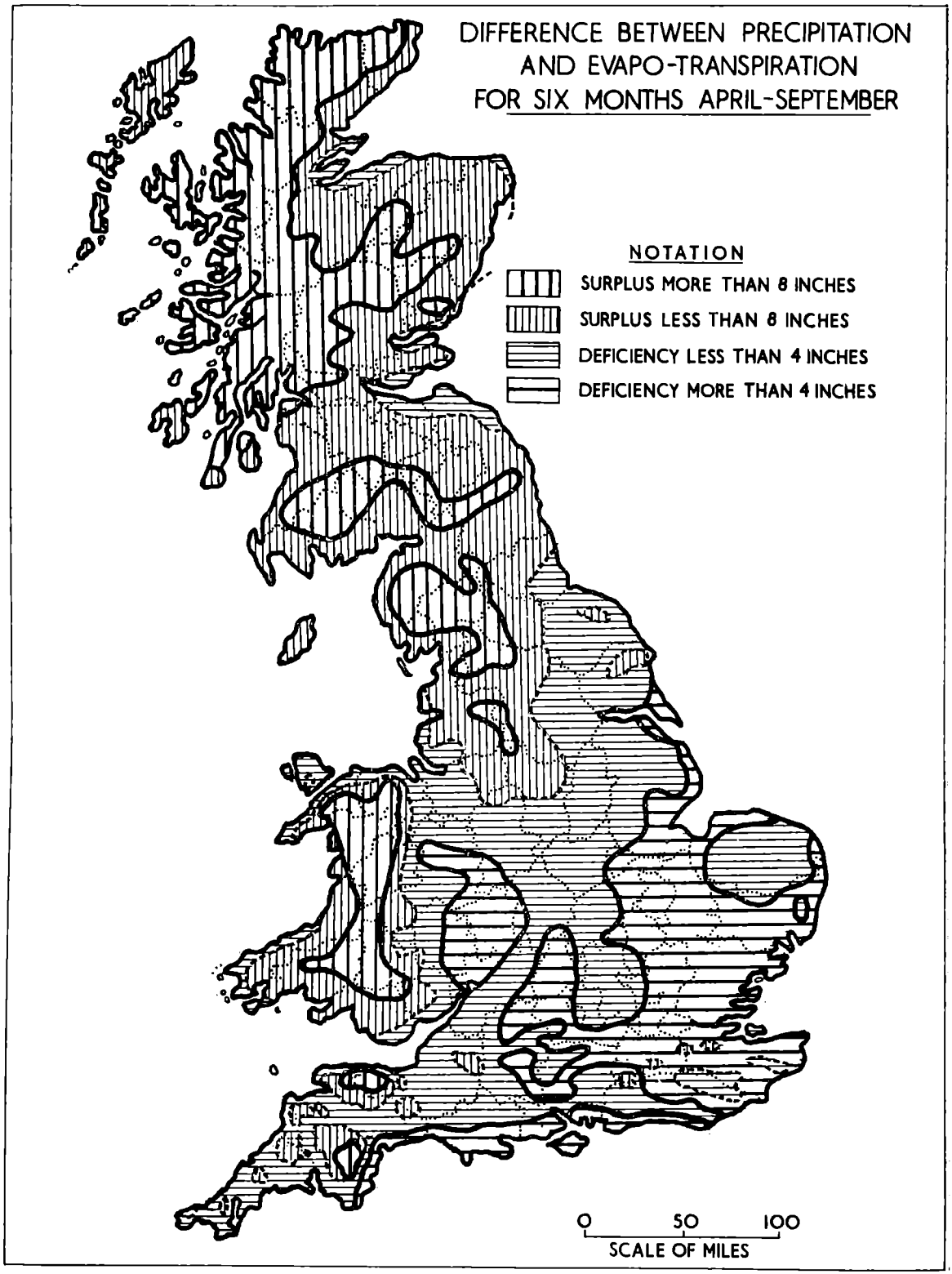

Fig. 7. Moisture Zones.

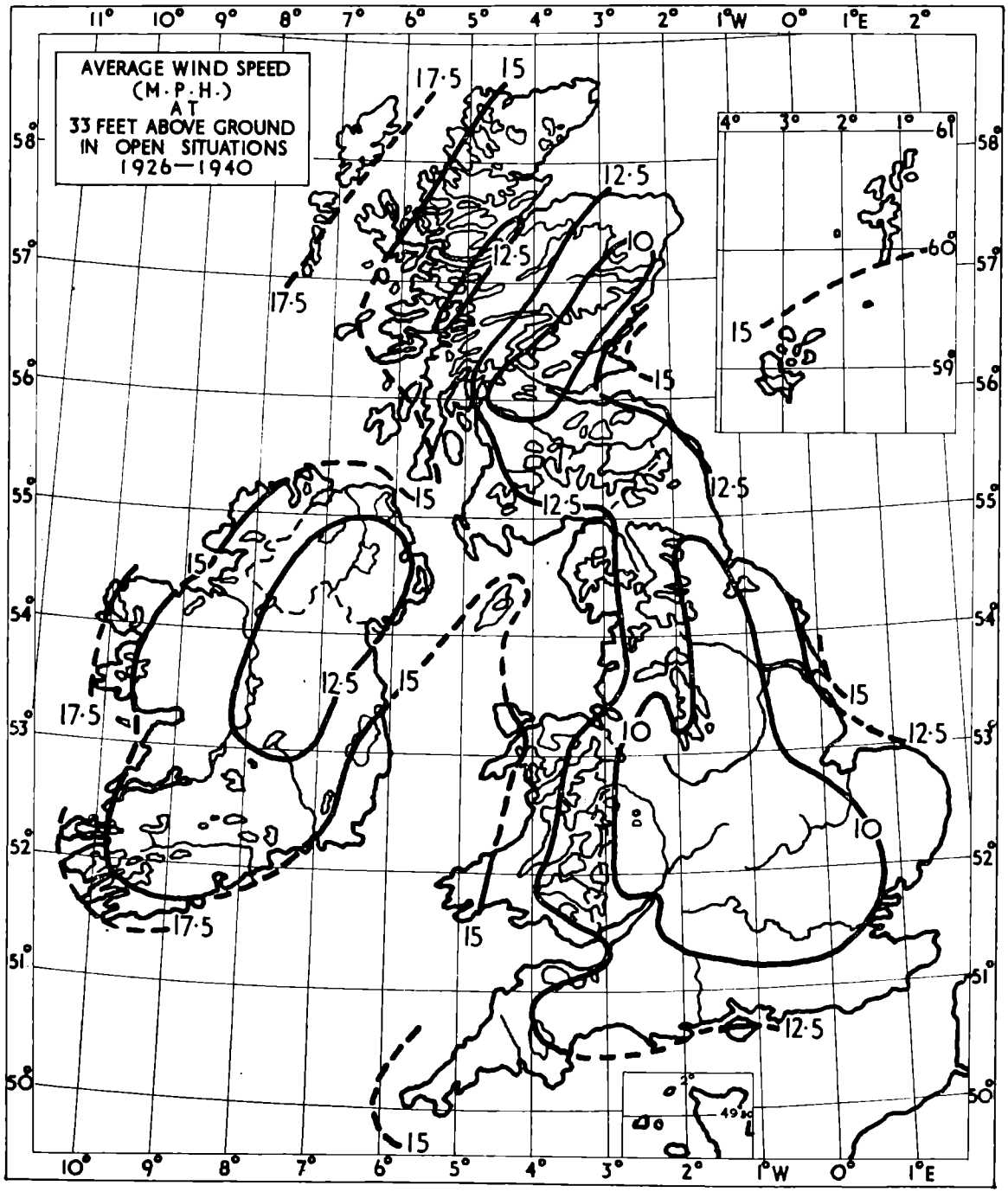

Fig. 8. Mean Wind Velocities.
(Climatological Atlas)

Severe summer droughts, when they do occur, are not normally followed by widespread damage to established plantations, but various growth abnormalities are associated with them (false rings, stem cracks etc.; Day (1954), Chalk (1951), Dobbs (1953). Since the dry summer is a hot summer, species requiring warmer conditions than are usual in Britain often respond by enhanced growth, and most species flower with more than average freedom in the *subsequent* year.

It is not at present possible to say what is the best expression of the British rainfall in relation to forestry; Anderson and Fairbairn (1955) use the May-September (inclusive) total, sometimes known as the "penta-precipitation".

Except at elevations which are too high for forestry in Britain, snow does not contribute materially to the annual total precipitation, and though snow is a common enough phenomenon in the British winter it is not a climatic feature which requires much comment. As regards storage of moisture it is probably of little significance to us.

Snow in Britain is usually moist and clinging; it is sometimes a factor in wind-throw. When it falls unseasonably, after broadleaved species have flushed, it may cause some damage by stripping branches.

Humidity. Britain has a moist atmosphere, the mean relative humidity averaged over the whole year is about 80 per cent in the drier districts, and mean afternoon values of relative humidity in the summer do not fall much below 60 per cent in any part of the country (Bilham 1938). The importance of humidity (by itself) as a factor in British forestry is not at all clear; certainly on the broad scale it is more profitable to consider the moisture factor in terms of rainfall and evaporation.

Evaporation. In the absence of reliable information on evaporation, some expression of growing season temperature may be used to distinguish between equal amounts of rainfall. Anderson and Fairbairn (1955) do this in their classification of Scotland. At least this avoids equating the same growing season precipitations at substantially different temperatures, but it gives no 'values' to the different amounts of rainfall; that is to say it does not suggest whether, or by what amount, they are in excess (or the contrary) of the evaporation.

Penman (1950) has derived a formula for the evaporation from a land surface which can make use of the weather records collected at stations making fairly comprehensive observations, including measures of temperature, sunshine, vapour pressure and wind speed. He has mapped about 100 such determinations for Britain, and finds that they agree well enough with the evidence from catchment areas, etc. Penman's map is reproduced here (Fig. 6).

Penman's determinations appear to show a broad regional pattern; they do not (usually) vary capriciously from place to place according to the local conditions. If local factors tend to annul each other, as seems to be suggested (increase in wind speed with elevation being compensated for by cloudier skies and lower temperatures, for instance) evaporation would be a useful basis for climatic zoning. A tentative effort has been made in this direction by superimposing the growing season rainfall on Penman's evaporation map (Fig. 7). The only claim that is made for this is that it is probably a great deal more informative than a map of annual, or of growing season, rainfall. It does, for instance, illustrate the fact that moisture conditions are at least as much a question of "north or south" as of "east or west". The driest English conditions are probably not to be equalled in the northern half of Britain, irrespective of the rainfall. This is confirmed by silvicultural experience with the more moisture-loving species.

Other Climatic Factors

Exposure. This is a complex factor, in which wind velocity is the most important component. Britain is undoubtedly a 'windy' country; the prevailing direction is from the south to west quarter; the strongest winds also usually emanate from this quarter. The average wind speed at 33 feet above ground level is mapped in the Climatological Atlas, see Fig. 8. The windiest districts are on the west coasts, but average wind speed falls off markedly inland from all coasts.

The average annual frequency of gales, i.e. winds of velocity exceeding 39 miles per hour, also falls off inland, but more markedly from the north-west of the country to the south-east. Hence, on average, the exposed regions of north-west Scotland, the tip of the Pembroke peninsula (Wales), Land's End and the Lizard (Cornwall), all have thirty gales per year; whereas at the other end of the scale much of central England has only two.

Inside the general pattern, there is of course a great deal of local variation. The important local factors are elevation (particularly relative elevation), and aspect. A survey of sites for wind-power conducted by the Electrical Research Association (Golding and Stedhart, 1950) located a number of hills on the west coast, less than 1,000 feet in elevation, with estimated annual average wind velocities of 20 miles per hour and over. These are remarkably high values.

It is not at present possible to quote any expression of wind velocity which will serve to draw a limit for tree growth; and there is a good deal of doubt about the other components of 'exposure'. Salt spray is locally of importance, but probably not to any distance inland. Moisture loss from active

foliage is probably a more important factor in stunting than the physical buffeting. The actual temperature of the wind is often of some importance. Certain species (*Sequoia sempervirens* is a good example) appear to be more damaged by freezing easterly winds than by any other climatic vicissitude.

Exposure is under active investigation at the present time, since it is of particular importance in Britain to know how far the planting of wind-tolerant species in pioneer crops or shelterbelts can modify the micro-climate in exposed environments otherwise suitable for afforestation. The effects of shelterbelts are analysed in a recent paper by Gloyne (1954).

There is no doubt that exposure is the most limiting factor to height growth of trees in Britain (Macdonald, 1951). It has even been used by Anderson (1931) as a basis for climatic zoning, quite good agreement with the distribution of conifer Quality Classes in Scotland being obtained; however, as previously mentioned, it is hopelessly confounded with temperature.

Apart from the limitation of height growth and yield, which is no doubt a function of high mean velocity rather than of occasional extreme speeds, the hazard of wind-throw must be mentioned. The disaster of January 31st, 1953, to the forests of the east of Scotland is an extreme example (Steven 1953, Andersen 1954). This storm was accompanied by gusts of wind exceeding 100 miles per hour. With winds of this speed woodlands in the region concerned may be completely devastated, as they were in this instance. Fortunately, nothing comparable in scale is on record (Steven 1953), but past evidence suggests that two or three 'lesser' disasters may be expected in each half century. Probably of more importance (in the aggregate) are the gales which are of annual occurrence (most frequent about the equinoxes), and which somewhere or other reach gust speeds sufficient to cause local wind throws.

Sunshine. Little attention has been paid to sunshine as a forest influence on its own account. Excellent records are available for Britain; the *Climatological Atlas* maps the average means of daily sunshine for each month and for the year, also the percentage of possible sunshine. The yearly means of daily sunshine vary from 4.5 hours on the south coast of England, to 3 hours over much of north-west Scotland; and the corresponding percentages of possible sunshine range from 40 to 20 per cent. Bilham (1938) observes that there is (a) a general increase of sunshine from north to south; (b) a decrease of sunshine from the coasts inland; and (c) a decrease of sunshine with altitude. It is plain that the principal features of this pattern are also seen on a map of accumulated temperatures.

Atmospheric Pollution. Industrial smoke, of which sulphur dioxide is the chief harmful constituent, is an adverse factor over fairly considerable areas of potentially afforestable land in the Pennines between the industrial concentrations of Lancashire and the West Riding of Yorkshire. The generally greater susceptibility of conifers to atmospheric pollution is important here, since much of the afforestable area concerned is exposed and unsuited to broadleaved trees.

Acknowledgments

I am indebted to the Meteorological Office for permission to reproduce Figures 1 to 3, 5, and 8; to Mr. S. Gregory of Liverpool University for Figure 4; and to Dr. H. L. Penman of Rothamsted Experimental Station for Figure 6.

R.F.W.

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TABLE 3: METEOROLOGICAL DATA FROM SELECTED TYPE STATIONS

ABERDEEN OBSERVATORY. LATITUDE 57° 10′ N.; LONG. 2° 6′ W.; 37 FEET ABOVE MEAN SEA LEVEL. (a) *
EAST SCOTLAND, COASTAL

Temperatures (°F)	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Mean	39	39	40	43	48	53	57	56	53	48	42	40	47
Daily maximum	43	43	45	48	53	59	62	62	58	52	46	43	51
Daily minimum	35	35	36	38	43	47	51	51	47	43	38	36	42
Extreme maximum	59	64	70	74	75	80	86	83	82	77	63	61	86
Extreme minimum	4	6	10	21	29	30	38	33	30	25	13	6	4
Rainfall (in.) Mean	2.2	2.1	2.4	1.9	2.3	1.7	2.8	2.7	2.2	3.0	3.0	3.2	29.5

ROTHESAY (BUTE). LAT. 55° 50′ N.; LONG. 5° 4′ W.; 200 FEET ABOVE MEAN SEA LEVEL. (b) *
WEST SCOTLAND, MILD ISLAND CLIMATE

Temperatures (°F)	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Mean	40	40	41	45	50	55	57	57	53	49	43	41	48
Daily maximum	44	44	47	51	57	62	64	63	59	53	47	45	53
Daily minimum	36	36	36	38	43	47	51	51	48	44	39	37	42
Extreme maximum	56	56	64	71	78	85	84	83	81	69	61	57	85
Extreme minimum	12	11	20	22	30	33	39	36	32	25	20	19	11
Rainfall (in.) Mean	4.5	4.0	3.6	3.0	3.0	3.1	4.0	4.9	4.0	4.4	5.1	5.4	49.0

FORT WILLIAM (INVERNESS). LAT. 56° 49′ N.; LONG. 5° 7′ W.; 171 FEET ABOVE MEAN SEA LEVEL. (c) *
WEST SCOTLAND, HIGH RAINFALL

Temperatures (°F)	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Mean	39	39	41	44	51	55	57	57	53	48	42	40	47
Daily maximum	44	44	47	51	58	63	65	64	60	54	47	44	53
Daily minimum	35	35	35	37	43	47	50	50	47	42	37	35	41
Extreme maximum	57	56	63	73	83	86	84	85	85	74	63	66	86
Extreme minimum	5	10	11	20	26	35	37	36	30	22	11	11	5
Rainfall (in.) Mean	9.6	7.4	6.6	4.4	3.9	3.5	4.8	6.1	6.3	7.0	8.1	10.1	77.8

COLMONELL (AYR). LAT. 55° 8′ N.; LONG. 4° 53′ W.; 170 FEET ABOVE MEAN SEA LEVEL.
SOUTH-WEST SCOTLAND, COASTAL

Temperatures (°F)	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Mean	40	40	42	45	51	55	58	57	54	49	43	41	48
Daily maximum	45	45	48	52	59	62	65	64	61	55	49	46	54
Daily minimum	36	35	35	38	43	48	51	51	47	43	37	37	42
Extreme maximum	55	56	67	72	82	82	82	88	77	74	63	60	88
Extreme minimum	13	12	16	16	26	33	34	28	28	21	12	14	12
Rainfall (in.) Mean	4.3	3.9	3.4	2.5	2.6	2.5	3.1	4.0	3.5	4.5	5.0	5.6	44.8

* See Table 4, p.23.

BRAEMAR (ABERDEEN) LAT. 57° N.; LONG. 3° 22′ W.; 1,120 FEET ABOVE MEAN SEA LEVEL. (d) *
CENTRAL SCOTLAND, ELEVATED VALLEY CLIMATE

Temperatures (°F)	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Mean	34	34	36	41	46	53	55	54	50	44	38	35	43
Daily maximum	40	40	42	48	55	62	63	61	58	50	44	40	50
Daily minimum	29	29	30	33	38	44	47	46	42	37	33	29	36
Rainfall (in.) Mean	3.1	2.7	2.9	2.3	2.4	1.9	2.6	3.4	2.5	3.8	3.9	3.6	35.1

GREAT YARMOUTH (GORLESTON) (NORFOLK). LAT. 52° 35′ N.; LONG. 1° 43′ E.; 5 FEET ABOVE MEAN SEA LEVEL.
EAST ENGLAND, COASTAL

Temperatures (°F)	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Mean	41	40	42	46	51	57	62	61	58	52	45	41	50
Daily maximum	44	44	47	51	57	63	68	68	64	57	49	44	55
Daily minimum	37	36	37	41	46	51	55	55	52	47	41	38	45
Extreme maximum	57	60	66	72	81	81	87	89	82	74	64	60	89
Extreme minimum	10	13	18	19	31	37	42	41	33	27	23	15	10
Rainfall (in.) Mean	1.7	1.5	1.8	1.5	1.7	1.8	2.3	2.5	2.0	2.9	2.4	2.4	24.5

HOLYHEAD (ANGLESEY). LAT. 53° 19′ N.; LONG. 4° 37′ W.; 26 FEET ABOVE MEAN SEA LEVEL.
NORTH WALES, MILD ISLAND CLIMATE

Temperatures (°F)	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Mean	44	43	44	46	51	55	59	59	57	53	47	45	50
Daily maximum	46	46	48	50	55	59	63	63	61	55	50	47	54
Daily minimum	42	40	40	42	47	51	55	55	53	49	44	43	47
Extreme maximum	55	59	67	75	76	83	85	86	78	76	62	56	86
Extreme minimum	20	17	26	26	32	40	43	45	40	32	29	26	17
Rainfall (in.) Mean	2.9	2.4	2.6	2.1	2.0	2.1	2.6	3.2	2.7	4.0	4.1	4.2	34.9

FALMOUTH (CORNWALL). LAT. 50° 9′ N.; LONG. 5° 5′ W.; 167 FEET ABOVE MEAN SEA LEVEL. (e) *
SOUTH-WEST ENGLAND, COASTAL, EXTREMELY MILD

Temperatures (°F)	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Mean	44	44	45	48	53	57	61	61	58	53	47	45	51
Daily maximum	48	48	50	53	59	63	67	67	63	58	52	49	56
Daily minimum	40	39	40	43	48	52	55	55	53	48	43	41	46
Extreme maximum	57	58	63	70	75	82	85	83	78	72	62	58	85
Extreme minimum	20	22	23	29	30	40	44	44	36	32	23	24	20
Rainfall (in.) Mean	4.2	3.7	3.5	2.6	2.2	2.3	2.8	3.3	2.9	5.0	4.8	6.3	43.6

* See Table 4, p. 23.

CAMBRIDGE (CAMBS.). LAT. 52° 12′ N.; LONG. 0° 8′ E.; 41 FEET ABOVE MEAN SEA LEVEL. (f) *
EAST-CENTRAL ENGLAND

Temperatures (°F)	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Mean	39	40	42	46	53	58	62	61	57	50	43	40	49
Daily maximum	45	46	50	55	63	68	71	71	66	58	49	45	57
Daily minimum	34	33	34	38	44	48	52	52	48	42	37	35	41
Extreme maximum	59	67	70	84	88	88	95	96	93	80	65	60	96
Extreme minimum	4	6	12	21	25	32	36	38	28	23	8	0	0
Rainfall (in.) Mean	1.5	1.3	1.5	1.3	1.8	2.1	2.2	2.3	1.6	2.4	1.9	1.9	21.8

BUXTON (DERBY). LAT. 53° 16′ N.; LONG. 1° 55′ W.; 1,007 FEET ABOVE MEAN SEA LEVEL. (g) *
WEST-CENTRAL ENGLAND, ELEVATED VALLEY CLIMATE

Temperatures (°F)	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Mean	36	37	39	43	49	54	57	57	53	47	41	37	46
Daily maximum	41	41	44	49	57	61	64	64	59	52	45	41	52
Daily minimum	32	32	33	36	41	46	50	50	46	41	36	33	40
Extreme maximum	56	58	66	73	79	83	89	88	86	77	61	58	89
Extreme minimum	0	—11	1	8	19	30	31	33	29	18	12	—4	—11
Rainfall (in.) Mean	4.5	3.8	4.1	2.9	3.1	3.2	3.9	4.4	3.2	4.9	4.7	5.7	48.4

STATION—YORK (YORKS.). LAT. 53° 57′ N.; LONG. 1° 5′ W.; 57 FEET ABOVE MEAN SEA LEVEL. (h) *
NORTH-CENTRAL ENGLAND

Temperatures (°F)	*Jan.*	*Feb.*	*Mar.*	*Apr.*	*May*	*June*	*July*	*Aug.*	*Sept.*	*Oct.*	*Nov.*	*Dec.*	*Year*
Mean	39	40	42	46	53	57	61	60	56	50	43	40	49
Daily maximum	44	45	48	53	61	66	69	68	64	56	48	44	55
Daily minimum	35	35	36	39	44	49	53	52	48	43	38	35	42
Extreme maximum	60	61	73	78	82	88	89	90	92	78	66	60	92
Extreme minimum	3	3	8	11	24	34	37	37	30	23	14	—5	—5
Rainfall (in.) Mean	1.8	1.5	1.7	1.6	2.0	2.1	2.5	2.5	1.6	2.7	2.1	2.2	24.3

The above data are quoted, with acknowledgments, from E. G. Bilham: *The Climate of the British Isles*, and from the *Book of Normals*.

TABLE 4: DATA FOR STATIONS a—h EXPRESSED ACCORDING TO KALELA'S SYSTEM

Station	*a*	*b*	*c*	*d*	*e*	*f*	*g*	*h*
Number months with mean temp. 10°C. = 50°F. or more	4	5	5	4	6	6	4	6
Mean temp. of months in question (C°)	13	12	13	12	14	14	13	13
Mean temp. of months in question (F°)	55	54	55	53	57	57	55	56
Mean temp. of warmest month (C°)	14	14	14	13	16	17	14	16
Mean temp. of warmest month (F°)	57	57	57	55	61	62	57	61
Number months with mean temp. 0°C. = 32°F. or less	none	none	none	none	none	none	none	none
Mean of these months (C°)	—	—	—	—	—	—	—	—
Mean of these months (F°)	—	—	—	—	—	—	—	—
Mean of coldest months (C°)	4	4	4	1	7	4	2	4
Mean of coldest months (F°)	39	40	39	34	44	39	36	39
Mean annual range (C°)	10	10	10	12	9	13	12	12
Mean annual range (F°)	18	17	18	21	17	23	21	22
Mean annual precipitation (inches)	29.5	49	77.8	35.0	43.6	21.8	48.4	24.3
Mean annual precipitation (millimeters)	749.3	1244.6	1976.1	889.0	1107.4	553.7	1229.4	617.2

* See Table 4 below.

Chapter 3

SOILS

In a country where there is no great extent of forest, and where what there is, is largely of an artificial character, it is not easy to discover any clear-cut relationship between soils and tree-growth except of the most general kind, and much work has yet to be done before the responses of the individual forest species to the soils on which they have been placed, can be properly elucidated. We have, of course, built up a substantial body of empirical knowledge relating to the most widely-used of the exotic trees and, where soil imposes limits on growth, we know roughly what those limits are, although our knowledge lacks precision. But, for some of the minor exotic trees, we lack even this amount of information.

Much of the forestry programme in Great Britain consists of afforesting bare land on which there is little tree growth, or none at all, to serve as a guide; where tree growth does occur, it is usually of a sort quite different from the exotic conifers which are being put in. In the circumstances, foresters have naturally tended to select for planting, species which establish themselves readily; and though experience has shown that a tree which forms a crop easily will usually continue to grow well, there is no certainty that all the exotics which we are planting will eventually find themselves at home on all the soils on which they have been placed. This is a subject on which research is needed, for the failure of an exotic tree to develop beyond a certain point on a particular soil might raise serious problems both in silviculture and in management.

The practice of ploughing before planting, which is now general on land about to be afforested, has a bearing on any discussion of soils in relation to exotic trees. We know that ploughing promotes earlier establishment of most species and that, in the more extreme cases, it converts a site which is unsuitable for planting into one on which a crop of trees becomes a possibility; but we are still uncertain about the long-term effects of preliminary cultivation or partial cultivation. If it could be shown, for example, that by doing more than the minimum cultivation necessary for establishment we could increase the growth of a species by one Quality Class, then it would probably pay us to plough more intensively to begin with.

The planting of exotic trees, and the subsequent growth of the crop, provides a field for studying the effect of the trees on the soil. This is of some importance because it is necessary for the planter to appreciate the consequences of his action in introducing a long-lived tree from another country. The effects may differ according to the type of soil, the climate, whether the crop is pure or mixed, the treatment, grade of thinning, and so on; and it is advisable to find out as much about them as possible.

There is thus wide scope in the exotic plantations of Great Britain for soil research, and now that we have numerous crops of many species in canopy, or approaching the stage of canopy-formation, there is a good range of material on which to work. Fortunately there is growing interest in forest soil research and much stimulating and important work is now going on in various research Institutes and Universities.

Tansley (1939) in his book *The British Islands and their Vegetation* gives an excellent account of the soils of the country in relation to climate and vegetation, in the course of which he states: 'For various reasons, mature, fully developed soil profiles are far from occurring over the whole surface of the country. Anything like typical examples, indeed, have to be very carefully sought. We have seen that the conditions of a steep slope do not admit of the maturation of the profile—the soil remains permanently immature. Hard rocks which weather slowly have only been exposed over most of the country to a climate of anything like the existing type during the few thousand years since the Pleistocene glaciation, and even during that time the climate has undergone significant changes so that in many cases the soils have not had time to develop a mature profile. Soils with impeded drainage, and thus wholly or partially waterlogged, cannot develop the profile characteristic of the climatic type. Again, many profiles have been partly eroded and thus truncated, so that, for example, the B horizon, which was formed at some little depth, may appear on the surface; and these actually occupy the greatest area of the country. Others, again, have been disturbed by various agencies, of which by far the most important and widespread is cultivation.....'

This quotation brings out some of the difficulties met with in attempting to discuss briefly the soils of Great Britain, in relation both to the planting of exotic trees and to the kinds of land which are available for forestry. The geology of the country is varied and, in some parts, exceedingly complex, much of the land is covered by glacial drifts of various sorts, and there is superimposed the effect

of continued land-use over a prolonged period of time. Any system of classification for this purpose is open to some objection, but the most convenient available is possibly that used by the Soil Survey of Great Britain. In their classification the following major soil groups have been recognised:

(a) Organic soils, (b) Podzolized soils, (c) Gley soils, (d) Brown earths, (e) Calcareous soils.

Organic Soils

This group of soils is of the greatest interest to foresters in Great Britain because it includes the peats which cover large areas in the north and west, areas of low utilisation value for other purposes, on which forestry is being encouraged to expand. Although Zehetmayr (1954) in his work *Experiments in Tree Planting on Peat* has accepted as a peat any soil with a superficial covering of organic matter more than six inches thick, the Soil Survey requires a depth of 9 or 12 inches before a soil is admitted into this class. Zehetmayr's definition is useful for the purposes of practical forestry, but it will be more convenient, in this discussion, to follow the practice of the soil surveyors. Peat deposits are variously distinguished but the main separation is into local peat deposits and climatic peats. The former are formed in hollows and depressions where poor drainage or high rainfall lead to their accumulation, and they are generally of small extent and for this reason of little interest to forestry. In some districts they are more widespread in occurrence, and where they have a high base status, they are valued for agriculture, and trees are rarely grown on them. The climatic peats, occurring in districts of high rainfall, high humidity and low insolation, have been divided by G. K. Fraser (1933) into 'hill peat' and 'blanket moss', the first of which, situated at relatively high elevations, has not generally been used for forestry, although some experimental plantations have been attempted on it; while the second, which covers large areas, is the most important for afforestation in Scotland and the north of England.

This 'blanket' peat is variable in depth and in structure. In some places it forms deep bogs; on slopes and flats it is thinner though often of considerable depth, and it becomes quite thin where it covers rocky knolls and morainic mounds. It has been classified as to structure into amorphous peat, pseudofibrous peat and fibrous peat, each of which is often indicated by the presence in quantity of characteristic plants—the purple moorgrass, *Molinia coerulea*, on amorphous peat; heather, *Calluna vulgaris* and cotton grass, *Eriophorum* spp. on the pseudofibrous peat; and deer grass, *Trichophorum* (*Scirpus*) *caespitosum*, on the fibrous peat. When streams or drainage waters traverse the peat, 'flushes' are formed in which conditions are much better for tree growth. On these flushes, Norway spruce or Sitka spruce is the usual choice for planting. On the amorphous peats Sitka spruce is largely used, but if plants such as *Trichophorum*, *Calluna* or *Vaccinium* are prominent among the *Molinia*, then a proportion of pine is introduced and the spruce is usually given phosphate at the time of planting. Scots pine is often used, but if exposure is a factor to be taken into account, *Pinus contorta* is used instead. Generally, the greater the frequency of *Calluna* the more caution must be taken in using spruces. The fibrous peats with *Eriophorum* are more difficult and require close draining; Sitka spruce is often used on these sites and requires phosphate if it is not to go into check. Pines, which are used in mixture with the spruce, also benefit by the application of a phosphatic fertiliser. The pseudofibrous peats characterised by *Trichophorum* are the subject of much experimenting because we are not yet certain that it is safe to embark on full-scale afforestation on this type of land. It has been shown that on some of the worst of these, a crop of *Pinus contorta* can be established, but we do not yet know how crops of this sort will develop. Most of the peat lands are subject to exposure to a greater or less degree; in extreme cases this may make it impossible to proceed with planting and in others it may affect the choice of species.

Podzolized Soils

Podzols are frequent in the north-east (Muir 1940) and the east of Britain, and they are also found, well developed, on the Eocene in the south of England. For reasons given by Robinson (1935) well-developed podzols are uncommon in Wales. They are normally associated with a heath type of vegetation. Much land of this kind has been available for afforestation in the last thirty-five years and a considerable body of information has been built up on methods of planting it with trees.

Well-developed podzols such as form under pine forest in the north-east of Scotland can be planted with Scots pine, a species which grows slowly but produces high-quality timber. Those of the sort found, say, on the extremely infertile Eocene deposits at Wareham, in the south of England, do not offer much encouragement to anyone who plants them direct, though in other districts the podzolized Bagshot sands of the Eocene can be planted successfully without ploughing. Within recent years, however, it has become the general practice to plough all podzols before planting, even in old woodland, wherever this can be done.

Where a hard pan occurs, ploughing is essential as, without it, only a stunted crop of pine can be grown. Much of the land of this type is associated with moist heath conditions and is often subject to considerable exposure, but it is commonly rather level

land and convenient for ploughing. As Steven (1940) says "This treatment (i.e. ploughing) mixes the different horizons together, tends to stabilize water relations during winter and summer, and improves aeration. The vegetation type is influenced, at least temporarily, grasses increasing in amount and luxuriance".

Peaty podzols which have a mor layer several inches thick have usually a thin iron pan. The conditions usually are moister and the vegetation approaches the moorland rather than the heath type; in the south of Scotland, for example, this type of soil is found usually where the rainfall is at least 40 in. per annum and is then associated mainly with *Molinia coerulea*.

The choice of species for planting on podzols and podzolized soils is not always easy to make. On the characteristic dry heathland podzols, a pine is the obvious choice, the native Scots pine being in general use, although the Corsican pine gives good results in the south of England. European larch has grown well on soils of this type in various parts of Britain and good results have sometimes followed the use of Douglas fir. On the more difficult podzols, especially those with hard iron pan, much experimental work has been conducted with a view to finding suitable species which would be more highly productive than Scots pine. Sitka spruce has given some promise although it is often necessary to apply a phosphatic fertiliser at the time of planting; Norway spruce is generally unsuitable as it checks badly in the presence of *Calluna* while Japanese larch, which establishes itself readily, is to some extent suspect on account of its susceptibility to damage by drought.

The peaty podzols are difficult to afforest and they require to be ploughed to improve the drainage. On many sites where this type occurs, a mixture of Scots pine and Sitka spruce is being planted, but *Pinus contorta* is used in place of Scots pine where exposure is severe.

Gley Soils

Gley soils which have developed under conditions of intermittent or permanent waterlogging are of wide distribution. In the lowland regions, where originally they carried a wet type of deciduous woodland, they are now mainly under agriculture and, in parts of England, have long been under permanent grass. In these districts, though no large-scale afforestation goes on, there is a considerable amount of woodland in small patches, planted mostly with mixed deciduous species.

In upland regions, soils showing gleying are frequent and some of them are used for forestry. A common type in upland districts is the peaty gley which has been planted extensively in the Borders where Scotland and England meet.

Gley soils require drainage before a crop of trees can be established, and on the ground-water gleys this must be reasonably deep and must be well maintained. For the surface-water gleys, drainage need not be so deep, but it is nevertheless essential.

In lowland districts, the ground-water gleys are not much used for forestry but crops of poplar are sometimes raised on them; the surface water gleys will grow a variety of species, but young tree crops are often slow to establish.

In upland districts, the better ground-water gleys grow Norway spruce very well, but on other types, Sitka spruce is better.

Brown Earths

Soils of the brown earth type are of wide occurrence but they vary in fertility according to the richness or poverty of the parent material. They would normally carry deciduous forest, mainly of oak, but in upland districts, where they are not cultivated, they may be associated with a sort of acid grassland or even grass-heath. They are often well drained naturally, but imperfect drainage with a certain amount of gleying at some depth is not uncommon.

On the richer, lowland brown earths, there is a great variety of trees which can be grown, and the choice is usually dictated by considerations other than those of soil.

In hill country, conifers are the usual selection and, where exposure is not severe, a number of different species can be safely grown, of which the larches and the spruces are the commonest.

Calcareous Soils

The soils already mentioned are all acid, from the acid peats to the best brown earths which have moderate or slight acidity. The calcareous soils, therefore, stand out as a class apart and they are naturally much more restricted in distribution being confined to chalk and limestone formations and to the chalky boulder clays of the east Midlands. The rendzinas and rendziniform soils in this group have recently been discussed from the forester's points of view by J. M. B. Brown (1953). The characteristic soils of the chalk and limestone are dry and alkaline and these features limit the species which can be grown. Most of the conifers are unsuitable, although several will make pole crops, and the staple species for planting is beech.

The calcareous soils on the chalky boulder clay frequently exhibit impeded drainage with some gleying. They usually carry crops of oak and ash, where they are not under agriculture.

Coastal Sands

Stretches of dunes and coastal sands have been made available for planting at various times, the most important of these being at Culbin, Morayshire; Tentsmuir, Fife; Pembrey, Carmarthen; and Newborough, Anglesey. Pines are the principal species used.

J. M.

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Chapter 4

TECHNIQUES OF ESTABLISHMENT AND TENDING

The techniques mentioned in this chapter are those generally applied both to exotic and to native trees. The most important technique in establishing a forest in Britain is planting, for though natural regeneration and direct sowing are occasionally carried out on a very limited scale, in practice they are of small account.

On private estates most of the planting has been on old woodland sites for which long-established techniques are suitable. In contrast, between one-half and two-thirds of the Forestry Commission's recent planting has been on bare upland. Methods of mechanical cultivation and draining have therefore been developed by the Forestry Commission to a greater extent than would have been justifiable for a private owner working on a much smaller scale and in different conditions.

Nursery Work and Planting Stock

Forest nurseries in Britain are classified into 'heathland' or 'woodland' nurseries, and 'agricultural' or 'established' nurseries. The soils of the former are characteristically light and sandy, and may contain a certain amount of peat; they are also acid and intrinsically infertile. In the first years after formation, heathland and woodland nurseries are extremely free from weeds. The soils of agricultural nurseries are rather heavier, as they are mainly light to heavy loams with slightly acid reaction (pH 5.0—6.5); they are intrinsically fertile.

Heathland nurseries were first used for large-scale production of seedlings in 1945 and achieved immediate success, producing high yields of top quality seedlings at relatively low cost. The area has increased in recent years and now a large proportion of our coniferous seedlings are raised in nurseries of this type. Agricultural nurseries are now mostly used for lining out seedlings, often those sent in from heathland nurseries, and for raising hardwood species.

The period since 1945 has been one of extremely active research into the problems of nursery nutrition in Britain (Crowther *et al.* 1951-1956); many of the conclusions reached have been incorporated into current practice. The fertility of nursery soils is maintained by application of inorganic fertilizers supplying nitrogen, phosphorus and potassium. Organic matter is usually applied to heathland nurseries in the form of hop-waste and, in some agricultural nurseries, by the introduction of a green-crop into the rotation. Lime is applied only in very acid nurseries, and that infrequently and in very light dressings. A three to four year rotation is usually practised but the actual cropping varies according to local conditions.

Seedbeds are normally prepared in spring, and sowing takes place from mid-March to mid-April, autumn sowing being limited to hardwoods. Most seed is still sown broadcast by hand, but the practice of sowing by machine, either in drills or broadcast, is becoming more widespread, and in larger nurseries it is likely soon to become the standard practice. The density of sowing is calculated by taking into account the number of viable seeds per pound, the experience of previous years with the same species in a given nursery, and whether it is intended to produce one-year or two-year old seedlings.

SEED QUALITY, SOWING DENSITY AND YIELD FOR SELECTED CONIFERS

TABLE 5

Species	*Normal Seed Qualities*			*Sowing Density (Normal Quality Seed)*		
	No. Pure Seed per lb. (Thous.)	*Germination percentage*	*No. Viable Seed per lb. (Thous.)*	*Desirable Stocking at first year. No. of Seedlings per Sq. Yd.*	*Recommended Density of Viable Seed per Sq. Yd.*	*Recommended Normal Sowing Density (Sq. Yd. per lb.)*
Scots pine	75	90	67	500	1,200	56
Sitka spruce	190	90	170	1,000	2,000	85
Tsuga heterophylla	290	60	175	900	3,000	58
Abies grandis	23	25	6	300	500	12

Table 5 gives seed qualities, sowing densities and expected yields of some of the conifers commonly used; the densities are those recommended for crops which will be lifted at the end of the first year.

After sowing, the seed is usually covered with $\frac{1}{8}$ to $\frac{1}{2}$ inch of coarse sand or gravel which should be free from lime or silt, the depth being dependent on the species. A cover depth of $\frac{3}{16}$ inch is standard for most conifers, but *Abies* germinates better under thicker cover and *Tsuga* under thinner cover.

Seedlings remain in the seedbeds for one or two years according to species and rate of growth. Seedlings of larches, Douglas fir and most pines, as well as spruces in many heathland nurseries, are usually lifted at the end of one year. *Abies* species normally stand for two years.

The lining-out spacing depends on the species, size and vigour of the seedlings, and varies from $1\frac{1}{2}$ inches $\times$ 6 inches to 3 inches $\times$ 10 inches.

Undercutting of seedlings as a substitute for lining-out is only practised on a very small scale and is still the subject of experiment.

Weed control is an essential part of British nursery practice and has been revolutionised in recent years by the widespread use of mineral oils; pre-emergence sprays of vaporising oils at the rate of sixty gallons per acre are applied to seedbeds in almost all nurseries. Post-emergence sprays of white spirit are not so commonly applied, but where they are used, pines and spruces are sprayed at rates of up to thirty gallons per acre, depending on the time of year; larches, Douglas fir and western hemlock are more sensitive and can only safely be sprayed at rates not exceeding fifteen gallons per acre. Hardwoods are easily damaged by post-emergence spraying. In transplant lines, in some nurseries, weeds are controlled with sprays of vaporising oil or white spirit at rates up to forty gallons per acre. Mechanical methods of weed control are also being developed for use in the larger nurseries.

Transplants are the type of stock in general use for forest planting. For sites where there is little shelter and little weed competition, e.g. on ploughed heath or moorland, small transplants up to ten or twelve inches are preferred. On unploughed ground or on old woodland sites where weed growth may be strong, larger and older plants up to twenty-four inches tall are usually planted.

Seedlings of the major coniferous species have been used for planting experimentally on a fairly large scale since 1930, but their survival rate is lower and the weeding costs higher than for transplants (Guillebaud, 1933). Nowadays, seedlings of pines, spruces and larches are used only when transplants are not available and then only on sheltered sites on ploughed ground. Edwards and Holmes (1951) showed that the sturdier the seedling, the better the chances of survival following planting.

Ground Preparation and Planting Methods

Fencing against stock is generally carried out, and rabbit fencing is usually necessary. Myxomatosis has reduced the rabbit population very materially, and if the position can be maintained considerable economies in fencing will result; also natural regeneration may become a more practicable proposition. In certain districts, plantations must be fenced against deer.

In the restocking of broadleaved woodland, coppice or scrub, partial or complete clearance of woody weed growth may be necessary. However, wherever possible, trees are planted under the existing cover, which is then gradually removed. This reduces the costs of weeding. Where it is necessary to clear completely, repeated cutting back of woody regrowth is required until the new crop has closed canopy.

Drainage is an essential preparatory measure on the moist upland sites, moorlands and peats. It may also be required on heavy soils in areas of low rainfall. While much draining is still done by hand, particularly on small planting projects, the use of draining ploughs has become general on the more extensive operations. On peat, both hand and plough

draining methods are designed to provide inverted turfs for planting on, in addition to the primary objective of drainage. Hand methods commonly provide single turfs, which are spaced at the proper planting distance.

The draining plough most frequently used is the Cuthbertson single mould-board plough. This makes an excellent drain and turns out a turf ridge, which may either be planted where it lies, or cut up into slices and spread between the furrows. On the very poorest deep peat the furrows are usually spaced five to six feet apart, but often on the better peats they are about seventeen to twenty-two feet apart, allowing two or three rows of turfs to be spread between the furrows. Often, as an alternative to the spreading of turfs, the Cuthbertson double mould-board plough, which turns out two turf ridges, is used between the drains made by the single mould-board plough. A lighter plough, the Begg, is also widely used on shallow peat and on grassland where a small turf is satisfactory.

Cleaning of drains, and the occasional deepening of selected channels, has to be carried out from time to time, and this is often done immediately before the crop forms thicket, and again just after each thinning. Drain cleaning is essential to maintain the stability of the crop.

Cultivation by ploughing is carried out on several important types of land. Little cultivation is now performed by hand, except for what may be done in the act of planting.

On heathland sites, the object is to suppress heather (*Calluna*), to reduce soil compaction, and to break the hard pan if present. The plough most frequently used has till recently been the "R.L.R." (named after R. L. Robinson—later Lord Robinson —Chairman of the Forestry Commission from 1932-1952). It is now however being replaced by the Forestry Commission Tine plough. Ploughing is usually carried out at planting spacing, i.e. at about five foot intervals.

Ploughing is also practised on upland grasslands and on chalk downlands, where cultivation is of lesser importance and suppression of competing vegetation is the main objective. These sites do not call for such strong implements as are required for drainage or heathland cultivation. On chalk downland, strengthened agricultural ploughs have been used.

The tractors in general use for ploughing by the Forestry Commission have been standard commercial makes of about thirty to forty horse power, for example the Caterpillar D 4 and the International TD 9 and the recently introduced BTD 6; for very soft peatland the Howard Platypus and a modified Fordson County have been successful.

The normal method of planting is notching, using a spade or mattock. On uncultivated sites where the ground vegetation is dense, a small patch is 'screefed' clear of vegetation with a mattock before each plant is put in; on steep slopes a step on which to plant the tree is often made. On hand-prepared turfs, the plants are notched into the top of the turf in the same way as in planting the tops of plough ridges. Pit planting is practised only when large plants are necessary, for example on old woodland sites.

Where the site has been ploughed, the position for planting will depend on whether ploughing has been done mainly for drainage or for cultivation. On drained sites, the plants are placed either on the top or in the side of the plough ridge, and where the soil is peat the plants are put in deeply to allow for contraction of the peat when it dries out in summer. On heathland, it is preferable to put the plants in the bottom or at the side of the furrow; in this position the roots are amongst that part of the soil which has been most disturbed by the plough, and the plants are sheltered to some extent by the ridge. In the wet hollows which are occasionally found, however, the plants must be placed on the ridge. Where ploughing has been undertaken mainly for weed suppression, the spot most likely to remain weed-free is chosen for planting; usually, this is in the bottom of the furrow.

Planting can be carried out from autumn to early spring, i.e. October to April, wherever weather conditions permit. Most planting, however, is done in the spring. In the north of the country and at higher elevations, planting may continue into May with certain species.

Phosphatic fertilisers are applied at the time of planting on the poorer peats, characterised by deer grass (*Trichophorum*) and cotton grass (*Eriophorum*), and also on the more difficult *Calluna* heaths. Basic slag has been widely used, but ground mineral phosphate is the commonest form of phosphate in use at present. Superphosphate is also used, but not so generally. The usual dosage of ground mineral phosphate is 1½ to 2 oz. per plant. Manuring with elements other than phosphorus is not practised at present, nor are fertilisers normally applied except to expedite establishment, but the whole subject of nutrition of forest crops is under investigation at the present time.

Spacing

The common convention has been to plant pines at four-and-a-half feet spacing, spruces at five to five-and-a-half, and larches and Douglas fir at six feet. Practice varies according to local circumstances, but the general tendency in recent years has been to widen the planting distance for most species.

Direct Sowing

Although it has been used on many occasions in

the forest, direct sowing is rarely practised today. The method is not as reliable as planting, and it costs nearly as much.

Natural Regeneration

There are examples of crops which have been regenerated naturally but they are few in number. Uncertainties in seed production, and the presence of rabbits and other enemies of young seedlings, have discouraged the use of natural regeneration as a system.

Beating-up

Beating-up, the replacement of dead plants in young plantations, normally takes place up to three years after the ground has been planted, the object being to ensure that there are sufficient plants to make a well-stocked plantation.

Weeding

On very weedy sites, weeding is often necessary for four years after planting, and occasionally longer; it has to be continued until the young trees are sufficiently tall and sturdy. On sites where weed growth is slow, and on ground which has been ploughed, little weeding may be required; the elimination or the reduction of this laborious and costly operation is an important result of ploughing.

Brashing and Pruning

Brashing—the removal of dead branches up to a height of about six feet, is carried out in conifer plantations shortly before first thinning. The aim is to obtain satisfactory access for marking, felling and removal of the thinnings. The commonest practice is to brash about two-thirds of the stems in a crop and to confine the work to those trees which will not be felled in the first thinning. Normally no brashing is necessary in hardwood plantations.

Pruning has been undertaken on a small scale for many years, but the profitability of pruning in Britain is still open to doubt. In certain special cases, e.g. poplars, it is demonstrably essential. The height to which stems are pruned seldom exceeds twenty feet. Only selected stems are pruned.

Thinning

Thinning of plantations is usually begun when the average height of the crop is 25 to 30 ft. In the second half of the nineteenth century it was the practice to thin lightly and to keep the crop dense all its life. During the twentieth century the trend has been towards progressively heavier thinnings.

The thinning grade now most widely practised is the moderately heavy (C/D) grade; most of the data to be found in the Revised Yield Tables for Conifers (Hummel and Christie, 1953) are based on fully-stocked crops thinned to this grade. Larch crops are however generally given a heavy (D) grade thinning.

J.R.A.

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PART II

Exotic Coniferous Trees in Great Britain

In the following accounts, which deal with conifers, we have included most of the genera, even though some of them are of no importance to foresters in Great Britain, because we took the view that it might be of interest to people in other countries to know how trees, which might be of importance to them, have fared under other conditions. We have therefore included all coniferous genera, species of which have been grown in the open air in Great Britain regardless of whether they have had to receive protection to keep them alive.

Abies Miller

Nearly, if not all, the true firs (of which Dallimore (1948) lists some forty species) are in cultivation in Britain. Many are of considerable arboricultural value.

Taking the genus as a whole, North-west America, Europe and Japan are the sources of the most successful *Abies* introductions into Britain. Species from China and the Himalayas have presented difficulties in cultivation; a number of them are notoriously liable to damage by late spring frosts.

Three species are, or have been, of silvicultural importance, namely:—*A. alba*, *A. grandis*, and *A. nobilis*, and these will be dealt with in detail.

A number of others have been planted to varying degrees on a purely experimental scale, and individual mention will be made of the following, all of which are represented in trial plantations. *Abies amabilis*, *A. balsamea*, *A. cephalonica*, *A. concolor*, *A. lasiocarpa*, *A. magnifica*, *A. nordmanniana*, *A. pinsapo* and *A. veitchii*.

Of these, the only ones which so far show any prospects of entering forestry are:—*A. amabilis*, *A. concolor*, *A. nordmanniana* and *A. veitchii*.

Of the numerous other species in cultivation little need be said. North American species from lower latitudes include *A. venusta* from California and *A. religiosa* from Mexico; both are very susceptible to frost damage. *A. fraseri* from the Alleghany Mountains is usually poor in cultivation, but a plot at Crarae, Argyll, has attained a height of 27 ft. in 18 years and is growing vigorously.

Several other European or North African species are in cultivation. *A. cilicica* from Asia Minor and North Syria is rare in cultivation but a few good specimens exist, notably one at the National Pinetum, Bedgebury, Kent, recorded in 1954 as 88 ft. in height. *A. numidica*, from Algeria, is better represented, and several specimens exceeding 80 ft. are known. *Abies bornmülleriana*, an intermediate between *A. cephalonica* and *A. nordmanniana* from Asia Minor, has only recently been introduced. *A. sibirica*, the Siberian fir, does very poorly; it is presumed that it is ill-adapted to the shorter summer day of British latitudes.

Of the Asians, a taxonomically difficult group of Chinese species including *A. fabri*, *delavayi*, *fargesii* and *georgei*, are most decorative subjects in the arboretum but are spring frost susceptible and also specially prone to honey-fungus (*Armillaria*) attack.

The remaining Japanese firs have not attracted much attention for forest planting, but *A. homolepis*, *A. holophylla* and *A. firma* are represented in arboreta and the two former species appear capable of attaining respectable dimensions.

The Himalayan species *A. pindrow* and *A. spectabilis* have a bad reputation for spring frost damage, and have performed best in the west and north-west (though the latter species has almost succumbed at Crarae, Argyllshire). Other species in cultivation include the Asians, *A. mariesii*, *recurvata*, *sachalinensis*, *koreana*, *chensiensis* and *squamata*.

DISEASES AND PESTS

Few diseases peculiar to *Abies* are observed in Britain. *Rehmiellopsis bohemica*, causing a needle cast and death of shoots has been fairly frequently

reported, certainly on *A. grandis* and *A. alba*, and probably on other species. *Nectria cucurbitula* has been recorded associated with severe canker and dieback on *A. cephalonica*.

The insect pests of *Abies* are probably of greater importance. The silver firs are the hosts of *Adelges nüsslini* C.B. and *A. piceae* Ratz., and the attacks of the former species on *Abies alba* are serious. Other species of *Abies* are more resistant to attack.

Abies alba Miller. (*A. pectinata* De Candolle)

COMMON NAMES—Silver fir, since the time of Evelyn (1664).
Timber: Silver fir (British Standard Nomenclature of Timbers, 1952).

COUNTRY OF ORIGIN AND PROVENANCE

Native of the mountains of central and southern Europe, it is specially prominent in the Vosges, Jura, in the Black Forest and in Northern Bavaria. The distribution, which is complex, is illustrated by Schmucker (1942). *Abies alba* contacts *Abies cephalonica* in the Balkans and intermediate forms have been described (Turrill 1925, 1937).

No British evidence is available on the provenance attributes of *A. alba*, which are discussed by Guinier (1949) for France.

It is not known whence the original introductions of *Abies alba* came. Little seed has been imported in recent years but what small amounts have been acquired have emanated from French sources.

HISTORICAL NOTES AND EXTENT OF PLANTING

Silver fir, like Weymouth pine, is an example of an exotic of some importance in its day which is no longer planted.

The introduction, or more correctly the first planting of the tree in Britain is usually ascribed to Sergeant Newdigate, who (according to Evelyn) planted two Silver firs at Harefield Park, Middlesex, in 1603.

Abies alba appears to have been an object of arboricultural interest from an early date. Loudon (1854) mentions the use of the tree to "distinguish the residence of the large landed proprietor from those of his more humble neighbours" and notes that Silver fir eventually yielded place to the cedar for this estimable purpose. No doubt the large dimensions attained by such purely decorative specimens excited interest in the possibilities of Silver fir as a commercial proposition.

An early reference to more extensive planting of the tree is an award in 1797 to Henry Vernon of Hilton Park near Wolverhampton for planting some 6,000 Silver firs. This may well have been a period of considerable interest in *Abies alba*. Hutchison (1885) remarks that "compared with the desire for its more extended propagation throughout the country at that period, it is somewhat singular to find this tree in comparatively little favour with planters at this day". Hutchison, who was mainly concerned with Silver fir in Scotland, gives a picture of a tree which had been very widely planted throughout the country but nowhere apparently in the form of extensive plantations. Rather it had been planted as single specimens, as avenues, in 'clumps' of a few dozen trees (often amongst hardwoods), or sparsely in mixture with other conifers.

Michie (1870), writing rather earlier, gives much the same picture, and it may be assumed that Silver fir was never planted extensively in pure crops in Scotland. The position in England and Wales seems to have been rather similar, Silver fir being used very frequently in the enrichment of broadleaved woodlands, but rarely if ever in pure plantation.

Prior to the second World War, large old Silver firs scattered through oak woods (and often standing out some 20 ft.-30 ft. above the oak crowns) were quite a common feature in the eastern counties of England.

Hutchison makes it clear that Silver fir had not yet been supplanted by the "new-fangled introductions", and considered it the highest yielding conifer available to the planter of his time. In his view its frost susceptibility and slow early growth were the main drawbacks, and he thought *Abies nordmanniana* the most probable replacement.

Silver fir appears to have increased in popularity in the latter part of the nineteenth century, and one of the commonest uses of the tree at that time was in underplanting European larch, particularly plantations affected by canker and heavily thinned in the removal of diseased trees. Unfortunately, however, *Adelges nüsslini*, which may have been in the country since about 1820 (Varty 1956) appears to have become a really serious pest by the turn of the century, and further plantations of Silver fir on any scale became hazardous. Also, about this time, *Abies grandis* began to appear in experimental plantations, and its relative freedom from adelgid attack and rapid early growth encouraged foresters to regard it as an acceptable substitute for *A. alba*.

Table 6 shows the areas occupied in 1947 by Silver fir of various age classes.

The current rate of planting is negligible.

CLIMATIC AND SITE REQUIREMENTS

Abies alba reaches its finest development in Scotland, but does not appear to have very well marked preferences, since large specimens have been recorded in almost all districts. It tolerates exposure quite well, and has been a productive species at

ABIES ALBA: HIGH FOREST AREAS, PURE AND MIXED STANDS COMBINED, BY AGE CLASSES, 1947

TABLE 6 Acres

	Age Class								*Uneven Aged*	*Total*
	1–10	11–20	21–30	31–40	41–60	61–80	81–120	*Over* 120		
*Privately owned and Forestry Commission	22	11	22	43	20	47	87	42	185	479

Note * Practically the whole privately owned.

fairly high elevations in Scotland (Hutchison 1885). It behaves reasonably well even in coastal districts. Gunn (1885) notes that it behaved "particularly well" at Cleascro on the island of Lewis. A few Silver firs can be seen making a fair showing in blasted broadleaved woodland not far from the Lizard peninsula in Cornwall.

It does not appear over-fastidious as to soils; Michie (1870) claims that it does well on heavy soils, but not on sands or gravels. It is certainly not suited to very dry and infertile sands, nor to peat soils.

The frost susceptibility of *A. alba* has discouraged planting in the open on frosty flats or hollows, and it has usually been established under some degree of cover affording a protection from radiation frosts.

ESTABLISHMENT TECHNIQUE

NURSERY PRACTICE. No recent experience is available, but treatment differs little from that for *A. grandis* and *A. nobilis*.

VEGETATIVE PROPAGATION. (where required in genetical work) also follows closely that for *A. grandis*.

PLANTING. No special techniques appear to have been developed.

SPACING. Various early authors draw attention to the necessity for close spacing in plantations or groups in order to discourage heavy limbs and consequent large knots. Self pruning is certainly slow.

TENDING AND THINNING

There is no current practice to record. The possibility of mitigating the severity of *Adelges* attack by various methods has been discussed in the literature, but there appears to be little evidence in support of any economical operation.

OTHER SILVICULTURAL CHARACTERISTICS

The high degree of shade tolerance of *Abies alba* is one of its outstanding characteristics. Continental sources claim that its rooting system is deep and searching, particularly in comparison with that of the spruce, but no investigations have been made in Britain.

RATE OF GROWTH AND YIELD

The slow initial growth of *Abies alba* is frequently mentioned as one of its drawbacks. After it is thoroughly established however, it is a very considerable volume producer, and till the advent of Douglas fir, was considered to be the most productive species available to British foresters. Even now many of the largest conifers in Britain are Silver firs. Trees over 120 ft. tall with breast height girths 12 ft. or more are by no means exceptional; the largest specimen is thought to be a tree at Kilbride, Inveraray, Argyll; measured by A. F. Mitchell in 1954 this was 180 ft. tall and girthed 20 ft. 9 in. at breast height. This tree has a good claim to be the tallest in Britain.

No British Yield Table (other than a provisional set of figures by Maw (1912)) has been published, and plot measurements are scarce. What information is available was collected between 1919 and 1921 when five temporary plots were measured, two in south-west Scotland and three in the south-west of England, as shown in the first five entries in Table 7 following. All these plots were on moderately exposed sites ranging from 300 to 620 feet in altitude.

TABLE 7 ABIES ALBA: GROWTH AND PRODUCTION

Locality	*Age Years*	*Mean Height (ft.)*	*Mean Girth at Breast Ht. (in.)*	*Standing Volume per Acre (Hoppus ft. Over Bark)*
Endsleigh, Cornwall	48	69	39	6,410
Stevenstone, Devon	42	56	41	5,370
Okehampton, Devon	53	67	39	5,675
Dunskey, Wigtown	51	48	34	5,960
„ „	55	54	45	7,065
Drummond Hill, Perth	31	42	21	2,200

Data for a younger plot now growing at Drummond Hill, Perthshire, have been added as the sixth entry. This plot is at about 1,000 ft. elevation and is on a south-facing slope surrounded by larch plantations of the same age but greater height. All dominant and co-dominant trees are healthy and current annual height growth is up to twenty-four inches.

Height for age, the best growth attained here is approximately that of (British) Quality Class II Norway spruce, but the volume production either on a height or age basis is more impressive.

DISEASES AND PESTS

No specific diseases are known. The continental experience that *Abies alba* is less prone to butt-rot due to *Fomes annosus* than most coniferous species appears to receive some confirmation from Hutchison (1885) who says Silver fir is not susceptible to "rot in soils where both larch and spruce are severely deteriorated thereby". Experience during the 1939-45 war gave further confirmation because it was rare to find a rotted Silver fir even on sites where other conifers were badly decayed.

Adelges nüsslini attacks *Abies alba* so severely that the planting of the tree in Britain has been virtually suspended. (Varty 1956.)

OTHER FORMS OF DAMAGE

WINDBLOW. *A. alba* appears to be a fairly windfirm species.

ATMOSPHERIC POLLUTION. *A. alba* is not known to differ from other *Abies* species, all of which abhor polluted atmosphere.

OTHER. The high degree of frost susceptibility of *A. alba* has been noted. It is of importance only when the tree is young.

SEED AND SEEDBEARING

European Silver fir commences flowering between 25 and 30 years of age while maximum seed production in Britain probably begins between 40 and 60 years of age (although there are few data available about this). Flowering normally takes place in May.

Cone collection should be done as soon as the cones begin to open and before they fall apart. The normal time is early or mid-September and the latest time is usually the end of September (Matthews 1955).

GENETICS AND BREEDING

No seed sources have as yet been registered, but breeding for resistance to Silver fir *Adelges* may become worthwhile. Six plus trees have been selected and recorded for their great size and good growth habit.

NATURAL REGENERATION

Abies alba has frequently produced quite prolific crops of seedlings, particularly in Scotland and in East Anglia. Gilchrist (1875) describes a case of successful regeneration of Silver fir in Aberdeenshire. Here an 80-year-old plantation of European larch, Scots pine and Norway spruce had a small percentage of Silver fir dominants scattered throughout, which had regenerated in gaps due to windblow and exploitation; thriving uneven-aged groups of Silver fir up to 8 feet in height were to be found about the plantation. McNeill (1945) describes the conditions under which Silver fir (amongst other species) is regenerating on Dunecht Estate near Aberdeen. Inveraray, Argyllshire, is an estate where natural regeneration of Silver fir is fostered and accepted in the management of the woodlands.

TIMBER

Home-grown Silver fir has not been of any great commercial importance owing to the relatively small and inconstant supply. It has however received a good deal of favourable comment. Le Maire Witham (1841) describes an early experiment in which the bending strengths of European larch and Silver fir were compared, the results (somewhat surprisingly) being in favour of the latter.

Hutchison (1885) mentions a trial of home-grown Silver fir sleepers on the Highland Railway in which they compared very favourably with imported Baltic timber.

The timber kiln-dries well, with some tendency to check and for knots to loosen. The weight of the seasoned wood usually falls between 25 and 30 lb. per cubic foot.

It is not durable and is moderately resistant to impregnation by wood preservatives, but satisfactory penetration can be obtained either by a hot and cold tank or a pressure treatment.

It works well, machine and hand tools giving a good finish, and it holds nails well.

According to the home timber trade it has been used mainly for estate work. Sawn timber, which air seasons well with little degrade, has been supplied to the building trade for carcassing and roof boarding. It has also been used for built-in furniture where it was well liked on account of its clean appearance.

It may be regarded as a general purpose "whitewood" type of softwood.

POTENTIALITIES OF THE SPECIES IN THE NATIONAL ECONOMY

But for the ravages of *Adelges nüsslini*, there seems little doubt that this long established and well-tried species would have an important (if not a primary) place in British forestry. As it is, the hazards are too great to permit of any large scale usage. It is just possible that a silvicultural or even a provenance solution might be found, in which case the species would undoubtedly gain ground.

Abies amabilis (Douglas) Forbes (Plate 17)

This tree was introduced by Douglas from the Pacific coast in 1830. According to Elwes and Henry (1906/13) few of Douglas' original seedlings (if any) survived the nineteenth century, but a considerable reintroduction from Oregon was made in 1882.

The tree has never been widely planted, Elwes and Henry record few specimens of any merit and speak of it as a failure in cultivation. More recently however, some very successful individuals have been reported; a specimen 99 ft. tall at Blair Atholl in Perthshire appears to be the largest in the country at present.

One established experimental plantation exists, at Crarae, Argyllshire. The species here appears extremely successful, and has attained a height of 38 feet in 23 years, with a mean breast height girth of 15 inches, and a standing volume of 2,000 Hoppus feet per acre, 396 Hoppus feet having been removed in thinnings.

No information is available on provenance. It is presumed that the most promising environment for this species will be in the west of Britain, perhaps on the better mountain soils. On general climatic grounds it is thought that it may have an advantage over its western North American neighbour *Abies grandis* in cool high rainfall districts (Wood 1955). It is known to be extremely shade tolerant, and may be useful in underplanting or in the conversion of poor broadleaved scrub to high forest.

Abies balsamea (Linnaeus) Miller

Little need be said of this eastern North American species, which is only mentioned since it has been long in cultivation in Britain and has occasionally been tried in the forest. Few trees in Britain appear to have exceeded 50 feet in height. It has, curiously enough, shown some degree of promise on an inclement peat site at Inchnacardoch, Inverness-shire. (Zehetmayr 1954.)

Abies cephalonica Loudon

The Greek fir, introduced by General Napier in 1824. is quite common in cultivation, and has reached large dimensions in certain parts of the country. There are numerous records of trees exceeding 80 feet in height and many of over 100 feet; the largest recorded specimen appears to be a tree measured by the Hon. Maynard Greville at Tendring Hall, Suffolk. In 1953 this was 135 feet tall with a breast height girth of 12 feet 7 inches. Many of the largest trees are in the east of England.

Little attention has been paid to *A. cephalonica* as a plantation tree, probably on account of its coarse branching habit and frost susceptibility. A young plot exists in the Forest Garden at Bedgebury, Kent, where the tree has been difficult to establish due to damage by spring frosts, but at Benmore under the mild conditions of the west coast of Scotland a plot planted in 1949 quickly became established and is now growing vigorously at the rate of more than one foot a year.

Abies concolor (Gordon) Engelmann (Plate 17)

Following Rehder's nomenclature, the variant with the markedly pectinate leaf arrangement (often accorded the name *A. lowiana*) is not distinguished here as a separate species.

The species (in the broad sense) was introduced from California by Lobb in 1851. It has been widely planted in arboreta, and attains impressive dimensions. One of the finest specimens, at Durris, Kincardineshire, had a height of 145 ft. and breast height girth 14 ft. 4 in. in 1955. There are several trees at Blair Atholl, Perthshire, exceeding 120 ft. in height.

There are a few experimental plantations of *A. concolor*, and while none are sufficiently old to have given useful yield data, the early development of some of the stands is distinctly promising. At Bedgebury, Kent, the trial plot has attained 32½ ft. in height in 20 years, with a standing volume of 1,250 Hoppus ft. and a total yield to date of 1,589 Hoppus ft. per acre. Here *A. concolor* compares favourably with the more frequently planted *A. nobilis*, but is slower in the first 20 years of its life than *A. grandis*.

A plot, described as *A. lowiana*, at Crarae, Argyll, is growing well, and at 21 years of age measures 39 ft. top height and has a mean girth of 18 in. Its height is the same as that of *Abies grandis* of equal age, but the volume is rather greater. Next to this plot is one described as *Abies concolor* which grew very similarly until recently, but now that it has closed canopy it is suffering severely from 'die-back', and appears likely to fail completely. Its height averages 23 ft. These differences are presumably due to the different provenances of the seed, the "*lowiana*" type from Oregon and California and the "*concolor*" type from Colorado, Arizona and New Mexico.

We have not sufficient evidence to determine the climatic or soil requirements of *A. concolor*, but it does not appear to be unduly demanding as regards soils—not more so than *A. grandis*. It has performed quite well in low rainfall districts, but does not appear to tolerate exposure—particularly in high rainfall districts—nearly as well as *Abies nobilis*. It may be very difficult to find a place for it distinct from that of *A. grandis*.

Little is known of its provenance attributes, but it is a reasonable assumption that the north-western part of its range (where it overlaps with *Abies grandis*) will be the most suitable source of seed for British conditions.

Abies grandis Lindley

The tree is generally referred to under its botanical name. The timber has attracted no common name as yet.

COUNTRY OF ORIGIN AND PROVENANCE

Western North America, from California through Oregon and Washington to (and including) Vancouver Island in British Columbia. Eastwards to Montana and Idaho in the centre of its range.

The provenance attributes of *A. grandis* have not been studied in Britain. The principal seed sources for the Forestry Commission have been (i) Vancouver Island, (ii) Washington—especially the foothills of the northern Cascade Mountains. These regions are considered to represent a reasonably close approach to British climate (Wood 1955). The Danes attach considerable importance to the provenance of *Abies grandis* and appear to favour the same general territory (Tillisch 1952); this author quotes German experiments in which seed sources east of the Cascades proved unsuitable. (See also Müller 1938.)

HISTORICAL NOTES

Abies grandis was discovered by Douglas on the Columbia river in 1825 and seed was sent home by him in 1830 (Harvey 1947). This seed was received by the Horticultural Society of London in 1831 but very few plants were raised (Elwes and Henry). The re-introductions by Veitch's collector William Lobb, probably from Northern California, and by Jeffrey from the Fraser river (Johnstone 1939) reached Britain in 1852 and constitute the entry of this species into continuous cultivation.

Abies grandis attracted attention as a possible forest exotic at an early date, due to its extremely fast growth in numerous arboreta. Hutchison (1883) discussed its possibilities as a timber species for Scotland, and noted that it had proved "perfectly hardy and adapted to the climate", and was also much faster in growth than the common Silver fir (*A. alba*). Henry (1915) considered *Abies grandis* decidedly the most promising of the Pacific Silver firs, and noted that on favourable sites its growth could be even faster than that of Douglas fir.

The first trial plantations of *Abies grandis* date from the latter part of the 19th century. A group of some 20 trees planted in 1888 at Inveraray, Argyllshire, may represent the oldest existing "plantation", but the two-acre plot planted in 1900 at Novar, Ross-shire, has probably had the greatest influence on the subsequent use of the tree. (Marriott 1907, Mackenzie 1937.) The history of the species as a forest exotic in Britain is, however, to all intents and purposes contained by the period since the end of the first World War in 1918.

EXTENT OF PLANTING

This is quite small at present, though it is increasing rapidly. The areas of *Abies grandis* existing in Great Britain, arranged by ownership and age class as in 1949, are shown in Table 8.

The current rate of planting is a good deal higher, something over 1,000 acres having been planted in Commission forests alone since 1949. It is probable that the area would have been considerably greater but for difficulties in obtaining seed.

CLIMATIC REQUIREMENTS

Abies grandis shows no very clear-cut climatic responses in Britain, but certain trends are noticeable. It is quite healthy over a wide range of annual precipitations and, suitably sited, may grow very satisfactorily with a mean annual rainfall of as little as 30 in. However, the tree responds to increasing rainfall, and the highest yielding stands are found in distinctly moist districts—perhaps of 40 in. or more in the north and 45 in. or more in the southern half of the country. *A. grandis* is not so demanding on moisture supply as Sitka spruce or Japanese larch amongst our more important exotics. The temperature requirements of *A. grandis* do not appear to limit its usefulness in Britain; it is not discernibly less productive in the north than in the south.

SITE REQUIREMENTS

There are certain clear restrictions to the usefulness of *Abies grandis*. It is very sensitive to exposure, and consequently its altitudinal range is in most places not great. In this it compares very unfavour-

ABIES GRANDIS: HIGH FOREST AREAS, PURE AND MIXED STANDS COMBINED, BY AGE CLASSES, 1947

TABLE 8 — Acres

	Age Class							*Uneven Aged*	*Total*
	1–10	11–20	21–30	31–40	41–60	61–80	81–100		
Private Woodlands	45	24	32	19	11	—	1	8	140
Forestry Commission	199	216	15	9	5	—	—	44	488
Total	244	240	47	28	16	—	1	52	628

ably with its American neighbour *A. nobilis*, which is most tolerant of exposure. It is ill-adapted to peat soils or to the poorest leached heathland soils. Its fertility requirements are however not fully known—they are certainly not excessive—as the tree has succeeded quite well on sites of low nutrient content, as at Bedgebury, Kent (Forestry Commission, 1955). The general impression appears to be that it is unsuited to highly calcareous soils. It has been little planted on heavy clays, and what evidence there is suggests that it will be unsuited to such soils. Like most firs it has an obvious preference for fresh moist conditions.

Its high degree of shade tolerance renders it a useful species for underplanting, and it is frequently used in the conversion of poor broadleaved types—birch scrub, oak coppice etc. Such usage automatically sites it on the better soils in upland districts, and especially on brown earths as against podzolized soils.

ESTABLISHMENT TECHNIQUE

NURSERY PRACTICE. No special measures are necessary in the preparation or manuring of seedbeds. Sowing, however (as with other *Abies* species) is best done much earlier than for the general run of conifers. Exact data are not available, but the indications are that February or early March are suitable periods (provided soil conditions are reasonable); stratification for periods up to three months may take the place of early sowing.

The seed should be covered to a depth of ½ in. with one of the standard grits. *Abies grandis* seedbeds are frequently shaded during hot summer weather, but it is not certain that this practice is essential. Mineral spirit weedkillers may be used on *Abies grandis* seedbeds, but caution is required when applying post-emergent treatments since this species is not among the most resistant conifers.

Abies grandis may be lifted and lined out as one-year seedlings, for it is the only *Abies* species which reaches usable dimensions at one year with any frequency; however, it is more commonly lifted after two years in the seedbeds. Plantable stock may be obtained after one year in the lines, but in poorer nurseries or where larger stocks are required, it is customary to leave it for two years.

VEGETATIVE PROPAGATION. This is used only in breeding work.

Grafting. The method employed for *Abies* species in general is the whip graft. This is carried out under glass in late March, potted rootstocks being used. Scions of *A. grandis* and other *Abies* species should be taken from the leading shoots of strong side branches in the upper part of the crown, as grafts from low branches often produce mis-shapen trees.

Cuttings. As with other *Abies* species, propagation by cuttings is difficult.

PLANTING. No special techniques are required. Under partial shade, take is usually fair to good. *Abies grandis* does not "check" to the same degree as other *Abies* species, but grows rapidly within a few seasons of planting.

SPACING. *Abies grandis* is usually planted at 5 ft. 6 in. spacing, but as with other species the modern tendency is to go wider. It is frequently planted at irregular spacing in the conversion of poor hardwoods or underplanting of light canopied conifers.

TENDING AND THINNING

WEEDING. No special weeding prescriptions are followed. Due to its high degree of shade tolerance, annual weedings can often be delayed till the late summer. Also overhead cover (broadleaved scrub, etc.) can be maintained for a considerable period, if desired, with consequent reduction of ground weeding. It is a common practice to ring-bark worthless hardwoods standing over *Abies grandis*.

THINNING. As with other conifers in Britain, moderate to moderately heavy low thinnings are the common practice. These commence when the crop is about 30 ft. in height. Locally, crown thinning is practised, and *Abies grandis* can easily, if desired, be brought into an irregular canopied stand at least for a period.

PRUNING. By reason of its extremely fast rate of growth, pruning has an excellent chance of proving a profitable operation with this species.

OTHER SILVICULTURAL CHARACTERISTICS

The form of the stem is good, without marked taper. Coarse dominants are not so common as in Douglas fir, and an ample selection of well-formed trees is usually available.

The litter of *Abies grandis* breaks down readily in the forest, and is relatively high in mineral contents (Ovington 1953-4). It is near to Douglas fir in this respect, and compares favourably with most conifers.

RATE OF GROWTH AND YIELD

Early growth is rapid—especially so for a species of this genus. On good quality sites the species may attain 50 ft. in 20 years. At Dunster, Somerset, *Abies grandis* is 106 ft. tall at 41 years of age. There are many fine individual specimens in arboreta, and some of these have reached extremely impressive dimensions. The tallest recorded, measured in 1955 at Leighton Hall in Wales by the Hon. Maynard Greville, has a height of 168 ft. and a breast height girth of 12 ft. 2 in. It was planted in 1888. There is no doubt that *Abies grandis* is capable of attaining

dimensions in Britain comparable with those in its native habitat, and it will certainly be represented amongst the tallest trees in Britain.

The continuation of rapid height growth in *Abies grandis* is particularly closely connected with the degree of exposure.

A provisional yield table (Lewis 1956) has recently been prepared for *Abies grandis* in Britain but not yet published. It is based on 17 permanent and 17 temporary plots well distributed over the country. Four Quality Classes are recognised, typified by rates of growth which appear likely to represent top heights at 50 years of age of 120 ft., 110 ft., 100 ft. and 90 ft. respectively. Comparing the yields of *Abies grandis* with those of Douglas fir and Sitka spruce at equivalent top heights of 110 ft., the total production of *Abies grandis* (13,890 hoppus ft. O.B.) is 810 hoppus ft. greater than that of Sitka spruce and 1,610 Hoppus ft. greater than that of Douglas fir. There is little doubt that *Abies grandis* is likely to give rise to the most productive stands of any commonly planted species in Britain.

Table 9 gives figures from the above-mentioned provisional yield table.

YIELD OF ABIES GRANDIS AT 50 YEARS OF AGE

TABLE 9 Hoppus feet per acre, over bark

Quality Class	*Top Height (ft.)*	*Main Crop*	*Cumulative Thinning Yield*	*Total Crop Yield*
I	120	7,430	8,370	15,800
II	110	6,810	7,080	13,890
III	100	6,160	5,830	11,990
IV	90	5,470	4,630	10,100

DISEASES AND PESTS

No specific diseases are known. The fungus *Rehmiellopsis bohemica*, causing a needle cast and death of shoots, has been reported on *Abies grandis*.

The seeds of *Abies grandis* are often hollowed out by the Chalcid seed flies *Megastigmus milleri*, *M. pinus*, *M. rafni* and *M. suspectus*.

OTHER FORMS OF DAMAGE

WINDBLOW. *Abies grandis* is moderately susceptible to windblow, but probably somewhat less so than Douglas fir. As a rapid growing tree planted on a relatively small scale, plantations of *Abies grandis* are apt to be outstanding objects in the general environment, and hence run an unfair risk of being thrown. It is perhaps as frequently broken by wind as actually thrown.

ATMOSPHERIC POLLUTION. *A. grandis* has no place in regions of high atmospheric pollution.

Stem crack (Day 1954) is relatively common in *Abies grandis*. It is, perhaps, a somewhat less frequent occurrence than in *Abies nobilis*.

SEED AND SEED BEARING

Abies grandis has so far been a poor seed producer in Britain. The first flowering occurs between 30 and 35 years of age and the first sizeable cone crops are produced between 40 and 45 years of age. Crops have occurred at intervals of 3 to 5 years. Flowering usually takes place in May, and the normal time for seed collection is late August or early September.

Little experience of home seed is available, only five lots having passed through the Commission Seed Laboratory. These had the same average weight as the seed imported (65 lots) during the same period—19,000 per lb., but germination capacity was very low indeed, averaging no more than 1 per cent against the imported seeds' 15 per cent.

The high proportion of 'empty' seed (in fact, resin filled) is probably due to failure of pollination, seed collection having been made from isolated trees; *Megastigmus* flies (see Diseases and Pests) also take their toll.

GENETICS AND BREEDING

The following seed sources have been registered:—'Plus' and 'Almost Plus': two stands totalling 1½ acres. Fifteen 'Plus' trees have been selected in the general programme for recording and preserving outstanding trees in Britain.

NATURAL REGENERATION

An appraisal of the possibilities is not yet possible, but a number of instances have been recorded. *Abies grandis* is one of several species which regenerate with some regularity at Bedgebury. (Forestry Commission 1955.)

TIMBER

The timber kiln seasons well, without checking, but with a slight tendency to warp and collapse. It weighs about 25 lb. per cubic foot when seasoned. It is not naturally resistant to decay.

Tests have been made on two consignments of home-grown thinnings. The results indicate that the timber has rather a low resistance to impact. It works well with machine and hand tools, but may spring badly during sawing.

Information from the home trade indicates that it has so far been used mainly for estate work. It may be regarded as a general purpose "whitewood" type of softwood except that it should not be used where it would be subjected to suddenly applied loads.

POTENTIALITIES OF THE SPECIES IN THE NATIONAL ECONOMY

Since *A. grandis* is unsuited to the poorer coniferous sites, and is further restricted due to its intolerance of exposure, it is not likely to be planted on a very large scale. Its high productivity will however encourage increasing use of the species on the better sites, particularly in the conversion of poor hardwoods and in succession (by underplanting) to Japanese and European larch. Early timber tests are sufficiently encouraging to warrant increased planting of *Abies grandis*.

Abies lasiocarpa (Hooker) Nuttall

This is the least successful of the North-west American *Abies* species. Some efforts have been made to bring it into cultivation as a plantation tree, without in fact its having distinguished itself first in the arboretum. The best specimen reported to the 1931 Conifer Conference was 106 feet tall, at Eastnor Castle, Ledbury, Hereford; this, however, appears exceptional. A plot at Benmore, Argyll, is growing well after a slow start, and is 13 ft. high at 14 years of age. A nearby plot attributed to *A. lasiocarpa* var. *arizonica* is also healthy but only averages 5 ft. in height at 12 years of age. The natural range of *A. lasiocarpa* is very great and it would be surprising were there not provenance differences of importance.

Abies magnifica A. Murray

This tree, introduced by John Jeffrey in 1851, has probably no chance of finding a place in our forests. It closely resembles *Abies nobilis* (and is frequently mistaken for it), but almost always grows more slowly. It has, however, been tried in plantation, and at Crarae, Argyll, a plot 23 years old has attained 23 feet in height with mean breast height girth of 15 in.; it appears quite healthy. *A. magnifica* forms an extremely handsome object in the arboretum, and some sizeable specimens exist. A tree 108 ft. tall at Dunkeld (measured in 1955 by A. F. Mitchell) appears to be the tallest in the country. Few others have been recorded as attaining 100 feet, and it appears improbable that it will reach the ultimate dimensions of *A. nobilis*.

Abies nobilis Lindley (*A. procera* Rehder). (Plate 2)

The name 'Noble fir' is sometimes used but less commonly than the botanical name. The timber has no common name in Britain.

COUNTRY OF ORIGIN AND PROVENANCE

A. nobilis has a fairly restricted range (in comparison with many other North-west American species) in the Cascade Mountains of Oregon and Washington. It is a tree of the higher elevations, between 2,000 ft. and 5,000 ft.

The provenance attributes of *A. nobilis* have not been studied in Britain, nor (so far as is known) elsewhere in Europe. Seed sources for use in Britain have not been delimited; the majority of the seed imported to date has come from the Cascade Mountains of Washington.

HISTORICAL NOTES

Abies nobilis was discovered by Douglas in 1825, and seed sent home by him arrived in Britain in 1831. (Harvey 1947.)

The Oregon Association obtained several consignments of seed in the 1850's through the efforts of Jeffrey, Murray and Beardsley. Certain of these importations failed to provide plants because the seed was infested with *Megastigmus pini* (Murray 1857).

Messrs. Veitch, through their collector Lobb, also imported seed in the 1850's. It quickly became a favourite ornamental tree and its distribution was facilitated by its habit of coning and producing fertile seed at an early age. (Archer and George 1859.)

Home seed, however, yielded poor progeny in many cases (probably due to self fertilisation), and this built up a certain prejudice against the collection of seed from home sources, which took some little time to dispel (Fowler 1880).

The history of the species as a plantation tree is short, and largely confined to the period since the first World War. As usual, however, a good distribution of arboretum specimens and a few pioneer plantations provided evidence for the further development of the species. Amongst notable early plantings may be mentioned those at Ardverikie,

ABIES NOBILIS: HIGH FOREST AREAS, PURE AND MIXED STANDS COMBINED, BY AGE CLASSES, 1947

TABLE 10 — Acres

	Age Class							*Uneven Aged*	*Total*
	1–10	11–20	21–30	31–40	41–60	61–80	81–120		
Private Woodlands	5	4	74	80	59	56	60	45	383
Forestry Commission	38	100	25	—	2	—	—	9	174
Total	43	104	99	80	61	56	60	54	557

Inverness-shire. Here the tree was planted by Sir John Ramsden on some scale from about 1878, and its success at elevations between 800 ft. and 1,200 ft. attracted much attention (Stirling-Maxwell 1911). It was also planted by Sir John Stirling-Maxwell at Corrour, Inverness-shire, from 1892 onwards (Stirling-Maxwell 1929). Planting of the tree as a decorative species in Scottish 'policy' woodlands in the late nineteenth century has resulted in a small number of mixed stands in which *A. nobilis* is dominant.

EXTENT OF PLANTING

This is still relatively small. In 1947 the areas by age classes in Forestry Commission and private woodlands were as shown in Table 10, page 39.

Since this date the rate of planting has increased somewhat, but over the country as a whole *Abies nobilis* accounts for much less than 1 per cent of coniferous planting. Locally, however, the species is of some importance, and it is regularly if not extensively planted in Scotland and Wales.

CLIMATIC REQUIREMENTS

While this tree (in common with most other coniferous species) exhibits no well-defined climatic limits in Britain, it does seem reasonably clear that its best development is to the north and west. Excellent individual specimens are to be found in south-eastern arboreta, but large trees are far commoner in Scotland. It is probably a species of relatively low heat requirements; it is likely also that it appreciates the low evaporation rates of the north. It is perfectly hardy to winter cold in Britain, but can be damaged by late spring frosts.

SITE REQUIREMENTS

The most useful characteristic of the species is its tolerance of exposure, which is the principal adverse factor operating at high elevations. At Beddgelert, Caernarvonshire, where *A. nobilis* is represented amongst many other species on a very exposed site at approximately 1,000 ft. elevation, it is one of the most successful species as regards freedom from blast symptoms (deformation of crown, seasonal defoliation). It is conspicuously superior to its North-west American neighbour *A. grandis* in this respect. It does not appear to be a species of high nutrient requirements, and has grown very successfully on quite poor tills and morainic deposits. It has been recorded as growing well on certain types of peat—particularly flushed amorphous peats. (Stirling-Maxwell, 1929; Zehetmayr, 1954.) (Here, however, *A. nobilis* will certainly be surpassed by several other species such as Sitka spruce and *Thuja plicata*.) It has even made some showing on the extremely infertile Bagshot beds (Eocene) at Wareham, but only with the assistance of a leguminous nurse, broom (*Sarothamnus scoparius*). Cadman (1953) regards *A. nobilis* as a species of high promise for exposed sites in the Welsh mountains, where nothing to date has been found more resistant than Sitka spruce. He also notes that the moisture requirements of *A. nobilis* appear to be less than those of Sitka spruce.

ESTABLISHMENT TECHNIQUE

NURSERY PRACTICE. There is little to distinguish *A. nobilis* from *A. grandis* in seedbed technique. It rarely, however, attains 'usable' dimensions in one year in the seedbed, and is commonly lifted as a two-year-old seedling. It usually remains in the transplant lines for a further two years; it is intolerant of moving and makes little growth the first year after transplanting.

VEGETATIVE PROPAGATION. This is only practised in the propagation of desirable individuals or horticultural varieties.

Grafting. The method employed is that described for *Abies grandis*. It has been recognised for some time that *A. alba* is not a good rootstock for *A. nobilis* because of the extremely rapid early diameter growth of the latter.

Cuttings. Propagation by cuttings from young trees used to be practised in the mid-nineteenth century, but is not an easy method.

PLANTING. No special planting techniques have been developed for *A. nobilis*. Like *A. grandis* and *Tsuga heterophylla*, it is often planted under partial cover (oak or birch scrub). The take is usually better under such conditions, but it is not nearly so shade tolerant as the aforementioned species and the only benefit is in initial survival.

SPACING. In pure plantations *A. nobilis* is usually planted at 5 ft. 6 in. spacing; on highly exposed sites a closer spacing may be adopted.

TENDING AND THINNING

TENDING. *A. nobilis* is slow in starting to make height growth, and weeding may be prolonged. It is particularly sensitive to the competition of the common heather (*Calluna vulgaris*), and control of heather, by mulching, cultivation, etc., is highly beneficial.

THINNING—is usually carried out to a moderate or moderately heavy low grade. A noticeable feature of young stands of *A. nobilis* is the marked irregularity of height and diameter growth. It is desirable to pay early and close attention to the distribution of dominants in this species. Some predominants may be very coarse, more markedly so than in *Abies grandis*.

PRUNING—is not regularly practised, but there is probably a good case for it to obtain clear material for box making.

TABLE 11 ABIES NOBILIS: GROWTH AND PRODUCTION

Locality	*Elevation* ft.	*Age* yrs.	*Top Ht.* ft.	*Mean Girth Breast Ht.* in.	*Volume Per Acre Hopp. ft. over Bark*	*Total Volume Production Per Acre Hopp. ft. over Bark*
Temporary Plots						
Alltcailleach, Aberdeen	850	22	38	20	1,927	—
Loch Eck, Argyll	300	24	39	23½	2,660	—
Glen Branter, Argyll	300	24	49	21	3,311	—
Glen Finart, Argyll	50	24	40	16½	1,747	—
Benmore, Argyll	100	25	47	23	3,809	—
Glen Urquhart, Inverness	800	26	44	21	3,744	—
Drumtochty, Kincardine	450	26	42	19½	2,875	—
Ardgoil, Argyll	100	26	42	20½	2,478	—
Douglas, Lanark	680	27	52	21	3,960	—
Radnor, Radnor	1,250—1,500	27	44	24½	3,074	—
Baledmund, Perth	900	28	47	19½	3,630	—
Barcaldine, Argyll	75	28	43	15	2,338	—
Dovey, Merioneth	400	28	40	17½	2,260	—
Loch Eck, Argyll	120	29	46	27	2,471	—
Monreith, Wigtown	100	31	59	28½	6,508	—
Balcarres, Fife	300	42	65	27½	7,806	—
Lynedoch, Perth	240	45	79	50	9,210	—
Permanent Plots						
Durris, Kincardine	300	33	57½	20½	5,066	6,001
Benmore, Argyll	300	28	54	23½	3,758	5,022
Ratagan, Inverness	550	22	37	18½	2,907	3,515
Gwydyr, Caernarvon	250	28	43	20½	2,752	3,119
Bedgebury, Kent	300	25	33	15½	1,609	1,899

OTHER SILVICULTURAL CHARACTERISTICS

The upper part of the stem of *Abies nobilis* tapers more markedly than that of most conifers.

Tolerance of shade has been mentioned above; the species under British conditions appears to be distinctly less tolerant than *Abies grandis*. Experience in the cultivation of *A. nobilis* in mixture is limited; its slow early development renders it unsuitable for intimate mixtures; it is probably better to plant it in groups.

RATE OF GROWTH AND YIELD

The tree always grows slowly for a few seasons after planting. When established, however, *Abies nobilis* is by no means slow. At Beddgelert (Y Gyrn Forest Garden) under conditions not untypical of those for which *Abies nobilis* would be prescribed today, a small plot averaged 32 ft. in height at 26 years of age, and was growing at the rate of 20 in. per annum. Elevation here is 1,000 ft., rainfall about 100 in. per annum, and the site is very exposed. The soil is a stony till of no great depth. (Nearby on a deep peat *A. nobilis* has taken 24 years to reach 11 ft., but remains healthy.) Similar rates of growth are recorded for the pioneer plantations at Ardverikie, Inverness-shire (Stirling-Maxwell, 1911) where the tree averaged 15 in. per year for the first 30 years on land between 800 ft. and 1,200 ft. elevation. Under exposed and elevated conditions *A. nobilis* may often grow as fast as any other species, including Sitka spruce. On sites more generally favourable, however, it is likely to be surpassed by such species as Douglas fir or *Abies grandis* in rapidity of height growth.

Yield tables for *Abies nobilis* in Britain have not yet been prepared. Data are available from five permanent and seventeen temporary plots and these are summarised in Table 11.

Abies nobilis appears to be a high yielding species. At equivalent heights its volume production seems likely to resemble that of the top two (British) Quality Classes of Douglas fir. With top height 50 ft., a total volume production of 4,500 Hoppus ft. may be expected.

No measurements of crops 50 or more years old are available. There are, however, numerous records of older individual trees, many of which exceed 100 ft. in height. Exceptionally fine trees are those at Duncraig Castle, Ross-shire, and Inveraray, Argyll. The former was 148 ft. tall in 1952, with breast height girth 11 ft.; the latter in 1954 measured 147 ft. in height with breast girth 10 ft. 1 in. This tree is recorded as having been planted in 1873.

The appearance of the larger trees does not suggest that many will greatly exceed 150 ft. in height in

Britain. A very common occurrence is the loss of the leader following heavy cone bearing.

DISEASES AND PESTS

No specific diseases are known. The fungus *Rehmiellopsis bohemica*, causing a needle cast and death of shoots, has been reported from Corrour, Inverness-shire.

The seeds of *A. nobilis* are hollowed out by the Chalcid fly *Megastigmus pinus* (Hussey 1954). This is of some importance in reducing the yield of viable seed. *A. nobilis* appears resistant to the attacks of *Adelges nüsslini*, the serious pest of *A. alba* (Varty 1956).

OTHER FORMS OF DAMAGE

WINDBLOW. *A. nobilis* is considered a moderately windfirm species; the evidence so far suggests (at least) that it may be above the average in this respect.

It is very resistant to snow damage and was particularly free from injury in the severe glazed frost of 1940. (Sanzen-Baker and Nimmo 1941.)

Stem crack of the type ascribed by Day (1954) to drought is a common phenomenon. Such cracks often bear witness to markedly spiral grain. The vigour of the tree seems to be quite unimpaired.

ATMOSPHERIC POLLUTION. In common with the rest of the genus *A. nobilis* is highly susceptible to atmospheric pollution in industrial neighbourhoods.

SEED AND SEED-BEARING

A. nobilis is probably the best seed producer of the *Abies* species commonly planted in Britain. Flowering begins between the 25th and 30th years, and the first worthwhile cone crops are obtained between the 30th and 35th years. Good cone crops are produced at approximately three year intervals. (Matthews 1955). The normal time for cone collection is late August or early September.

Home collected seed has been on average of poorer quality than imported seed. Table 12 briefly summarises experience in the Commission Seed Testing Laboratory.

In some years home seed has been very heavily infested by *Megastigmus* seed flies.

ABIES NOBILIS: SEED TESTING

TABLE 12

	No. of Samples Tested	*Average No. of Seeds Per Lb.*	*Average Germination Capacity*
Home	65	16,000	13%
Imported	45	13,000	22%

GENETICS AND BREEDING

The following seed sources have been registered: "Plus" and "Almost Plus"—1 stand of 10 acres; "Normal"—2 stands totalling 2 acres. Sixteen "Plus" trees have been selected in the general programme for the preservation of outstanding trees in Britain.

NATURAL REGENERATION

The regularity and freedom of coning certainly offers a chance of securing regeneration by natural means. At Ardverikie, Inverness-shire (one of the pioneer sites of the species) quite prolific regeneration occurred around isolated trees, and seedlings were lifted in considerable numbers for lining-out in the nursery. (Anderson 1928.)

TIMBER

No tests have been carried out on this species. According to information received from the home timber trade, the timber air seasons quickly, is not durable, but works well with machine and hand tools giving a good finish.

It has mainly been used for estate work, but has been supplied sawn to the building trade for carcassing and for roof boarding.

It may be regarded as a general purpose "whitewood" type of softwood.

An interesting side-line has been the export of green branches to Iceland for the making of wreaths! (Watson, 1948.)

POTENTIALITIES IN THE NATIONAL ECONOMY

It seems probable that this species will be planted to an increasing extent, without at any time becoming one of the first ten exotic conifers in Britain. It appears to be finding a real place in our silviculture in the Scottish and Welsh hills and may perhaps replace Sitka spruce on some of the drier sites at present planted with that species, particularly where exposure is an important factor.

Abies nordmanniana (Steven) Spach

This Caucasian species was introduced to Western Europe in 1848. There is some doubt as to the date when it reached Britain. It is, of course, a much more recent arrival than the related *Abies alba*. *A. nordmanniana* is a tree which impresses as an individual specimen in many collections. There are numerous records of trees exceeding 100 ft. in height, and it appears to be without marked climatic preferences. Nor are its soil requirements easily defined. In spite of the fact that the tree has been well spoken of for many years, there appear to have been few trial plantations, though it was planted in some quantity in mixture at Benmore, Argyll, in the 1870's (Stalker 1883). Possibly this comparatively late

European arrival has suffered from the keen interest paid to the North-West American firs, *A. nobilis*, *A. grandis* and *A. concolor*, which are faster growing species. The important question with *A. nordmanniana*, however, is whether it will prove an adequate replacement for the silviculturally valuable *A. alba* now almost lost to us due to *Adelges nüsslini*.

N. D. G. James (1951) describes a trial plantation of *A. nordmanniana* at Cirencester, Glos., growing on shallow soils over the (calcareous) Great Oolite formation, the local precipitation being approximately 35 in. The stand was established by underplanting larch and *Robinia pseudoacacia*, the overwood being later removed. He gives the following data for the fir at an age of 43 years: 994 stems per acre, 49¼ ft. top ht., 23 in. girth at breast height, 230 ft. (Hoppus) basal area per acre, and 4,070 Hoppus ft. per acre volume. The volume is similar to that of an adjacent stand of *Thuja plicata*.

A 21-year-old plot at Benmore, Argyll, averages 19½ ft. in height, and there is a recently established trial plot of *A. nordmanniana* at Bedgebury, Kent.

Abies pinsapo Boissier

This fir was introduced from Spain by Widdrington in 1839, but has scarcely emerged from the arboretum. It is an interesting tree in that it appears to belong to the relatively small group of coniferous species adapted to calcareous soils. It is also well suited to the drier and warmer parts of the country. Common in arboreta, it never reaches large dimensions (90 ft. seems to be about its limit) and it frequently displays poor stem form often with multiple leaders. One of the few plantations of the tree is a large group at Lilford Hall, in Northamptonshire, and there is also a plot of some 50 trees at Crarae, Argyll, which averaged 13 ft. in height after 20 years.

Particularly good specimens of the tree are to be seen at Westonbirt in Gloucestershire and Rhinefield Drive (New Forest), Hampshire; measured in 1956 and 1955 respectively these trees had attained 90 ft. and 91 ft.

Abies veitchii Lindley

This is a relatively recent introduction from Japan (by Maries in 1879). It now appears to be the easiest of the Japanese firs in cultivation in Britain. It seems relatively resistant to spring frost, and healthy specimens are to be seen in most parts of the country. Arboretum records suggest that it will attain its best development in the west and north, in fact it already appears to have reached dimensions comparable to those given for its native habitat. A. Mitchell records trees 71 ft. tall at Blairquhan, Ayrshire (1956) and Murthly, Perthshire (1955), the latter planted (it is thought) in 1885.

A plantation made at Crarae, Argyll in 1939 is growing very vigorously. At 16 years of age the trees ranged in height from 15 ft. to 30 ft. At Windsor, Berkshire, a plantation 14 years of age is approximately 25 ft. tall, and the tree appears equally healthy in this much drier climate.

Small groups of *A. veitchii* have been planted at Beddgelert and Gwydyr in North Wales and a plantation was established in the Bedgebury Forest Plots in 1949. *A. veitchii* cones freely and produces viable seed in Britain.

R.F.W.

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Agathis (Lambert) Steudel

No tree belonging to this genus will develop in Great Britain out-of-doors and it is mentioned only because individuals of *Agathis australis*, which was introduced in 1823, are occasionally found in gardens and arboreta in the mildest parts of the country. They rarely reach more than 10 or 12 feet in height.

This and several other species are grown successfully under glass in Botanic Gardens.

J.M.

Araucaria Jussieu

With one exception, species of the genus *Araucaria* are not hardy in Great Britain. Trees such as *A. bidwillii* and *A. cunninghamii* have reached a good size and have survived for many years in the Temperate House at Kew and these and other species may be found under glass in various parts of the country in Botanic Gardens. *Araucaria excelsa*, the Norfolk Island Pine, is not uncommon as a pot-plant in houses, shops, etc., while in the extreme south-west of England it occasionally survives out-of-doors. The best examples are at Tresco Abbey in the Scilly Isles where there is an avenue of trees of this species (Hill 1920) which have succeeded moderately well where the exposure is not too great. One of these trees, measured in 1952 by D. F. Fourt, had reached a height of 40 feet and had a girth of 5 ft. 4 in. At Tresco there is also a small specimen of *A. angustifolia*, from Brazil, growing in the open air. The only member of the genus, really hardy in Great Britain is *Araucaria araucana*.

Araucaria araucana (Molina) K. Koch (Plate 1)

This remarkable tree, commonly known as the Monkey Puzzle, was introduced shortly after 1795, when Archibald Menzies presented to Sir Joseph Banks a few plants which he had raised on board ship from seeds obtained in that year in Chile. One of these plants survived at Kew until 1892 when it died (Anon. 1893). The principal introduction was effected by William Lobb in 1844 and after that time the tree became widely distributed all over Great Britain. Although a few plantations of the species were formed it was used mainly for ornamental purposes, as specimen trees or in avenues. There is no doubt that on a suitable site, and given ample room, the Monkey Puzzle can be a most impressive tree; but current standards of taste condemn it and it must therefore languish unused until the wheel turns and it comes back into fashion once more.

A. araucana does not seem to be able to reach any great height under our conditions and not many trees exceed 80 feet. The tallest trees of which we have record occur chiefly in the west and south-west as for example, at Bicton, Devon, 84 ft., Westonbirt, Gloucestershire, 82 ft., Lochnaw, Wigtown, 84 ft., Blairquhan, Ayrshire, 81 ft.; it is almost certain that the heights ultimately reached by Monkey Puzzles in the milder parts of the country exceed those which are possible in the east and north-east.

Araucaria araucana does not grow rapidly in height with us and it is unlikely to average as much as a foot in annual height growth throughout its life. It also tends to be a slow starter and it may make very little growth for some years after it has been planted. Its girth increment, however, is satisfactory

and it may reach ten or twelve feet in circumference by the time it is approaching a hundred years of age.

There are indications that *A. araucana* is not a long-lived tree in Great Britain and that individuals will not survive for much more than a century. It is true that the well-known avenue trees at Bicton, now more than a hundred years old, are still reasonably healthy; but there is evidence from other parts of the country of a gradual and sometimes rapid deterioration round about that age, of the death of the lower branches, and of the slow disappearance of the live crown. A recent illustration of this has been reported by Williams-Ellis (1956) who described the ruins of a plantation of *Araucaria* formed just over a century ago at Portmeirion in North Wales. His photograph showed trees with lower branches all dead and with small flattened crowns which were gradually being eaten into by the death of their lower members.

Araucaria appears to withstand exposure well in Great Britain but it does not seem to have been used to provide shelter although the Forestry Commission have recently planted a small quantity experimentally for this purpose on the Lizard Peninsula in Cornwall. We do not know whether it would mix well with other trees but we presume that it would not.

Established trees of *A. araucana* appear to be quite hardy and able to withstand low temperature in winter as well as severe late spring frosts. Dallimore (1948), however, mentions that at Bedgebury several young trees, six feet high, were killed to ground level by a temperature of —15°F. in January 1940 and, later, sprang again from coppice shoots.

Very few plantations of Monkey Puzzle have been made and there are measurements for only one, a small plantation at Monreith in Wigtownshire which extends to 1.7 acres. This crop is now approximately 40 years old and a measurement made recently (1956) showed the mean height of the trees to be 25½ ft., the mean breast-height girth 31 in.; and the mean volume per tree 6 cubic ft. Hoppus measure. There were 415 trees per acre and the estimated volume standing per acre was 2,500 Hoppus ft.

In this plantation there is a considerable range in height over the individual trees, for although the average height of the crop was 25½ ft. the tallest tree was 36 ft. Irregularity seems to be a feature of crops of Monkey Puzzle to judge by what little evidence is available in Great Britain, irregularity not only in height growth but in habit and general development. There has been some speculation as to whether trees of different sex have different habits of growth (Elwes and Henry) but there seems to be no agreement among the authorities on this point.

Where male and female trees are in proximity, cones are produced in most years by the females and seed production is reasonably good. Seed was being produced in England in the eighteen-seventies by trees of Lobb's introduction of 1844, while it is reported (Hadfield 1956) that in 1872 between 8 and 10 bushels of seed were yielded by the fifty trees in the avenue at Bicton. Seedlings occasionally appear at some distance from any possible parent tree and it is assumed that they are spread by birds. Our home produced seed is generally of good quality and if stratified in moist peat for three or four months at a temperature of 36°F., it germinates well after sowing. It does not present any difficulty in the nursery.

In November 1951, 19 lb. of seed was collected at Tortworth in Gloucestershire, divided into three lots and stored at 36°F. in the following different ways.

(a) stratified in moist peat,
(b) stratified in dry peat,
(c) stored dry in a sealed container.

After storage for four months, the seed was sown with the results shown in Table 13.

J.M.

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TABLE 13 ARAUCARIA ARAUCANA: SEED TESTS

Treatment	*Number of seeds per lb.*	*Number of Viable (1) Seeds per lb.*	*Production of one yr. Seedlings per lb.*	*Germination survival (2) factor*	*Mean height of one yr. Seedlings in.*
A	125	115	88	.77	2.36
B	125	115	39	.34	2.35
C	125	115	58	.50	1.59

Notes: (1) By tetrazolium test.
(2) Germination survival factor = $\frac{\text{Total seedling production per lb.}}{\text{Number of viable seeds per lb.}}$

Athrotaxis Don

Athrotaxis cupressoides and *A. laxifolia* are met with occasionally in shrubberies and arboreta but *A. selaginoides* is not often seen. None of them will ever be of economic value in Great Britain. According to Dallimore and Jackson, *A. laxifolia* has been known to reach a height of 46 feet in Cornwall, but this is exceptional and specimens of this genus generally do not reach half that height.

J.M.

Callitris Ventenat

Although specimens of one or other of the species of *Callitris* may occasionally be found in gardens in the mildest parts of Great Britain, plants of this genus are usually seen only under glass in this country. Under British conditions *Callitris* is much too tender for use outdoors.

J.M.

Cedrus Trew

Cedars are familiar trees, particularly in the southern parts of Great Britain, where they have long been used for ornamental planting rather than forestry. The cedar of Lebanon (*C. libani*), the Atlas cedar (*C. atlantica*) and the deodar (*C. deodara*) have all been extensively used; the Cyprus cedar (*C. brevifolia*) is rarely seen.

Cedrus atlantica Manetti

The Atlas cedar, when well grown and given ample space in the right setting, is an extremely handsome tree, particularly in its glaucous variety, and there are, fortunately, many fine specimens now to be seen. A native of the Atlas Mountains in North Africa, it is of interest as being almost the only tree from that continent which flourishes in the British Isles. It was introduced in 1845.

Cedrus atlantica has scarcely been used in forestry but one or two trial plantations have been made. At Gravetye, in Sussex, a plot 52 years of age had a top height of 72½ ft., a mean girth at breast height of 50 in., and a volume per acre of 5,500 Hoppus ft. The total volume production was 6,860 ft., giving a mean annual increment of 132 Hoppus ft. per acre. The periodic annual increment between the ages of 46 and 52 years was 256 Hoppus ft. per acre. At Bedgebury a plot of this species had reached a height of 20½ ft. at 20 years while at Buriton, Hampshire, on the chalk, another plantation of the same age had attained only 12 ft. There would appear to be a reasonable prospect that the Atlas cedar would make a productive crop on good sites in the South of England but it is a tree which obviously starts slowly, becoming more vigorous only later. Cones are regularly produced in Great Britain but the quality of the seed is low and inferior to that of imported seed. In our climate, the cones are very difficult to open and no really satisfactory method for dealing with them has yet been devised. The seed germinates well under normal conditions. It is difficult to keep because it deteriorates rapidly in storage, and it has been suggested that it might be stored in the cones; its keeping qualities have not been tested in cold storage. Few specimens of *Cedrus atlantica* in Great Britain exceed 100 ft. in height, the tallest recently measured being two at Eastnor Castle, Hereford, 119 ft. and 117 ft. respectively. Other trees over 100 ft. in height are to be found at Cuffnells, Lyndhurst, Hampshire, 109 ft.; Beauport, Sussex, 110 ft.; and Westonbirt, Gloucestershire, 104 ft.

Cedrus deodara (Roxburgh) Loudon (Plates 3 & 17)

The deodar was introduced into Great Britain from India during the period 1820-1830, but there is some doubt as to the actual year in which the first introduction was made.

As a forest tree, *C. deodara* is little used in Great Britain and there are few plantations now available for study, but during the middle of the nineteenth century, it had a small vogue in the Royal Forests. The Commissioners of Woods and Forests began importing substantial quantities of seed in 1853, which they obtained from the East India Company, and in subsequent years, many deodars were planted in the Royal Forests in the South of England (Commissioners of Woods 1853). Some of these still survive as individual trees in the oak woods at Alice Holt, and also in the New Forest, but the experiment does not seem to have succeeded and it was not pursued. Among existing plantations from which figures of growth and production are available, is a plot in Bagley Wood, near Oxford, which, at 45 years of age, had a top height of 62½ feet, a mean girth of 28 inches and a standing volume of 3,665 Hoppus feet per acre. The total volume production of this deodar crop was 5,918 Hoppus feet, which gave a mean annual increment of 132 Hoppus feet per acre. The periodic mean annual increment between 35 and 40 years of age was 225 Hoppus feet per acre, and between 40 and 45 years, 146 Hoppus feet.

A small plot at Abbotswood, in the Forest of Dean, aged 35 years, had a top height of 65 feet, a mean girth at breast height of 30½ inches, and a volume per acre of 2,006 feet. At Bedgebury, in Kent, an irregular plantation, 20 years old, averaged only 11½ feet in height, but at Crarae, in Argyll, a 21-year-old crop had a top height of 27 feet and a mean girth of 13½ inches. There is the suggestion, in these figures, that *C. deodara* may grow more rapidly in height in the moister, milder western districts—but this is, as yet, by no means clear. Like *C. atlantica* this species has shown that it can grow in plantation form in Great Britain, but it is doubtful whether

either of these cedars has any prospect of being used other than in a very small way.

There are numerous good specimen trees of *C. deodara* in the country but, generally speaking, it does not seem to have yet reached as large dimensions as the other cedars commonly planted. Among some of the tallest trees are specimens at Eastnor Castle, 110 and 109 feet, Bicton, Devon, 103 feet and Stanage Park, Radnor, 105 feet.

Cedrus libani Loudon

This tree has been grown in Great Britain at least since the seventeenth century and there are numerous fine specimens, particularly in southern districts. It is an impressive tree when well grown and can be a great ornament to a park.

It has not been used in forestry and, so far as can be determined, there are no trial plantations.

Among specimen trees of which recent measurements have been taken are individuals at Albury Park, Surrey, 117 feet, Cobham Hall, Kent, 117 feet, Leaton Knolls, Shropshire, 114 feet, Park Place, Henley, Oxfordshire, 112 feet, and Brahan, Ross-shire, 104 feet. Some of the cedars of Lebanon have large girths, for example, 27 feet 4 inches at Cobham Hall, 26 feet at Terling Place, Essex, and 24 feet 7 inches at Warwick Castle.

J.M.

CEDRUS: REFERENCE

Commissioners of Her Majesty's Woods, Forests and Land Revenues, 1853: Thirty-first Report.

Chamaecyparis Spach

Of the six species which make up this genus, only one, *C. formosensis*, a native of Formosa, is not hardy in Great Britain, although occasional specimens have survived for a short time in the open air. Of the others, *C. lawsoniana*, from Western North America, is of forest importance in this country, while *C. nootkatensis*, from the same region, though much less important, is a tree which may yet find a small place in our silviculture. The two Japanese species, *C. obtusa* and *C. pisifera*, have been little used in the forest, and, in view of the better performance of *C. lawsoniana*, are unlikely ever to find a regular place as forest trees. *C. thyoides*, a native of the Eastern and South-eastern United States and the first of the genus to be introduced, has rarely succeeded when planted in Great Britain; so far as is known, it has never been used in the forest.

This genus, which is thus of limited silvicultural importance, is nevertheless of the greatest consequence in horticulture because a characteristic of *C. lawsoniana*, *C. obtusa*, *C. pisifera*, and, to a less extent, of *C. thyoides* and *C. nootkatensis*, is their extraordinary capacity for varying under cultivation and producing an astonishing number of forms and varieties. Variations in colour, in habit, in type of foliage and branching are common, while *C. pisifera* produces some well-known varieties, the "*Retinosporas*", the main characteristic of which is the retention, throughout their lives, of the juvenile type of foliage.

Although some of these varieties of the *Chamaecyparis* species are more curious than beautiful, many are extremely handsome and well worth the attention they receive. It is unlikely that interest in them will decline.

Chamaecyparis lawsoniana (A. Murray) Parlatore

This tree is generally referred to as Lawson cypress. The timber grown in Great Britain has scarcely come into commerce and it has no trade name.

COUNTRY OF ORIGIN AND PROVENANCE

A native of Western North America, Lawson cypress is found naturally in the forests of south-western Oregon and north-western California in the coastal region and at elevations mainly below 3,000 feet (Elwes and Henry).

No studies of the provenance of Lawson cypress have been made in Great Britain. Owing to abundant seed production of trees in this country, it is rarely necessary to import seed from America for forestry and horticultural purposes.

HISTORICAL NOTES

This tree was first introduced in 1854 by William Murray, whose first consignment of seed, from the Upper Sacramento Valley in California, was sent to Messrs. Lawson, the seedsmen, of Edinburgh. A larger introduction followed in 1855, and very soon afterwards Lawson cypress became popular and well distributed in parks and gardens. It did not appear to be tried as a forest tree until some considerable time later.

The remarkable tendency to vary in cultivation, which has been referred to, led to the selection of a large number of varieties, the best of which have been kept in existence by vegetative propagation. The standard work *Handbook of the Coniferae*, by Dallimore and Jackson, lists over fifty varieties and there are doubtless many more. Lawson cypress is also a favourite tree for garden hedges as it clips well and keeps its shape.

EXTENT OF PLANTING

At present, Lawson cypress is one of the minor coniferous species and there are few signs of much interest in its possibilities. Table 14 shows the areas under this species recorded during the Census of Woodlands 1947-49. Since then, a small amount of planting has been done annually and the area increased, but not to any important extent.

CHAMAECYPARIS LAWSONIANA: HIGH FOREST AREAS, PURE AND MIXED STANDS COMBINED, BY AGE CLASSES, 1947

TABLE 14

Acres

	Age Class							Uneven Aged	Total
	1–10	11–20	21–30	31–40	41–60	61–80	81–120		
Private Woodlands	25	10	11	50	17	19	2	83	217
Forestry Commission	472	69	2	4	1	—	—	30	578
Total	497	79	13	54	18	19	2	113	795

It will be noted that most of the planting in recent years is in the forests of the Forestry Commission.

CLIMATIC REQUIREMENTS

There is scarcely any part of the populated districts of Great Britain where one cannot find a specimen of Lawson cypress, but its altitudinal limits have not yet been determined. Generally it seems to grow better in the western, moister parts of the country. There are suggestions that it may grow faster in regions of higher temperature; but this is by no means certain, and the evidence which we have shows it to be quite productive in the north. We have little to guide us, in plantations, about the resistance to exposure shown by this species, but in some exposed situations it has shown less resistance than several other species. Low temperatures in winter do not harm this tree, but it is sometimes damaged by frosts in the spring, all the foliage turning brown and shoots and buds dying (Day and Peace, 1937). It shows good powers of recovery from frost damage.

SITE REQUIREMENTS

Lawson cypress has been tried as a first crop on a number of sites with varying degrees of success. It failed on the Lon Mor, Inchnacardoch, Inverness-shire, on a deep *Trichophorum* (*Scirpus*) peat, only a few plants surviving to reach a height of two to four feet in twenty years (Zehetmayr 1954). At Beddgelert, Caernarvonshire, on a less difficult *Eriophorum-Molinia* peat, it reached 21 feet in height 25 years after planting; at Kielder, Northumberland, on a *Molinia-Calluna* peat it has reached 11 feet after 16 years, and appears to be quite healthy. On a dry upland heath over the Jurassic at Allerston in Yorkshire, Lawson cypress planted on ploughed ground in 1939, grew very badly, even when phosphate was applied at the time of planting, and the young trees went seriously into check. In 1945, a mulch of cut heather was applied to half the plantation, and this was effective in bringing the plants out of check and enabling them to grow. The effect of the mulch was investigated by Leyton (1955) who found that mulching had increased the uptake of nitrogen and phosphate and had led to improved soil moisture conditions, a matter of importance on a dry site. At Wareham in Dorset, on a strongly podzolized lowland heath, Lawson cypress similarly went into check after planting and, similarly, showed a response to mulching. On the other hand, on a high-lying, exposed heath near Bodmin, in the south-west of England, Lawson cypress has established itself in a vegetation of *Calluna*, *Ulex gallii* and *Molinia*, where Sitka spruce has checked very badly (Grant, 1948). On a heavy clay soil, in Rockingham forest, Northamptonshire, Lawson cypress has been used experimentally as a first crop on old arable land and on old woodland after it had been clear cut. On both sites it has grown slowly but satisfactorily, reaching 18 ft. in height in 23 years. As a first crop, Lawson cypress is unsuitable for the poorer peats and for the dry type of heath, although it appears likely to succeed on the moister heathlands of the west and south-west. It establishes itself readily on brown earth soils but grows slowly on the heavy clays. We have little evidence as to its behaviour on the highly calcareous soils of the chalk.

As it stands shade well, this species can be used for underplanting other conifers or for bringing in under hardwood scrub. It was also one of the shade-bearing trees used at Novar, Ross-shire, for introducing into larch plantations (Anon. 1906) in the early years of this century.

ESTABLISHMENT TECHNIQUE

NURSERY PRACTICE. *C. lawsoniana* is not a difficult subject in the nursery and normal nursery treatment is adequate. Seed is usually sown broadcast at 40 sq. yd. per pound, and a light covering of sand or grit is satisfactory. Stocks raised in heathland nurseries are usually large enough to lift at the end of the first growing season; in other nurseries, they may have to run to two years before they are large enough to handle. Losses in lining-out are not usually high and no special precautions are needed.

VEGETATIVE PROPAGATION. This is not used in raising nursery stocks for planting in the forest but is important in horticulture.

PLANTING. Lawson cypress is not difficult and the standard methods are satisfactory.

SPACING. Lawson cypress is usually spaced at 4½ ft. or 5 ft.

TENDING AND THINNING

WEEDING. Normal weeding treatments are all that are necessary. If the cypress has been used for underplanting it will stand quite happily under moderately dense shade, though it will not grow much. Cleanings are not often required because the dense shade cast by the cypress, generally suppresses weed trees and shrubs which have come into the plantation.

THINNING. The correct regime has not yet been worked out but to thin Lawson cypress is slightly disconcerting. Each tree which is removed leaves a neat hole in the canopy and these holes do not close over quickly because crown spread is slow. Lawson cypress seems to be sluggish in its responses and it may be run on a longer thinning cycle than most conifers.

PRUNING. Pruning is not usually practicable. It might prove a costly operation owing to the numerous small branches on the stem. Natural pruning is very slow, for green branches may be found quite low on the stem, even when the canopy appears to have just closed.

OTHER SILVICULTURAL CHARACTERISTICS

One unpleasant feature of Lawson cypress, repeatedly found, is the forking of the stem which often begins below breast height and may be repeated higher up the stem. The cause is still unknown. Although one might not expect that crowding trees of an extremely shade-bearing species would be effective in reducing the number of forks materially, it has been found, in a spacing experiment at Rheola, in South Wales, that the more widely-spaced plots had a much smaller proportion of trees without forks, than the plots where the trees had been planted close together. For example, with 3 ft. spacing, 70 per cent of the trees were without low forks; whereas with 8 ft. spacing, only 40 per cent were free from this defect. This record relates only to trees forking below breast-height.

RATE OF GROWTH AND YIELD

There is no yield table for Lawson cypress in Great Britain. A few permanent sample plots have been established and maintained and measurements have also been collected in several small plantations. Data from those measurements are given in Table 15.

Height growth in Lawson cypress is not rapid, for heights of just over 60 feet at 50 years are poor when compared with those of other exotic conifers from Western North America. On the other hand, volume for a given height tends to be high; this is due to the generally dense stocking in plantations of this species. Its narrow, columnar crown, and its tolerance of shade allow much denser stocking than can be kept with most other species.

Individual specimen trees are not often found with heights greater than 100 feet but trees of 80 to 100 feet high are common. Among the tallest specimens recently recorded are trees at Inveraray, Argyll, 102 ft. by 11 ft. 9 in. at breast height and 102 ft. by 9 ft. girth; 100 ft. by 7 ft. 7 in. at Murthly, Perthshire; 100 ft. by 12 ft. 7 in. in the New Forest, Hampshire; 99 ft. at Blair Castle, Perthshire, Buchanan Castle, Stirlingshire and Kirkennan, Kirkcudbrightshire; and 98 ft. at Muncaster, Cumberland.

DISEASES AND PESTS

Lawson cypress has not suffered from any specific disease since its introduction and it is generally remarkably healthy in appearance. No insect attacks have been reported except for damage caused in a dense young crop of natural seedlings in the Forest of Dean by the weevil *Otiorrhynchus singularis* L.

TABLE 15 CHAMAECYPARIS LAWSONIANA: GROWTH AND PRODUCTION

Locality	*Elevation (ft.)*	*Age (yrs.)*	*Top Height (ft.)*	*Mean Girth (in.)*	*Volume per acre (h. ft. over bark)*	*Total Production (h. ft. over bark)*
Caio, Carmarthen	800	16	20½	14	1,198	—
Thornthwaite, Cumberland	650	19	27	17	1,648	—
Llanover, Monmouth	700	21	28	14½	1,066	—
Inchnacardoch, Inverness	200	21	34	13½	1,463	—
Gwydyr, Caernarvonshire	400	23	45	20	3,127	4,376
Bedgebury, Kent	300	25	39½	18	2,184	3,117
Ardgartan, Argyll	50	27	32	19	2,073	—
New Forest, Hants.	140	31	48	22½	2,543	—
Chopwell, Durham	700	45	42½	23	2,397	—
Petworth, Sussex	200	47	62½	26	4,819	—
Novar, Ross-shire	250	51	61½	28	5,517	11,778
Atholl, Perthshire	800	54	61	24½	3,555	—

Trees in the small pole stage are sometimes damaged by deer which rub the stems.

OTHER FORMS OF DAMAGE

WIND. There are scarcely enough plantations on which to base a judgment on the susceptibility of Lawson cypress to windblow. One sample plot, at Novar in Ross-shire, blew down in the great gale of January 1953, but on this occasion the Lawson fared no worse than most other species. Isolated trees, of which there are large numbers in the country, seem to be windfirm, for they rarely blow down although they occasionally break in wind, particularly if they are forked. The probability is that this species will be windfirm on most soils.

SNOW. There is one record of damage to a plantation, in the Forest of Dean, by heavy wet snow which laid flat most of a plantation almost forty years old. We do not know whether this was an exceptional case or whether other plantations will suffer in the same way.

ICE. Lawson cypress was little damaged by the severe glazed frost of 1940 (Sanzen-Baker and Nimmo 1941). Its habit of growth probably allows it to recover quickly from the effects of a phenomenon of this sort.

ATMOSPHERIC POLLUTION. This tree will tolerate a moderate amount of pollution such as is found on the outskirts of cities and large towns, but it does poorly if the pollution is heavy.

SEED AND SEED BEARING

Flowering begins early with this species in Great Britain and flowers appear from the fifth year onwards. Good crops of cones are available from the twentieth year, the maximum seed production occurring between 40 and 60 years of age (Matthews 1955). Good crops of seed occur at three-yearly intervals, but there is some seed every year.

GENETICS AND BREEDING

Two 'plus' stands extending to 3½ acres have been registered as well as one 'normal' stand of ¼ acre. Nine 'plus' trees have been selected and recorded.

NATURAL REGENERATION

It is too early to speak about natural regeneration although it may well become possible to regenerate this species naturally in future if it is desired to do so. Lawson cypress is a frequent, and often abundant, producer of seed and the seedlings tolerate shade. Provided there is a clean forest floor, with mineral soil, natural seeding may be easy. Seedlings are frequently found in our plantations now and, in the snow-damaged plot in the Forest of Dean, a very dense crop of natural regeneration appeared.

TIMBER AND FUEL QUALITY AND USES

Very little timber of Lawson cypress has come on the market but small poles from thinnings are usually put to the same uses as other coniferous poles, for mining timber, fencing, etc. No special uses have been found for home-grown Lawson timber and it is regarded, at present, as a general purpose softwood.

The timber weighs about 27 lb. per cubic foot when seasoned. Heartwood is resistant to decay but, at the same time, difficult to treat with preservatives. Satisfactory penetration is only achieved under pressure. The timber works well with machine and hand tools and gives a good finish.

The foliage is in great demand by florists and good prices are obtained for clippings.

POTENTIALITIES OF THE SPECIES IN THE NATIONAL ECONOMY

Although Lawson cypress appears to be at home in most parts of Britain and to grow reasonably well on a variety of soils, it is not likely to have an important place in our silviculture in future chiefly because the sites which suit it best, suit other species even better. One cannot see it making ground at the expense of *Abies grandis*, *Tsuga heterophylla* or *Thuja plicata* on good sites, but it may have a limited use as a pioneer species on certain types of land. On the better ground, it may spread by natural seeding.

Chamaecyparis nootkatensis (Lambert) Spach.

The Nootka cypress, discovered by Archibald Menzies in 1793, was not introduced into Great Britain until 1853. It has been planted as a specimen tree and an ornamental in most parts of the country and it has succeeded; but it has not grown anywhere as tall as Lawson cypress. It has exceeded 90 ft. in height at Dupplin, Perthshire (93 ft.); at Westonbirt, Gloucester (93 ft.) and at Eastnor Castle, Hereford (91 ft.), but most of the best specimens do not reach more than 80 ft. In spite of reasonably good growth in many districts, it has not been tried in forestry save on a very small scale, and although a mild interest has been taken in it during the last thirty years, as a possible tree for high-lying peat-covered land, the results of experiments which have been carried out so far are not encouraging. *C. nootkatensis* is winter hardy and does not seem to be greatly affected by late spring frosts; it also appears to withstand exposure. Its great disadvantage is that it grows extremely slowly in its early years. It may yet be possible to find a small place for it in our silviculture, but this is less likely now than it seemed at one time.

At Bedgebury, Kent, *C. nootkatensis* reached 16½ ft. in 20 years in a plantation. At Cirencester, Gloucestershire, a plantation formed in 1906 on a

shallow soil over the Great Oolite limestone, has grown slowly and at 22 years of age, was only six feet high. This crop is interesting, because it contains two highly distinct types of tree; one, with single straight stems growing at approximately the same rate as *Thuja plicata*; and the other, with a strong tendency to fork at low levels and much poorer in growth. There is possibly a genetical difference between the two lots. At Benmore, Argyll, Nootka cypress has grown better, having reached 32½ feet in 25 years. As a first crop on peat *C. nootkatensis* has been tried at various places. At Inchnacardoch, Inverness-shire, on deep peat it largely failed, while on shallower slope peat in the same forest, it has grown very slowly, even with the aid of phosphate, so that, in twelve years, it was no more than three feet high. At Achnashellach, Ross-shire, on thin peat, 8-24 in. deep, with a *Trichophorum* (*Scirpus*)-*Calluna* vegetation, Nootka cypress planted in 1930 averaged only 2.7 ft. in height in 1946, but a few plants which had been put out on a grass flush were from 6 to 8 feet high. This lot of *nootkatensis* was badly damaged by the severe cold of the winter of 1946-47. On a moist upland heath at Clocaenog, North Wales, this species reached 5½ ft. in height in 15 years; on a heavy clay soil at Rockingham Forest, Northamptonshire, it was no more than 7 ft. after 20 years' growth, while, on the chalk, at Friston, in Sussex, it reached only 3½ ft. after 25 years. *C. nootkatensis* appears to be subject to damage by deer.

The seed of this species is difficult to germinate and requires stratification for up to a year before sowing. Seed collected in Great Britain is generally of low quality. Otherwise, it presents no problem in the nursery. *C. nootkatensis* is one of the parents of the hybrid cypress, *Cupressocyparis leylandii*.

Chamaecyparis obtusa (Siebold and Zuccarini) Endlicher

A native of Japan, this tree was introduced in 1861 and is not infrequently met with in Great Britain as an ornamental or specimen tree, though it is much less common than *C. lawsoniana* and scarcely as abundant as *C. pisifera*. Some of its varieties are common in gardens. As a specimen tree, it rarely exceeds 60 ft. in height and, as most of the good specimens occur in southern England, it is probable that it prefers warmer conditions than are available over most of Great Britain. Among the tallest trees recently measured are specimens at Westonbirt, Glos., 63 ft.; Cuffnells, Lyndhurst, Hants., 62 ft.; Linton Park, Kent, 57 ft.; Kew Gardens, Surrey, 53 ft.

This species has been little planted as a forest tree and there would seem to be no advantage in using it. It has been tried on deep peat but has failed and other small trials have not yielded much success.

Chamaecyparis pisifera (Siebold and Zuccarini) Endlicher

Also Japanese, this species was likewise introduced in 1861 and, next to *C. lawsoniana*, it is now the commonest cypress in Great Britain, in the typical form and in its many varieties. For forest planting, it has been used only experimentally on a very small scale and the results indicate that it will never find a place in silvicultural practice. There is a tree of the typical *C. pisifera* 65 ft. high at Heatherside, Camberley, Surrey, one at Rossdhu, Dumbarton, 60 ft. and one at Murthly, Perthshire, 56 ft. The varieties, *plumosa* and *squarrosa*, with juvenile foliage, grow as well as the typical form, if not better; there are specimens of *plumosa* at Wisley (Royal Horticultural Society Garden), 74 ft.; at Linton Park, Kent, 69 ft.; Redleaf, Kent, 66 ft.; and at Methven, Perthshire, 60 ft. Of *squarrosa*, a tree at Bicton, Devon, is 80 ft. high; and one at Wisley, 69 ft.

C. pisifera has failed when planted on peat and it went out very quickly when tried on an exposed upland heath at Clashindarroch, Aberdeenshire. At Lael, Ross-shire, it has reached 12 ft. in height in 17 years, in a grass-bracken herbage on good soil. At Benmore, Argyll, where it was damaged by field voles, it reached 20 ft. in 27 years, and at Beddgelert, Caernarvonshire, a height of 10 ft. was made in 20 years on an acid soil with thin peat.

Chamaecyparis thyoides (Linnaeus) Britton, Sterns and Poggenberg

This tree, introduced in 1736 from eastern North America, survives in Great Britain, but never reaches more than a small size. The tallest tree is probably that at Kew which is only 42 ft. in height. It has not been used in the forest. During the severe spring frosts of May, 1935, specimens escaped damage entirely, in a hollow where the temperature was known to have fallen to 15°F. (Day and Peace, 1937.)

J.M.

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Cryptomeria D. Don

Cryptomeria is a monospecific genus, the only species, *C. japonica*, being of minor forest importance in Britain. The tree reaches quite sizeable dimensions and has been planted in a number of small plots and trial plantations in this country.

Cryptomeria japonica (Linnaeus filius) D. Don. (Plate 17)

Cryptomeria japonica is a native both of China and Japan and is one of the most important timber trees of the latter country.

The Chinese variety (*C. japonica* var. *sinensis*) was discovered in 1701 by J. Cunningham and was first introduced into Great Britain by Captain Sir Everard Home in 1842. The Japanese tree, though the first to be discovered (by Kaempfer in 1692), was not introduced for certain until 1879 when it was brought in by Maries. No provenance comparisons have yet been made but seed from a number of Japanese sources has been sown in the nursery and a small provenance experiment is planned. As far as is known all existing plantations have been raised from Japanese seed.

Cryptomeria can be raised in the nursery by standard techniques. It is somewhat prone to damage by autumn frosts. Seedlings grown in a good agricultural type nursery may be expected to be liftable at the end of the first year and to be fit for planting at the end of one year in the transplant lines. Results in heathland nurseries have been rather variable.

The early growth of the few existing plantations has been rapid but irregular. At Bere Forest, Hampshire, in a plantation of 1¼ acres, the biggest trees were 15-20 feet in height ten years after planting. In Bedgebury Forest, Kent, twelve years after planting, heights ranged from 2-25 ft. while the average height after 23 years was 30 ft. Though good, this rate of growth is by no means outstanding and is exceeded by a number of species in the forest plots at Bedgebury.

In the Forest of Dean, at the southernmost end of the border between England and Wales, a 17-year-old plot was 31 ft. in height and had a standing volume of 2,116 Hoppus feet per acre. A nearby plot of *Abies grandis* of the same age was a little taller but had no greater yield.

At Beddgelert in North Wales, on an exposed site at an elevation of 1,000 ft., two groups of trees averaged 18 ft. at 15 years and 13 ft. at 13 years respectively, and are among the most promising trees on this site.

In the west of Scotland, at Lael in Wester Ross, and in several sites in Argyll, young plantations or species plots are to be found. At Lael the trees were only 16 ft. high in 16 years and very irregular, while at Crarae, Argyll, the crop averaged 41 ft. in height and 24 in. in girth 21 years after planting. The standing volume of this plot was about 2,500 Hoppus ft. per acre, and compares favourably with the volume production of any other species in the very comprehensive collection at Crarae.

At Knapdale in Argyll, on an old woodland site, a small 23-year-old plantation had a top height of 54 ft. and an average girth of 37 in.

The oldest crop measurement comes again from the Forest of Dean, where a group of trees 35 years old averaged 65 ft. in height. The average girth was 47½ in.; but this figure is probably higher than it would normally be because of the number of outside trees in the group.

Among the biggest recorded specimens of *Cryptomeria japonica* are trees: 111 ft. by 10 ft. 1 in. at Bicton, Devon; 111 ft. by 10 ft. 3 in. at Redleaf, Kent; 111 ft. by 6 ft. 9 in. at Leaton Knolls, Shropshire; and 100 ft. by 10 ft. at Benmore, Argyll. The age of these trees is unknown and it is perhaps possible that some are the Chinese variety and not the Japanese.

The site requirements of *Cryptomeria* do not seem to be exacting. The tree grows quite satisfactorily on infertile silt at Bedgebury and gravelly clay at Bere, both sites receiving about 30 in. mean annual rainfall. However, the species does appear to grow most rapidly in the west in the areas of higher rainfall. At Beddgelert, the tree has withstood quite severe exposure at 1,000 ft. without becoming browned or defoliated. This site is cold and liable to heavy winter snowfalls and some snow-break has occurred.

At Lael, trees on bracken/grass vegetation have done well, while trees in an adjacent plot on *Calluna* have gone into check.

When canopy is closed, a dense shade is cast and ground vegetation is quickly suppressed. At Knapdale the crop has been remarked on for its ability to clean itself, being similar to the larches in this respect. The tree is very shade tolerant and has been proposed as a possible species for planting in hardwood coppice areas.

The only pests reported are voles which are said to prefer the species to many other conifers.

An unusual characteristic of *Cryptomeria* is its ability to throw coppice shoots. Elwes and Henry report that coppicing occurs in Japan, while in Britain it has been reported from Bedgebury when the forest plot was 15 years old. Elwes and Henry also mention that lower branches of some British specimens have taken root and formed a colony or grove around the parent stem.

Cryptomeria is readily propagated vegetatively. Cuttings can be struck by taking one-year shoots with a heel in late August or September (i.e. early autumn) and putting them in a cold frame in a 50% mixture of

peat and sand. They should be ready for transplanting in the following spring.

There are many cultivated varieties of *C. japonica;* Dallimore and Jackson (1948) list twenty, some of which have been propagated on a large scale for ornamental planting. Var. *elegans*—with perpetual juvenile foliage and var. *elegans nana*, a dwarf with juvenile foliage, are two varieties that have been particularly widely planted. Var. *elegans* was introduced from Japan in 1861 by J. G. Veitch but it is believed originally to have come from China (Elwes and Henry).

Seed, both home collected and imported, is seldom of good quality. The average germination of 23 lots tested at Alice Holt (Forestry Commission Seed Testing Station) in the period 1949-55 was 12 per cent, the maximum being 48 per cent. Small home collections of seed have been made and the seed was found to be no worse than imported seed.

Sporadic natural regeneration has been recorded.

The future of *Cryptomeria japonica* as a forest species in Britain is uncertain. Present indications are that it will be a high volume producer doing well under a range of conditions including those of moderately exposed mountain sides, and it is possible that the species will find a permanent place on such sites in the milder parts of the country.

J.R.A.

Cunninghamia R. Brown ex Richard

Cunninghamia lanceolata (Lambert) Hooker filius

This noteworthy Chinese conifer was introduced into Great Britain in 1804 but it is not a common object with us because it grows only in the warmer districts and has been little planted within recent years. It is usually rather unsightly because it is subject to frost damage, and according to Dallimore particularly so in the autumn, with the result that the tips of branches are often killed. The dead portions are later thrown off, and litter the ground, while the tree makes new shoots from the point of damage. It is sometimes injured during severe winters but often escapes damage, and it would seem to be, on the whole, reasonably resistant to winter cold. The probability is that summer temperatures in most of Great Britain are not high enough for it. It is of no forest interest.

The tallest specimen recently measured is at Bicton, Devon; this is 92 ft. in height with a girth at breast height of 7 ft. 3 in. (1949). At Linton Park, Kent a tree planted in 1843 is now 74 ft. tall; at Bury Hill, Dorking, Surrey, a specimen of *Cunninghamia* planted in 1840 was 66 ft. high in 1954.

J.M.

Cupressocyparis Dallimore

This genus was created by Dallimore to cover a bigeneric hybrid between *Cupressus macrocarpa* and *Chamaecyparis nootkatensis* discovered in Wales and recognised as a hybrid in 1925.

Cupressocyparis leylandii (Jackson and Dallimore) Dallimore

This hybrid tree was discovered at Leighton Hall, Welshpool, Montgomery, and was obtained on that estate on two separate occasions, the first in 1888 when *C. nootkatensis* was the female parent and the second, in 1911, when the reciprocal hybrid was secured.

C. leylandii is not a common tree because it has not produced fertile seed itself and the production from the original parents was low. Now that the technique of raising it from cuttings is better understood it is likely that it will become more frequently represented in our plantations.

There are some good specimens in various parts of the country. One of the original trees at Leighton, from the 1911 stock, was blown down in 1954 when after 44 growing seasons it had reached a height of 90 ft. and contained 69 Hoppus ft. of timber. At Kew, a tree planted in 1930 was 53 ft. tall in 1956, and at Bedgebury, a 28-year-old tree had reached a height of 52 ft. There are specimens over 60 ft. in height at Inveraray, Argyll; Yester, East Lothian, and Wakehurst, Sussex. A small plot formed with rooted cuttings has been planted at Bedgebury and is growing well, while an older plantation on the estate of Mr. A. L. F. Hills at Redleaf, Kent, is showing great promise.

It is too early yet to say how this hybrid will behave generally in the country but it has already shown that it can grow with vigour in a variety of conditions and one can, therefore, regard it as a promising new acquisition. It seems to be frost hardy, having survived the severe winter of 1940 at Bedgebury when many cypresses were killed.

At the present time, it is reproduced exclusively from cuttings. Cuttings four to six inches long, with a heel of older wood, are taken either in the third week of March or in late June or early July and inserted in a medium consisting of equal parts of coarse silver sand and granulated peat. In an unheated frame, the cuttings will root in about twelve months, but electrical soil heating increases the speed of rooting and the number of plants which take root. The cuttings, when rooted, may be lined out in the nursery in September or in April. They make good plants after one or two seasons in the transplant lines.

C. leylandii has a columnar habit of growth and produces a dense mass of foliage. It is said to be a useful hedging plant (Pearce, 1956). Seven distinct clones are being propagated for testing under forest conditions.

The timber of the tree which was blown down at Leighton in 1954 was examined by the Forest Products Research Laboratory at Princes Risborough (1956). It was found that the timber had good strength qualities, dried well in the kiln and was easy to work. The heartwood was found to be highly resistant to fungal decay.

Because of its rapid growth, and the indication that it will produce timber of good quality, this tree will be used more frequently in future, if supplies of planting stock become available.

J.M.

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Cupressus Linnaeus

This genus consists of about a dozen species, some of which are too tender for outdoor cultivation, and none of which is really hardy over all Britain. *Cupressus cashmeriana* is not uncommon as an indoor plant but will scarcely survive in the open air; nor will *C. duclouxiana. Cupressus arizonica, C. goveniana, C. macnabiana, C. sempervirens* and *C. torulosa* will survive only in the mildest parts of the country, and even in these districts they are rarely seen. *Cupressus lusitanica* is slightly hardier and is more often met with, but here again usually in the western and southern regions, although occasional trees survive and grow in other districts. Hardiest of all is *C. macrocarpa*, a tree which is quite common in the south and south-west and which extends north for a considerable distance along the western seaboard. This last is the only true cypress of any interest to British forestry, but the extent of that interest is limited.

Cupressus funebris Endlicher

This species, a native of central China, was discovered in 1793 and introduced into Great Britain in 1848.

A small plot, planted by Sir George Campbell at Crarae in Argyll, has grown surprisingly well but there the climate is mild. At 23 years of age, the mean top height of the plot was 31 ft., and the mean girth, at breast height, 20½ in. This plot has been slightly damaged by wind, but the crop is now standing at about 470 trees to the acre, with a basal area, per acre, of 109 sq. ft.

Cupressus goveniana Gordon

This tree has been known in Great Britain since 1848 when seeds were sent from California. It is rarely met with. A small plot, planted at Crarae, is not faring well; many of the trees have died and the survivors are most unhappy. Early growth, 7½ ft. in six years, was satisfactory.

Cupressus macrocarpa Gordon

COMMON NAME—Sometimes talked about as Monterey cypress, mostly it is referred to as 'macrocarpa'.

COUNTRY OF ORIGIN AND PROVENANCE

This species is of very limited occurrence naturally, being confined to a small area near Monterey in California and to the island of Guadalupe, off the coast of Lower California.

HISTORICAL NOTES

It is reported that *C. macrocarpa* was first cultivated in England, by the Horticultural Society, in 1838, from seed sent by Lambert. The most important early introduction was by Hartweg in 1846.

EXTENT OF PLANTING

Cupressus macrocarpa has been little used as a forest tree and the area at present under plantations is quite trivial.

CLIMATIC REQUIREMENTS

Throughout its history as an exotic in Great Britain, *C. macrocarpa* has shown that it is highly susceptible to low temperatures in winter and there are records of the death of fairly large trees during exceptionally severe frosts in winter-time as, for example, in 1860, 1895 (Elwes and Henry) and 1940 (For. Comm. 1955). This susceptibility has restricted *macrocarpa* to the south and the west and to districts within easy reach of the sea. It is, therefore, an uncommon object in the midland and north-eastern parts of the country although it succeeds, quite far north, on the western side, near the sea. On the other hand, it is not greatly troubled by late spring frosts. It resists exposure to salt winds from the sea and is often used in southern coastal districts as a shelter or screen.

SITE REQUIREMENTS

C. macrocarpa is limited more by climate than by soil, for it appears to be at home on most soils of the brown earth type. From what little experience we have, it does not relish very acid soils; it was tried on a *Molinia-Juncus* bog at Beddgelert, Caernarvonshire, and died out, save for two trees, which are growing well (Zehetmayr 1954). One interesting characteristic of this tree is its growth on chalk soils near the coast, in the south of England. It was used as a first crop on chalk downland by Sir William Somerville (1909) and his success has been repeated, on a small scale, in the same district.

ESTABLISHMENT TECHNIQUE

NURSERY PRACTICE. The seed of this species has a very low germination per cent as the number of empty seeds is high; for first quality seed, it is considered that a germination percentage of 30 is satisfactory. The seed germinates easily, requiring no special treatment before sowing, and the nursery production is high, having regard to the number of viable seeds. In a good nursery, the seedlings should be large enough to lift at the end of the first year; in some heathland nurseries they have reached a foot high as one-year seedlings. It is possibly better to confine this species to nurseries which can produce seedlings large enough to line out at the end of the first year; because experience, in the past, has shown that two-year-old seedlings often suffer very heavy losses after lining-out. The lifting of transplants for use in the forest requires careful attention, if failures are to be avoided after planting. It was found, about 20 years ago (Macdonald 1935), that while transplants lifted in April from the nursery and planted in the forest at once, suffered losses by death after planting of 78 per cent, only 12 per cent of deaths resulted with transplants which had been lifted in the previous September and kept heeled in, in the nursery, until April. Early lifting of transplants would seem to be desirable. It is not known, however, whether autumn planting is better than planting late in spring.

VEGETATIVE PROPAGATION. This is not used in forest practice and there is no information from experiments. Cultivars of other true cypresses are usually grafted on rootstocks of *C. macrocarpa* by the nursery trade.

DIRECT SOWING. This is not practised in Great Britain.

PLANTING. *Cupressus macrocarpa* has been a troublesome tree in this respect, and planting was, not infrequently, followed by wholesale failure. This appeared to be due more to nursery treatment than to actual methods of planting.

SPACING. There is little information; *C. macrocarpa* would probably be planted today at spacings of 5 ft. or 5½ ft.

TENDING AND THINNING

There is not enough experience on which to base a pronouncement, but methods used for other conifers will probably be applicable. If clean timber is wanted, it will be necessary to prune.

RATE OF GROWTH AND YIELD

Table 16 gives details which have been obtained from measurements in different parts of the country.

Of the plots, listed below, those at Friston and Poverty Bottom (Macdonald, Fourt and Christie 1954) are growing on the chalk, on dry sites in a region of low rainfall. That at Bedgebury, though further from the sea and, on a slightly acid moderate loam, is broadly in the same climatic region. It will be seen that growth in these districts is slower than in the high-rainfall and on the acid, though fertile, soils in Argyll. At Cumlodden (Wood and Thomson 1955) the plots marked (a) and (b) are both part of the same plantation, but plot (b) was measured on shallow soil, slightly higher up the slope, and plot (a) on deeper soil at a slightly lower elevation.

DISEASES AND PESTS

In the nursery, *C. macrocarpa* is highly susceptible to attack by *Botrytis cinerea* which often does considerable damage. As a forest tree, it has not been troubled in Great Britain with fungal diseases or insect pests.

OTHER FORMS OF DAMAGE

WINDBLOW. There are too few plantations of this species in the country to enable us to say whether it is liable to windblow, or not. One sample plot, in Argyll, was blown down some years ago, but elsewhere the tree has remained firm. It is possible that on moist, shallow soils, it may suffer damage of this sort but that on deeper or drier soils, it will prove windfirm.

ATMOSPHERIC POLLUTION. Here also, evidence is lacking. It is frequently found in towns as a hedge plant but the districts where it is possible to use it for this purpose are not, as a rule, smoky. It is probable that it will show little resistance to atmospheric pollution.

TABLE 16 CUPRESSUS MACROCARPA: GROWTH AND PRODUCTION

Locality	*Elevation* (*ft.*)	*Age* (*yrs.*)	*Top Height* (*ft.*)	*Mean Girth True* (*in.*)	*Volume per acre* (*h. ft. o.b.*)	*Total Volume* (*h. ft. o.b.*)
Bedgebury, Kent	250	21	32	10½	583	614
Largie, Argyll	400	22	45	22½	2,826	2,949
Cumlodden, Argyll (a)	—	25	46	22	2,360	—
Cumlodden, Argyll (b)	—	25	40	17	1,470	—
Friston, Sussex	250—300	25	39	15½	1,178	1,409
Poverty Bottom, Sussex	300	35	55	29	3,904	4,242

SEED AND SEED BEARING

Cupressus macrocarpa is known to have yielded fertile seed in Great Britain but little is known about its production.

GENETICS AND BREEDING

Little has been done on *C. macrocarpa* but four 'plus' trees have been selected for further work on the hybrid *Cupressocyparis leylandii*.

TIMBER

There is no information about the timber of this tree grown in Great Britain.

POTENTIALITIES OF THE SPECIES IN THE NATIONAL ECONOMY

These are exceedingly small, if *C. macrocarpa* is regarded as a possible forest tree in its own right, because apart from limited use on chalk soils in the south, or as a shelter tree near the sea in the south and south-west, there does not seem to be a place for it anywhere. On the other hand, it might acquire some importance as a parent of the hybrid Leyland cypress.

Cupressus sempervirens Linnaeus

The famous Mediterranean cypress has been known in England for a long time, because it was in cultivation in the middle of the sixteenth century and later references indicate that it was fairly plentiful well into the seventeenth century. It is now a rare tree, found only in the milder districts, except where it has special protection, and no doubt the early fashion for planting waned after each severe winter. It is too tender for use in Great Britain.

In a small plot at Crarae, Argyll, it has reached 14 feet in height in 22 years. There are individual trees of 67 and 66 ft. in height at Exbury, Hampshire, one of 66 ft. at the Royal Botanic Garden, Edinburgh, and one of 46 ft. at Whittingehame, East Lothian.

J.M.

CUPRESSUS: REFERENCES

Forestry Commission. 1955. *Guide to the National Pinetum and Forest Plots at Bedgebury*. H.M.S.O.

Macdonald, J. 1935. Nursery treatment of Cupressus macrocarpa. *J. For. Comm.* 14, 112-114.

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Wood, R. F., and Thomson, J. H. 1955. Cupressus macrocarpa plantations at Cumlodden, Argyll. *Quart. J. For.* 49. 126-128.

Dacrydium Solander

Very few species in this genus have been introduced into Great Britain and though specimens of *D. cupressinum* and *D. franklini* are occasionally met with in the warmer parts of the country, they have rarely reached more than 20 feet in height. Both species have survived for 30 years in the National Pinetum at Bedgebury where, however, they are no more than bushes.

J.M.

Fitzroya Hooker, filius

Fitzroya cupressoides (Molina) Johnston

Fitzroya cupressoides, which was introduced in 1849, is a native of Chile and Patagonia where it grows as a tree of some considerable stature. In Great Britain, however, though it withstands the climate and appears to have a wide tolerance in respect of soil, it is rarely found as anything but a bush or small tree. Individual plants have been recorded, thirty feet or so tall, but generally the specimens occurring in gardens and shrubberies do not usually exceed half this height. It is unsuitable for forest use.

J.M.

Ginkgo Linnaeus

Ginkgo biloba Linnaeus. The maidenhair tree of Japan, *Ginkgo biloba*, was discovered in 1690 by Kaempfer and introduced into Europe about forty years later. It was first brought into England about 1754, and the first record of its flowering in Europe was at Kew in 1795. Male trees in England are reported to flower abundantly at intervals, but there was no record of fruiting by female trees until 1919 and 1922 (Dallimore, 1922).

The ginkgo grows moderately well in many parts of southern England but it is nowhere common, occurring almost invariably as a tree planted singly in gardens and parks. It tolerates town conditions to some extent—it was reported by le Sueur as the only conifer growing in the City of London (le Sueur, 1934) but it is undoubtedly better in an unpolluted atmosphere. Little is known about its requirements and although it is found growing on a range of soils it does not seem to flourish on the most acid. So far as is known, ginkgo has never been tried as a plantation tree.

The ginkgo might be used more frequently as an ornamental, but there seems to be no future for it in forestry in Great Britain. There are some good individual specimens in England still surviving. At Linton Park, Kent, a ginkgo planted in 1844 was 90 feet high with a girth of 7 ft. 7 in. in 1956; at Chiswick House in London a tree reported to be 57 feet high in 1889 was 88 feet in height in 1952 and had a girth of 8 ft. 7 in. Other trees of about 90 feet in height are

reported from Sherborne and Melbury in Dorset. The well-known tree at Kew, planted in 1754, is 70 feet high with a girth of 12 feet 8 inches at 2 feet from the ground. All the trees of any size occur in the southern part of England. In Wales there is a tree of about 70 feet in height at Powis Castle, Montgomery.

J.M.

GINKGO: REFERENCES

Dallimore, W. 1922. The fruiting of Ginkgo biloba at Kew. *Kew Bull.* 262-265.
le Sueur, A. D. C. 1934. Trees of the City of London. *Quart. J. For.* 28, 92-100.

Glyptostrobus Endlicher

Glyptostrobus pensilis (Staunton) K. Koch

A native of China, where it is said to be unknown in the wild state, *Glyptostrobus pensilis* is much too tender for use in Great Britain in distinction to the allied *Taxodium distichum* which has reached a considerable size in several places. Specimens of *Glyptostrobus* have been reported from various districts in the south of England where they are growing in the open air but, generally, this tree rarely survives long when planted out of doors.

Henry (1926) suggested that *Glyptostrobus pensilis* might be used for planting on swampy sites in sub-tropical regions.

J.M.

GLYPTOSTROBUS: REFERENCE

Henry, A. 1926. The Swamp Cypresses of China and North America. *Trans. R. Scot. Arb. Soc.* 40, 105-107.

Juniperus Linnaeus

This genus is notable because it includes one of the three native conifers of Great Britain, *Juniperus communis*, which occurs as a bush or, rarely, as a small tree, in various parts of the country. It has two main habitats, the chalk downs of Southern England, where it is one of the characteristic plants of the scrub which precedes the appearance of beechwood, and the pine and birch woods of the Highlands of Scotland. It is rarely more than ten feet in height in the wild state.

The junipers belong to a genus which is widely spaced over the Northern Hemisphere, mainly in mountainous districts, and there are numerous species many of which have been in cultivation here for a long time, in gardens and parks. It is interesting to note that, of the exotic junipers, *J. sabina* was introduced in the sixteenth century; *J. virginiana*, *J. phoenicea* and *J. bermudiana*, in the seventeenth; *J. oxycedrus* and *J. thurifera* in the eighteenth; and *J. californica*, *J. chinensis*, *J. drupacea*, *J. occidentalis* and *J. recurva*, among others, in the nineteenth century; while the present century has seen the introduction of a number of other exotic species. Many of them are shrubs in their native habitats. Most of the introduced junipers remain as shrubs or bushes in Great Britain and only *J. chinensis* and *J. virginiana* normally reach the status of being small or medium sized trees. Of these two species, there are numerous horticultural varieties, some of which are commonly used in gardens. There is no place for any of the junipers as a forest tree in this country but many of them will continue to hold a strong horticultural interest. It should be noted that the East African species, *J. procera*, cannot be grown out of doors with us.

Keteleeria Carrière

There are two species in this genus, both Chinese in origin, *Keteleeria davidiana* and *K. fortunei*. Both have been tried from time to time in Great Britain, but with little success. *K. davidiana*, which was introduced in 1888, is occasionally seen in gardens and arboreta in the milder parts of the country but it does not really thrive and it is liable to be damaged by early frosts in the autumn and by late frosts in the spring. *K. fortunei*, which appears to have been first introduced in 1848, is rarely met with in Great Britain where climatic conditions are unsuitable.

J.M.

Larix Miller

The genus *Larix* is a small one, distributed chiefly in the colder regions of the northern hemisphere, and consists of about ten species. The larches form a valued constituent of the forest in Europe, Asia and North America. The taxonomy of the larches is complicated by their distribution, particularly in Asia, where the varieties of *L. gmelini* have been given specific rank by some authors, but by others are considered as geographical varieties. In the same way there are close similarities between *L. griffithii* and its nearest neighbour *L. potanini*.

The only species which are sufficiently important in British silviculture to warrant detailed consideration are *Larix decidua*, *Larix leptolepis*, and the hybrid between them—*Larix eurolepis*. Of the remaining species, most have been tried in Great Britain but only *L. occidentalis* has been tested in the forest on a variety of sites. Larches from the mainland of Asia have done badly wherever they have been planted.

Although only the European and the Japanese larches will be used on a large scale in forestry there may be a place in tree-breeding for one or other of the species which have not succeeded.

DISEASES AND PESTS

DISEASES. All species of larch appear to be susceptible to butt-rot caused by *Fomes annosus*. Larch canker,

associated with the fungus *Trichoscyphella* (*Dasyscypha*) *willkommii*, is of major importance in the genus and will be treated at some length under *L. decidua*. Various other larch species are also affected, but Japanese larch and hybrid larch are relatively immune, as are some of the eastern provenances of European larch.

Little is known about the pathology of the less common larch species; no specific diseases have been noted on them in Britain.

INSECT PESTS. The larches grown in Britain suffer from the attacks of a wide variety of insect pests, of which the most obvious are the defoliators and the sap-suckers.

The sawfly group of defoliators comprises seven British species. These are *Pristiphora erichsoni* Htg., *P. laricis* Htg., *P. wesmaeli* Tisch., *P. glauca* Bens., *Pachynematus imperfectus* Zadd., *Anoplonyx destructor* Bens., and *Cephaleia alpina* Klug. European, Japanese and hybrid larch are all subject to attack but the sawflies usually show a preference for Japanese larch and hybrid larch over European larch. This is probably because the more succulent foliage of the former species provides either better egg-laying sites or food with a higher survival value to the larvae. The large larch sawfly, *P. erichsoni*, caused serious damage during the first decade of the present century in North Wales and the Lake District of England (Hewitt, 1908; Hanson, 1951), but, although widely distributed, has been quiescent since then. *A. destructor* and *P. laricis* are common and widespread, the former in particular causing foliage browning and occasionally complete defoliation in many parts of the country from year to year (Crooke, 1953). The other sawfly species mentioned are of little importance.

Two Lepidopterous defoliators of larch are *Coleophora laricella* Hbn., whose attacks, which cause foliage wilting and browning, are frequent but not serious; and *Eucosma* (*Semasia*) *diniana* Guen. which, although an important pest on the continent of Europe, has never been responsible for serious damage to larch in Britain.

Infestations of the sap-sucking *Adelges viridis* Ratz. and *A. strobilobius* Kalt. are frequently heavy and obvious in British larch crops without producing serious adverse effects on the trees. It should be mentioned, however, that *Adelges* spp. are implicated in the complex producing die-back of European larch (Macdonald, 1949) as are the shoot-boring larvae of *Argyresthia* spp. There is some evidence that the forest behaviour of these adelgids is different on Japanese larch and hybrid larch from that on their original European larch host (Crooke, 1953).

Megastigmus seitneri Hoff. infests larch seed but is not troublesome at the present time. It could, however, possibly become of importance in seed orchards.

The larches support a number of species of bark beetle but only one of them, the recently introduced *Ips cembrae* Heer, is an important pest (Crooke and Bevan, 1957).

Larix decidua Miller (*L. europaea* De Candolle) (Plates 4 and 12)

COMMON NAME. European larch, applied to both the tree and its timber.

COUNTRY OF ORIGIN AND PROVENANCE

European larch has a discontinuous distribution over Europe and falls into four groups: (a) Alpine; (b) Sudeten; (c) Polish and (d) Tatra, the latter three being sometimes bracketed under the term "Carpathian". Each of these occurs in distinct areas, but, due to afforestation over many years, foreign provenances have been introduced into all these regions, so that it is difficult to ensure that seed collected in the Sudeten and Tatra areas, in particular, is from genuine aboriginal stock. As differences in seed provenance are of considerable importance in European larch these natural regions will be described more fully.

(a) ALPINE. This covers the entire extent of the central Alps from south-east France through Switzerland, northern Italy and south Germany to Austria and ends in the Wienerwald just west of Vienna. It ranges from low elevations (900 feet near Vienna) to 8,000 feet in the French Alps and 7,500 feet in the Italian Tyrol. At these great elevations it is little better than scrub, and its zone of best growth is from 4,200 feet to 4,500 feet (Tschermak, 1935). It has a characteristically discontinuous distribution within this region, sometimes being entirely absent from the western, windward side of a mountain while completely covering the lee side. In the High Alps it avoids shady valley bottoms and is prominent on high ridges, but in Lower Austria it is the shady mountain sides which are colonized (McComb, 1955). Numerous provenance trials on the Continent (Rubner, 1941; Schober, 1949) and in Britain (Macdonald, 1937; Edwards, 1953) have shown that there is considerable variation between the growth of different provenances of Alpine larch. Experiments in Britain show that high altitude origins are to be avoided, while those from low elevations are more suitable.

(b) SUDETEN. Trees of this group are found only on the east slope of the Altvater mountains in the Sudeten region, which now forms the border between Czechoslovakia and Poland. The true Sudeten larch occurs mostly between 950-2,600 feet (Rubner, 1952). The climate is transitional between the continental one experienced in the Alpine region and the maritime one of north-western Germany. Unfortunately, Alpine provenances have been planted within the region and there must always be uncertainty about

bulk seed collections from this area. The provenance experiments mentioned above (in particular Edwards 1953) have shown the superiority of genuine Sudeten larch over all other provenances. Confusion has been caused, especially in early provenance experiments, by the use of seed from Silesia. This was reported to be of Sudeten provenance, but plantations in Silesia (as elsewhere) are mixed and sometimes give progenies of Alpine type, so that 'Silesian' cannot be recognised as a distinct provenance.

(c) POLISH. Originally widely distributed over much of south-eastern Poland, it has now been reduced to a few areas centred in the Lysa Gora region. It is typically a low-elevation provenance occurring between 450-1,800 feet, and experiencing a moderately continental climate (McComb, 1955). It is separated geographically from the truly continental *L. sibirica* which gives a greatly inferior performance in Britain.

(d) TATRA. The natural range of the Tatra larch includes the High and Low Tatra mountains and the northern edge of the Erzgebirge on the border between eastern Czechoslovakia and southern Poland. It occurs mostly between 1,800 feet and 4,000 feet, elsewhere it is somewhat scattered.

There is obviously a link between the Tatra and the Polish larch but it is not thought that Sudeten larch is so nearly related (Rubner, 1943). All three, however, have the typical small cone type of the Carpathians which is very different from the cone types of the Alpine larch. Little is yet known about the growth in Britain of larch from the Tatra region.

There is no clear record of the provenances of the earliest larches imported into the British Isles, but from the appearance of the remaining trees they are of the Alpine rather than the Carpathian type. Some of them succeeded so well in England, and particularly in Scotland, that extravagant claims were made for the species. For the next 200 years opinions differed as to whether it was better to collect seed from existing larch stands in this country or to use imported seed, but the first provenance experiments were not laid down until 1929. Alpine seed origins have given a variable performance, growing only slightly less vigorously than Sudeten larch on good sites and, though they tend to suffer more from dieback (see Diseases and Pests, page 57), this has not been a killing disease on the best areas. On the poorer sites, however, the Alpine provenances have produced a sorry picture, with slow growth and very destructive attacks of dieback. The worst results have been with the larch from the highest elevations. It was unfortunate that for the first fifteen years of its existence the Forestry Commission used these Alpine origins for the majority of its seed imports.

From 1927 onwards substantial collections were made from the old stands in Scotland, in fact, in 1934 nearly four times as much seed was collected in Scotland as was purchased from the Alps. The behaviour of provenances from Scottish stands of larch has been variable in respect of dieback, some appearing resistant while others are badly affected. In view of the heterogeneous nature of our old plantations, some of which may be composed of the progeny from canker-resistant individuals of the original crop, while others are known to be the result of direct importation of Alpine seed, this result is not surprising. By 1933, Swiss Alpine seed was becoming suspect, though a few importations were made up to 1946, when the last big consignment of Swiss seed arrived. The result of this wide-scale use of seed from the High Alps has presented British foresters with many problems, since early growth has often been perfectly satisfactory up to the thicket stage, when dieback begins. In recent years the emphasis has swung round to the Sudeten and Polish provenances and there have been fairly large imports from these areas. Neither Polish nor Tatra larch has ever been used in Britain on any scale, but there has been excellent growth of Polish larch in Scotland (Hunter-Blair, 1948) and small scale importations just after the recent war have grown outstandingly well. The first seed specifically stated to be from the Tatras was received in 1954, but it is possible that some of the early "Silesian" seed came from the Tatra region.

To sum up, the high Alpine provenances have frequently grown slowly and suffered severely from dieback, those from the lower elevations in the Alps and Austria have given a very variable performance, while those from the Carpathian group (Sudeten, Tatra and Polish) have given the best results of the imported larch. Trees which originate from the best old Scottish stands are sometimes not inferior and may be superior in height growth and resistance to dieback.

HISTORICAL NOTES

Known to be in England by 1629 (Parkinson), larch was not used as a forest tree until the end of the seventeenth century, when a plantation was made at Goodwood, Sussex. In Scotland the earliest trees known, apart from one mentioned in 1683 in the Botanic Garden, Edinburgh, and the trees at The Lee, Lanark, of doubtful date, are the trees at Dawyck, planted in 1725. But the first large-scale use of larch in Britain was by the Duke of Atholl at Dunkeld, after 1750. There seem to have been larch at Dunkeld from 1727, but there is also much in the old accounts to suggest that the trees used traditionally as the main source of seed were planted in 1738. The first plantations were themselves used as seed-sources and thus was established the "Dunkeld" larch used in much of Central Scotland.

TABLE 17 LARIX DECIDUA (EUROPEAN LARCH): DISTRIBUTION BY COUNTRIES AND PERCENTAGES OF HIGH FOREST AREAS OCCUPIED, 1947

Ownership	England			Scotland			Wales			Great Britain		
	Area Acres	Percentages		Area Acres	Percentages		Area Acres	Percentages		Area Acres	Percentages	
		of conifers	of all species		of conifers	of all species		of conifers	of all species		of conifers	of all species
Private Woodlands ...	59,752	31	8	34,890	13	9	7,116	34	7	101,758	21	8
Forestry Commission ...	13,406	7	5	13,179	7	7	4,560	6	5	31,145	7	6
Total ...	73,158	19	7	48,069	10	9	11,676	11	6	132,903	14	8

TABLE 18 LARIX DECIDUA (EUROPEAN LARCH): HIGH FOREST AREAS, PURE AND MIXED STANDS COMBINED, BY AGE-CLASSES, 1947 Acres

Ownership	1–10 yrs.	11–20 yrs.	21–30 yrs.	31–40 yrs.	41–60 yrs.	61–80 yrs.	81–120 yrs.	Over 120 yrs.	Uneven aged	Total
Private Woodlands	13,481	19,469	19,507	14,385	17,987	7,987	1,951	441	6,550	101,758
Forestry Commission	5,635	16,807	6,004	652	573	270	439	6	759	31,145
Total	19,116	36,276	25,511	15,037	18,560	8,257	2,390	447	7,309	132,903

EXTENT OF PLANTING

Larch is generally distributed in Great Britain but nowhere makes up a large proportion of the total area of high forest. It is widely planted in small patches for general estate and farm use. In Scotland it is most prominent in Perthshire where it makes up sixteen per cent of the area of conifers, but it is well represented throughout the Highlands. It has frequently been planted in the south of Scotland and it occurs in fair proportion in the north of England. The main distribution further south is in the western half of the country, i.e. North Wales, Shropshire, Hereford and Gloucester. In 1947 there were 132,903 acres of larch stands in Britain, of which fifty-five per cent were in England, thirty-six per cent in Scotland and nine per cent in Wales. (See Tables 17 and 18.) Larch is more often used in mixture, than any common conifer. Only forty-two per cent of the total area consists of pure stands. 101,758 acres, or seventy-seven per cent, were privately owned, a higher proportion than that of any other common conifer. The low percentage (thirty-three per cent) of larch in Commission Forests is partly a reflection of their predominantly less fertile soils. Although it has been widely planted for 200 years, it becomes ripe for felling early in life and few old stands remain. As Table 18 shows, only two per cent is more than eighty years old.

The way in which European larch has been largely replaced by Japanese larch can be seen in the Annual Reports of the Forestry Commission (1921-1954). In 1921 the Forestry Commission planted 2½ million European and Japanese larch, of which number the vast majority were European. By 1932 the peak of European larch planting had passed, and by 1952 only 382,000 European larch were used compared with 16 million Japanese larch. This figure for European larch represents less than one per cent of the total numbers of plants used. Since 1952, there has been a trend towards planting more European larch, and in 1955 nearly 2½ million plants were used. More seed is now being collected from selected Scottish stands.

CLIMATIC REQUIREMENTS

In its native homes larch experiences a considerable range of climatic conditions from the extreme Continental to the moderately maritime. In Britain the incidence of late spring frosts is one of the chief factors governing its use in afforestation. This was realised by the earliest planters and in the woods of the fourth Duke of Atholl it was noted in 1795 that plantations above 600 feet at Dunkeld escaped "dieback", while those woods on the lower slopes of the Tay Valley (in the frost pool) often became frosted and diseased (Atholl 1832). Day and Peace (1937) reported that European larch was not one of the conifers most affected by the severe mid-May frosts of 1935, but Day (1951) noted that March and early April frosts are the important ones with this species. The chief damage caused by frost is in killing the newly flushed shoots and thus making

conditions favourable for larch canker; damage is also done to seedlings in the nursery and the flowers of mature trees.

While larch appears to have a definite preference for continental conditions in Central Europe its behaviour in this country does not appear to be limited by climatic factors since good stands and old individuals are found in all parts of Great Britain. Where, however, a non-retentive soil is combined with a low rainfall, larch fails to prosper, e.g. Culbin, Morayshire and Thetford, Norfolk.

Larch does not seem to require a high summer temperature for optimum growth in Britain, since speed of growth varies little from north to south of the country. Good stands occur both in those regions which have a long growing season and an oceanic climate, and in those where the growing season is appreciably shorter and which have a moderately continental climate, such as Upper Deeside and the Upper Tay valley in Scotland.

Larch is not a tree which stands up well to exposure to strong winds, though it succeeds on sheltered sites at a high elevation. On wind-swept sites the trees develop a pronounced lean and seldom grow very high. It is well adapted to withstand much colder winters than any it experiences in Britain, but it does not withstand exposure to sea-winds (Anderson, 1929).

SITE REQUIREMENTS

"This species is typically a tree of the middle and higher but sheltered slopes. It makes considerable demands on the fertility of the soil, while its relatively high rate of transpiration necessitates a continuous and moderate supply of water. The slopes around Dunkeld have shown themselves a second home of the species. Here we have morainic or *in situ* soils of mica schist and slate." (Steven, 1927). On such sites it grows to 100 feet in height in eighty years and even 1,000 feet up a height of eighty feet is attained. "On the whole it requires at least moderate base-richness in the soil and fails on infertile sites. It is not happy, however, on extremely base-rich sites. Fresh, light, loamy soils suit it best, but it is often capable of growing for a short time on rather heavy marls and on shallow limestone sites." (Anderson, 1950). Anderson also concludes that there are three types of European larch site:

(a) It may be grown to maturity as a pure crop on fertile hill sites with a grass-heath vegetation (these types are frequently invaded by bracken).

(b) On more fertile sites with a greater supply of soil moisture, prime larch can be grown to a considerable size.

(c) On the less fertile grass-heath types it can be used in mixture with Scots pine as a soil-improving species.

According to the same author (Anderson, 1956) the roots of larch seem particularly capable of dissolving metallic cations from the parent material of the soil; these cations are transmitted to the leaves and returned to the soil through leaf-fall. Ovington (1956) notes the high phosphorus content of larch leaves and the improved phosphorus status of the soil beneath larch stands. This soil-improving characteristic of larch was noted in the early Atholl plantations, but has only recently been explained. Where the soil is poor in metallic cations such as on acid or peaty soils, larch does not improve the soil appreciably, and Jacks (1932) has noted that it is likely to produce an acid humus. On deep peat larch is a failure, but on a fertile shallow peat it has grown moderately well (Zehetmayr, 1954).

Being a species well adapted to deep root penetration on suitable soils it does not prosper where its root development is restricted by a high water table or an impermeable layer in the soil (Day, 1947). Aird and Stone (1955) showed that there was a strong correlation between good height growth and soil depth and moisture content. European larch has been planted on many sites where the soil is known to be far from ideal. Dry sands, heavy clays and highly calcareous soils give poor results.

The problem of the most suitable aspect is not simple. "A northerly aspect may be an advantage in places where there is a risk of frost. A southern aspect may be better because the European larch is a tree which, in its native habitat, is used to bright sunlight and a high light intensity. This may be of importance on the cloudy west coast where, in fact, there are examples of good larch plantations with a southerly aspect; but on the other hand, soils with this aspect dry out more rapidly in times of drought." (Macdonald, 1949).

The effect of elevation is of less importance than shelter, but it is difficult to separate the two. In a survey of Deeside woods, stands of Quality Class II were found at 1,640 and 1,730 feet. Larch occurs in the Loch Ericht plantations, Inverness-shire, up to 2,000 feet, and excellent stands exist nearly to the top; although height growth is slow there, the trees are twice the height of Scots pine of the same age. Another high elevation stand was in Caenlochan Glen, Angus, at an elevation of 2,200 to 2,400 feet where larch about 110 years old had reached 62 feet in height and had a girth of 68 inches. Roger (1941) has reported stunted natural larch seedlings as high as 2,950 feet on Glas Maol in the Grampians, growing amidst a typical arctic-alpine flora.

ESTABLISHMENT TECHNIQUE

NURSERY PRACTICE. The nursery treatment of European larch is similar to that of other conifers. The seeds are rather variable in size and weight,

averaging 75,000 per pound. Germination of different consignments is erratic and the mean of a large number of tests is only 24 per cent. Imported seed tends to have a higher germination percentage than home seed. With seed of 24 per cent germination it should be sown at a rate of 25 square yards of bed per pound.

To produce one-plus-one-year transplants, larch is normally sown in agricultural type nurseries, where it grows fast enough to produce a plant fit for lining-out after one year. Nitrogenous manures are often omitted in fertile nurseries.

VEGETATIVE PROPAGATION. In breeding work, grafting can be carried on out of doors, giving fifty to eighty-five per cent success. Scions are collected when still dormant in February and are grafted in late March; for grafting under glass, collection can be made early in January and grafting done from the end of January to mid-February. The root-stocks are one-plus-one year Japanese or hybrid larch for normal purposes, but, for rapid production of material, plants of five years or older can be used. One-year wood is used for scions, as stout as possible and at least three inches long. Side-veneer grafting or top-working are equally successful.

Cuttings of larch from trees up to about twenty years old will root, but attack by *Botrytis* can on occasions wipe them out. Half-ripened shoots inserted in early July into peat-sand or peat-vermiculite resist *Botrytis* better if the top inch of newest growth is removed. Bottom heat helps in rooting and glass is necessary; under good conditions a thirty per cent success has been achieved.

DIRECT SOWING. This is not a suitable method for raising larch in Great Britain.

PLANTING. The best type of plant is a sturdy (nine to eighteen inches) one-plus-one-year or two-plus-one-year transplant. Seedlings have been tried on numerous occasions (Guillebaud, 1933-1935 and Macdonald, 1937) but have never proved so satisfactory as transplants.

On many of the sites on which larch is planted, ground preparation by ploughing is either not needed or impossible, though on *Calluna*-covered hill land it is nearly always beneficial. The normal method of planting is notch planting in a prepared screef, and this should be done in February or March preferably during mild or open weather. Planting must be done well before flushing starts or it may lead to heavy losses.

SPACING. At the turn of the century, when close spacing was normal practice for all species, 3 ft. by 3 ft. was not uncommon for larch. The earlier Atholl plantations had been established using 5 to 6 ft. spacing, and today 5½ ft. spacing is regarded as a minimum. 6 ft. to 7 ft. spacing is now regarded as suitable, though where a good market exists for small poles Ackers (1938) has proposed 4½ ft. spacing. The results of one spacing experiment in Aberdeenshire with European larch suggests a slight superiority of the closer spacings (3 ft. and 4½ ft.) over the wide spacings (6 ft. and 8 ft.) on a poor exposed site. A similar experiment at Fleet Forest, Kirkcudbrightshire, in a sheltered area, originally showed a poorer height growth for the wider spacings (6 ft. and 8 ft.) but now there is little difference in top height.

Densely planted groups, with wide spaces between groups, planted in the manner advocated by Anderson (1951) have not proved superior to normal planting. The outside trees in many of the groups have become dominant, while the central trees are suppressed, resulting in a crop with coarse branching and one-sided crowns on these outward-leaning dominants.

Although very frequently stated as a fact, there seems to be little solid evidence that wide spacing enhances the capacity of a plantation to resist canker and "dieback"; in fact Marshall (1906) reports a case where larch planted at twelve feet by twelve feet in old coppice was badly cankered.

TENDING AND THINNING

WEEDING. It is generally agreed that larch is very intolerant of shade and must be well weeded in the years following planting; but, as it has no early check period, weeding can be relaxed earlier than with many other trees.

THINNING. It is one of our most strongly light-demanding species. Thinning should begin early, perhaps as early as twelve to fifteen years, and should be heavy. If larch has been planted closer than five feet apart, thinning should certainly start at about this age, but where six or seven feet spacings are used it may be twenty years old before thinning is needed.

The interval between successive thinnings should be about three years for the first three or four thinnings but may later increase to five years.

The crop is much lighter on the ground than any other conifer and in properly thinned woods ground vegetation becomes re-established in a very short time. Although it is agreed that heavy thinning is generally desirable for larch, a large percentage of the larchwoods in this country have not been heavily thinned in the past.

PRUNING. Natural pruning takes place rapidly in closed stands. Larch plantations are not often brashed before thinning, and a large percentage of the dead branches on the crop trees which are left may be knocked off by the falling thinnings.

It is unusual for high pruning to be carried into the live crown, but where it is done it does not

result in the production of so many epicormic branches as in other species.

OTHER SILVICULTURAL CHARACTERISTICS

Anderson (1940) has listed nine silvicultural characters, some of which have already been noted. Anderson also mentions its deep root system, which is adapted to the heavy demands made on soil moisture. Larch's high water requirements directly after flushing mean that on sites where the surface soil dries out in spring and early summer it may be difficult to establish. Free-draining slopes, or sites where the soil remains cold after flushing, lead to heavy losses even though growth may be satisfactory when the root deep system is established. Because it is deciduous it withstands snow damage and winter exposure and is thus adapted to high elevations.

As mentioned under "Extent of Planting, " page 60, nearly sixty per cent of all larch crops are in mixture with other species. The first use of larch in the Atholl plantations was in mixture and it was not until later that extensive pure plantations were formed.

In the north it was commonly planted with Scots pine and Norway spruce in an intimate mixture, and, on reasonably fertile ground, the larch grew faster and suppressed the pine. Where the ground was infertile or the situation frosty, the pine succeeded best, while on wet ground the spruce became dominant. In the south, larch has been more often used in the past as a nurse for broadleaved species, with somewhat variable results. The chief dangers lie in neglecting to remove the nurse before it smothers the nursed species, and in planting too high a proportion of nurse trees. At present, very little larch is being used as a nurse for oak, its place having been taken by Norway spruce, which casts a heavier shade and suppresses the vegetation quicker. Larch still finds a use in mixtures, as a cash crop, which can be felled at an early age, or left to grow on to produce larger timber with the hardwood crop.

Owing to the large areas of larch which have suffered from dieback, the question of how to treat them has long been important. One well-known attempt to obviate the worst effects of the disease was made at Novar in Ross-shire (Mackenzie, 1910). The problem of dieback has exercised foresters greatly during recent years because of the large areas involved, and in some cases an over-pessimistic view was undoubtedly taken and much unnecessary work done in affected plantations. Current practice follows Macdonald (1949) who pointed out that affected stands fall into four classes: (a) If nearly all trees have died, the only solution is to replant with another species. (b) If "dieback" is only partial, and on a site known to be capable of carrying good larch, it should be thinned out but left as an open crop of larch, as in fifteen years time the stocking will be nearer normal. (c) Where the soil is moderately fertile, the open crop of larch may allow an undesirable vegetation to develop and so underplanting should be done sooner or later to prevent this. (d) Where the soil or site is unsuitable the larch should be replaced at once by another species.

RATE OF GROWTH AND YIELD

The British yield table for European larch (Hummel and Christie, 1953) is based on fifty-eight plots and the data adequately cover the range of ages up to sixty years. The few older plots, being scattered throughout all Quality Classes, justified the extension of the yield tables to seventy-five years. Only five plots are in Quality Class I; over half the plots are in the second Quality Class. Most of the plots are found at elevations up to 1,000 feet, and no plots of the first two Quality Classes are found above this height. Plots of third and fourth Quality Class are found at all elevations up to 1,500 feet.

The plot with the highest standing volume per acre in Great Britain is one at Tintern, Monmouthshire, which although thinned to a D grade, had a volume of 4,200 hoppus cubic feet over bark per acre when the last volume assessment was made in 1944. Several other plots have recorded volumes of 3,500 to 4,000 hoppus cubic feet per acre.

The total volume production of Quality Class I at fifty years of age is 5,570 Hoppus feet, over-bark, per acre, and this falls to 1,320 Hoppus feet in the lowest Quality Class. Since the majority of the stands in Britain are in Quality Class II or III, the mean production averages about 3,760 Hoppus feet per acre from fully stocked stands.

Current annual increment culminates at an early age in European larch. In Quality Class I at 20 years it is already decreasing, and in the other Quality Classes it is decreasing throughout the yield tables. The culmination of mean annual increment is reached at an early age. In Quality Class I this point occurs at 45 years, and in Quality Class III at about 53 years, at which time only about sixty per cent of the volume is of saw timber size. The increment of individual trees remains high, but because larch is an extreme light demander the trees must be widely spaced apart. It follows that for the latter part of the rotation the whole site potential is not being used and hence it is logical to underplant or to grow larch in mixture with a slower growing species.

Where underplanting has been carried out, the meagre evidence at present available suggests that it has little or no effect on the rate of growth of larch trees in the overcrop, provided that the undercrop is not allowed to interfere with the crowns of the larch.

Mitchell (1956) has given records of the growth of individual larch trees notable for their great size or rapid growth. There are many records of old trees with heights over 130 feet and more than ten feet in girth. Because it has been grown here for three centuries, European larch is one of the few exotics whose approximate size limits in Britain are known, and Mitchell states that trees with a total height exceeding 145 feet and a girth at breast height greater than 18 feet, will be very rare.

DISEASES AND PESTS.

The insect pests of European larch have been considered under the genus.

The leaf cast fungus, *Meria laricis*, causes occasional setbacks in the nursery, but can be controlled by spraying.

The canker and dieback of plantations of European larch have provided British foresters with one of their toughest problems. Dieback first becomes apparent when the tips of the branches at the level of the vegetation begin to die. At a later stage, when the crop closes canopy, tip dieback increases and branch cankers appear, followed by stem cankers and a general appearance of debility. At this stage the trees often have an infestation of *Adelges laricis*. In bad cases the branches die back for a long way up the stem, which becomes badly cankered, and the tree is finally killed. Every great extension of larch planting has been followed by an outbreak of the disease; in the plantations made during the last wave of larch planting in 1920-30, dieback has occurred over hundreds of acres, particularly in the north-east of Scotland and in South Wales (Macdonald, 1949).

Dieback was described in the Atholl plantations in the eighteenth century, and over a period of more than a century there have been many attempts to explain the causes; amongst others, incorrect spacing or thinning, bad drainage, heavy snowfall, mist and fogs, attacks by *Adelges laricis*, by *Coleophora laricella* or other insects, planting on old fields, use of home-collected seed, or, alternatively, use of foreign seed, have all been suggested at one time or another as likely causes. It is now believed that canker and dieback are caused by frost damage in association with the fungus *Trichoscyphella* (*Dasyscypha*) *willkommii*, and the wrong choice of provenance. The trouble is often accentuated by unsuitable soil and site factors, for example a frost hollow or the floor of a narrow valley.

The importance of provenance has already been noted, and it is also clear that frost plays a major role in the disease, since there are a great many examples where the lower part of a plantation, which is exposed to frost, shows all the symptoms of dieback, while the upper part, which is untouched by frost, is free from the disease.

OTHER FORMS OF DAMAGE

WIND. European larch has been long regarded as a windfirm tree though exceptional gales have caused considerable damage (Michie, 1885). Larch proved more resistant, even to the hurricane of January 1953, than Scots pine or any other common conifer (Lines, 1953; Andersen, 1954). The age of the crop is important, as young plantations on fertile sites are rather prone to wind-sway, but later, resistance stiffens and the crop is windfirm until root rot and senility become important. The major gales in Britain come at a time when larch is leafless, but larch is prone to damage from the rare unseasonable gale (Gosling, 1936). When larch is blown it is very rare to find trees broken by the wind; they are uprooted.

ATMOSPHERIC POLLUTION. Larch was noted by Fisher (1895) as less susceptible to smoke pollution than Silver fir or spruce, but more so than Scots pine. Peace (1952) regards it as one of the susceptible conifers.

Peace has also found that it is very susceptible to fluorine in the atmosphere.

SEED AND SEED-BEARING

The best account of this is given by Matthews (1955). Flower buds of larch open in March or April, earlier than most other conifers and are therefore often damaged by frost. The male and female flowers are intimately mixed over the whole crown of the tree. The female flowers normally open first, though this may be reversed on occasion, depending on the spring weather (Leven, 1951). This is an important factor in the production of hybrids with pollen from Japanese larch. The flowering times of the two species have been shown to overlap so that both crosses can occur naturally in the field.

The cones should be collected from October onwards; if collection is delayed until after December some seed is likely to be lost. Larch commences seed-bearing at ten to fifteen years old, but the first good seed crop comes between twenty-five to thirty years of age. Maximum production begins between forty and sixty years, and open-grown specimens continue to produce good crops of seed until well over one hundred years of age. Good seed crops come at

intervals of three to five years, and there is seldom a year without some seed. The cones do not open very easily, due to resin on the scales.

Good seed years appear to be those with a mild spring and, in the previous year, a dry warm summer to initiate flower development; though fruiting is probably less affected by the variation in summer temperatures than by the occurrence of sharp frosts in March, at which time the flowers are very susceptible. Irregular fluctuations in production are evident.

GENETICS AND BREEDING

Larch early attracted tree-breeders because of its great natural variation, the early report of a promising hybrid and the short time between generations. European larch readily forms hybrids with Japanese larch, and possibly with tamarack (*Larix laricina*), and intraspecific crosses between provenances (Alpine × Sudeten) may prove promising.

In Britain 360 'Plus' trees have been selected, sixteen stands of 320 acres have been registered as 'Almost Plus' seed sources, and eight stands of sixty-five acres as Normal seed sources. A one-acre seed orchard is already established at Drumtochty, Kincardineshire, and sixty acres of seed orchards are planned. These should provide a high proportion of the European larch seed used in Britain.

NATURAL REGENERATION

There have been some cases of successful natural regeneration of larch in Britain, the most notable being Tom an Uird wood near Grantown, Morayshire. Here there has been fairly complete regeneration over 400 acres, the seed coming from an adjoining unfelled stand. Larch now forms a complete crop, mixed in places with Scots pine.

Other occurrences of natural regeneration were noted in north-east Scotland during the 1947 Census and nearly all were on northern aspects.

TIMBER

The timber kiln seasons with a tendency to distort and for knots to loosen; pieces showing spiral grain can be particularly troublesome. The weight of the seasoned wood is about 37 lb. per cubic foot.

The heartwood is durable, but that in the vicinity of the pith is less durable than the outer heartwood (a phenomenon which may be more widespread than is often realised). Larch heartwood is very resistant to penetration by preservatives.

Larch is stronger and heavier than most other softwoods; its strength properties are compared with those of home-grown Scots pine in Table 19.

Prior to the tests at the Forest Products Research Laboratory, a number of bending and crushing tests were made on pitprops and beams and gave much the same results (Hudson Beare, 1922-4).

According to information received from the home timber trade, European larch air seasons fairly rapidly with some tendency to split and warp. It is more difficult to convert than most other softwoods, largely on account of spring, and a different saw set is often required.

It is particularly well liked for estate work, and in those parts of the country where oak is not the traditional fencing material, the European larch post is the criterion by which all other softwood posts are judged by users.

For paper pulp and fibre-board manufacture, European larch old enough to have heartwood is not generally acceptable at present.

Larch is not generally acceptable for telegraph poles, because it sometimes develops deep and wide checks, and it is said that movement due to spiral grain can throw a cross-arm out of alignment.

Sawn European larch is used for waggon and lorry building and good quality material is in demand for vat making, boat building and trawler equipment. It is also used for river defence works, pier and bridge building. It is regarded as a special purpose softwood especially suited to service in conditions of repeated wetting and drying.

POTENTIALITIES OF THE SPECIES IN THE NATIONAL ECONOMY

A few years ago it would have been true to say that the prospects for European larch in Great Britain were not bright because of the widespread die-back, but with the realisation of the importance of site and provenance there has been a swing back towards greater use of this tree. Nevertheless, larch is unlikely ever to form a high proportion of our forest area. The sites on which it flourishes will support other and higher yielding species, and

TABLE 19 LARIX DECIDUA (EUROPEAN LARCH): STRENGTH OF TIMBER

	Modulus of Elasticity	*Bending Strength*	*Compression Parallel to the Grain*	*Sheer*
European larch (*Larix decidua*)	1,100,000 lb. sq. in.	2,200 lb. sq. in.	1,600 lb. sq. in.	200 lb. sq. in.
Scots pine (*Pinus sylvestris*)	1,200,000 lb. sq. in.	1,600 lb. sq. in.	1,200 lb. sq. in.	200 lb. sq. in.

LARIX EUROLEPIS (HYBRID LARCH): HIGH FOREST AREAS, PURE AND MIXED STANDS COMBINED, BY AGE-CLASSES

TABLE 20 Acres

Ownership	1–10 *yrs.*	11–20 *yrs.*	21–30 *yrs.*	31–40 *yrs.*	41 *yrs. and over*	*Uneven aged*	*Total*
Private Woodlands	1,079	1,564	1,333	537	162	31	4,606
Forestry Commission	727	455	338	—	—	—	1,520
Total	1,806	2,019	1,671	537	162	31	6,126

hence the use of European larch depends essentially on its peculiar merits. Its value for general estate purposes and the early returns which can be obtained from small-sized material make it attractive to the private owner in whose planting programmes it will continue to figure largely. R.L.

Larix eurolepis Henry.

COMMON NAME

Hybrid larch. Although other larch hybrids exist, the name "hybrid larch" is understood in Great Britain to refer only to the hybrid between *L. decidua* and *L. leptolepis*. In practice no distinction is made between the trees of the first cross and later filial generations or back crosses; in fact there is often no record of whether the plants are first, second or even third generation stock.

HISTORICAL NOTES

The first tree to yield the hybrid was a young Japanese larch standing next to two European larches, about 300 yards east of Dunkeld House, Perthshire (Chittenden, 1932, p. 583).

The hybrid itself was first described by Henry and Flood (1919). Other places where the hybrid has occurred naturally are Glamis, Angus; Darnaway Estate, Morayshire; Strathconon, Ross-shire and Barbeth, Kirkcudbrightshire, all in Scotland, and at Cockle Park, Northumberland, in England. The cross was later made in many European countries. Interest remained centred in the Dunkeld region of Scotland and the majority of hybrid larch in Britain has come either from the original Japanese larch in the Avenue there or else from first generation plantations on the Atholl Estates nearby.

The Japanese larch trees on the Avenue at Dunkeld, from which most of the seed was collected, were planted in 1887. The first seed was collected about 1900 and the earliest recorded hybrid seedlings were planted at Inver, near Dunkeld in 1904. (Henry and Flood, 1919.) Recently, however, a plantation has been found at Lagrennich, near Blair Atholl, which appears to antedate the Inver trees by several years.

At Dunkeld and some other places hybrid seed has also been collected from the European parent with the Japanese parent supplying the pollen.

EXTENT OF PLANTING

Hybrid larch is classified as a Minor Tree Species in the Census of Woodlands 1947-49, which records an area of 6,126 acres occurring chiefly in Private Woodlands in Scotland. Table 20 shows the distribution by age-classes.

It is of interest to note that nearly half the total area lies within the county of Perth.

Scarcity of seed has restricted the greater use of this desirable hybrid, and this has now been tackled by planting seed orchards to produce the first generation hybrid.

LARIX EUROLEPIS: (HYBRID LARCH) NUMBER OF PLANTS USED FOR PLANTING AND BEATING-UP IN COMMISSION FORESTS

TABLE 21 Thousands of plants

Year	*England*	*Scotland*	*Wales*	*Total*
1946	180	116	16	312
1947	244	64	1	309
1948	19	53	—	72
1949	1	12	—	13
1950	58	32	1	91
1951	4	238	—	242
1952	—	744	2	746
1953	57	1,056	59	1,172
1954	1	438	23	462
1955	—	1,441	38	1,479

Table 21 shows the numbers of plants used for planting and beating up by the Forestry Commission during the last ten years. The varying numbers reflect the fluctuations in seed supply.

There is no information about the number of plants used in Private Woodlands in the same period, but most estates with seed-bearing hybrid larch collect cones from them either for their own use or for sale.

CLIMATIC REQUIREMENTS

We have no information to suggest that hybrid larch differs from European or Japanese larch in its climatic requirements, although, due to its growth vigour, it has succeeded better under poor and exposed conditions than either of these species. In particular, it is superior to Japanese larch in maintaining a good growth form where the latter would be distorted by strong winds.

SITE REQUIREMENTS

Hybrid larch has been used in a number of experiments on the upland heaths and also on shallow and deep peat. The results on peat have been summarised by Zehetmayr (1954) who notes that it is a hardier tree than Japanese larch, probably in every respect, and it grows consistently faster, especially where exposure is an important factor. Some of the tallest and most striking plots on peat are hybrid larch, but in places where it does not thrive, heavy losses occur early and it does not linger in a state of check as do the spruces. On the heaths it has also made rapid growth and is almost invariably taller than Japanese larch and much taller than European larch of the same age.

In normal Forestry Commission practice there has been a tendency to utilise this tolerance, and to plant hybrid larch on rather exacting sites. But on many private estates it is used on sites for which European larch would be the obvious choice. This is done to obtain a crop which gives more rapid early returns and a higher rate of increment than most provenances of European larch would yield.

ESTABLISHMENT TECHNIQUE

NURSERY PRACTICE. The general nursery treatment for hybrid larch does not differ from that of the other two common larch species.

It is a common practice to pick out seedlings of hybrid larch (which have arisen by free pollination) from seedbeds of home-collected Japanese larch. With progeny from some stands a fair proportion of hybrids is a normal occurrence, and it is not difficult to pick out the more vigorous hybrid plants, which are then lined-out separately. It is likely that there remain other hybrids which have not disclosed their heterotic nature, but this is the normal method of selecting the hybrid population.

TENDING AND THINNING

The treatment of hybrid larch as regards planting, tending and thinning, does not differ from Japanese larch.

OTHER SILVICULTURAL CHARACTERISTICS

Because a given origin of 'hybrid larch' may be the first generation cross from a Japanese larch mother tree, or from a European larch mother, or the second generation cross from hybrid parents or the back-crosses to either parent species or even a third generation cross, it is unlikely to give the same results as hybrid larch of a different origin. When open-pollinated generations of hybrid larch were compared experimentally, it was found that the first generation hybrid was best, followed closely by the second generation, while the third generation hybrid (collected from a second generation hybrid larch plantation) was decidedly inferior.

Hybrid larch is valued in British silviculture for its very vigorous growth, its hardiness and freedom from larch dieback, and its straightness of stem, which resembles that of the European parent. Hybrid individuals showing outstanding vigour are a relatively common feature in some stands of European and Japanese larch from home-collected seed, and as they tend to be favoured in thinning they will come to form a higher proportion of the final crop. If the majority of seed comes from home collections, at the end of several rotations, few pure stands of European or Japanese larch may be left.

RATE OF GROWTH AND YIELD

The oldest sample plot was established in 1933 in the crop planted in 1908 at Lower Warren, Dunkeld (Table 22) and measurements have been made in seventeen other plots, all but five in Scotland. Measurements have also been made in six temporary plots in Scotland.

Nearly all the hybrid larch sample plots are equivalent in height growth and volume increment to Quality Class I Japanese larch.

The growth rate has been compared with that of Japanese and European larch by Edwards (1956), who concluded that, in eight cases where there were comparable adjacent plots, the hybrid larch were taller than the Japanese, and both were taller than the European plots.

DISEASES AND PESTS

Hybrid larch does not differ greatly from Japanese larch.

TABLE 22 LARIX EUROLEPIS (HYBRID LARCH): GROWTH AND PRODUCTION

Locality	*Elevation Ft.*	*Age yrs.*	*Top Height Ft.*	*True Mean Girth in.*	*Vol. per acre H. Ft. O.B.*	*Total Production per acre H. Ft. O.B.*	*Remarks*
Atholl, Perthshire	270	48	86	40½	2,985	7,386	One of the oldest plantations
Drumtochty, Kincardine	650	29	53½	26½	1,585	3,401	
Glenbranter, Argyll	100	26	60	30	2,130	4,010	
Drummond Hill, Perthshire	960	31	60½	30	2,160	4,241	1st Generation
do.	960	31	58½	29	2,178	4,186	2nd Generation
Achnashellach, Ross-shire	150	29	64	30	2,380	4,113	80 in. rainfall
Bedgebury, Kent	300	26	55	29	2,263	4,266	33 in. rainfall
Leighton, Montgomeryshire	700	29	63	27½	2,190	4,214	

SEED AND SEED-BEARING

Hybrid larch bears cones much earlier than either Japanese or European larch, and this feature often distinguishes hybrids in plantations of those species. The small amount of data on seed suggest that it resembles Japanese larch in seed weight, but European larch in germinative capacity. It resembles the parent species in the frequency of good cone crops and in its phenology.

GENETICS AND BREEDING.

Seed plantations have been established from 1931 onwards by Lord Dundee at Birkhill, Fife, to produce the back cross *L. decidua* × *L. eurolepis*. The first seed orchard for the production of first generation hybrid larch was established at Newton, Morayshire, in 1951, using twelve clones of Japanese larch and three of European larch. The first cone crop was obtained in 1956 and from now on an appreciable supply of first generation hybrid larch seed should become available from this and other seed orchards. Fifty-five acres of seed orchards are to be planted by 1960. Eight first generation plantations of hybrid larch have been registered as seed sources.

TIMBER

Very little is known about the timber as it has not been tested for strength or working properties by the Forest Products Research Laboratory. Chowdhury (1931) investigated the anatomy of the timber of a single specimen and reported that it resembled the Japanese parent in its fine structure. It has a good reputation amongst the few private estates which have dealt with large numbers of thinnings, being used for similar purposes to European larch.

POTENTIALITIES OF THE SPECIES IN THE NATIONAL ECONOMY.

Hybrid larch has been in cultivation for about fifty years and has shown itself to be one of our fastest growing trees. It has grown well over a fairly wide range of sites and may be especially useful as a pioneer crop on upland heaths and peat. Its freedom from "die-back" and canker enable hybrid larch to be used with confidence, and a regular supply of seed of the first generation hybrid from selected parents should result in wider use of this tree in British silviculture.

R.L.

Larix gmelini (Ruprecht) Litvinov

This tree, native to Siberia, Korea, Manchuria and the Kurile Islands, was introduced into this country in 1827. It appears to be a variable species and some well-known varieties exist, of which var. *japonica*, the Kurile Larch, and var. *principis-rupprechtii* are also in cultivation.

Neither *L. gmelini* nor any of its varieties is suitable for use in Great Britain, as they suffer severely from spring frosts. Various groups of *L. gmelini* and small plantations have been attempted at various places, but with little success. There are some fairly good individual specimens which have survived, including one of *gmelini* at Wakehurst, Sussex, which is 63 ft. in height, one of var. *japonica*, 41 ft. high at Brocklesby, Lincolnshire, and one of var. *principis-rupprechtii* at Kew, which is 36 ft. in height.

Larix griffithii Hooker

This east Himalayan species has been tried on several occasions, but usually fails to survive our oceanic climate with its unseasonable frosts; plants at Bedgebury died within two years of planting. There is a tree 77 feet high and 7 feet 7 inches in girth at Strete Raleigh, Devon, and another 39 feet tall at Wakehurst Place, Sussex.

Larix laricina (Du Roi) K. Koch

This larch has an almost transcontinental range from Alaska through Canada to the north-east

coast of the U.S.A. It was introduced in 1760, and planted soon after by the Duke of Argyll at Whitton, Middlesex; it was also planted on the Atholl estates about 1770. It has never made any mark as a forest tree in Britain, being of poor stature and somewhat prone to canker. It has however been used with some success at Blairquhan, Ayrshire, in very frosty wet hollows; the trees are of good habit with narrow crowns, but the stems are not very straight. The tallest tree at Blairquhan is 58 feet high, while there is a tree 85 feet high and 4 feet 3 inches in girth at Warnham Court, Sussex. It has been little used in plantations, but an experimental plot at Ceiriog, Denbigh, planted in 1908, showed quite good growth, reaching 29 ft. at 20 years of age.

R.L.

Larix leptolepis (Siebold and Zuccarini) Gordon

COMMON NAME

Japanese larch, applied to both the tree and its timber.

COUNTRY OF ORIGIN AND PROVENANCE

The species originates in Japan, its natural range being confined to a small region in the centre of Honshu Island, between 35° and 37° North and 137° to 140° East. It ranges from elevations of roughly 4,000 feet above sea level to 8,000 feet or to an extreme limit of 9,200 feet on Fujiyama.

Since the natural distribution is so limited, it is not surprising that geographical races have not been distinguished. A Japanese experiment, quoted by Lindquist (1955), suggests that there are probably several climatically different provenances, each well adapted to various temperature and moisture conditions, but in Britain the reactions of different provenances are too small to be detected without very precise experimentation (Edwards and Pinchin, 1953). However, progenies of different individual trees have shown significant variations with respect to the vigour of the parents (Wood, 1950) and these experiments have also shown marked morphological differences in crown type (Lines, 1955, and various continental authors listed by Lindquist, *ibid*).

It has been planted in Hokkaido and seed is now also imported from that island.

HISTORICAL NOTES

The Japanese larch was introduced into Britain in 1861 by J. G. Veitch. At first it was a neglected tree, little planted even for ornament, but the Duke of Atholl brought seed from Japan in 1883 and first used the species for forestry (Chittenden, 1932). The famous trees he planted on the Avenue at Dunkeld, Perthshire, are described by Matthews (1954). The oldest plantation so far traced is Lagrennich Wood at Blair Atholl, Perthshire, where seven acres were planted in 1895. The oldest plantation in England is said to be that of 1898 at Cockle Park, Northumberland (Macdonald, 1931; Forbes, 1925), and these trees, which are next to plots of European larch, have yielded hybrids, just as happened at Dunkeld (see page 66), though the same interest has not been shown in seed collection.

EXTENT OF PLANTING

Japanese larch has now become one of the most important exotics planted in Britain, in spite of a rather late introduction and lack of seed supplies during two world wars. See Tables 23 and 24.

It may be noted that the areas in private and state forests are almost equal, Japanese larch thus occupying a place between European larch, with the majority in private woodlands, and such species as Sitka spruce and Douglas fir with the majority in Commission forests.

In England, at the time of the 1947-1949 Census, the status of Japanese larch was similar to that of Douglas fir, but Japanese larch has since been increasing and Douglas fir decreasing in popularity, so that by now, Japanese larch has probably an advantage. In Scotland, Japanese larch was ahead of Douglas fir in 1949, the disparity now (1957) is even greater, and the same is even more true in Wales, for Japanese larch has long been extensively planted there, where the climate is suitable and the soils moderately fertile.

In recent years the number of plants used annually by the Forestry Commission, excluding plants used for beating up, has been about fourteen million, a figure only exceeded by Sitka spruce and Scots pine.

CLIMATIC REQUIREMENTS

Japanese larch comes from a latitude equivalent to that of the Mediterranean region, which probably accounts for its rapid growth and tendency to harden off late in the autumn, when it may suffer damage by frost (Veen, 1954). In Japan it enjoys a summer rainfall climate with over forty inches of rain per annum, and it is thus only suitable for the moister parts of Britain. Although planted fairly extensively at first in the southern and eastern parts of England, it tended to stop height growth comparatively early in life and also suffered from drought, especially on sandstone formations and similar dry sites. Notably after the dry summer of 1911 there were numerous reports of the failure of Japanese larch in these parts of the country. Elsewhere, even where the rainfall is heavier, deaths amongst young trees are not uncommon in years of summer drought where Japanese larch has been planted on shallow soils over rock or other places where the soil may dry out, or in a heavy grass mat.

TABLE 23 LARIX LEPTOLEPIS (JAPANESE LARCH): DISTRIBUTION BY COUNTRIES, AND PERCENTAGES OF HIGH FOREST AREAS OCCUPIED, 1947

Ownership	England			Scotland			Wales			Great Britain		
	Area Acres	Percentages		Area Acres	Percentages		Area Acres	Percentages		Area Acres	Percentages	
		of conifers	of all species		of conifers	of all species		of conifers	of all species		of conifers	of all species
Private Woodlands	12,420	6	2	10,190	4	3	3,564	17	4	26,174	6	2
Forestry Commission	8,849	5	4	7,844	4	4	12,191	15	14	28,884	6	5
Total	21,269	5	2	18,034	4	3	15,755	15	8	55,058	6	3

TABLE 24 LARIX LEPTOLEPIS (JAPANESE LARCH): HIGH FOREST AREAS, PURE AND MIXED STANDS COMBINED, BY AGE-CLSSES, 1947 Acres

Ownership	Age-class								Total
	1–10 yrs.	11–20 yrs.	21–30 yrs.	31–40 yrs.	41–60 yrs.	61–80 yrs.	Over 80 yrs.	Uneven aged	
Private Woodlands	6,043	8,524	7,988	2,183	637	80	1	718	26,174
Forestry Commission	12,855	12,801	2,776	105	49	—	—	298	28,884
Total	18,898	21,325	10,764	2,288	686	80	1	1,016	55,058

It does not appear that the range of Japanese larch is limited by temperature in any part of Britain where trees will grow. Coming as it does from the mountains of Japan, this is not unexpected, and there are many examples of good growth of Japanese larch at relatively high elevations, especially in Wales.

Japanese larch will grow under conditions of considerable exposure, provided that the soil is not impoverished, although the tree may lean over and twist badly, especially if the plantation is established with large plants. The branches, being repeatedly killed back and growing again, may form a very dense thicket, but the tree continues to grow.

SITE REQUIREMENTS

Japanese larch is an accommodating species and it has been used on a wide variety of sites. Though it requires a fertile soil for its fullest development, within the climatic limits already indicated it is a good pioneer species and soon overcomes competing vegetation. Day (1947), who investigated the soils on which Japanese larch had been planted in Wales, showed that it occupied an intermediate position between European larch, planted on more fertile soils of brown earth type, and Scots pine, which had been planted on degraded or podzolized soils. It has thus been used considerably to extend the range of larch, partly because it is a species more resistant to exposure and also because it is able to grow on degraded or leached soils such as the upland heaths. Here, if assisted by ploughing and, where necessary, by the application of phosphate, it establishes itself rapidly. Japanese larch is used in much the same way in Scotland.

It is even grown successfully where *Trichophorum* (*Scirpus*) is present (Macdonald, 1953), but where it does well on such sites the soils have probably been degraded by burning and grazing, rather than being fundamentally poor. Zehetmayr (1954) describes experimental work on deep peat, where Japanese larch has been grown successfully in experiments with the use of phosphate fertilisers, but such sites may be beyond the proper range of Japanese larch.

Japanese larch has been planted on chalk soils on the South Downs, but as a rule it is even less satisfactory than European larch under such conditions.

ESTABLISHMENT TECHNIQUE

NURSERY PRACTICE. Japanese larch is treated in the same way as European larch in the nursery. The seed is rather smaller, averaging about 115,000 to the pound, and the germination capacity is usually larger, normally averaging forty per cent. Thus the sowing area per pound of seed is larger, usually some fifty to sixty square yards.

There is no difficulty in obtaining usable one-year seedlings and in fact it is sometimes found that raising the fertility in established nurseries by special manuring and sterilisation, etc., results in larch seedlings unnecessarily large and unbalanced. This may also happen in heathland nurseries. Frequently top dressings of nitrogen are omitted or reduced. This is specially necessary for Japanese larch because of its tendency to harden off late in the season.

Japanese larch, like European larch, tends to be sensitive to mineral spirit weedkillers and it should be treated in the same way as the latter species.

VEGETATIVE PROPAGATION. Again, Japanese larch behaves similarly to European larch but grafting, carried out for purposes of tree breeding, is usually done out of doors, after the European species, in late March. Cuttings of Japanese larch take root more easily than those of European larch.

DIRECT SOWING. Direct sowing of Japanese larch has sometimes been tried (Wood and Nimmo, 1952) but with little success, and there is no doubt that the use of plants is to be preferred.

PLANTING. Planting is almost universally carried out with one-plus-one-year plants, which may range from about eight to twenty inches in size, the larger plants being used for fertile soils and weedy sites, and the smaller ones for exposed and for ploughed sites. On ploughed land, if the site is likely to be dry, it is especially important to plant near the bottom of the furrow with this species. On unploughed sites notching or screefing with spade or mattock is usual.

Japanese larch flushes early in the spring, and therefore early planting is most important, larches being the first species to be dealt with at the beginning of the season. Autumn planting, as sometimes recommended for deciduous species, is not usually found satisfactory.

Although fertilisers are not required on many soils where larch is used, phosphate is usually essential on heath and peatland. Japanese larch is particularly sensitive in its response to fertilisers, and to other factors such as lack or excess of moisture, and although if conditions are suitable its early growth is fast, if they are unsuitable it does not go into a state of check like spruce but fails to survive for long (Zehetmayr, 1954).

SPACING. In early plantations Japanese larch was closely spaced. It was believed to be a rather more shade-bearing species than European larch and with a coarser branch form. However, as its rapid early growth and light-demanding characteristics became known, spacings were widened, until nowadays five and a half or six feet to seven feet is normal, or even eight feet in the west where the early growth is exceptionally fast.

TENDING AND THINNING

WEEDING. Japanese larch grows vigorously in its early years so that weeding is not usually carried on for long.

THINNING. Many older crops, closely spaced at the start and lightly thinned thereafter, had their live crowns seriously reduced, and though later thinnings released them, crown recovery has often been slow and the crops have suffered permanent damage. Heavy (D) grade thinnings are now normal practice, and such thinnings start early in life when the crop reaches a top height of about twenty-five feet. Hiley (1952) is an exponent of a policy of heavy thinning to leave an extremely low number of stems per acre, controlled quantitatively, instead of silviculturally, by the canopy classification of the trees.

PRUNING. Natural pruning takes place readily, and artificial assistance has not usually been found desirable. But with wide spacing at planting, and heavy thinning, pruning may be necessary.

OTHER SILVICULTURAL CHARACTERISTICS

Japanese larch is a strong light-demander, although rather less so than European larch (Anderson, 1940). A special characteristic, unusual in a deciduous light-demanding tree, and first noted by Forbes (1925) is "its power of quickly killing off surface vegetation, and a mixture of it with any species possesses distinct silvicultural advantages". This has led both to the extensive use of Japanese larch as a fire belt round plantations (Forestry Commission, 1939) and also to the extensive use of Japanese larch as a nurse. It was formerly recommended as a nurse for broadleaved species, but on the soils suited to them the larch grows too vigorously and becomes uncontrollable. Now, its success as a pioneer on upland heaths has led to its use with other more demanding conifers such as spruce. Intimate mixtures with these which have been used involve difficulties in tending, and three row strips of nurse and nursed species are now more commonly used.

The fast growth of Japanese larch in youth has commended it for use on old woodland sites if the regrowth is not so tall as to necessitate the employment of a more shade-bearing species.

Its tolerance of exposure, coupled with its fast growth, makes it especially suitable for shelterbelts, provided that the exposure is not too severe (Cadman 1953).

A system of heavy thinning in middle life, which has been extensively recommended, is sometimes practised and affords an opportunity of underplanting with a shade-tolerant species, to form a two-storeyed forest which may terminate either in a mixture of the two species or in the treatment of the larch simply as a pioneer, involving its early

removal. In this case the Japanese larch serves the function of producing an early intermediate yield of small timber and is of great service in easing the problems of forest finance.

RATE OF GROWTH AND YIELD

Figures for growth and yield are contained in the British yield tables (Hummel and Christie, 1953) which give details up to the age of fifty years. The tables are based on records from ninety-six permanent sample plots. At fifty years of age the first Quality Class has a top height of ninety feet and the last (V), fifty feet, these figures being ten feet higher than the corresponding ones for European larch.

The mean total volume production per acre from Quality Class I at fifty years is 7,500 Hoppus feet, and that for Quality Class V, 2,600 Hoppus feet.

Nineteen of the sample plots are at elevations of one thousand feet or more, and at this height they fall mainly in Quality Class III, with one plot in Quality Class II. There is one plot over 1,500 feet, and it is in Quality Class V.

Not many trees appear to have reached 100 feet in height yet, but there are many records of quick growth in youth, e.g. heights of twenty-five feet in eight years, forty feet in eleven years (Devon), fifty-nine feet in twenty-one years and seventy-nine feet in thirty years (Argyll).

Mention should be made of the theory that Japanese larch ceased height growth at an early age, a notion probably derived from the high proportion of trees which were measured in the drier part of the country (Macdonald, 1951). Successive revisions of the yield tables, based on a higher proportion of plots in moister climates, have shown that the theory is unfounded.

DISEASES

In the nursery, the leaf-cast caused by *Meria laricis* has recently been found. In the autumn, Japanese larch is also rather subject to attacks by Grey Mould (*Botrytis cinerea*), but so far the damage has not been serious. In the forest, canker and die-back of the kind found on European larch is only occasionally reported. Severe cankering of the brashed stem sometimes occurs, and has been variously attributed to frost and to the fungus *Phomopsis pseudotsugae*. Japanese larch seems particularly susceptible to *Armillaria mellea*, the honey fungus.

PESTS. See the note on the genus *Larix*.

OTHER FORMS OF DAMAGE

WINDBLOW. There is no reason to believe that Japanese larch differs from the European larch in its susceptibility to damage from storms.

ATMOSPHERIC POLLUTION. Japanese larch was planted to a considerable extent on the Nottinghamshire sandstones partly on account of its resistance to damage by smoke, and where it did not die of drought, it was successful. On poor soils in the Pennines it is not showing the same capabilities. Where soil conditions are good it is possible that this species shows greater resistance to atmospheric pollution than its European counterpart. (Conder, 1957).

FROST. In the early years of its use, Japanese larch was considered to be resistant to frost but Day (1950) investigated cases where it had suffered both frost damage and canker, though not in the same manner as European larch; and he considered that the differences in susceptibility to frost between Japanese larch and the hardy provenances of European larch are small.

SEED AND SEED-BEARING

Japanese larch commences flowering in late March or early April, but, as with other species of larch, the flowers are often damaged by spring frost and potentially high seed production is reduced. In most years the cones should be collected in September.

The first flowers are produced between the fifth and tenth years and good crops of cones may be collected from the fifteenth to twentieth years. The maximum production is reached between the fortieth and sixtieth years, and good seed crops usually occur at intervals of three to five years. (Matthews, 1955.)

GENETICS AND BREEDING

Registered seed sources comprise six "Plus" and "Almost Plus" stands, totalling about fifty-five acres, and nineteen "Normal" stands totalling about 117 acres. Eighty-six Plus trees have been selected, for use both in the improvement of Japanese larch and as parents of the hybrid larches *Larix eurolepis* and *Larix gmelini* × *leptolepis*.

Seed orchards are being planted and it is proposed to establish forty acres by 1963. This, it is estimated, will produce about one quarter of the current annual seed requirement in Britain, which is about 2,000 lb.

NATURAL REGENERATION

Natural regeneration occurs occasionally but it rarely persists, and it is not as yet made use of in forest management.

TIMBER

The timber is used mainly for estate work and for pit-wood. It is not liked for packaging purposes as it tends to split when nailed and is too resinous to be used in boxes for foodstuffs. Its high resin content also

Plate 1. *Araucaria araucana*. Height 60 ft. Girth 8 ft. Whittingehame, East Lothian.

Plate 2. *Abies nobilis*. 28 years old. Top height 43 ft. Mean girth 20½ inches. Volume per acre 2,752 Hoppus feet. Tree on right showing drought crack. Gwydyr, Caernarvonshire.

Plate 3. *Cedrus deodara*. 45 years old. Top height 62½ ft. Mean girth 28 inches. Volume per acre 3,665 Hoppus feet. Bagley Wood, Berkshire.

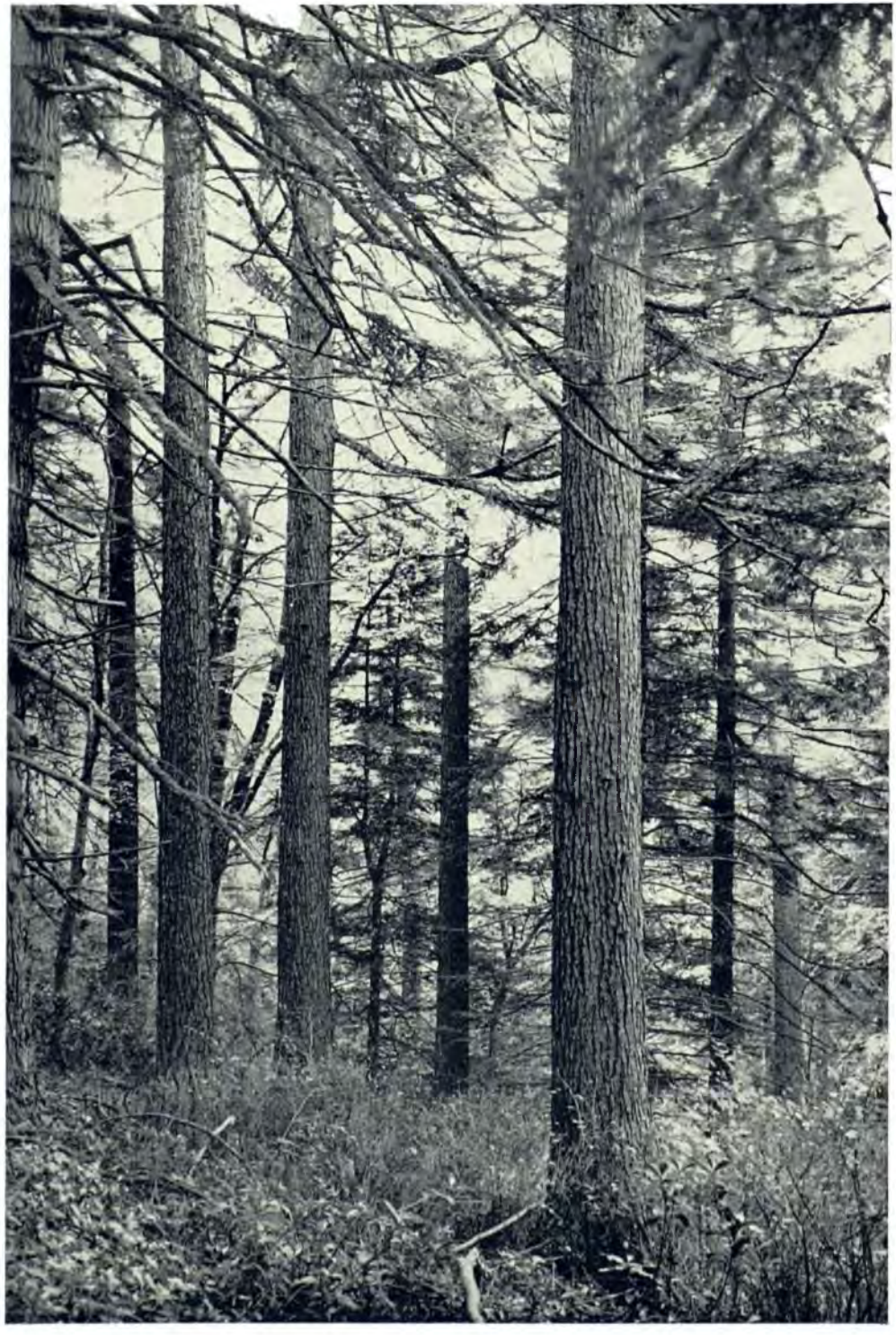

Plate 4. European larch, *Larix decidua*. Selected plus trees. 140-150 years old. Ballindalloch, Banffshire.

Plate 5. Norway spruce, *Picea abies*. 54 years old. Top height 93¼ ft. Mean girth 40 inches. Volume per acre 5,300 Hoppus feet. Tintern, Monmouth.

Plate 6. *Picea omorika*. 23 years old. Mean height 22 ft. Rockingham Forest, Northamptonshire.

Plate 7. *Pinus contorta*. 31 years old. Dalbeattie, Kirkcudbrightshire.

Plate 8. Corsican pine, *Pinus nigra* var. *calabrica*. 54 years old. Top height 80 ft. Mean girth 45 inches. Thetford, Norfolk. Volume per acre 4,270 Hoppus feet.

Plate 9. Douglas fir. *Pseudotsuga taxifolia*. 96 years old. Mean height 125 ft. Mean girth 9ft. 1 in. Volume per acre 9,740 Hoppus feet. Bolderwood, New Forest.

Plate 10. *Pinus ponderosa*. 28 years old. Top height 42½ ft. Mean girth 21½ inches. Thetford, Norfolk. Volume per acre 2,060 Hoppus feet.

Plate 11. *Pinus radiata*. 23 years old. Top height 38 ft. Mean girth 25 inches. Volume per acre 1,650 Hoppus feet. Wareham, Dorset.

Plate 12. European larch, *Larix decidua*, underplanted with *Thuja plicata*. Larch 63 years old; 70 feet high. *Thuja* 40 years old; 53 feet high, with a mean girth of 26 inches. Dymock, Gloucestershire.

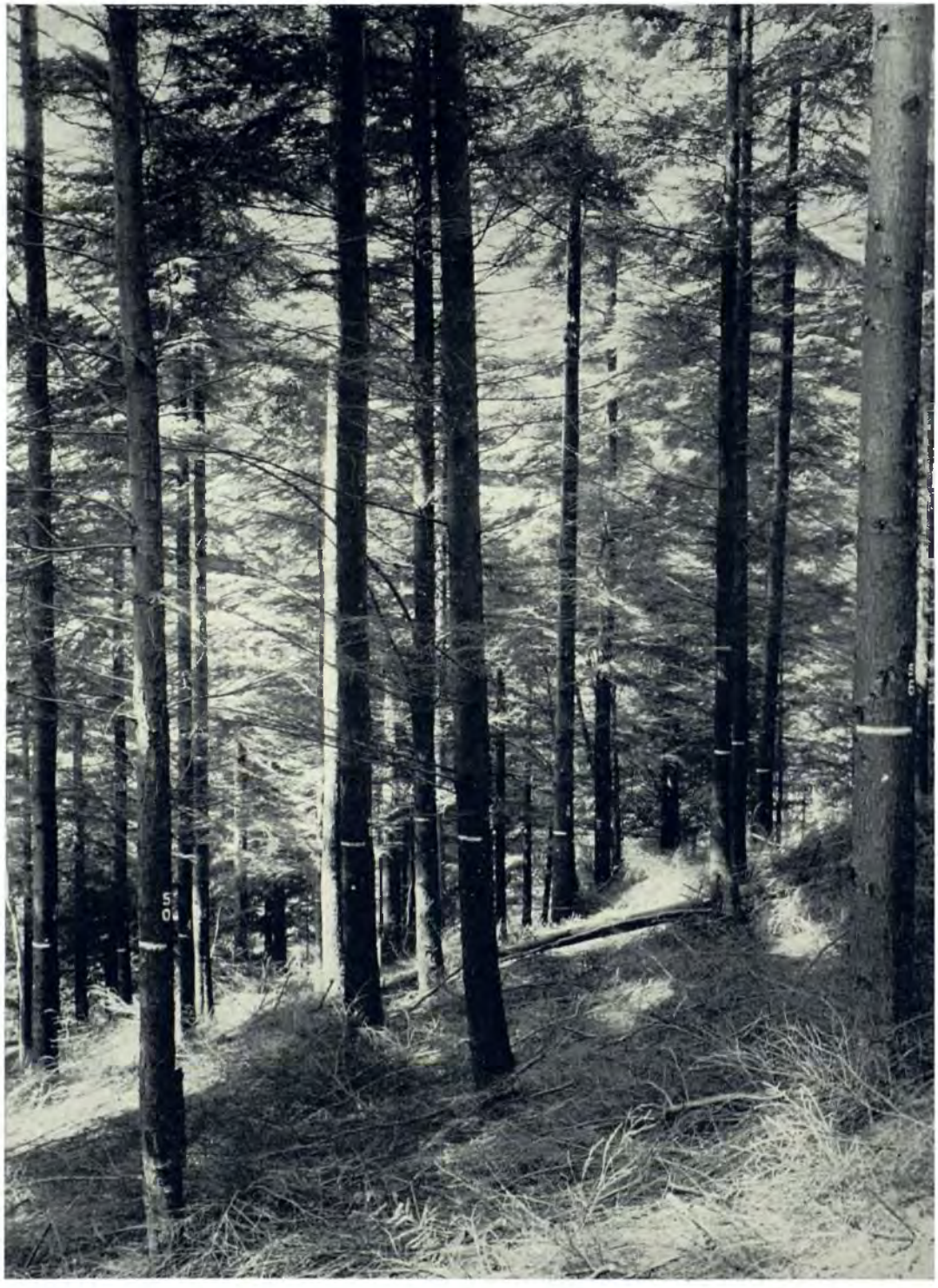

Plate 13. *Tsuga heterophylla*. 25 years old. Top height 53½ ft. Mean girth 21 inches. Volume per acre 2,140 Hoppus feet. Gwydyr, Caernarvonshire.

Plate 14. *Eucalyptus gunnii* '*whittingehamensis*'. Planted 1840. Age 116 years. Height 96 ft. Girth 22 ft. 9 inches. Whittingehame, East Lothian.

Plate 15. *Nothofagus procera*. 20 years old. Height 42 ft. Planted under European larch, *Larix decidua*. Haldon, Devon.

Plate 16. Red oak, *Quercus borealis*. 51 years old. Top height 73½ ft. Mean girth 30½ inches. Volume per acre 1,969 Hoppus feet. Herriard Park, Hampshire.

Plate 17. Exotic trees in Crarae Forest Garden, Argyll, showing, left to right, *Abies concolor*, (with *Cryptomeria japonica* behind), *Cedrus deodara*, *Sequoiadendron giganteum*, *Sequoia sempervirens*, *Eucalyptus urnigera*, and *Abies amabilis*.

renders it unsuitable for the manufacture of wood wool and for fibre boards.

Japanese larch has obtained a reputation inferior to that of the European species, but there is some doubt if it is really poorer. Recent strength tests, carried out on small clean specimens and joists cut from a rather limited number of thinnings, show that it has roughly the same strength properties as European larch, although it is about four pounds per cubic foot lighter. Present indications are that it may find a use as a structural timber on account of its good strength/weight ratio.

POTENTIALITIES OF THE SPECIES IN THE NATIONAL ECONOMY

Japanese larch is extensively planted because it is a good pioneer species on the better-drained and moderately fertile soils, and because the timber is useful for estate work and other purposes. It has perhaps no particular place of its own, but owes its popularity to its ease of establishment, rapid early growth and yield, and the desire to break up pure blocks of other species such as spruce. If, as expected, the timber of the two larches proves to be equally valuable, then the potentialities of Japanese larch are greater than European larch, because of its ability to grow under more difficult conditions. But the volume production of larch is low compared with other exotic species which can occupy similar sites; the uses for which the timber is suitable are somewhat dissimilar, and these factors will no doubt operate in determining the future status of the species.

M.V.E.

Larix occidentalis Nuttall

The Western larch; a native of North America where it is found between the Rocky Mountains and the Cascade Range in Oregon, Washington and southern British Columbia at elevations of from 2,500 to 6,000 ft. above sea level. It was introduced as recently as 1881, although it had been discovered by David Douglas in 1826. Many trial plantations were made about the beginning of this century, a list of which is given in a paper by A. Henry (1922), but it has been little planted in the last forty years. Although it grows quite well in many districts, it is nowhere able to rival either the European or the Japanese larches, and for this reason there is no place as a forest tree for it. As an example of its growth in plantation as a young tree, reference may be made to a plantation at Gordon Castle, Morayshire (Macdonald, 1930) where in 20 years it had a mean height of 34½ ft. and a volume of 750 hoppus ft. per acre, a rate of growth similar to that of European larch of Quality Class II.

Larix pendula Salisbury

This tree is mentioned because it is frequently referred to in the literature, but there seems to be no agreement about what it is. The general view is that it is a hybrid with *L. laricina* in its ancestry. There have been several good trees of *L. pendula* in Great Britain, the best known of which, now felled, was a specimen at Woburn, Bedfordshire. It was 105 ft. in height and was well over a century old.

Larix potaninii Batalin

Introduced in 1904 from Western China, this tree is rare in Great Britain and, so far, has not shown any prospect of success. Nothing is known about its rate of growth or site requirements.

Larix sibirica Ledebour

A species of wide distribution in the northern parts of the Soviet Union, *L. sibirica* was introduced in 1806 by the Duke of Atholl. It has proved to be unsuitable for use in this country because it flushes very early and is cut back by spring frosts. The leaf buds have been known to break in January. Here and there individual trees have survived and have made good progress as, for example, a specimen at Kew which grew to 68 feet in 57 years. This, however, is exceptional.

J.M.

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Libocedrus Endlicher

The genus *Libocedrus*, which has representatives in both the Northern and the Southern Hemispheres, has not figured prominently in Great Britain, even in arboriculture, for not all the species are hardy and of those which do survive in our conditions, only one, *L. decurrens*, can be said to grow well. Of the others, *L. chilensis* and *L. tetragona* are occasionally met with while *L. plumosa*, which is very rare, survives only in the mildest parts of the south-west.

Libocedrus chilensis (D. Don) Endlicher

A native of Chile, this tree was introduced in 1847, but has had little success. Its appearance is not attractive and this may have discouraged planters from trying it more frequently; but where it is found in Great Britain it is growing slowly and has really little to commend it. A small plot of *L. chilensis* which was planted at Bedgebury because it was felt at the time that it might have some use in the forest, has grown moderately well, the trees having reached 16 ft. in height in 13 years, but the crop seems to be lacking in vigour, and does not suggest much promise for the future. Although it was reported by Elwes and Henry that most of the plants of the original introduction were killed by frost, recent experience at Bedgebury indicates that the tree has a measure of frost hardiness. Individual specimen trees of up to 50 ft. in height have been recorded.

Libocedrus decurrens Torrey

This tree, known as the Incense cedar, is a native of Oregon and California and was introduced into Great Britain in 1853. It has been planted widely as a specimen tree and has been most successful as an ornamental because of its rich green colour and its strictly columnar habit of growth. It does not seem ever to have been used as a forest tree, not even in trial plantations on a small scale, and this is surprising when one considers how much better it has grown in many places than some of the conifers which have been tested in this way.

Though widely distributed as a planted tree in Great Britain, it is not common and relatively few young specimens are found. From existing evidence there seems to be no climatic bar to its use but there is insufficient information about its soil requirements as existing trees are found only on the better soils.

There is only one recent record of a tree of *Libocedrus decurrens* with a height of more than 100 ft., at Westonbirt, where one specimen is 101 ft. high with a breast height girth of 8 ft 6 in. Trees of over 90 ft. in height have been recorded from Westonbirt, Glos.; and from Dropmore, Buckinghamshire; West Dean, Sussex; Nuneham, Oxfordshire and Eastnor Castle, Herefordshire.

Libocedrus tetragona, Endlicher

Libocedrus tetragona was introduced by William Lobb from South America as long ago as 1849, but it has never thrived in Great Britain and is not often seen.

J.M.

Metasequoia Hu and Cheng

Metasequoia glyptostroboides Hu and Cheng

The discovery of this tree in China in 1945 aroused interest all over the world among botanists and foresters because it had been known previously only from fossil records. The first seed came to Great Britain in 1948 from the Arnold Arboretum in America, and a second consignment was brought in later. The number of plants raised from these introductions of seed was relatively small but it was soon discovered that *Metasequoia* could be reproduced readily from cuttings and the stocks so produced have been widely spread by planting. It is probable that there is only a limited number of clones represented in the country and, if any of them should prove unsatisfactory, this may have unfortunate effects on the tree's future.

Trees planted in this country have generally grown rapidly soon after planting, and by 1956 several trees in different districts had exceeded 12 ft. in height, though none, so far as is known, had exceeded 25 ft. So far, *Metasequoia* has not been greatly troubled by frost, but it succumbed to an attack by *Armillaria mellea* on one occasion. One tree is reported to have borne fertile seed.

The tree is readily propagated by cuttings taken in June and July and inserted in an unheated propagating frame (Matthews, 1952).

One or two trial plantations of *Metasequoia* have been formed but these are still in their early stages. We cannot say what will be the future of this tree which, as yet, is no more than an interesting novelty.

J.M.

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Picea A. Dietrich

This is a large genus, with species distributed over the temperate zone of the Northern Hemisphere, most of which have been grown in Great Britain at one time or another. The exotic spruces vary greatly in importance; they include two of our most important forest trees *Picea abies* and *P. sitchensis*; several which have been used in a small way in forestry at various times, like *P. omorika*, *P. glauca* and *P. engelmanni*; and one, *P. orientalis*, which has been strangely neglected although it grows quite well. Others, such as *P. breweriana*, possibly the most handsome conifer in cultivation, and *P. pungens*, have been used chiefly for ornamental purposes. Of the rest, although several have been tried in experimental plantations and many have been planted widely as specimen trees, there is none which has given any promise of wide usefulness. Many of the spruces are trees of small stature with us and easily damaged by frost.

DISEASES AND PESTS

INSECTS. The spruces are subject to attack by quite a large number of defoliating insects. Seven species of sawfly—*Pristiphora abietina* Christ., *P. subarctica* Forssl., *P. saxeseni* Htg., *P. ambigua* Fall., *P. amphibola* Forst., *Pachynematus scutellatus* Htg., *P. montanus* Zadd., and *Gilpinia hercyniae* Htg.—occur on spruce, of which *Pristiphora abietina* is the commonest and does the most damage although it is not really a serious pest. *Gilpinia hercyniae* is a potential menace of some note. Of the two bud-feeding species, *Pristiphora ambigua* is more numerous on Sitka spruce and *P. amphibola* on Norway spruce. Amongst Lepidopterous species which feed on spruce, *Eucosma tedella* Clerck, a needle-mining type, causes a considerable amount of damage on occasion, whilst *E. diniana* Guen. is of minor importance on Sitka spruce. An aphid, *Neomyzaphis abietina* Wlk., occurs on many *Picea* species (Fox-Wilson, 1948).

In Norway spruce crops grown for Christmas trees, attacks of the red spider, *Paratetranychus ununguis* Jac., cause foliage browning and defoliation, and the gall-forming Adelgid species can also be troublesome. The latter group also, of course, occurs on forest crops but is of no practical significance (Forestry Commission, 1952a).

Of the bark beetles occurring on spruce in Britain, *Polygraphus poligraphus* L. is the most harmful species. *Ips typographus* L., another important spruce bark beetle, has entered Britain in large numbers (Laidlaw, 1947) but has not become established.

The larvae of *Dioryctria abietella* Schiff. are fairly commonly found mining the interior of Norway spruce cones, whilst *Megastigmus strobilobius* Ratz. infests Norway spruce seeds.

FUNGI. These are described below under *Picea abies*, *P. sitchensis* and *P. omorika*. Not much information about the minor species is available, but all species of spruce appear to be susceptible to butt-rot caused by *Fomes annosus*.

Picea abies (Linnaeus) Karst. (*P. excelsa* Link) (Plate 5)

COMMON NAME

Norway spruce. The timber is usually known as spruce or Norway spruce.

COUNTRY OF ORIGIN AND PROVENANCE

"The tree is a native of Europe where it has a wide distribution, ranging from the Pyrenees, Alps, and Balkans, northwards to South Germany and East Prussia, to Scandinavia and eastwards through the Carpathians and Poland to West Russia". (Dallimore and Jackson, 1948.) In northern Scandinavia and Western Russia there is a very wide zone where hybrids occur between Norway spruce and Siberian spruce, *P. obovata* (Wright, 1955).

There are a few experiments which illustrate the reaction of certain European provenances to conditions in Great Britain. As the oldest are only twenty years of age, results are not conclusive. Edwards (1955) observes "Norway spruce of south-east European provenances grows more vigorously than any others tested. Provenances from Finland, Norway and Sweden have been the least successful, especially those from the most northern regions. Provenances from German and Alpine sources are intermediate in vigour of growth".

HISTORICAL NOTES

Norway spruce was present in Great Britain in pre-glacial times, but did not return to this country or to the coastal fringe of western Europe, except in Norway, at the end of the last glacial period.

For many years it has been accepted that spruce was in cultivation in Britain in the first half of the 16th century. Loudon (1838) stated: "Turner includes it in his "Names of Herbes", published in 1548; and both Gerard and Parkinson not only give very good engravings of it; but speak of its being found in great quantities in different parts of the island. The early British writers on trees, however, appear to have often confounded the Scotch pine with the spruce fir. . ." and it is reported by Boodle (1917) that after examination of the writings of these authors there was "no confirmation of the . . . . opinion that this tree had been introduced by the middle of the 16th century. . . .". Although the date of its introduction is not known, Norway spruce is accepted as one of the earliest introductions to Great Britain.

TABLE 25 PICEA ABIES (NORWAY SPRUCE): DISTRIBUTION BY COUNTRIES, AND PERCENTAGES OF HIGH FOREST AREAS OCCUPIED, 1947

Ownership	*England*			*Scotland*			*Wales*			*Great Britain*		
	Area Acres	*Percentages*		*Area Acres*	*Percentages*		*Area Acres*	*Percentages*		*Area Acres*	*Percentages*	
		of conifers	*of all species*		*of conifers*	*of all species*		*of conifers*	*of all species*		*of conifers*	*of all species*
Private Woodlands	15,435	8	2	29,223	11	8	2,953	14	3	47,611	10	4
Forestry Commission	26,122	13	11	41,562	21	21	17,858	21	21	85,542	18	16
Total	41,557	11	4	70,785	16	12	20,811	20	11	133,153	14	8

TABLE 26 PICEA ABIES (NORWAY SPRUCE): HIGH FOREST AREAS, PURE AND MIXED STANDS COMBINED, BY AGE-CLASSES, 1947 Acres

Ownership	*Age-class*								*Uneven aged*	*Total*
	1–10 yrs.	*11–20 yrs.*	*21–30 yrs.*	*31–40 yrs.*	*41–60 yrs.*	*61–80 yrs.*	*81–120 yrs.*	*Over 120 yrs.*		
Private Woodlands	6,509	6,227	10,618	6,719	7,655	3,766	1,180	182	4,755	47,611
Forestry Commission	39,697	32,192	9,307	1,138	306	112	71	—	2,719	85,542
Total	46,206	38,419	19,925	7,857	7,961	3,878	1,251	182	7,474	133,153

EXTENT OF PLANTING

Norway spruce has been a favourite tree for forest planting for very many years, and it is now found throughout Britain. The Census of Woodlands made in 1947-49 (Forestry Commission 1952) gives some interesting figures and Table 25 has been made up from the Census Report.

The importance of the species may be seen when it is realised that the area covered (8 per cent) is surpassed only by the three native species, oak (24 per cent), Scots pine (20 per cent), beech (9 per cent) and by one introduction, Sitka spruce (9 per cent).

In high forest stands up to thirty years of age, Norway spruce is the species which occupies the third greatest area in both privately owned woods and in Forestry Commission areas; it is surpassed in the former by Scots pine and European larch, and in the latter by Sitka spruce and Scots pine. When privately owned and Forestry Commission woods are considered together, Norway spruce still holds third place—to Scots pine and Sitka spruce.

Table 26 above, which has been compiled from the County details of the Census Reports (Forestry Commission, 1953) gives the age-class distribution; the great increase in planting by the Forestry Commission after 1927 can be seen.

Planting of Norway spruce has continued on a large scale in recent years and it is estimated that in the six years following the Census, that is from 1950 to 1955, at least a further 38,000 acres of Norway spruce have been planted by the Forestry Commission. This figure is exceeded only by Sitka spruce, Scots pine and Japanese larch. No figures are available for the same period for privately owned woods but it is certain that a substantial acreage has been planted.

CLIMATIC REQUIREMENTS

Norway spruce, though a continental tree, is a very accommodating species and has grown well in this country in many different localities. In general it does least well in areas with an annual rainfall of less than 35 to 40 inches, but there are many examples of Norway spruce growing satisfactorily on moist sites where the annual rainfall is less than this.

Low winter temperatures rarely affect Norway spruce, but spring frosts can do considerable damage to young trees (Day and Peace 1946); although they are often severely cut back by frost, it is very unusual for any to be killed completely.

Norway spruce does not withstand exposure well. On exposed sites where it can be established, the needles become brown, many are lost, and the tree grows very slowly. But resistance to snow is very good, especially in the narrow crowned forms. It is very susceptible to salt-laden winds. Only in relatively sheltered inland areas do the trees grow satisfactorily at an elevation of over 1,000 feet.

SITE REQUIREMENTS

Norway spruce has done well on many different site types, in particular moderately fertile moist, grassy or rushy land, damp old woodland sites, and the more fertile shallow peats. One of its main requirements is an adequate supply of moisture, and because it is often planted on shallow soils, it is very liable to be affected by drought, not only on normally dry sites but in damp areas which are liable to dry out in exceptionally dry weather. On moist, porous soils it can root deeply; but it is also capable of growing in shallow wet soils and this is one of the tree's most important features. On shallow peats overlying clays, a good drainage system to prevent the formation of wet hollows is considered most important.

It is liable to go into check, which may last for many years, on heather land; and is not suitable for planting on the poorest dry heaths or wet moors. Check is a complex phenomenon in which competition for nitrogen between the trees and the heather is an important factor (Leyton 1951). Norway spruce is unsuitable for calcareous soils.

ESTABLISHMENT TECHNIQUE

NURSERY PRACTICE. Norway spruce seed, which does not need any special treatment beforehand, should be sown early in the spring. The most satisfactory broadcast sowing density is 50 square yards of seedbed per pound of seed of 85 per cent germinative capacity. After sowing, the seed is covered with $\frac{1}{4}$ inch of coarse sand or grit, but no overhead seedbed covers, for example lath screens, are needed as a protection against frost.

A two-year-old seedling is commonly preferred for lining-out, but one-year-old seedlings are sometimes grown to a satisfactory size in heathland nurseries. The seedlings are lined out at a spacing of about 2 inches by 9 inches with the object of producing a two-year-two-year plant. Occasionally two-year-one-year plants are large enough for planting.

VEGETATIVE PROPAGATION. Vegetative propagation is used on a small scale for tree breeding work.

Grafting. For rootstocks, well-grown, sturdy transplants are used, of one of two sizes, either plants 9 to 15 inches in height and about the thickness of a pencil at the base, or plants more than 18 inches in height and from $\frac{1}{2}$ to $\frac{3}{4}$ inches in diameter at a height of 6 inches. The age of the plant varies with local conditions. The scion wood is collected in March for grafting under glass, and in April for grafting in the open nursery. Scions for immediate use may be collected in April; one-year wood is almost always suitable as scion wood.

Grafting may be done under glass in March, and in the open from the middle of April to the first week in May. The best method is probably the "veneer side" graft, using rootstocks of the smaller size under glass, and of both sizes in the open nursery. The cutting back of the rootstock begins when the scion has become very active; it must be done slowly and carefully.

Norway spruce has been found difficult to graft; the success achieved has varied from 25 up to 40 per cent according to the quality of the material.

Cuttings. Summerwood cuttings taken in late June and in July, consisting of one-year-old wood 4 to 6 inches long, have been found to be the most satisfactory; cuttings from old trees have often been difficult to root.

DIRECT SOWING. Some recent trials have shown that it is possible to establish Norway spruce on heathland by sowing on prepared patches with the help of nitrogen and phosphate fertilizers, but the method is an uncertain one. On peat moorland, the trials showed that early weed growth smothers the young seedlings.

PLANTING. Planting is the only method employed in practice for establishment, and stock of normal sizes are used. On good lowland sites where this species is so often planted, no ground preparation is usually required, although some screefing may be done. Where there is a very strong growth of grass, some form of cultivation is desirable to give the plants temporary freedom from weed competition and this is usually achieved by ploughing at five foot intervals. On the better moorland peats, usually characterised by the grass *Molinia coerulea*, it is sufficient to plough at wider intervals, usually 17 or 22 feet, and to plant the trees on turfs cut from the plough ridges and spread between the furrows at a spacing of about five feet in both directions.

Fertilisers are scarcely ever used, as Norway spruce is not normally planted on the poorer heaths and moors.

SPACING. The commonest spacing used for Norway spruce is 5 feet by 5 feet (1,740 plants per acre) but on poorer sites the spacing is sometimes reduced to $4\frac{1}{2}$ feet (2,150 plants per acre).

TENDING AND THINNING

WEEDING. Even on the best sites Norway spruce grows slowly for the first year or two, and some weeding is usually necessary.

THINNING. Norway spruce is a moderately fast growing tree and on Quality Class II sites reaches a height of 32 feet in 20 years (Hummel & Christie, 1953). Factors which influence thinning practice are, first, Norway spruce is a moderate shade bearer, and sub-dominant trees, if freed in time, show great powers of recovery (Forestry Commission 1951); secondly, wolf trees are very uncommon; thirdly, growth in a plantation for the first 20 to 30 years

tends to be patchy except on the very best and most uniform sites; fourthly, when planted on shallow soils, as it often is, it is liable to windblow.

The practice for many years was to give light low thinnings and this produced dense crops of high standing volumes. More recently, with the general tendency for earlier and heavier thinnings, Norway spruce has been thinned when the top height is 30 to 35 feet; moderately heavy low thinnings have continued at intervals of four to six years, and this has resulted in a more valuable intermediate yield. Crown thinnings with Norway spruce are easier to carry out than with most other species, and light crown thinnings have been practised on a small scale for many years; a heavier type of thinning, which gives special attention to a limited number of crop trees per acre, has recently found favour in some parts of Britain.

PRUNING. Brashing practices are the same as for other conifers except that woods in which thinning has been delayed until after the normal time, usually do not need any brashing, as access is no problem.

Pruning to improve timber quality has been undertaken on only a small scale. Green pruning is rarely practised owing to the risk of fungal infection.

OTHER SILVICULTURAL CHARACTERISTICS

Norway spruce is a moderate shade bearer. It can be successfully used for underplanting, but requires great care in handling to ensure that it gets enough light. It is a useful tree for growing in mixture with others, especially hardwoods, and it is used in particular in England as a nurse for oak. One mixture not now used, which found great favour at the end of last century and the beginning of this century, was a mixture with Scots pine and European larch; the larch was removed in early thinnings for use as fencing posts, etc., the spruce and pine remaining as an intimate mixture for many years; on dry sites a final crop mainly of pine was left, while on damp sites a mixed crop, or one mainly of spruce, remained.

RATE OF GROWTH AND YIELD

The most recent yield tables were published in 1953 (Hummel and Christie), and are based on measurements made in 55 permanent sample plots which have been thinned to five intensities: light, moderate, moderately heavy, and heavy low thinnings, and light crown thinning. Very few plots are in crops older than 50 years. Four Quality Classes are recognised, and these show top heights at 50 years of 80 feet, 70 feet, 60 feet and 50 feet, for Quality Classes I to IV respectively. Most of the plots are at elevations of less than 500 feet and of these the majority are either Quality Class I or II; the few plots between 1,000 and 1,500 feet are either Quality Class III or IV. Most of the plots occur in areas where the annual rainfall is between 41 and 60 inches, but it is interesting to note that there are six Quality Class I plots in areas where the rainfall is only 26 to 40 inches per year.

The total volume production at 50 years of age in Quality Class I stands averages 10,310 Hoppus feet. The differences in production between Quality Classes are greater than with any other species for which British volume tables have been prepared, these differences being as much as 2,310 Hoppus feet between Class I and II and 1,910 Hoppus feet between Classes III and IV. Differences for Sitka spruce, for example, are some 500 Hoppus feet less, although the total volumes at this age are greater.

There are several plots in Scotland with standing volumes per acre of over 6,000 Hoppus feet; the plot with the largest standing volume is at Grandtully Estate, Perthshire, where a B grade (lightly thinned) plot at 56 years of age, with 496 stems per acre and a top height of 80½ feet, has a volume of 8,319 Hoppus feet. The fastest growth recorded is at Coed y Brenin Forest, Merionethshire, where the top height was 67 feet at 29 years of age.

Periodic annual increment culminates between 30 and 35 years in Quality Class I and at about 50 to 60 years in Quality Class III. The following statement shows the percentage of the total volume removed in thinnings at various top heights, assuming the moderately heavy thinning grade adopted in the yield tables, calculated as a percentage of the total volume production:

Top height in feet	*Percentage of total volume removed in thinnings*
30	3
40	14
50	24
60	31½
70	37½
80	42

A set of sample plots laid out in 1930 at Bowmont Forest, Roxburghshire, is unique for any species in Britain, as it was possible at Bowmont to replicate four thinning treatments four times on an even site. This experiment has shown that a significantly greater total volume production has been obtained in the more heavily thinned plots. (Hummel 1947).

Individual trees frequently grow to very large sizes. At Invertrossachs, Perthshire, 60 old trees measured in 1953 had heights of 106 feet to 121 feet, and heights over 100 feet are not uncommon. The tallest tree recorded was at Studley Royal, Yorkshire, which had a height of 156 feet and a girth of 14 feet 2 inches in 1952, although the top 16 feet were then dead.

DISEASES AND PESTS

Apart from *Fomes* butt rot, no fungal diseases seriously affect Norway spruce. It is, however, frequently affected by crown dieback. This is sometimes the result of ordinary drought, but more often is associated with increased water losses from the crown, consequent on heavy thinning or the removal of shelter.

OTHER FORMS OF DAMAGE

WINDBLOW. Norway spruce has not a good reputation as a windfirm tree. At least in part, this liability to windblow is due to its being planted on soils where the effective rooting depth is limited, as for example on shallow peats overlying impervious clays, or in porous soils with a high water level. In severe storms, the roots, although spreading widely, have no depth in which to obtain a hold, and are easily torn loose. The large plate of surface soil and roots which has peeled off the ground, is a common sight on a windblown Norway spruce. It is believed that the maintenance of a good drainage system throughout the life of the crop will reduce the risk of windblow on these sites. On dry ground, breaking of the stems occurs quite frequently.

ATMOSPHERIC POLLUTION. Norway spruce is susceptible to fumes and is not planted as a forest tree in industrial areas.

SEED AND SEED-BEARING

Flowering usually begins between the 20th and 25th year, and the first good cone crop, that is one which would be economic to collect, occurs between the 30th and the 35th year. There is little information about the time of maximum cone production, but it is thought that it probably begins when the tree is 50 to 60 years old. Good cone crops generally occur at intervals of three to five years, though in many seasons the seed does not ripen well in Great Britain. Flowering takes place in May and the cones should be collected between October and December (Matthews 1955).

Data from the Forest Research Station at Alice Holt, Hampshire, show that the average yield of seed in Britain is about 12 oz. per bushel of cones. The number of seed per pound ranges from about 45,000 to 100,000, with an average of 65,000. The germination capacity of fresh seed is usually between 70 and 80 per cent. The seed fly *Megastigmus strobilobius* attacks seed of Norway spruce but so far no damage of economic importance has been done.

GENETICS AND BREEDING

One seed stand of about two acres at Inveraray, Argyll, has been described as "almost plus", and ten stands totalling about 111 acres have been classified as "normal" for seed collection. Forty-nine "plus" trees have been selected, but no seed orchards have yet been established.

NATURAL REGENERATION

Sporadic germination of seed occurs in many places especially in the drier parts of the country, but it is most unusual for the seedlings to persist and become established; the reasons for this are not fully understood, but frost-lift, lack of light, and smothering by weeds, may all play a part.

TIMBER

The timber is well known and has been extensively used in Britain for a long time, so that the species is now hardly an exotic in the timber trade. It is one of the best of the "whitewood" type of coniferous timbers, being used in many kinds of box and packing case manufacture, building, joinery, fibre and chipboard manufacture. It is particularly favoured for the packing of foodstuffs and manufacture of wood wool because of its clean appearance and freedom from resinous odour. Estate work consumes considerable quantities of timber, and it is often impregnated by the hot-and-cold tank method for these purposes, but it is somewhat resistant to preservatives and pressure treatment is preferable. Large quantities are used for pit-props. Tests have been carried out both on thinnings and mature timber, indicating that its strength properties are comparable to those of whitewood timber from the Baltic. It works well and gives a better finish than Sitka spruce, though a tendency to tear, in the early wood of fast grown material, has been noted.

An important economic use which has increased greatly in the last ten years is for Christmas trees, and large numbers of small trees and tops of thinnings are sold for this purpose each year. This is such a valuable form of minor produce that it is now a widespread practice to leave as much thinning as possible until late November and early December, when each top may be worth at least twice the value of the pole.

POTENTIALITIES OF THE SPECIES IN THE NATIONAL ECONOMY

Norway spruce has been an important forest tree in Great Britain for many years, and with the great increase in its planting during the last two decades, particularly by the Forestry Commission, it now occupies a more important place than ever before. The timber is well known and has a goodreputation.

The silvicultural limitations of the species—its susceptibility to drought, to heart rot and to windblow—have long been realised. Despite these limitations, however, there are very many suitable areas where Norway spruce will be the main species, and the tendency may be for it to displace Sitka

spruce from many sites where the latter is being planted at present. It has also an important place as an associate with broadleaved species. There seems good reason to believe that Norway spruce will remain one of the most important coniferous species in Great Britain.

G.G.S.

Picea asperata Masters

This spruce was introduced in 1910 from Western China by E. H. Wilson and has been widely distributed, so that it is now not infrequently met with either as a specimen tree, when it is often a rather shabby object, or in small trial plantations of which several have been made in various parts of the country. The tree grows slowly, especially in its early years, and it is subject to damage by late spring frosts which are apt to hinder its establishment. It is unlikely to find a place in forestry in Great Britain. Probably the earliest plantations are those formed in 1916 in the Forest of Dean and at Dawyck, Peebles-shire. In the Forest of Dean, where *P. asperata* suffered from attacks by the fungus *Armillaria mellea*, it reached an average height of 38 ft. in 40 years, with a range of from 25 to 48 feet. At Dawyck, in a less genial climate and on a poorer soil, *P. asperata* had a top height of 33 ft. at the same age, and a volume of 1,350 Hoppus ft. per acre. These rates of growth are below the mean of Quality Class IV, Norway spruce. Among younger plantations which have been recorded are plots at Beddgelert, Caernarvonshire, and Bedgebury, Kent, both of which at 24 years of age had an average height of 15 ft.

Several varieties have been recognised, such as var. *ponderosa* and var. *notabilis* which have been planted in the Forest of Dean in small plots with no great difference in results. The status of these varieties is doubtful as is that of a closely related species, P. *retroflexa*, which has also been tried on a very small scale.

Picea bicolor (Maximowicz) Mayr

Introduced in 1861, this Japanese species is not common, though occasionally found in arboreta. It does not usually reach any great height although a tree at Dolphinton, Lanarkshire, has reached a height of 82 ft. *Picea bicolor* has been planted in a small plot at Crarae, Argyll, on peaty ground but it has done poorly having reached only five feet in height in 18 years.

Picea engelmanni (Parry) Engelmann

Engelmann's spruce, which has a wide range in western North America, was introduced into Great Britain in 1864 and is not infrequently met with as a specimen tree. It is slow growing, however, and often looks unhealthy, while it is liable to be damaged by frost. Although it has been tried experimentally in various places, it has not shown great promise and is unlikely to be used much in future. Individual trees of up to 42 ft. in height have been recorded. Various small plantations have been made. At Dawyck, Peebles-shire, a plot of *P. engelmanni* had a top height of 28 ft. at 32 years of age and at Benmore, Argyll, a 20-year-old plantation reached a top height of 27 ft. In Lael Forest, Ross-shire, there is a small plot growing slowly at an elevation of 800 ft. in an exposed situation; there, the trees, originating from seed from British Columbia, have a healthy appearance, but the best were no more than 16 ft. in height after twenty years.

Picea glauca (Moench) Voss

The White spruce of North America has long been known in Great Britain for it is believed that it was introduced about the year 1700. It has aroused a mild interest among foresters from time to time in the past, particularly for use in exposed places (Fraser 1828, Annand 1901, Chittenden 1932) and one can still find it occasionally round the edges of old plantations in exposed isolated places in hill country where it was planted in the past to give shelter. It is little used now, largely because the performance of Sitka spruce is so much better on similar sites, and it is difficult to imagine any important use for *P. glauca* in the near future. It may be that somewhere in the wide natural range of the White spruce, a provenance may be found better suited to our conditions but, even so, it is unlikely to surpass Sitka spruce. It is hardy and withstands exposure to wind but it is generally slow growing. It rarely reaches any great height, for the tallest tree recorded in Great Britain is one of 75 ft. in the New Forest.

An example of an older plantation in which White spruce has been used, is found at Borthwick Hall, Midlothian, where at the relatively high elevation of more than 1,600 feet, on a poor soil and in full exposure, *P. glauca* reached a height of 40 feet in 85 years. In this plantation the White spruce, though growing slowly, have full, vigorous and healthy crowns whereas Norway spruce, which also occurs in the crop, is very badly blasted. At Lael, Ross-shire, again on an exposed site, White spruce has withstood exposure well and has reached 16 ft. in height in twenty years. At Benmore, where exposure is less severe, it reached 20 ft. in 25 years, and at Crarae, on a *Calluna* site, it has reached 11 ft. in 17 years. Younger plots at Bedgebury and Beddgelert are growing more rapidly in their early stages, but the general impression given by the species in Great Britain is one of slow growth.

Picea glehnii (Fr. Schmidt) Masters

This species, introduced from Japan in 1877, is not a common tree although specimens may be found in most parts of the country. Of these, the tallest is probably a tree at Murthly, Perthshire, planted in 1897, which had reached a height of 60 ft. by 1955. It is doubtful whether this species will ever reach a large size in Great Britain.

A trial plot, planted on a moderately deep *Molinia-Calluna* peat at Crarae, is of interest because on this type of ground *P. glehnii* is growing remarkably well and is looking better than several other spruces nearby. The trees are healthy and reasonably vigorous and have reached 20 ft. in height in the same number of years. At Benmore, in a plot on better land, this tree reached 14 ft. in 17 years.

Picea jezoensis (Siebold and Zuccarini) Carrière

Introduced in 1861, *P. jezoensis* may be seen in arboreta and gardens in many parts of the country but is not common although it grows slightly better than most of the spruces from Asia. At Benmore, and other places, specimens of up to 90 ft. in height are found. It seems to be easily damaged by frost in its early years as a planted tree. A small plantation of this species has recently been established at Bedgebury but so far it has made little growth.

The variety *hondoensis*, sometimes planted, appears to be easier to establish than *jezoensis* proper because it is more resistant to frost in its youth. Generally, however, it does not grow any more rapidly than the type once it has been established.

Picea koyamai Shirasawa

Little is known about this tree, which was introduced from Japan in 1914, but a small trial plot at Crarae on acid peaty loam has grown quite well, having reached a height of 18 ft. in 18 years. A specimen tree at Bedgebury was 8 ft. high in 1931 and 42 ft. in 1954, and one at Warnham Court, Sussex, grew from 18 ft. in 1931 to 61 ft. in 1956. These are impressive growth rates.

Picea likiangensis (Franchet) Pritzel

This Chinese spruce was introduced in 1910 and is not infrequently met with in arboreta and collections, either as the type or the variety *purpurea*, which does not differ greatly from it. It suffers, like *P. asperata*, from frost in its early years, but grows moderately well once established and out of danger. But there is nothing remarkable about its performance. A small plot, reported to be var. *purpurea*, was planted in 1916 in the Forest of Dean and made slow growth in its early years, being 7 ft. high at fourteen years of age and reaching an average height of 33 ft. at 40 years. A tree at Warnham Court, Sussex, is 66 ft. tall at 45 years of age.

Picea mariana (Miller) Britton, Sterns and Poggenberg

The Black spruce of North America has been known in Britain for a long time, having been introduced early in the eighteenth century. It survives but grows slowly, its growth being less than that of the White spruce, and although it may be planted in future for ornamental purposes, there is no prospect of its being used in forestry. Specimen trees rarely reach any great height and the tallest specimen recently measured is a tree of 75 ft. in the New Forest.

Picea obovata Ledebour

The widely distributed Siberian spruce is not really suited to conditions in Great Britain and it does not often succeed. Nevertheless in a small plot at Crarae it had reached a height of 20 ft. in 20 years.

J.M.

Picea omorika (Pančić) Purkyne (Plate 6)

COMMON NAME

Serbian spruce. The timber is not marketed in its native country or in Britain, and there is no accepted common name for it.

COUNTRY OF ORIGIN AND PROVENANCE

Europe, Yugoslavia. It has a very limited distribution in its native country where it occurs in small isolated areas in the Dinaric Alps. It succumbs to competition with other species and is poorly adapted to its present environment, but it holds its own when competition is absent on north-facing cliffs, screes or mountain summits at elevations of 3,000 to 5,500 feet, where the microclimate is moist and cool. It is limited to limestone soils (Wardle 1956). Nothing is known of provenance differences.

HISTORICAL NOTES

It is believed that seed was first distributed by Messrs. Frobel of Zurich about 1884 and a second introduction was made via Belgrade in 1889. Some plants from the second introduction were planted at Kew, and in 1956 the tallest of these was 64 ft. and had a girth of 2 ft. 4 in.

EXTENT OF PLANTING

Picea omorika has never been planted extensively and the earliest plantings were probably at Corrour and Fersit, Inverness-shire, where a few groups were established in 1908. There are now many other small plantations of the species in Britain but there is no accurate estimate of the total area planted, which is probably slightly less than 500 acres.

PICEA OMORIKA: GROWTH AND PRODUCTION

TABLE 27

Locality	*Elevation Ft.*	*Thinning Grade*	*Age Yrs.*	*Top Ht. Ft.*	*Mean Girth Breast Ht. ins.*	*Volume Per Acre Hopp. ft. over bark*	*Tot. Prod. Per Acre Hopp. Ft. over bark*
Bedgebury, Kent	300	Light Crown	24	45	14½	2,037	3,690
Bedgebury, Kent	300	B (Light)	24	43	14	3,653	3,710
Bedgebury, Kent	300	D (Heavy)	24	40½	16	1,876	3,274
Kerry, Montgom.	1,450	C/D (Mod. to Heavy)	26	31	17½	1,907	No record
Forest of Deer, Aberdeenshire	250	C/D (Mod. to Heavy)	30	33	20½	2,541	3,362
Newcastleton, Roxburghshire	750	C/D (Mod. to Heavy)	28	33½	18	1,876	2,019

Note. B, C, and C/D thinnings are all Low Thinnings.

CLIMATIC REQUIREMENTS

Wardle (1956) has described the native habitat of the tree in great detail and from his account it is clear that there should be no climatic limitations to its growth in Britain. Experience has shown this to be generally true and examples of vigorous plantations are to be found in most parts of the country, both in the mild wet western districts and the much drier north-eastern and south-eastern regions. According to Splettstösser (1952) Serbian spruce can withstand more drought than Norway spruce, and is outstandingly hardy, while Oksbjerg (1953) in Denmark comments on its unexacting nature as regards moisture and nutrients, and its resistance to wind and frost.

SITE REQUIREMENTS

P. omorika is a relict species occupying a somewhat specialised environment, but as an exotic in Britain, its tastes appear to be quite catholic. (There are other similar instances.) It has been planted on a wide range of sites, and there is very little difference in its performance under diverse conditions. It has perhaps distinguished itself best on moist moorland soils and on peat.

Macdonald (1934) reports that Serbian spruce at Corrour, Inverness-shire, planted on boulder till over granulite and schist, grew at a rate of twelve inches a year after canopy closure. On the Lon Mor, Inchnacardoch Forest, Inverness-shire, Serbian spruce, with the addition of basic slag, had the tallest dominant heights (nineteen feet after twenty-five years) and highest rate of survival in a trial of sixteen species. Good growth is also reported on *Molinia-Trichophorum-Calluna* and *Molinia-Juncus* sites (Zehetmayr 1954). It appears that Serbian spruce can withstand competition from *Calluna* to a slightly greater extent than Norway or Sitka spruce, but it is certainly liable to go into check on the more difficult heaths.

It is unusual (an exception is mentioned above) to find *Picea omorika* the fastest species in trials on any site, and the better the site, the less likely it is that *Picea omorika* will appear impressive in rate of growth. An interesting example of its apparent insensitivity to site difficulties is provided by its behaviour in two trials of species at Rockingham Forest, Northamptonshire. These are on soils of similar nature, but one is an old woodland site and the other, before planting, was under agriculture. On the old woodland site *P. omorika* attained 27 ft. in height in 23 yrs., *P. abies* by comparison was 30 ft. tall. On the 'agricultural' site *P. omorika* was 19 ft. tall at the same age, *P. abies* only 10 ft. tall. So far as is known, the adverse factor in this case is the poorer physical structure of the soil (a heavy boulder clay) after an agricultural history.

It would appear logical to plant *P. omorika* on calcareous sites, but trial plantations are still too young to provide useful evidence.

P. omorika has frequently been stated to be frost hardy. It is certainly not completely immune to spring frost damage, but it is probably somewhat hardier than Norway spruce and definitely more so than Sitka spruce. It has sometimes been planted on extremely frosty sites as a local substitute for Sitka spruce.

ESTABLISHMENT TECHNIQUE

NURSERY PRACTICE. As for Norway spruce.

PLANTING. The methods of planting and types of plant are similar to those used for Norway spruce.

SPACING. Owing to its extremely narrow crown *P. omorika* can be planted at very close spacing without wasteful losses before trees have reached sizeable pole dimensions. With a good market for this sort of produce, a planting distance of 4½ ft. would not be too close.

TENDING AND THINNING

WEEDING. No specific problems arise.

THINNING. Experience in thinning *Picea omorika* is very limited. At Bedgebury, Kent, there are compara-

tive thinning plots of light (B), heavy (D) and light crown grades. It is obvious that an extremely dense stand of good-looking poles can be obtained by thinning to the lightest low grade. The dominants do not seem to respond very much to thinning.

OTHER SILVICULTURAL CHARACTERISTICS

Picea omorika has a beautifully straight stem and an extremely narrow crown. Its branching habit is light.

Its litter appears to break down very slowly and it has a strong tendency to form mor humus (Ovington 1953).

Like certain other conifers, its lower branches are capable of rooting. This has been observed at Beddgelert on *Molinia* peat.

RATE OF GROWTH AND YIELD

There are only six sample plots of *Picea omorika* in Britain, and summarised data from these appear in Table 27.

Picea omorika does not appear to differ much from Norway spruce with respect to form factor and basal area increment at equivalent heights.

There are numerous specimen trees in Britain, and amongst the best is the specimen at Walcot Park, Shropshire, which was seventy-seven feet tall and had a girth of five-and-a-half feet in 1955. Another fine tree is growing at Prested Hall in Essex, and this was seventy-six feet tall with a girth of two feet nine inches in 1954. In Scotland one of the best specimens was planted in 1910 at Dawyck, Peebles-shire; this tree was fifty-nine feet tall and had a girth of three-and-a-half feet in 1954. It is not a species which seems likely to reach very large dimensions in Britain.

DISEASES AND PESTS

P. omorika appears particularly susceptible to attack by *Armillaria mellea*.

At Bedgebury, Kent, a plantation of *P. omorika* has experienced trouble similar to the crown dieback of Norway spruce. The affected trees are confined to a fairly narrow belt along an exposed flank.

OTHER FORMS OF DAMAGE

ATMOSPHERIC POLLUTION. According to Dallimore (1945) the tree is fairly tolerant to atmospheric pollution at Kew, and it grows reasonably well in the Royal Botanic Garden, Edinburgh, where other conifers are suffering from pollution.

SEED AND SEED-BEARING

Trees commence flowering between the fifteenth and twentieth year, and the first good crop is produced between the twentieth and twenty-fifth year.

The species shows promise of being a good seed producer, good cone crops occurring at intervals from two to three years. Flowering takes place during late April and early May and cone collection should be made in September (Matthews 1955).

In 1943, 70½ lb. of seed were collected from the plantation at Bedgebury, which has an area of 1½ acres. Home collected seed appears to be of similar quality to imported. Three home collections sampled and tested at Alice Holt averaged 124,000 seed per lb. with a germination percentage of 73. For comparison, a recently imported lot gave 141,000 seed per lb. with a germination percentage of 76.

GENETICS AND BREEDING

A few suitable seed stands have been registered, and a number of 'plus' trees selected.

Hybrids of *P. omorika* × *P. sitchensis* have occurred naturally at Barcaldine, Argyll. At Murthly hybrids of *P. omorika* × *glehnii*, or × *P. sitchensis*, have also been recorded.

TIMBER

Little is known of the properties of the timber grown in Britain.

POTENTIALITIES OF THE SPECIES IN THE NATIONAL ECONOMY

Picea omorika is an interesting and attractive spruce. It grows well under diverse conditions, but there does not seem to be any important site on which it is outstanding. It may have some small place on peat, and again (as has been suggested by European authors) on calcareous soils, but no evidence for the latter has been produced in Britain. In all probability, it will have a very minor role to play in British forestry.

R.F. and R.F.W.

Picea orientalis (Linnaeus) Link

A native of the Caucasus and Asia Minor, this spruce was introduced in 1839 and it has grown almost as well as Norway spruce in many districts. It is curious, therefore, that more attempts have not been made to try it as a forest crop. Among the few recorded plantations, the best known is that at Dawyck, Peebles-shire, which was planted in 1921 at an elevation of 650 feet; at the present time, this crop has a top height of 48 ft. and a volume of 2,580 Hoppus ft. per acre, while the total production in 36 years has amounted to 4,235 Hoppus ft. per acre. This is an excellent yield, corresponding to that of Norway spruce of Quality Class II. Generally, however, the growth of *P. orientalis* is not quite good enough to make it a serious rival to Norway spruce, but it might be tried experimentally a little more. There are numerous good specimens of this tree in various parts of the country and fine examples occur as far north as

Blair Atholl in Perthshire. Trees at Stourhead, Wiltshire, and Bicton, Devon, are a hundred feet and more in height while many others in widely separated districts are only slightly shorter.

Picea rubens Sargent

The Red spruce of North America, which was introduced about two centuries ago, has been planted as a specimen tree in many parts of the country but today it is by no means common. Individual trees of up to 90 ft. in height have been recorded, but, as a rule, the examples which we have are not nearly so tall.

It has been little used in the forest. A small plantation at Dawyck, Peebles-shire, 40 years old, had a top height of 36 ft. and a volume of 1,230 Hoppus feet per acre. At Benmore, Argyll, it has reached 21 ft. in 18 years and at Lael, Ross-shire, on an exposed site, 12 ft. in 20 years. A small number of trees planted in the King's Forest, Suffolk, in a sandy soil overlying chalk and in a low rainfall region, are 12 ft. high after 20 years, having suffered severely from spring frosts during the first ten years of their life.

Picea schrenkiana Fischer and Mayer.

Introduced from Central Asia about 1875, this tree is rarely seen and where it occurs, is generally growing poorly. Trees in a small plantation, which was formed at Crarae, Argyll, are only 4 ft. high after 18 years growth.

J.M.

Picea sitchensis (Bongard) Carrière

COMMON NAME

Sitka spruce. Both the timber and tree are known by this name in Britain.

COUNTRY OF ORIGIN AND PROVENANCE

Sitka spruce is a native of western North America. It is unique among the spruces in that the greater part of its distribution lies at quite low elevations. It has a great latitudinal range from Kodiak Island, Alaska, in the north, to Mendocino county, California, in the south. It does not penetrate deeply into the mainland, but is chiefly a tree of the coastal region and islands. On the mainland, it may be found up to 100 miles inland in the valleys. Locally, it may ascend to 3,000 ft. or more, but it is not usually an important constituent of the forest above 2,000 ft. (Sudworth 1908).

Although its latitudinal range is great, no geographic varieties have been distinguished (Wright 1955).

Important provenance differences in susceptibility to frost have been recorded by workers in the north of Europe (Hagem 1931), and in Britain it has been observed that Oregon and Washington provenances are more susceptible to early autumn frost in the nursery than plants raised from seed collected in the Queen Charlotte Islands in Canada (Macdonald, 1927; Edwards, 1953).

Of greater importance is spring frost damage to young trees in the forest, and this also is related to provenance. At Newcastleton, Roxburghshire, six-year-old trees of Washington provenance were severely damaged by spring frost, whereas those originating from the Queen Charlotte Islands were only slightly affected (Zehetmayr, 1954). On a less frosty site at Radnor Forest, Radnorshire, neither Queen Charlotte Island nor Washington provenances were seriously damaged by frost, but spruce from Oregon sustained some injury, and Californian spruce was seriously damaged. There is thus a strong suggestion that, for this particular species, spring frost susceptibility in Britain is related to the latitude of origin of the seed.

Provenance experiments in Britain also suggest that there is a cline for decreasing vigour from Oregon to Alaska, but the position is often complicated because the southern provenances are more susceptible to frost which may retard their early development. An unreplicated series of plots at Radnor, planted in 1929, had when measured in December 1955 the following mean heights:—California, 59 ft.; Oregon, 66 ft.; Washington, 55 ft.; Queen Charlotte Islands, British Columbia, 48 ft.

It is considered that the southern provenances are not safe for general afforestation in Britain, and since even Queen Charlotte Island spruce may prove a failure on the most frosty sites, experiments have been started to find whether certain Alaskan provenances may be useful under such conditions. It is also thought possible that Alaskan Sitka spruce might be of value at higher elevations (Wood, 1955.) However, the Queen Charlotte Islands have provided some 85 per cent of the seed imported to Britain during the past thirty-five years, and no change in the seed collecting area for general afforestation appears necessary.

HISTORICAL NOTES

Sitka spruce was discovered by Archibald Menzies in May 1792 in the Puget Sound area of Washington and it was introduced into Britain in 1831 when the first seeds were brought back by David Douglas. A few plants were raised from this first lot of seed in one of the Horticultural Society's gardens and some of these still survive. The first major consignment of seed was introduced by the Oregon Association in 1852 (Johnstone, 1939). Prior to 1920-22 much of the seed was imported into Europe by Rafn of Copenhagen, and it is most likely that it came from Washington. After 1922 the main seed imports came to Britain from the Queen Charlotte Islands,

although a small proportion was still imported from Washington.

Specimen trees were planted on many estates in Great Britain in the mid-nineteenth century and their early growth in Scotland was amply described by Hutchison (1878). From his list it appears that the earliest Scottish records are for trees at Terreagles, Kirkcudbrightshire, and Keillour Castle, Perthshire.

One of the first plantations was at Wooplaw, Roxburghshire. Planted about 1866 at an elevation of 900 feet, the trees, which were spaced twenty to thirty feet apart, probably in mixture with another species, reached a height of 110-120 feet and had girths up to 16 ft. at breast height after 90 years; volumes per tree ranged from 400 to 600 hoppus feet. Another early and very successful plantation was established in 1879 at Durris, Kincardineshire, with plants spaced six to nine feet apart and mixed with Scots pine (Crozier, 1910). A further important example was the plantation at Darnheath on the Drumlanrig estate in Dumfries-shire, established in 1900; by 1946, this had produced a total yield of 10,940 Hoppus ft. per acre, and averaged 88½ ft. in height.

These and other successful plantations of Sitka spruce which were mostly sited on favourable ground, encouraged great interest in the tree because of its rapid rate of growth, high volume production and apparent ease of establishment. As a result, a number of plantations were made in the early years of the present century in various parts of the country and on a wide range of sites. A number of these failed because the trees went into check, in particular those planted where heather (*Calluna vulgaris*) was prevalent.

The recent history of Sitka spruce in Britain is also that of the development of methods of establishment of plantations on peatlands and moist mountain grasslands, since it is the species above all others on which we have come to rely for these important environments, and most of the experimentation has been carried out with Sitka spruce as the subject. Zehetmayr (1954) has reviewed this field of work. One of the most important advances was the introduction of a modified version of the Belgian turf planting technique by Sir John Stirling Maxwell which enabled successful establishment to be achieved on peats dominated by the grass *Molinia coerulea*. Hand draining and turfing methods have yielded place to ploughing, and with the use of machinery the range of Sitka spruce extended to poorer sites. The use of phosphatic fertilisers became general where Sitka spruce was planted on sites where heather (*Calluna vulgaris*) or the red deer grass (*Trichophorum*) was present. A further development was the planting of pines in mixture with Sitka spruce on these more difficult sites in order to hasten the suppression of the heather.

While such improvements in technique undoubtedly widened the scope of Sitka spruce, they perhaps encouraged an over-optimistic view of the prospects of the tree on the poorer sites, and in recent years the tendency has been to avoid planting it on the least fertile peats and on the heathlands. Sitka spruce has, however, without doubt attained the important position forecast by the late Lord Robinson (1931).

EXTENT OF PLANTING

Sitka spruce is the most extensively planted exotic in Britain, and the 1947-49 Census of Woodlands showed a total of 167,000 acres, this being seventeen per cent of the total area under conifers or nine per cent of the entire productive forest area in Britain (Forestry Commission 1952). Tables 28 and 29 give area details by ownership, country and age classes.

CLIMATIC REQUIREMENTS

The distribution of Sitka spruce in the coastal forests of north-west America suggests that it has a high moisture requirement. Wood (1955) has discussed the differences between the climate of this region and that of Britain, and considers that no

TABLE 28 PICEA SITCHENSIS (SITKA SPRUCE): DISTRIBUTION BY COUNTRIES, AND PERCENTAGES OF HIGH FOREST AREAS OCCUPIED, 1947

Ownership	England			Scotland			Wales			Great Britain		
	Area Acres	Percentages		Area Acres	Percentages		Area Acres	Percentages		Area Acres	Percentages	
		of conifers	of all species		of conifers	of all species		of conifers	of all species		of conifers	of all species
Private Woodlands	8,866	5	1	14,126	6	4	2,137	10	2	25,129	5	2
Forestry Commission	39,322	20	16	71,054	37	36	31,532	38	36	141,908	30	27
Total	48,188	13	5	85,180	19	15	33,669	33	18	167,037	17	9

TABLE 29 PICEA SITCHENSIS (SITKA SPRUCE): HIGH FOREST AREAS, PURE AND MIXED STANDS COMBINED, BY AGE-CLASSES, 1947 Acres

Ownership	*Age-class*								
	1–10 *yrs.*	11–20 *yrs.*	21–30 *yrs.*	31–40 *yrs.*	41–60 *yrs.*	61–80 *yrs.*	81–120 *yrs.*	*Uneven aged*	*Total*
Private Woodlands	6,141	8,138	7,174	1,530	592	145	7	1,402	25,129
Forestry Commission	71,986	58,323	9,766	284	85	—	1	1,463	141,908
Total	78,127	66,461	16,940	1,814	677	145	8	2,865	167,037

sharp limitation need be expected in Britain on the grounds of inadequate rainfall or low atmospheric humidity. The high moisture requirement of the tree may be satisfied in the drier eastern parts of Britain on very localised favourable sites, but as Macdonald (1952) says, Sitka spruce is rarely seen at its best in districts where the annual rainfall is less than 35 or 40 in. The lower evaporation rates of the north enable the tree to be grown at lesser rainfalls than would permit of its extensive plantation in the south. Current practice is, however, to confine the use of Sitka spruce to regions of considerable rainfall; it is little planted where the annual rainfall is less than 40 in.

There do not appear to be any definite temperature limits to the use of Sitka spruce in Britain.

SITE REQUIREMENTS

Sitka spruce can be easily established and will grow satisfactorily under a wide range of conditions. Its primary requirement, for adequate moisture, is readily met in the higher rainfall districts of the west. One of its principal virtues for British forestry is its tolerance of exposure, in which it is not surpassed by any other species in general use. Consequently it is normally carried to higher elevations than other commonly planted trees, and it is also a most useful subject for shelterbelts (Cadman 1953).

At Inchnacardoch, Inverness-shire, Zehetmayr (1954) records that after twenty-one years, Sitka spruce growing on an exposed site at 1,100 feet had dominant heights of twenty-three feet, and were surpassed in height growth only by *Pinus contorta* out of a range of seven coniferous species including *Pinus sylvestris*, *Pinus mugo*, *Picea abies* and *Picea glauca*. The altitudinal limit is a matter of local exposure; it is likely to be about 1,800 to 2,000 feet on sheltered sites, and 500 to 1,000 feet lower under exposed conditions in the west.

Sitka spruce is planted throughout the west of Britain on peats and acid grasslands. Peat soils supporting *Molinia*, *Nardus-Molinia* or rush-grass communities are regarded as favourable sites and are frequently planted with pure Sitka spruce. Cotton grass (*Eriophorum*), and more especially, deer grass (*Trichophorum*), indicate less fertile, more acid peats which will be difficult for Sitka spruce. Pseudo-fibrous peats with dominant *Trichophorum* are not considered plantable for Sitka spruce (Zehetmayr 1954).

The presence of *Calluna* is a warning note, since on the cessation of grazing it often becomes dominant and the spruce may go into check, a condition in which the plant becomes yellow, and grows slowly if at all. There has been much effort to extend the planting of Sitka spruce on to sites where *Calluna* is an important component of the vegetation, but this has frequently resulted in the spruce going into check.

A great deal of research work has been undertaken both by the Forestry Commission and the Imperial Forestry Institute at Oxford to determine the factors concerned with check. It is found that checking of growth is due to a complex of factors amongst which the presence of *Calluna* appears to be of primary importance (Zehetmayr, 1952; Leyton, 1954). The role of *Calluna* has been elucidated by observations in mixed plantations, where the *Calluna* is suppressed by the nurse trees of pine or larch (Macdonald 1936; Macdonald and Macdonald 1952; Weatherell 1953); and also by the suppression of *Calluna* by artificial shading (Leyton 1955) and by mulching (Leyton, 1954). The use of ploughing for cultivating the soil and for the suppression of *Calluna* has often proved a suitable method of preventing check, but on many sites the *Calluna* quickly revives and the spruce checks before it can close canopy. On the poorer heaths, Sitka spruce responds to phosphate applications, but nitrogen and calcium may become limiting to growth when phosphate levels in the soils are satisfactory (Leyton 1954).

As a result of this research work, it is concluded that Sitka spruce is not suited to the dry heathland sites, and despite the relative success of some plantations, the low rainfall and the nutrient deficiencies do not allow the species to develop its full potentialities.

On the moister heaths, where the rainfall is more than thirty-five to forty inches, Sitka spruce is often planted quite successfully following ploughing, either as a pure crop, or more often in a three row: three row mixture with Japanese larch, Scots pine or *Pinus contorta*.

The ecological conditions provide a most reliable guide to the ease (or otherwise) of establishment of Sitka spruce. They can be modified to a considerable extent by draining, cultivation, manuring, etc., but there will remain certain basic limitations to the usefulness of the tree. These are not yet clearly defined, but it is thought that certain soils will fall below the necessary fertility levels for Sitka spruce. This may be the case with the poorest peats and also with certain acid sands and gravels of which the Eocene Bagshot beds provide a notable example. Day (1954) has drawn attention to the possibility that certain soils, which are physiologically shallow for one reason or another, will support rapid growth of Sitka spruce in youth, but will fail to supply its requirements as it approaches maturity. Very shallow soils over impervious substrates and stony rapidly-draining profiles are considered unsuitable for Sitka spruce. Failure of moisture supply is the main danger.

Sitka spruce has however been planted extensively on soils which are not compatible with very deep root penetration, notably the boulder tills overlying fine-grained rocks such as the Silurian formations. So far the behaviour of the tree on these sites has given little cause for alarm, and it may be that the retentiveness and comparative fertility of the soils compensate for their physical disadvantages.

Sitka spruce is susceptible to spring frost injury; the provenance aspect of this has already been mentioned. In practice, this has had an important bearing on the choice of sites, since valley bottoms are now avoided following many unfavourable experiences, which unfortunately deprives the tree of some sites otherwise well suited to it. Norway spruce is preferred on the lower spruce sites where frost is expected to be an important factor.

Sitka spruce is (at any rate in Britain) intolerant of overhead shade, and is rarely used for underplanting.

ESTABLISHMENT TECHNIQUE

NURSERY PRACTICE. Most Sitka spruce seedlings are raised in heathland nurseries using standard techniques. The recommended sowing density in these nurseries is one pound of seed to sixty-five square yards of bed, assuming a normal germination capacity of 85 per cent. A three-sixteenth inch cover of coarse sand or grit is essential for obtaining the highest yield of seedlings (Faulkner, 1953; Macdonald, 1935). The seedlings are especially intolerant of soils with pH values greater than 6, and prefer moderately acid soils within the range of 4.5-5.4. In the older established nurseries on agricultural soils seedlings often show much better growth after partial sterilization of the soil, producing much higher yields of better quality plants suitable for lining-out. (Edwards, 1952; Faulkner and Aldhous, 1956; Benzian, 1956).

Because Sitka spruce exhibits well marked manurial responses and is generally sensitive to soil conditions, it has been much used of recent years as an indicator plant in nursery experiments.

VEGETATIVE PROPAGATION. This is only practised in tree breeding.

Grafting. Grafting is difficult but has been successfully accomplished on rootstocks of both Sitka spruce and Norway spruce. One-year-old scion wood, which is not too vigorous, is suitable for grafting under glass in early March, or outdoors in late March or early April. Scion wood does not keep well and must be used soon after collection.

The grafting method commonly employed is the "Veneer Side" graft but the "Cleft" graft has given some success. Cutting back the rootstock must be done slowly and carefully.

Cuttings. This method of propagation is usually quite successful and is preferred to grafting. Cuttings are prepared from one-year-old shoots, four to six inches long, taken from vigorous side branches growing in full light conditions. They are inserted in a rooting medium of equal proportions of silver sand and mild peat in early to mid-July. Cuttings from trees up to twenty-five years old have been successfully rooted. Applications of indolyl butyric acid in alcohol, used as a concentrated dip, increase the speed of rooting and the number of roots developed.

DIRECT SOWING

Small areas have been raised experimentally on the peats and heaths but the great care and attention needed to ensure their survival in the early years is far too costly for any wide-scale application.

PLANTING

At the present time, very nearly all the planting of Sitka spruce is done on sites prepared by plough draining or hand turfing methods, the former being the general practice in the Forestry Commission. On sites where ploughing is impracticable or unnecessary, and where intensive draining is not required, Sitka spruce may be planted directly into unprepared ground, usually by one or other forms of notching. Here rather large transplants (two year-one year or even two year-two year) may be preferred, particularly if heavy weed growth is expected; but for turves or plough ridges the one year-one year transplant is quite adequate and is becoming the standard type. Seedlings, both one-year and two-

year, have been planted on numerous occasions, and sometimes with success, but the general experience has been that the hazards outweigh the economies. The position of planting on ploughed ground is normally on top of the ridge, but on very exposed sites it pays to prepare a 'step' on the side of ridge, thus providing some shelter for the young plant (Zehetmayr 1953.) Planting in the furrow itself, a good position on dry ground, is not usually possible with Sitka spruce, since on the moist sites usually favoured the furrows serve as drains. Where turves have been spread, i.e. after hand draining or ploughing at more than planting spacement, the plants are simply notched into the turf. Sitka spruce is usually planted rather deeply, particularly on plough ridges which are liable to contract or erode.

It is standard practice to apply phosphate to Sitka spruce in the first planting season on sites where a worthwhile response is expected, or where it is feared the plants may go into check without phosphate. The presence of *Trichophorum*, *Eriophorum* or *Calluna* is normally regarded as an indication of conditions under which Sitka spruce will respond to phosphate. Ground mineral phosphate is the form most commonly applied, and the usual dosage is 2 oz. per plant.

SPACING. A spacing between plants of five to six feet is generally used.

TENDING AND THINNING

WEEDING. Sitka spruce gets away fast and weeding is not usually a serious problem. Plantations on ploughed sites are frequently established without any weeding at all.

THINNING. The thinning problems of Sitka spruce arise out of the large areas of fast-growing pole crops which we now have, rather than from any special features of the tree itself. The branching habit of the tree is somewhat coarse if allowed too much space, on the other hand if crowns are allowed to become too restricted, they do not recover quickly. Hence in forests with considerable areas covered by few age classes, it is somewhat difficult to plan thinnings to the best grade and frequency. Norway spruce is an easier crop to thin, since crowns recover readily from underthinning, and overthinning does not produce such coarse branching.

PRUNING. Natural pruning in Sitka spruce is slower than in Norway spruce, but perhaps rather faster than in Douglas fir. Young plantations are impenetrable before brashing, and brashing two-thirds of the trees up to a height of six feet, is essential for access. Artificial pruning is little practised. High pruning into the green crown results in the production of weak epicormic shoots along the bole.

OTHER SILVICULTURAL CHARACTERISTICS

The bark is thin and, even in old trees, is scarcely more than half an inch thick; it is therefore very easily damaged during timber extraction.

In young pole stands, the suppression of the vegetation is complete and a fairly thick deposit of needle litter builds up. This is much less apparent in older stands, when one or two thinnings have been carried out. Preliminary studies on the litter fall and mineral constituents of the needles have been carried out by Owen (1954) in North Wales. Ovington (1953) included Sitka spruce amongst a number of species studied with respect to the reaction of their litter and that of the soils on which they were growing. The question of the effects of pure Sitka spruce crops on the soils is of importance in view of the large areas involved, but it would be unsafe at this stage to comment on the work so far carried out.

RATE OF GROWTH AND YIELD

The current yield table (Hummel and Christie 1953) is based on data provided by sixty-five sample plots, the majority of which are less than thrity years old. The plots cover a range of sites up to elevations of 1,500 feet.

Sitka spruce is a fast-growing species and on first quality sites reaches a top height of 110 feet in fifty years, and even Quality Class V sites produce top heights of seventy feet in fifty years (equivalent to Quality Class II Norway spruce). Rates of growth slower than those recognised for Quality Class V are not represented in the yield tables, although lower classes might be distinguished for the poorer sites on which Sitka spruce is now grown. Stands of first quality are rare in areas which have an annual rainfall of less than forty inches.

Early underestimation of Quality Class may be made on sites where Sitka spruce has temporarily gone into check soon after planting.

Volume production is high and at fifty years total volume production for Quality Class I crops is in the region of 13,000 Hoppus feet, and even on Quality Class V sites the total yield is slightly more than half this figure, and is better than that of Quality Class I European larch. From the sample plot data it appears that, although the species grows best in the wetter west coastal districts of the country, very satisfactory yields can be expected elsewhere in Britain.

According to the yield tables, the current annual increment in Quality Class I reaches a maximum of about 400 Hoppus feet per acre at twenty years (the highest for any species in Britain for which yield tables have so far been published) but it then falls off rapidly. In other Quality Classes the current annual increment culminates later. The mean annual increment culminates before fifty years in the first three Quality Classes.

There are many fine specimen trees throughout Britain and two of the most noteworthy are at Murthly, Perthshire, and Stanage Park, Radnor. The former was 160 feet tall and had a breast height girth of fifteen feet two inches and the latter was 138 feet tall with a breast height girth of thirteen feet eight inches; both were 108 years old when measured.

PESTS AND DISEASES

INSECTS. The aphid *Neomyzaphis abietina* Wlk., causes severe defoliation on Sitka spruce. Although the damage, which is restricted to two-year-old needles, looks most threatening, recovery from attack is good except on sites where the soil moisture content is low.

Eucosma diniana Guen., which is usually regarded as a pest of larch, has within recent years caused severe defoliation of Sitka spruce in Hope Forest, Derbyshire. The bud-feeding sawfly *Pristiphora ambigua* Fally. is found more often on Sitka spruce than on other species.

FUNGI. Sitka spruce has been more affected than any other conifer by "Group Dying" associated with the fungus, *Rhizina inflata.*

In the nursery Sitka spruce is sometimes severely attacked by Grey Mould (*Botrytis cinerea*). This often follows initial injury by autumn frost.

MAMMALS. The field vole, *Microtus agrestis*, is commonly found on sites where Sitka spruce is planted but damage by voles is seldom serious, except when the population assumes plague proportions. Deer show no particular liking for Sitka spruce and rarely cause damage.

OTHER FORMS OF DAMAGE

WIND. In young plantations, providing that thinning has been regular and adequate and that surface water is removed by drains, little damage normally occurs. We do not have sufficient experience of Sitka spruce of the older age classes to say how it will compare with other species in gales of exceptional severity.

There have been many reports of Sitka spruce losing its leading shoots, particularly Lammas shoots, on sites where growth has been very fast.

ATMOSPHERIC POLLUTION. Although it has been stated that Sitka spruce is resistant to smoke damage, experience suggests that it may not be very tolerant, although it is certainly more tolerant than certain other conifers, for example, the *Abies.*

SNOW. Sitka spruce appears resistant to snow breakage.

SEED AND SEED-BEARING

In Britain the average yield of seed per bushel of cones is nine ounces; the number of seed per pound varies from 120,000 to 400,000 and averages 190,000, with a percentage purity of ninety-three and a germination percentage of sixty-nine. Sitka spruce starts to flower when twenty to twenty-five years of age, and gives the first economic seed crop when thirty to thirty-five years of age. Maximum seed production occurs when trees are between forty and fifty years of age. Seed production is periodic and heavy crop years occur at intervals. The trees flower in April and cones are collected in September (Matthews 1955). There are no problems in seed extraction.

GENETICS AND BREEDING

In Britain 133 "plus" trees had been selected by 1956. The figures are made up as follows: Scotland, 117; England, 10; Wales, 12. No seed orchards are proposed at present.

NATURAL REGENERATION

Natural seedlings have frequently been observed. Murray (1938) reports established seedlings up to three feet tall at Largie, Argyll, and Davies (1954) describes a dense stocking of natural seedlings at an elevation of 1,200 feet at Glasfynydd, Breconshire, on a shallow peat above a soil derived from Old Red Sandstone. There is insufficient experience of older crops to judge whether natural regeneration is likely to be a practical proposition.

TIMBER

The timber air seasons rapidly with some splitting and distortion. It kiln-dries with a tendency to warp, and collapse of the springwood has sometimes occurred.

It is not resistant to decay and the heartwood is difficult to impregnate with wood preservatives, but retentions of up to 11 lb. per cubic foot have been achieved under pressure. However, collapse of the timber is liable to occur if too high temperatures and pressures are used.

Tests have been carried out on six consignments of home-grown thinnings. The timber was found to be similar to Canadian-grown mature timber in some strength properties but much weaker in stiffness, bending and resistance to impact. It seems to be weaker than home-grown Norway spruce in most strength properties.

The strength properties of the two species are compared in Table 30. (Sunley 1956.)

Sitka spruce timber works well with machine and hand tools but does not finish particularly well owing to the crumbling of spring wood. Opinions have been expressed that clusters of knots, which blunt the saws, can be troublesome during conversion; and that in wood wool manufacture, it gives a lower yield, in pounds per cubic foot, than Norway spruce on account of its lower density.

SPRUCE (PICEA): STRENGTH OF TIMBER

TABLE 30

	Modulus of Elasticity lb. sq. in.	*Bending Strength* lb. sq. in.	*Compression Parallel to the Grain* lb. sq. in.	*Shear* lb. sq. in.
Sitka spruce .... (*Picea sitchensis*)	950,000	1,100	800	160
Norway spruce .... (*Picea abies*)	850,000	1,200	1,000	180

The timber is now widely used for pitwood, box-making and chipboard and there is a ready market where local industries are available to absorb the material. In recent years two new enterprises have been established in Scotland to utilise the increasing output of timber from thinnings, most of which is Sitka spruce. These are the Airscrew and Jicwood Company's chipboard factory at Annan, Dumfries-shire, and the Cowal-Ari Sawmill at Strachur in Argyll.

According to Bryan and Pearson (1955), the specific gravity of timber in young Sitka spruce trees is high near the pith and falls to a minimum fifteen to twenty rings out from it; thence it increases towards the cambial layer. Bryan and Pearson also noted an apparent relationship between the density of Sitka spruce timber, and the latitude of the site (in Britain) on which it was growing.

POTENTIALITIES OF THE SPECIES IN THE NATIONAL ECONOMY

Sitka spruce is particularly well adapted to our moist oceanic climate, is able to stand a high degree of exposure, and is readily established in a wide variety of conditions. It is well suited to grow on the acid grasslands of our northern and western hills. In addition, its rapid rate of growth and high volume production make it a valuable acquisition.

Experience has enjoined caution in choice of sites. It is not now planted on the drier heaths, and on the poorer peats and moist heaths it is usually planted in mixture with pines. Inside its proper range, it is probably less replaceable than any other species available for British forestry, and while it is probable that certain other north-west American species, notably its natural North American associates *Thuja plicata* and *Tsuga heterophylla*, will appear to a greater extent in forests now almost pure Sitka spruce, there seems little likelihood that the use of Sitka spruce will decline.

R.F. and R.F.W.

Picea smithiana Boissier

Known also as *Picea morinda*, this tree was first grown in Great Britain in 1818 at Hopetoun, West Lothian. It is quite hardy once it has grown beyond the risk of frost damage in spring, to which young plants are susceptible, and it makes a most handsome tree. There are many good specimens more than 100 ft. high. On the evidence provided by individual trees, it appears to grow better in the southern parts of the country, though trees at Taymouth Castle, Perthshire, and at Inveraray, Argyll, are among the largest which have been recorded. In spite of its good performance as a specimen tree, *P. smithiana* has not been tried in the forest. It might be worth trying in some of our southern districts.

Picea spinulosa Griffith

This spruce is also a native of the Himalaya. It was introduced in 1878, but the only promising specimens appear to date from about 1911. At Borde Hill, Sussex, there are several good specimens, the largest of which is 68 feet in height, by 6 feet 1 inch at breast height, at 45 years of age. This species is very rare in cultivation.

J.M.

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Pinus Linnaeus

The genus *Pinus* comprises some seventy-five species of which fifty-seven have been recorded as growing in Great Britain; *P. sylvestris* is the only native species. The most successful introductions have come from Europe and North America; species from sub-tropical latitudes are not hardy, while many of those from warm temperature latitudes seldom thrive, probably because of lack of summer heat. None of the Asian pines except *P. griffithii* shows any vigour here.

Of the five-needled pines of North America *P. strobus* and *P. monticola* are the most important in Great Britain, and have reached large dimensions, but their use is now entirely governed by the incidence of the white pine blister rust (*Cronartium ribicola*). *P. lambertiana* is occasionally found in arboreta and specimen trees of 80 to 100 ft. in height have been recorded. *P. balfouriana*, *P. aristata*, *P. flexilis* and *P. albicaulis* however occur very rarely; none of these have exceeded 35 ft., except *P. flexilis* of which one specimen 87 ft. tall and several trees 50 ft. tall have been recorded.

The only important three-needled pines from North America are *P. radiata* and *P. ponderosa*, both of which have been used to a small extent in the forest and are frequently met with as specimen trees. Of the others, *P. coulteri* and *P. jeffreyi* are recorded as growing to 80 and 100 ft. respectively, but while records of the former are limited almost entirely to arboreta in England and Wales, *P. jeffreyi* is found in a number of Scottish arboreta as well as in more southerly ones. *P. attenuata*, *P. rigida* and *P. sabiniana* are all hardy but do not thrive; most of the recorded specimens are found in the south of England, the tallest being a specimen of *P. rigida* 64 ft. high at Bolderwood, Hampshire. A group of *P. attenuata* at Bedgebury had a mean height 25 ft. when sixteen years old, but the trees were not healthy.

The five-needled and the three-needled pines of the southern United States, Mexico and Central America grow best in the south of England, but can scarcely be said to thrive even there, except on particularly favourable sites. All are rare in collections, except *P. ayacahuite*, which is one of the hardiest and most vigorous species of this group. *P. montezumae*, though surviving only in the south and west, has reached a height of 80 ft. in Cornwall; *P. patula* survives in mild positions in the south-west and has grown to 90 ft. *P. greggii* has been found at Bedgebury to be hardier than *P. patula* and *P. palustris* has also tolerated severe frost on the same site, but only small specimens of either *P. greggii* or *P. palustris* have been recorded.

P. torreyana, *P. cembroides*, *P. caribaa*, *P. taeda* and *P. teocote* are extremely tender and survive only in mild parts of the British Isles. A small plot of *P. cembroides* was planted and has survived at Crarae in Argyll but was only 4.2 ft. tall fifteen years after planting.

Pinus contorta is by far the most important of the two-needled pines from North America; *P. resinosa* and *P. banksiana* have been planted experimentally but no place has been found for them in our silviculture. *P. muricata* is quite frequently met with in arboreta and is recorded as growing up to 95 ft. This species has in the last two years been planted on an experimental scale in south-western England. Of the others *P. echinata* and *P. pungens* occur very rarely in Britain and are not recorded as exceeding 40 ft.; while *P. virginiana* is rare but exceeds 60 ft. at Borde Hill in Sussex.

Of the Asian five-needled pines, *P. parviflora* is hardy, and is not uncommon in arboreta. However it grows slowly and seldom exceeds forty feet in height. A small plot of *P. parviflora* at Crarae, Argyll, was only 5 ft. tall, fifteen years after planting. *P. armandi* is occasionally found in the south and west where it can grow to 50 ft. At Bedgebury, this tree has been badly damaged by winter cold. *P. koraiensis* has seldom been recorded, its best performance being about 50 ft. A small plot of *P. koraiensis* at Crarae was 8ft. tall fifteen years after planting. *P. pumila*, which is little more than a shrub in its native habitat, is very rarely encountered.

P. bungeana is the only three-needled Asian pine that has been introduced into Britain, and it is quite rare. It is hardy but grows slowly and has not yet exceeded 40 ft.

P. densiflora, a two-needled pine from Japan, is found only in a few southern arboreta and does not do well. At Bedgebury its health deteriorated after making good early growth, while trees in a small plot at Beddgelert, Caernarvonshire, are growing slowly; in 1952 when eighteen years old they were only 8.7 ft. high and were unhealthy.

P. tabulaeformis, a two-needled pine from China is rarely found, and its performance is usually poor.

Of the European five-needled pines, *P. cembra* is frequently seen in arboreta in all parts of Great Britain and often attains 60 ft. or 70 ft. in height; it has scarcely been used in the forest. *P. peuce* on the other hand is less common in arboreta but has been planted experimentally in several districts.

Of the European two-needled pines, the four main varieties of *P. nigra* have been planted but the only one of major importance is the Corsican pine. *P. pinaster* grows well near the south coast of England but is rarely met with elsewhere. *P. halepensis* is too tender for use in Britain and specimens of it are rarely seen. *P. pinea*, though hardier, is also uncommon. *P. heldreichii*, found in the Balkan peninsula and Southern Italy, is represented in the larger collections in Britain by var. *leucodermis*.

The insect fauna associated with pine forest in Britain contains a number of important forest pests and it will involve less repetition to consider here those which are of significance at different ages of the trees or crops, than to do so in accounts of each forest species.

Reference has already been made in Chapter 1 to the large pine weevil, *Hylobius abietis* L., and to the black pine beetles, *Hylastes* species, which although general coniferous feeders, typically breed most abundantly on pine and are important pests at the time of establishment.

In the first decade or so of the pine crop's life two sawfly species out of the eleven known to occur in Britain (Forestry Commission, 1955b) are sometimes prominent. They are *Diprion pini* L. and *Neodiprion sertifer* Geoff. Both cause defoliation and the latter species is probably more prevalent than the former at the present time. Attacks seldom result in tree death but often cause a reduction in height

increment. It is interesting to note that *P. contorta* suffers more damage from the attacks of *N. sertifer* than does the native *P. sylvestris*. At this stage of the crop's development, attacks of *Evetria buoliana* Schiff. and *E. turionana* Hbn., both of which produce stem distortions, often occur. *E. buoliana* attacks *P. contorta*, *P. sylvestris* and *P. nigra* in that order of preference (Brooks and Brown, 1936; Crooke, 1951) and *P. radiata* and *P. pinaster* are also attacked; but *P. strobus* appears to be free from attack. *E. turionana* occurs on *P. sylvestris* and *P. contorta;* but *P. nigra*, *P. pinaster* and *P. ponderosa* appear to be free from attack (Crooke, 1951).

In pole stage and older crops, bark beetles, weevils and defoliators become of importance. Of the many pine bark beetles present in Britain the most important are the *Myelophilus* species; and the adult feeding of both *M. piniperda* L. and *M. minor* Htg. can produce serious and permanent distortions of stem form. *M. piniperda* is widely distributed and occurs on many species of pine; *M. minor* is more restricted in distribution and the only two exotic pines on which it is known to occur are *P. pinaster* (Waddelove and Webb, 1948) and *P. radiata*. *Ips sexdentatus* Born. has also been responsible for damage in pine plantations (Forestry Commission, 1949) but its attacks are sporadic in nature. The banded pine weevils, *Pissodes* species, are fairly common pests (Forestry Commission, 1952). Of the defoliators, the pine looper moth, *Bupalus piniarius* L., never before known to have been troublesome, became very numerous, erupted in 1953 (Bevan, 1955) in two forest areas, and had to be controlled by the aerial spraying of insecticides (Crooke, 1956). In this case the major damage was inflicted upon Scots pine but *P. nigra*, *P. contorta*, *P. pinaster*, *P. ponderosa* and *P. strobus* are all known to be hosts of the pine looper in Britain (Forestry Commission, 1954). Another defoliator of pine of potential importance is the pine beauty moth, *Panolis griseovariegata*, Goeze.

Among the sap sucking insects, *Adelges pini*, Koch. and *Lachnus* (*Cinara*) *pini* L. occur on many species of pine, whilst *Adelges strobi* is restricted to *P. strobus*. None of them are of any great forest importance.

Important fungi affecting pines will be mentioned under the species, but mention must be made here of the needle-cast fungus *Lophodermium pinastri*. This pest is able to attack many of the exotic pines in this country but the resulting defoliation is seldom as severe as that occurring on Scots pine.

Pinus banksiana Lambert

This tree is the most northerly of the pines of North America and grows from near the Arctic Circle in the valley of the Mackenzie River through the Canadian forest belt and as far south as Maine. It was introduced into Britain early in the eighteenth century, the exact date being unknown. *P. banksiana* seldom grows well here and its form is poor. The two tallest specimens on record occur respectively at Blackmoor, Hampshire, where there is a tree 61 ft. and at Bedgebury, Kent, where there was a tree 56 ft. in height. A forest plot of the species at Crarae, Argyll, has grown surprisingly well and in 1955 when 23 years old had an average height of 31 ft. A very young plot at Bedgebury is growing with some vigour. Older trees there grew well for a while but later deteriorated in health. It is most unlikely that the species will find any place in British forestry. J. R. A.

Pinus contorta Loudon (Plate 7)

NAME

The name *Pinus contorta* is used for the whole species in a wide sense, although two varieties are often distinguished, or even, by some botanists, two separate species. These have been termed the shore or beach pine, *P. contorta* Loudon, and the lodgepole or Murray pine, *P. contorta* var. *latifolia* S. Watson, which is synonymous with var. *murrayana* Engelmann, or *P. murrayana* Balfour.

In North-west America, where the shore or beach pine is of little commercial value, the general name for the whole species is lodgepole pine, and in view of the difficulties in dividing the species, the name "lodgepole" pine for the whole species *P. contorta* is used in Britain. Sometimes the terms "coastal lodgepole" and "inland lodgepole" pine are used to differentiate the main seed provenance areas. The name "contorta pine" has also been employed, but is to be deprecated.

COUNTRY OF ORIGIN AND PROVENANCE

The range of lodgepole pine as a whole is very wide. The northern limit lies in the Yukon River (Klondyke district—64°N) and it stretches southwards through the Rocky Mountains and also the Cascade, Sierra Nevada and San Jacinto Mountains, through the Provinces or States of Alaska, Yukon, British Columbia (including the islands), Alberta, Washington, Montana, Oregon, Idaho, Wyoming, South Dakota, California, Nevada, Utah and Colorado to New Mexico. It is found from sea level up to 5,000 or 6,000 feet at the lower limits of the sub-alpine type in British Columbia, and up to the timber line at 11,500 feet in Colorado and southern Wyoming.

As in Europe, the earliest provenance experiments in Britain were carried out with seed from inland sources. A few plots were planted in 1928, and four provenances tested in the U.S.A. by Haasis and Thrupp (1931) and on the Continent of Europe,

were planted in several forests in 1930 and 1931. More comprehensive experiments have been started in the forests of Clocaenog, Denbigh; Clashindarroch, Aberdeenshire (1934-41); Teindland, Moray (1934-38); and Achnashellach, Wester Ross (1937-41); a closely comparable pair at Millbuie, Easter Ross, and Allerston (Wykeham), on the North Yorkshire moors, in 1938; and Kirroughtree, Kirkcudbrightshire (1939-41). Small experiments including Alaskan provenances were planted in 1954. The results indicate that, in general, there is a broad differentiation into fast-growing, rather coarse, bushyprovenances and slower-growing, narrower-crowned provenances. A description of the two types that may be seen at Clocaenog, noting the advantages of the coastal form as a pioneer or nurse crop, able to suppress heather quickly, and contrasted with the better form of the inland pine from Kamloops, British Columbia, is given by Wood (1950). More details of this experiment are furnished by Edwards and Pinchin (1953) who show that other characteristics of the coastal provenances are the greater number of branches per whorl, thicker branches, a wider crown, and a markedly shorter needle. Further evidence, from a wide collection of provenances, is given by Macdonald (1954). He also notes that the coastal type retains its needles on the branches for a greater number of years, and that the needles are a darker green than those of inland types. From the point of view of good form and appearance, the most extreme inland provenance so far introduced, from Alberta, has done well, both in experiments on peat (Zehetmayr, 1954) and in Scottish forests, where it has frequently been described with approval; but there have been indications that extreme inland provenances may on certain sites suffer from die-back, frost damage and subsequent attacks by fungi (Day, 1952; Macdonald, 1954). On the other hand, there is some reason to hope that the poor form and appearance of provenances of coastal type may improve with age. In one of the oldest crops of coastal lodgepole pine (31 years at Culbin forest Moray), photographs showed a marked contrast between its poor youthful appearance and its state after several thinnings.

These experiments indicate that there are wide differences in inherited characteristics, both botanical and silvicultural, and that there is no clear differentiation into two types. Instead, there are many intermediates both from the standpoints of vigour, habit, stem form, resistance to exposure or other characteristics, and these are best dealt with as separate provenances. The original shore pine was described from sandy coastal areas in the southern part of the entire range of *P. contorta*. But in Vancouver Island, for example, Wood (1955) reported that there were stands of *P. contorta* comparable in form with those found in the interior of the Mainland. The typically contorted and scrubby form of coastal pine appears to exist in a number of refuges where its low requirements give it a special advantage, such as the muskeg, or on exposed coastal dunes (Wood, 1955). Thus, it may be said that *Pinus contorta* is a polymorphic species, differentiated into ecotypes which may form ecoclines ranging from the coast to the continental zone east of the Rocky Mountains, and from 36°N to 64°N latitude, but it is not always possible to classify the morphological and physiological differences in relation to the provenance of the seed. Grouping into zones as, in British Columbia, the coastal, Skeena river, Thompson river and "east of the Rocky Mountain" zones; and in the U.S.A., the coastal, Cascade and Rocky Mountain zones, is partially satisfactory.

HISTORICAL NOTES

Discovered in 1805, the tree was introduced into Britain by Jeffrey in 1853 from the Siskiyou Mountains, Oregon, 43°30′ N, at 7,500 feet. (Johnstone, 1939.) Although older trees exist and had reached over seventy feet in height in 1931 (Chittenden, 1932), the oldest plantation so far traced is that at Ruttle Wood, Beaufort Estate, in eastern Inverness-shire. It was planted about 1910 or 1912, and is clearly of a coastal provenance. The first experiment with this species dates from 1921 (Achnashellach, Ross, where it failed when notch-planted), and planting of lodgepole pine did not become general until about 1930, though some was earlier used experimentally, and the chance seedlings that were frequently found in seedbeds of Sitka spruce and Douglas fir were utilized.

EXTENT OF PLANTING

Lodgepole pine has not been planted extensively until recently, and the 1947-49 Census of Woodlands only recorded 828 acres in England, 1,949 acres in Scotland and 483 acres in Wales; total 3,260 acres, about half pure and half in mixture with other species. Table 31 shows its distribution by age classes

Imports of seed re-commenced in 1946 after the war, and rose to over 600 lb. in 1951, when the species was first classed as "major" in Forestry Commission annual reports; they have averaged nearly 700 lb. per annum in the last five years to 1955. These increases are reflected in the rapid increase in the number of plants used for new planting each year, which has risen from 137,000 in 1946 to an average of about 7 million in 1953 to 1955.

The rapid increase reflects both the rise into favour of this species and also the larger proportion of poor land planted in recent years.

TABLE 31 PINUS CONTORTA (LODGEPOLE PINE): HIGH FOREST AREAS, PURE AND MIXED STANDS COMBINED, BY AGE-CLASSES, 1947 Acres

	Age Class, Yrs.					Uneven-aged	Total
	1–10	11–20	21–30	31–40	41 *and over*		
Private Woodlands	77	92	6	2	—	—	177
Forestry Commission	862	1,922	159	2	—	138	3,083
Total	939	2,014	165	4	—	138	3,260

The total number of plants used in the last ten years, some 35 million, suggests that the plantations cover about 17 thousand acres, but a great deal has been planted in mixture with, and as a nurse to, other species, and if these succeed, then the pine will probably be removed in thinnings.

It is also used in shelterbelts, for which it has been recommended by Guillebaud (1943) and Macdonald (1946), especially coastal provenances (Minist. Agric. Lond., 1951).

CLIMATIC REQUIREMENTS

The immense natural range of lodgepole pine demonstrates its ability to grow under diverse climatic conditions. In its home, the rainfall varies from about 15 in. per annum in Alberta, east of the Rockies, or 18 in. in the warmer temperatures of Colorado, up to 100 inches or more near the coasts of Vancouver Island and Washington. The driest season of the year varies from spring to late summer. Snowfall is considerable and lies till late spring over the whole inland region.

In Britain the species has not been in use for long enough for anyone to be able to draw very definite conclusions. There is obvious scope for allocating different provenances to different climates, but little evidence on which to make suitable decisions. The coastal provenances, even the most vigorous southerly ones from Washington which have been used in Britain, appear to be completely resistant to both winter cold and spring frost, and to stand great exposure even on poor soils. From the other extreme, as noted above, the farthest inland Alberta provenance has suffered damage and die-back, and younger crops from the inland regions further south, such as Idaho and Montana, though younger, appear to be following the same path, possibly even more rapidly. For use in Britain, there seems little doubt that the extreme inland Rocky mountain provenances are unsuitable and that a selection must be made from the coastal and coastal mountain regions from Alaska to Oregon, to suit different parts of the British Isles.

SITE REQUIREMENTS

The earliest use of lodgepole pine was for beating up plantations of other species, and this led to its experimental use on the poorer types of peat, where it soon found a place. Early reports on its success at Gwydyr Forest, Caernarvonshire, are described by Long (1936), and more details of the experimental plantings are given by Guillebaud (1938) and Macdonald (1945). A summary of its silvicultural qualities and uses, with special emphasis on the coastal provenances, is given by Anderson (1950).

In general, the poorer the site conditions the more outstanding is the growth of lodgepole pine when compared with other species, but on good ground it is seldom an attractive tree from any point of view. On good soils its coarse growth is accentuated. In any case, there is no object in planting this species on sites which give no trouble for the ready establishment of species that are more valuable and which produce a better timber or a greater volume. Though poor form, branchiness, liability to snow breakage and generally unattractive appearance are marked in the coastal types, so that inland types are frequently preferred, the coastal types have definite advantages in many places. They are desirable where the exposure is most severe and a probable limiting factor for tree growth, and also where quick suppression of heather (*Calluna vulgaris*) is required. Even on the deep peats of the poorest type, characterised by *Trichophorum* (*Scirpus*) *caespitosum*, where the tree roots can never reach the mineral soil, young plantations are being raised successfully on an experimental scale, using coastal provenances, after preparation of the ground with draining ploughs and the use of fertilisers. On the hard and sometimes podzolized boulder till of the upland heaths, prepared with a tine plough, the poorest sites are planted with lodgepole pine, though here inland provenances can be used except perhaps under extreme conditions.

Lodgepole pine appears therefore to be the outstanding pioneer species for difficult sites, whether the factors limiting growth are climatic or edaphic. In view of the discovery by American workers,

based on pollen analyses, etc., that lodgepole pine was a pioneer after the retreat of the ice in North-west America (Wood, 1955), such a conclusion would appear to be reliable and not unexpected.

In the south of England there are some marginal soils where, for reasons still obscure, lodgepole pine has not been successful.

ESTABLISHMENT TECHNIQUE

NURSERY PRACTICE. No differences from normal practice for species of pines appear to have been recorded, though lodgepole is a smaller-seeded and a rather slower growing species in the first year than many commonly used pines. It is now generally sown in the modern woodland or heathland type nurseries, which produce one-year seedlings large enough to line out. The germination capacity is usually good, and seed can be sown relatively sparsely.

Stratification, or moist pre-chilling of the seed, has been found beneficial. Lodgepole pine benefits more from partial soil sterilization than many other pines, and as the first year's growth is often small, in older nurseries soil sterilization may be of importance in practice.

Mineral spirit weedkillers can be used, but lodgepole pine is classed among the more sensitive species and post-emergent applications should be limited to 2½ pints per 100 square yards (15 gallons per acre).

VEGETATIVE PROPAGATION. There has not yet been much occasion to make use of vegetative propagation, but grafting techniques suitable for Scots pine have been successfully used.

DIRECT SOWING. In experiments in Scotland and the north of England from 1947 to 1951 lodgepole pine sown in some experiments gave better success, both in the percentage of patches that were stocked after three and six years, and in height growth, than did Scots pine, Sitka spruce or Japanese larch. But the general conclusion that planting is preferable was not upset.

PLANTING. As lodgepole pine is generally used on poor soils where the surrounding vegetation is not particularly vigorous, frequently in severe exposure, and where possible on ploughed ground, a small plant is usually best. A one-plus-one plant is therefore normal, but two-year seedlings can be used on peat with more success than most species. On sites with hard ground the plants are notched or mattock-planted, and a one-plus-one transplant is normally used.

Manuring with phosphate is often desirable and is essential on the very poorest soil types. However, after ploughing with modern ploughs, and especially if a vigorous strain of pine is being planted, phosphate is liable to accelerate the growth of the trees to such an extent that they become unstable; so it is sometimes omitted from the pines but given to any associated species for which the pine is being used as a nurse.

SPACING. Normal spacings for pines, of 4½ to 5½ feet, are in use. These are generally satisfactory, as the wide-crowned coastal provenances with coarse branches are normally planted on sites where quick closure of the canopy and suppression of vegetation are important. Where provenances with narrow-crowned trees are used, the same spacing proves adequate as quick canopy closure is less essential.

TENDING AND THINNING.

Weeding is not normally a difficulty on the poor sites on which lodgepole pine is planted. If a coastal provenance has been planted, an early cleaning to remove the very coarse and defective trees is very desirable. Many plantations of inland provenance do not need such cleaning, but some stands have tended to fork, the two stems then growing closely parallel; removal of such trees at an early stage is necessary.

Most of the older crops are of inland provenance with narrow crowns and these will continue to grow densely without apparent harm for a long time. This is a characteristic of the tree in its native habitat, but in Britain it has usually been considered desirable to give the crowns room to develop by thinning to a moderate grade. On very poor sites (e.g. sand dunes) the trees have shown signs of losing vigour even when their crowns appear to have room, and no doubt on such sites it will be found desirable to reduce the number of trees per acre. Few crops of coastal provenance have become due for thinning until recently, and it has been found desirable to remove badly shaped dominants, after which the stand has become more closely comparable to the inland type.

OTHER SILVICULTURAL CHARACTERISTICS

The unattractive appearance of lodgepole pine has led to its being used mainly as a nurse species, and other better-known trees have usually been mixed with it. On many sites, the pine has proved successful, suppressing competitive vegetation, and providing shelter so that the second species can gradually replace the pine. Sometimes, however, the discrepancies in growth between the species are too great and only the pine is successful. Attempts are made in thinning to favour the second species, but when the balance has swung too far only the pine survives. There is scope here for selecting a suitable provenance of pine to combine the vigour of the fastest growing coastal, and the straight

TABLE 32 PINUS CONTORTA: (LODGEPOLE PINE) GROWTH AND PRODUCTION

Forest	*Elev. ft.*	*Age yrs.*	*Top Ht. ft.*	*Mean girth in.*	*Vol. per acre Hoppus ft. over bark*	*Total production per acre Hoppus ft. over bark*	*Remarks*
Thetford, Norfolk	150	28	47	18½	1,850	2,500	—
Inchnacardoch, Inverness	230	23	41½	16½	1,840	2,600	Destroyed by heart rot and windblow
Culbin, Moray	40	32	50½	19½	1,300	2,700	C/D Grade. Comparative thinnings
Culbin, Moray	40	32	49	17½	2,000	2,800	A. Grade. Comparative thinnings
Ratagan, Ross-shire	130	22	32½	12½	800	1,000	—
Loch Ard, Perthshire	650	18	32½	15	960	1,530	—

narrow-crowned properties of the inland provenances.

RATE OF GROWTH AND YIELD

There are a number of records of individual trees having reached heights of 60 to 70 ft., and one at least has reached the 100-foot mark. Of plots, only thirty have yet been measured for growth and yield, and it will not be possible to add greatly to them until the extensive recent plantings reach the pole crop stage. The height/age curves for the measured plots fall around the curves for Scots pine of Quality Classes I and II. As lodgepole pine is usually confined to poor sites, these results may be considered very promising, and they tend to support the data from the experiments on deep peat (Zehetmayr, 1954) which show that lodgepole pine is well ahead of Scots on equally poor sites.

Table 32 gives details which have been obtained from measurements in different parts of the country.

DISEASES AND PESTS

Cases of die-back of shoots and browning of needles of lodgepole pine have been recorded from several forests. In two instances, Day (1952) ascribed this damage partly to frost and partly to poor site drainage. On the needles of such trees, the leaf cast fungus *Lophodermium pinastri* is usually abundant but possibly secondary. Day emphasises the difference in susceptibility towards frost damage displayed by various strains of lodgepole pine and points out the need for care in choosing the best strain. However, in general lodgepole pine is resistant to exposure and frost injury.

Neilson-Jones (1938 and 1945) described 'fused-needle' disease on young lodgepole pine at Wareham in Dorset. Characteristic symptoms were distortion and fusion of the needles accompanied by stunting of growth. The trouble was considered to be physiological, deriving from the marked infertility of the site where the disease occurred. Addition of certain composts, and also transference to a better quality site, improved the condition of affected trees.

In Scotland, a sample plot at Inchnacardoch Forest, Inverness-shire, was attacked by *Fomes annosus* and later destroyed by windblow.

In Great Britain, although no detailed studies have been made, it is known that many of the more important insect species associated with pines occur on lodgepole pine. These include, for example, *Hylobius abietis* L., *Myelophilus piniperda* L., *Bupalus piniarius* L., *Evetria buoliana* Schiff., *E. turionana* Hbn., *Diprion pini* L. and *Neodiprion sertifer* Geoff. Crooke (1951) records that attack by *E. buoliana* has more damaging results on lodgepole pine than on either Scots or Corsican pine, whereas Scots pine is more severely attacked than lodgepole pine by the closely related *E. turionana*. In general it can be assumed that the insect fauna associated with Scots pine can also occur on lodgepole, and that on the latter host the intensity of attacks and their silvicultural implications, are of much the same order as for Scots pine.

OTHER FORMS OF DAMAGE

WINDBLOW. Considering the small area of plantations of lodgepole pine large enough to be susceptible to windblow, it cannot but be regarded as having suffered severely. But investigations into blown plots often show that the pine was much taller than the surrounding plantations, and then the blow can be regarded as exceptional. In other cases the damage followed heavy and often delayed thinning. Damage by wind in the very young stages, already referred to, is the result of vigorous early growth caused perhaps by too rich a soil, or use of too much fertilisers, or in general the mishandling of an unexpectedly vigorous provenance due to inexperience. It is therefore too early yet to be able to define the status of the species in relation to wind-damage.

ATMOSPHERIC POLLUTION. Again, the evidence available is not adequate to form definite conclusions, but in experiments on poor soil in a heavily-polluted atmosphere in the Pennines, lodgepole pine shows some promise of being resistant to the combined effects of atmospheric pollution, exposure at a high elevation, competition from heather, and a poor soil.

SNOW. A number of comparisons between lodgepole pine and other species have been made, with the advantage usually in favour of lodgepole pine. But these examples concern the inland provenances, which are much more resistant to damage by snow than heavily branched ones from coastal areas, and it may be that snow damage will become of greater importance as the latter came into greater use.

MAMMALS. One of the disadvantages of lodgepole pine is its attraction for roe-deer, and when lodgepole pine is used for beating up in small groups, it may suffer severely. Macdonald (1954) notes that the coastal type suffers less severely than the inland, the heavier branch system of the former tending to keep the animals away from the leading shoot. Pines also suffer damage from blackgame when these birds are numerous, but lodgepole does not suffer as much as Scots pine. (Zehetmayr, 1954.) Allman (1946) records a case where hares preferred Corsican pine and left lodgepole and Scots pine undamaged, and Charles (1956) found that voles avoided lodgepole pine in favour of other species.

SEED AND SEED-BEARING

The first flowers are produced from the fifth to tenth year or exceptionally even earlier. Good crops of cones may be available from the fifteenth to twentieth year and there is some seed available in most years. Maximum production probably begins from the thirtieth to fortieth year, but there is little information yet available. Cones can be collected from December to February (Matthews, 1955). Anderson (1950) states that the yield is six ounces per bushel of cones. Scottish data from over 1,000 bushels collected from 1951 to 1953 show yields from two to four ounces, with a mean of about two-and-a-half ounces per bushel. The number of seeds per lb. unsorted (i.e. as cleaned commercially), has been found to vary from 130,000 to 222,000 (mean 160,000-180,000) in collections from trees of different provenances, mostly from inland-type trees. American seed runs from 102,000 to 135,000 seeds per pound on the average (Dep. Agric., U.S.A., 1948).

GENETICS AND BREEDING

The very great range of variation within the species, and its markedly differing reactions to different sites, together with the possibility of hybridization with other species of *Pinus*, offer great possibilities.

It is proposed to establish a seed orchard from one successful provenance, and further developments will take place as the various crops develop, and selection of plus trees becomes possible. There is already some evidence that the plants grown from home-collected seed are superior to those of the same provenance imported from America, and if this proves to be the case, then more suitable British cultivars of lodgepole pine may be developed, as has happened in the case of *Larix decidua*.

NATURAL REGENERATION

Natural seeding of lodgepole pine takes place freely along ride-sides, blown areas, etc., but seedlings are usually regarded as weeds which impede the growth of more favoured species.

TIMBER

The timber of lodgepole pine was used for railway ties (sleepers) in the Rocky Mountains, but it was not a highly valued timber. More recently it has come into prominence again for wood pulp, boxwood and for transmission-line poles. Timber from an old plantation at Ruttle Wood in Inverness-shire, referred to on p. 95, has been tested at the Forest Products Research Laboratory, Princes Risborough, where it was found comparable to Scots pine in seasoning and working properties and to Canadian lodgepole pine in strength. So far it has not come on the market widely in Britain. In East Scotland it is reported that straight pitprops with pronounced but not heavy whorls are acceptable by collieries when peeled and dressed. Unpeeled material quickly becomes discoloured. Small boards from thinnings have a hard timber, rather like imported *Pinus pinaster*.

POTENTIALITIES OF THE SPECIES IN THE NATIONAL ECONOMY

Lodgepole pine is the best pioneer species for the afforestation of difficult sites on the long-deforested uplands and poor soils of Britain. It is a tree that is not favoured where any other will grow successfully, but in its growth on poor mineral soils, rocky sites or, highly acid peat, combined with resistance to cold and exposure, and tolerance of competition from other plants such as *Calluna vulgaris*, it is unsurpassed.

On such sites, it has been used in pure crops to only a small extent, but more often as a nurse to other species; as a rule, where these others are successful, the lodgepole pine has been or is intended to be removed in early thinnings. On the very poorest acid peats and on high-lying and stony soils, lodge-

pole pine alone seems to make progress, and experiments with other species are not very promising. On such sites, a pure pioneer crop of lodgepole pine is the most likely solution to the problem, and the question of a change to a more favoured species, if by that time lodgepole pine has not found a place in the market, can be left to a later stage.

M.V.E.

Pinus griffithii McClelland
(*P. excelsa* Wallich; *P. wallichiana* A. B. Jackson).

The Bhutan pine, a native of the Himalayas, was introduced by Lambert in 1823 and is the most successful of the Asian pines in Britain. Specimen trees are quite often seen and may reach 90-100 ft. in height. The tallest recorded specimen, 110 ft., was a tree at Rossdhu, Dunbartonshire (Chittenden, 1932).

The Bhutan pine is not uncommon as an ornamental tree in city parks and seems to withstand smoke pollution better than many conifer species.

A small forest plot planted at Beddgelert, Caernarvonshire, on an exposed site, had an average height of 10.5 ft. eighteen years after planting. Though growing slowly, the plot is very healthy. A plot has also been established recently at the National Pinetum, Bedgebury, Kent.

It is unlikely that this tree will find a place in British forestry; its only probable use is as a parent of hybrids in the breeding of white pines resistant to blister rust.

Pinus monticola Lambert

The Western White pine, introduced into Great Britain by Douglas soon after 1831, occurs in Western North America from British Columbia to Idaho and Montana where it is the western counterpart of *P. strobus*.

In Britain, the growth of *P. monticola* is quite similar to that of *P. strobus*. A tree 106 ft. tall at Althorp, Northamptonshire (measured in 1930), and another 103 ft. tall at Redleaf, Kent (measured in 1953 by Maynard Greville), are the two tallest on record. An outstanding example of the rapid rate of growth of the species is to be found at Dawyck, Peebles, where two 21-year-old trees measured 61 and 57 ft. respectively.

There is one sample plot of *P. monticola* at Dawyck. When the trees in the plot were 32 years old their mean height was 50 ft. and their mean girth 27½ inches; there were 301 stems per acre and the volume per acre was 2,310 Hoppus ft. This rate of height growth compares favourably with Quality Class II Corsican pine, but the total volume production, at 4,805 Hoppus feet per acre is slightly greater.

The species is badly attacked by the White pine blister rust, and there is no future at all for it in Britain unless rust-resistant strains are found.

Pinus mugo Turra (*P. montana* Miller)

COMMON NAME. Mountain pine

Mountain pine is a species of variable habit, growing in the mountains of central and western Europe. The variety *rostrata* (syn. var. *uncinata*) is upright in habit, reaching 70-80 ft. in height, and is found in the Pyrenees, French Alps and, rarely, in Switzerland. The tree is dominant and forms high forest only where spruce is rare or absent. The 'dwarf' mountain pine, var. *pumilio*, is found at the upper limit of tree growth in the mountains of Central Europe. There spruce is a dominant species in the forests at lower elevations and appears to have ousted the upright form (Stirling Maxwell 1929.) A variety intermediate in habit, var. *rotundata*, is common in the Alps.

The first representative of the species to be cultivated in Britain was the variety *pumilio*, which was introduced in 1779.

Mountain pine has seldom been planted as a forest species. Stirling Maxwell at Corrour was one of the first to plant mountain pine on any scale; he found that the dwarf variety was extremely hardy and formed a good advance crop. The upright form did not do very well but "scarcely had a fair trial".

In the early experimental plantings carried out on the poorer peats by the Forestry Commission, mountain pine was found to grow even on severely exposed sites, and in the absence of intensive ground preparation and manuring. Its response to these treatments was less than that of most other species.

When grown in mixture with Scots pine or Sitka spruce, dwarf mountain pine was found to give shelter and to suppress vegetation. It was outgrown and quite suppressed once the spruce or Scots pine was growing well, and the early unremunerative thinnings were thus avoided. The only risk in planting such a self-thinning mixture is that if the spruce or Scots pine should fail, only a worthless crop of mountain pine is left.

In more recent experiments, mountain pine has been planted in mixture with two other species, in such a way that it gives shelter to a spruce and acts as a buffer between it and a faster growing pine or larch species (Zehetmayr, 1954). Dwarf mountain pine has been used very successfully on the outside edges of shelterbelts in exposed situations; the low dense foliage prevents the wind sweeping in under the canopy of the main plantation.

The growth of mountain pine is slow, especially with the dwarf varieties. Table 33 gives data from a number of experimental plots.

Few records of specimen trees exist. The tallest, a tree 75 ft. tall, was recorded in 1931 at Dawyck, Peebles.

TABLE 33 PINUS MUGO, MOUNTAIN PINE: GROWTH RECORDS

Location	*Age at measurement, yrs.*	*Mean Height ft.*	*Elevation of site ft.*	*Habit*
Kilcoy, Ross-shire	45	33	525	Upright
Beddgelert, Caernarvon	40	10.7	1,200	, (mixed)
Cairn Edward, Kirkcudbright	18	7.9	30	,,
Clocaenog, Denbighshire	19	14	1,200	,,
Inchnacardoch, Inverness-shire....	27	13	1,000	,,
Wareham, Dorset	16	7.5	50	Dwarf
Clashindarroch, Aberdeenshire....	18	5.5	1,380	,,
Lael, Ross-shire	16	5	800	,,

The dwarf mountain pine is likely to continue to be used as a nurse or shelterbelt species on marginal sites at high elevations in Britain; the upright variety is not likely to have a place in British forestry.

Pinus nigra Arnold

There is no English name in common use for the whole species, though the name (European) Black pine has occasionally been used in Britain. The common names approximating to the two most important varieties, *P. nigra* var. *calabrica* and *P. nigra* var. *austriaca* are Corsican pine and Austrian pine respectively.

COUNTRY OF ORIGIN AND PROVENANCE

Pinus nigra is found in Central Europe and the Northern Mediterranean region from Southern Spain to Asia Minor and the Crimea, the total range being from 35 to 49 degrees North latitude and from 3 degrees West to 34 degrees East longitude. It is predominantly a mountain tree but occurs at sea level along the shores of the Adriatic.

The distribution of the species is markedly discontinuous and the ecological conditions of the natural forests differ considerably one from another. As the natural stands became known to botanists, various subdivisions of *Pinus nigra* were made. Unfortunately, numerous classifications were used which differed greatly, so that the nomenclature has become confused and there is disagreement about the distribution of the various sub-species and about the varieties which should be recognised. (Delevoy, 1949; Elwes and Henry, 1906-13; Houtzagers, 1954; Schmucker, 1942 ; Schwarz, 1936.)

Four botanical varieties are now generally recognised:—

(1) *Pinus nigra* var. *austriaca* (Hoess) Ascherson and Graebner, found in Lower Austria, Northern and Central Italy, Yugoslavia and Albania. This variety also occurs in Southern Poland.

(2) *Pinus nigra* var. *caramanica* (Loudon) Rehder, occurs in the eastern parts of the range in Hungary, Bulgaria, Rumania, Greece, Crete, Cyprus, Turkey and the Crimea.

(3) *Pinus nigra* var. *calabrica* (Loudon) Schneider, found in Corsica, Sicily and Southern Italy.

(4) *Pinus nigra* var. *cebennensis* (Grenier and Godron) Rehder, occurs in the Cevennes of France, on the French and Spanish Pyrenees, and in Central and South Eastern Spain. A southern outlier is reported from Algeria.

Of the four varieties of *Pinus nigra*, two—the variety *calabrica* and the variety *austriaca*—have been widely used in Britain. The former is of great importance and is often used in place of Scots pine in the drier and warmer parts of England, and locally in Scotland and Wales. *P. nigra* var. *austriaca* has been used principally as a shelter tree in coastal areas and on limestone. *P. nigra* var. *cebennensis* has been tried on a small scale in chalk downland afforestation, but the variety *caramanica* is still confined to arboreta and provenance trials.

A few varietal and provenance trials have been laid down, in an attempt to obtain provenances which have a growth habit comparable to that of the Corsican provenance but which will extend the range of use in Britain to colder and wetter sites. However the geographical distribution of *Pinus nigra* does not really offer much encouragement (Wood and Pinchin, 1951).

Two provenance trials of *P. nigra*, planted between 1932 and 1934, have both been destroyed by fire, a trial at Bedgebury, Kent, being burnt in 1943 and a trial at Wareham Forest, Dorset, being likewise destroyed in 1949. The Wareham trial included two Corsican provenances and one each from Calabria, the Cevennes, Sicily and Turkey. Neither of these experiments gave any evidence to suggest that the Forestry Commission's policy in favouring Corsican provenances was incorrect (Wood and Pinchin, 1951). In 1951, two more small provenance trials were planted, one on a Welsh upland site at Clocaenog Forest, Denbighshire, and one on a coastal dune

site at Newborough, Anglesey. Plants were raised from seed from Calabria, Corsica, Spain and East Anglia. At Clocaenog the survival of the Calabrian provenance was 92 per cent—notably better than that of the others. The Spanish provenance had the lowest survival (62 per cent) while the figures for East Anglia and Corsica were 77 and 75 per cent respectively (Edwards and Pinchin, 1953). The most recent inspection (Nov. 1956) shows that the Calabrian provenance is distinctly more vigorous and is at present clearly the best provenance at Clocaenog. At Newborough, there is little to choose between the East Anglian, Corsican and Calabrian provenances in height growth. All are taller than the Spanish trees. Trees of the Calabrian provenance are greener and bushier than those of other origins.

Pinus nigra var. austriaca (Hoess) Ascherson and Graebner: Austrian pine.

The Austrian pine was first introduced by Lawson in 1835, and trees from the first introduction were planted at Dawyck in 1836-7 (Nasmyth, 1875). At that time the merits of the tree judged by its performance in its native habitat were being advertised (Lawson, 1837; Widdrington, 1841); and during the second half of the nineteenth century, Austrian pine was planted on quite a wide range of sites, mostly in arboreta and as windbreaks. Hutchison (1875) considered the tree useful for ornament or shelter, but thought Corsican pine and Douglas fir to be more profitable in plantation. By the beginning of the twentieth century it was apparent that on all except limestone sites, Corsican pine was to be preferred mainly because the Austrian is normally a rough heavily-branched tree, whereas Corsican has a long straight stem and much lighter branches. Since then, Austrian pine has been planted only on a very small scale, mainly to provide shelter.

The rate of height growth of Austrian pine is probably a little slower than that of Corsican. At Bedgebury a small plot of Austrian pine was 27 feet tall when 19 years old while a Corsican pine plot at the same age was 36 feet tall. At Queen Elizabeth Forest, on the chalk downs in Hampshire, Austrian pine planted as a nurse crop for beech was 27 ft. tall at 21 years of age, while Scots pine was 30 ft. At Vinnells Wood, Hampshire, a 30-year-old plot averaged 44 ft. in height and had a standing volume of 3,060 Hoppus feet. This is equivalent to Quality Class II Corsican pine in height and is a little better than Quality Class II in standing volume. At Berachwood, Carmarthen, a plot 37 years old was 36 ft. tall and had a standing volume of 3,285 Hoppus feet. This standing volume is equivalent to that of Quality Class II Corsican pine, but the height is only equal to Quality Class IV.

The tallest specimen Austrian pines recorded are:- a tree 112 ft. tall at Brocklesby Park, Lincolnshire, one 108 ft. tall at Audley End, Essex, and another 105 ft. tall at Dupplin Castle, Perth. A tree 118 ft. tall is recorded at Dropmore, Buckinghamshire, but doubt has been cast on its identity and it may be a Corsican pine.

The site requirements of the Austrian pine differ little from those of the Corsican pine, except that the former will thrive on chalk and limestone soils where the latter does not do so well.

Austrian pine is notably resistant to exposure and is thus often used for planting along the edge of shelter belts and in clumps to give protection. It is also able to withstand sea winds and has been much used in coastal districts for shelter; it is also able to withstand a certain amount of atmospheric pollution.

Pinus nigra var. calabrica (Loudon) Schneider (*P. nigra* var. *poiretiana* (Antoine) Ascherson and Graebner) (Plate 8.).

COMMON NAME

Corsican pine. It is from Corsica that by far the largest amount of seed of *P. nigra* var. *calabrica* has been imported into Britain. The few stands grown from Calabrian seed have also been called Corsican pine though this is perhaps undesirable and misleading. No seed has been imported from Sicily. In this account "Corsican pine" will be used in preference to "*P. nigra* var. *calabrica*", because it better expresses the affinities of the tree used in Britain. The name used for the timber is Corsican pine (B.S.N.T., 1952).

COUNTRY OF ORIGIN

The Corsican pine reaches its finest development in Corsica at elevations of from 3,000 to 4,000 feet, where it forms pure stands. At lower elevations it grows in mixture with *Pinus pinaster*, while at the higher elevations there is an understorey of beech (Steven, 1934). The soils are light, sandy loams, varying greatly in depth and derived from granite and porphyry. At their best the trees reach heights of well over 120 feet.

In Sicily, *Pinus nigra* var. *calabrica* is found on the slopes of Mount Etna growing on siliceous soils derived from volcanic formations.

With few exceptions, the quality of the plantations formed has been good. From 1919 to 1939 (with the exception of 1927 and 1928 when seed of dubious origin came in) the Forestry Commission was able to import sufficient seed of Corsican provenance to meet its needs. During the war years special steps were taken to collect all available seed from home

TABLE 34 CORSICAN PINE (PINUS NIGRA VAR. CALABRICA): DISTRIBUTION BY COUNTRIES, AND PERCENTAGES OF HIGH FOREST AREAS OCCUPIED, 1947

	England			*Scotland*			*Wales*			*Great Britain*		
	Area Acres	*% of Conifers*	*% of all species*	*Area Acres*	*% of Conifers*	*% of all species*	*Area Acres*	*% of Conifers*	*% of all species*	*Area Acres*	*% of Conifers*	*% of all species*
Privately owned woods	5,318	3	—	284	—	—	897	4	1	6,499	1	—
Forestry Commission	26,225	14	11	3,210	2	2	2,569	3	3	32,004	7	6
TOTAL	31,543	8	3	3,494	1	1	3,466	3	2	38,503	4	2

TABLE 35 CORSICAN PINE (PINUS NIGRA VAR. CALABRICA): HIGH FOREST AREAS, PURE AND MIXED STANDS COMBINED, BY AGE-CLASSES, 1947

	Age-Class, yrs.								*Uneven Aged*	*Total*
	1–10	11–20	21–30	31–40	41–60	61–80	81–120	*Over* 120		
Privately owned woods	617	820	1,372	1,046	1,037	588	28	24	967	6,499
Forestry Commission	8,798	15,717	6,852	159	245	66	3	—	164	32,004
TOTAL	9,415	16,537	8,224	1,205	1,282	654	31	24	1,131	38,503

sources and in 1942 and 1945, particularly good collections were made. Since the war the bulk of seed has again been imported, but in 1948 and 1950, 2,053 lb. and 1,849 lb. of seed were collected in Britain, and further large collections may be expected in future good seed years.

PROVENANCE

The stem form and branching habit of Corsican pine from Corsica is markedly better than that of the few plantations of Calabrian provenance in Britain. On the other hand there is a possibility that the early survival of the Calabrian provenance is superior to that of the Corsican. Steven (1934) notes that stands in Calabria show all intermediates between the dense dark green heavily branched Austrian pine and the more open light green foliage of Corsican provenances.

HISTORY

Corsican pine is thought to have been first introduced in 1759 under the name "*Pinus sylvestris maritima*" (Webster, 1885), but the identity of this introduction is uncertain (Steven, 1934). Until about 1840 the tree was planted primarily as an ornamental or for windbreaks, but then it began to come into favour and was planted quite widely, especially after 1870 when nursery stocks became cheaper (Agnew, 1916). Hutchison (1875) hailed the tree as a replacement for larch in the diseased plantations of that time. Corsican pine during this period was frequently planted at a very wide spacing (e.g. 9 ft by 9 ft.) in a matrix of other species, often Scots pine and European larch.

By the beginning of the twentieth century the tree had given way on some of the better ground to spruce and Douglas fir (McCallum, 1911) but Elwes and Henry (1906-13) speak highly of it saying that 'of all the conifers introduced into England, none except the larch has shown such good results as the Corsican pine, which has proved a hardy and vigorous grower on almost all sites and in almost all parts of Great Britain and Ireland.'

The Forestry Commission has planted the tree on a large scale since 1919 and put it on a wide range of sites especially in the years between 1920 and 1930, when the good promise of plantations established about the turn of the century became known. Wales, north and west Scotland, and the extreme south-west of England were less affected than other parts of the country by this revived interest in Corsican pine, which was then being planted as far north as Banff and Moray, as far up the mountains as 1,200/1,600 feet in Peebles and on many coastal dunes, as well as in East Anglia and south-east England where its success appeared assured. 1926 appears to have been a peak year for planting Corsican pine.

Shortly after 1926, some of the older plantations on upland sites (e.g. at Lake Vyrnwy, Montgomery) began to show symptoms of ill-health, associated with the fungus *Brunchorstia destruens*, and to dieback.

This failure on upland sites was attributed to their climatic unsuitability for the tree (Day, 1945).

EXTENT OF PLANTING

The 1947-49 Census of Woodlands recorded a total of 38,503 acres of Corsican pine in Great Britain. The distribution of plantations by countries and by age-classes is given in Tables 34 and 35, p. 103.

The high proportion of the total area of Corsican pine established by the Forestry Commission in England is apparent. Taking all plantations up to thirty years of age, the area occupied by Corsican pine in Forestry Commission plantations, namely 31,367 acres, makes it the fourth most important species. It is exceeded by Sitka spruce, Scots pine and Norway spruce. But in private woodlands, the picture is very different. Corsican pine is twelfth in order of area of plantations up to thirty years old, and it accounts for less than one-half per cent of ail privately-owned plantations.

A distribution map of Pine High Forest (For. Comm. 1952) shows that Corsican pine plantations are mainly concentrated in a few midland, southern and eastern counties, namely Nottinghamshire and Staffordshire, Yorkshire (North Riding), Norfolk and Suffolk, Hampshire and Dorset. The bulk of the remainder is on coastal dune sites, in particular, at Culbin on the Moray Firth and at Pembrey, Glamorganshire. The distribution map also shows that in counties where pines are important, Scots pine has been the more widely planted species. The only exception to this is Nottinghamshire where the Forestry Commission owns 70 per cent of the coniferous woodland area and has planted about three-quarters of it with Corsican pine. This was done largely because the principal planting sites are subject to smoke pollution. Since 1949, in England and Wales, about the same number of plants each of Scots and Corsican pines have been planted (5 to 6 million per year in England and 1 to 3 million in Wales). In Scotland, however, many more Scots pine were planted in this period. (Forestry Commission, 1950-1956.)

CLIMATIC AND SITE REQUIREMENTS

The performance of Corsican pine in Great Britain appears to be closely related to summer warmth. The higher Quality Classes are confined to districts where accumulated temperature values exceed 2,750 day degrees. The tree declines in health the closer it is planted to the cooler, moister regions. It is thus not a tree for the north except in the most favourable localities at low elevations. Further south, altitude becomes important. For instance, at Gwydyr in North Wales, a 35-year-old plantation declines markedly in vigour from 250 to 650 ft. above sea level, and there are numerous examples of dieback and loss of vigour in elevated situations.

Of the other factors which may affect growth, aspect is probably unimportant at low altitude in south and south-east England, but in less favourable districts the warmer south and west facing slopes appear better than cool north slopes. Soil and site drainage are also very influential near the limits of the tree's climatic tolerance, and in such areas healthy stands are most likely to be found on well-drained southerly slopes with a coarse textured or stony soil.

On coastal sites, Corsican pine is intolerant of exposure and salt spray right on the sea front, but, given some protection, has grown well on sand dunes. It is generally better on the east than on the west coast, presumably because there is less onshore wind. Away from salt spray, and where the general climate suits it, the tree stands exposure well.

Spring frost is seldom troublesome, the tree coming into leaf rather late, but it is not so resistant as Scots pine and some cases of serious damage are on record. Winter cold does not appear to be of any importance to the species in Britain.

In suitable climatic conditions, Corsican pine grows well on a wide range of mineral soils. Sands and gravels give better results than retentive fine textured and compacted soils subject to drainage impedance. Thus the tree is well suited to the Eocene sands and gravels of Southern England, to the glacial sands in East Anglia and to the Bunter Sand and Pebble Beds of the English midlands. It is less at home on clays, on compacted boulder till and on podzols with a relatively impermeable sub-soil. On the rather fine textured soils of the Welsh hills, Corsican pine grows well because the sloping ground and occurrence of boulders ensure adequate aeration in the root zone. However, the best growth of Corsican pine is not found on the Bunter and Eocene soils, though these have yielded some Quality Class I stands, but on fertile, well-drained loams such as support some small stands of this species scattered about the country.

Corsican pine has been little tried on peat in Britain; in an experiment at Beddgelert, North Wales, laid out in 1927 on deep basin peat, satisfactory establishment and early growth were followed after 20 to 25 years by debility, loss of foliage and gradual death. But the site of this experiment at 1,000 feet is such that Corsican pine could scarcely be expected to thrive beyond that age, even on a mineral soil.

On the tolerance by Corsican pine of highly calcareous soils, the evidence is somewhat conflicting. However, it appears less subject to chlorosis than Scots pine, though less at home on highly calcareous soils than some other varieties of *Pinus nigra*.

There is evidence also that where soil conditions

are far from the optimum, Corsican pine is more sensitive to climatic conditions. On coarse textured, well-drained soils the tree becomes somewhat more tolerant of an unfavourable climate, whereas an ill-drained or much compacted soil accentuates the unfavourable features of climate.

ESTABLISHMENT TECHNIQUES

NURSERY PRACTICE. Corsican pine seed is usually sown in heathland in preference to agricultural nurseries. 350 seedlings per sq. yd. is a desirable stocking for one-year-old seedlings; to obtain this, sowing will normally be at a rate of 600 viable seed per sq. yd. Seedlings are usually lifted and lined out at the end of the first year; if left for two years they do not survive transplanting so well. In its first year in the transplant lines, Corsican pine makes very little shoot growth; but small one-year, one-year transplants are often preferred to larger stocks. The lateral roots of Corsican pine seedlings and transplants are sparse and the taproot thick, and particular care has to be exercised in lifting plants in the nursery so that roots are not stripped.

Undercutting of seedlings at a depth of 3 to 4 inches has been carried out satisfactorily, and two-year-old undercut seedlings are not greatly inferior to one-year-one-year transplants. (Faulkner, 1953).

Corsican pine is particularly sensitive to bad handling in the nursery and great care must be taken to prevent drying out of roots. It is one of the most tolerant species to mineral oil sprays, both in seedbeds and transplant lines.

VEGETATIVE PROPAGATION *Grafting*: Scots pine has been found to be the best rootstock for Corsican pine (cf. Loudon, 1838) because it is easier to handle in the nursery. Scots pine plants of two sizes have been used—transplants up to fifteen inches high which are about the thickness of a pencil at the stem base, and transplants eighteen or more inches high which have a diameter of at least half an inch, measured six inches up the stem.

For scion wood, one-year-old shoots are almost always suitable, but very vigorous material should be avoided. Scions are collected in January or February for grafting under glass, and in late March or early April for outdoor grafting. The "veneer side" graft is used for small scions and the "apical veneer" graft for large scions. The grafting is done in late February or early March under glass and in April or May outdoors.

Speedy grafting and a relatively deep cut on the rootstock are necessary to reduce resin flow. Grafting under glass considerably increases success.

All the varieties of *Pinus nigra* are moderately difficult to graft but 75 per cent success can be obtained under glass with good scion wood.

Cuttings: Only a low percentage of cuttings from young trees under five years old have been successfully rooted, and it has been practically impossible to root cuttings from older plants.

DIRECT SOWING. Though the method is not in use at the present time, direct sowing of Corsican pine was practised on a small scale in the early 1920's. The first trial sowings were quite successful (Taylor, 1925), but most of the later sowings failed partially or wholly because of bird and insect damage (Steven, 1934). Experiments at Wareham, Dorset, showed the importance of thorough ground cultivation and phosphate for the survival and growth of direct sown Corsican pine on poor *Calluna* heaths. (Wood and Nimmo, 1952).

PLANTING. The best results in planting Corsican pine are obtained with small plants. One-year-one-year transplants are the standard type, but older transplants are sometimes used on weedy sites. Experiments on season of planting indicate that the period from December to February is less hazardous than either the autumn or spring seasons.

SPACING. The conventional spacing is 4½ ft. x 4½ ft. or 5 ft. x 5 ft.

TENDING AND THINNING

Growth of Corsican pine is usually good in the second and subsequent years after planting, and weeding is seldom necessary for more than two or three years. Corsican pine plantations are extremely easy to thin owing to the regularity of the crop and the infrequency of poorly formed stems. Purely 'mechanical' methods of thinning, e.g. the removal of one row in three, were used to some extent during the 1939-45 war as a quick means of producing pitwood, without seriously endangering the prospects of the crop. Hummel (1949) has examined the influence of various grades of thinning on the increment of Corsican pine.

There is a strong case for the pruning of Corsican pine, since natural pruning is slow and the pronounced whorls of heavy knots are the principal cause of weakness in the timber. Experiments have shown that pruning to half the height of the trees in pole crops does not appreciably reduce vigour.

OTHER SILVICULTURAL CHARACTERISTICS

Corsican pine has a strong inherent ability to form a straight and persistent main axis and does so under a wide variety of conditions. In plantations, trees with crooked stems, very large branches or wide crowns are rare.

The tree has been used on a considerable scale in recent years as a nurse for beech in the south and midlands of England, especially on chalk soils, where it is preferred to Scots pine, being less liable to lime-induced chlorosis.

Corsican pine is a strong light demander.

Corsican pine, being frequently planted on coastal sand and similar soils deficient in both moisture and nutrients, has proved a useful subject for research. Ovington (1951), working on the Culbin sand dunes, studied the moisture relationships, uptake of nutrients and return as leaf fall, and the micro-biotic breakdown of the litter. Wright (1955) continuing these studies, at a site where the pine was failing to develop vigorously, investigated the moisture content of the soils in relation to root density and grade of thinning, and his results suggest that on sandy soils where moisture and nutrients are limiting, abnormally heavy thinning treatment will be desirable.

PESTS AND DISEASES

The only disease specific to Corsican pine, rather than to the pines as a whole, is dieback in high elevations or in areas of high rainfall. The fungus *Brunchorstia destruens* is nearly always present on diseased trees but is probably seldom the primary factor.

On dry soils in East Anglia and elsewhere Corsican pine is very subject to root attack by *Fomes annosus*. Where there is special reason to fear *Fomes* attack, as in many parts of the extensive pine forest of Thetford, it is the practice to apply creosote to stumps immediately after thinning in order to prevent the germination of fungal spores and hence the spread of *Fomes* to new centres. The method follows the recommendations of Rishbeth (1951).

Lime-induced chlorosis has been reported on Corsican pine on chalk downland by Murray (1955).

While various insects have been reported attacking Corsican pine, none are specific.

OTHER FORMS OF DAMAGE

WINDBLOW. Where suitably sited, Corsican pine is a reasonably windfirm tree.

ATMOSPHERIC POLLUTION. Corsican pine is considered to be more tolerant of atmospheric pollution than most conifers, and is preferred to Scots pine, for example, on sites where a pine is indicated and the level of atmospheric impurity does not rule out conifers altogether. Steven (1934) notes its value on the Bunter sands and gravels of the Midlands, where there is some degree of pollution from industry.

RATE OF GROWTH AND YIELD

Yield and volume tables have been published for Corsican pine (Hummel and Christie, 1953, and Hummel, Irvine and Jeffers, 1951). The yield tables show that when 50 years old, average crops in each of the four Quality Classes have grown as shown in Table 36.

The Quality Classes are defined according to the average height growth of the hundred largest trees per acre (i.e. top height) when the crop is 50 years old; the top height of an average Quality Class I crop at 50 years is 80 feet, a Quality Class II crop 70 feet, Quality Class III 60 feet and Quality Class IV 50 feet.

Most of the measurements came from plots less than 50 years old. Data for older crops do exist but are insufficient to be used as a basis for yield tables.

The oldest crop in which there is a sample plot is in the New Forest. The most recent measurements in this plot and in three of the other older plots are as shown in Table 37.

All four plots are in Quality Class I and are maintaining a high rate of increment. The Gravetye plot is one of the fastest growing Corsican pine plots in Britain (in respect of height) while the Bere plot has the biggest standing volume.

The form factor of Corsican pine stems is 0.43 when the tree is 30 ft. high, it rises to 0.50 when the tree is about 60 ft. high and thereafter falls slightly as the tree continues to grow.

A specimen tree at Stanage Park, Radnor, had a height of 135 feet and a girth of 124 inches in 1952, when it was 124 years old. A tree at Cuffnells in the New Forest was 99 years old in 1955 and was 130 ft. high and 112 inches in girth. Another tree of unknown age at Leaton Knolls in Shropshire was 133 ft. high and 111 inches in girth in 1954.

Hiley (1926) discusses the financial return to be obtained from Corsican pine and shows that as

CORSICAN PINE (PINUS NIGRA VAR. CALABRICA): YIELD TABLE DATA

TABLE 36 — All volumes over bark

Quality Class	*Main Crop*				*Total Crop Yield H. Ft. Per Acre*	*Current Annual Increment H. Ft. Per Acre* (45-50 yrs.)	*Mean Annual Increment H. Ft Per Acre*
	No. of Stems Per Acre	*Mean Height Ft.*	*Mean Girth ins.*	*Standing Volume H. Ft. Per Acre*			
I	190	77½	41	5,000	9,890	230	198
II	225	67	35	4,420	8,010	196	160
III	350	57	30	3,750	6,220	164	124
IV	500	47	25	3,000	4,510	130	90

CORSICAN PINE (PINUS NIGRA VAR. CALABRICA): SAMPLE PLOT DATA

TABLE 37

Location	*Age yrs.*	*No. of Stems Per Acre*	*Mean Height Ft.*	*Mean Girth Inches*	*Standing Volume H. Ft. Per Acre over bark*	*Current Annual Increment H. Ft. Per Acre over bark*
Gravetye, Sussex	64	96	101	54½	6,140	195
Alice Holt, Hants.	69	112	100	52½	6,347	214
Bere, Hants.	69	200	102	46½	8,710	180
New Forest, Hants.	90	93	107½	58	7,296	182

long as the price of Corsican pine timber is more than 60 per cent of that of Scots pine, Corsican pine may be the more profitable species to grow.

SEED AND SEED BEARING

Corsican pine is a moderate seed producer in Britain. Flowers are first produced between 20 and 25 years of age, and the first heavy cone crops between 25 and 30 years. Maximum production occurs between 60 and 90 years but the trees are then usually so tall that the cones are difficult to collect. Good cone crops occur at three to five year intervals.

Flowering takes place in late May or early June and the cones may be collected from December until February. Most seed is produced in South-East and Eastern England.

There are advantages in collecting seed from the many fine trees and plantations in Britain, and treatments to induce flowering and increase seed production have been tested. Partial girdling of the stems of 20- and 28-year-old plantation trees has significantly increased cone production two seasons after application. The best time to apply this treatment is May (Holmes and Matthews, 1951). The application of phosphate and potash together has also appreciably increased the percentage of trees bearing cones in a 28-year-old plantation at Sherwood Forest, Nottinghamshire.

The behaviour of Corsican pine and Austrian pine seed during storage and germination is similar. The seed stores well; germination capacity is maintained at a high level for several years if seed of about 8 per cent moisture content is kept in a cold store in sealed containers. Austrian pine seeds are larger than Corsican pine, the former averaging about 22,000 and the latter 32,000 seeds per pound.

Productivity in the nursery is quite high and about 60 per cent of the viable seeds sown can be expected to produce one-year-old seedlings. The quality of home-collected seed has often been inferior to that of imported, but collections of first quality seed from English stands have been made. The germination capacity of first quality seed is about 80 per cent.

GENETICS AND BREEDING

The following seed sources of Corsican pine have been registered:

Plus and Almost Plus: 19 stands totalling approximately 558 acres. Normal: 12 stands totalling approximately 96 acres. 81 Plus trees have been selected and recorded.

Seed orchards are not being formed for Corsican pine but may eventually be required to produce seed of hybrids between provenances of *Pinus nigra* and hybrids between *P. nigra* and other pine species. Certain parts of existing plantations of Corsican pine will be converted into "Seed Stands" and treated to increase cone production—the methods used will probably include heavy thinning, partial stem girdling and fertiliser applications.

NATURAL REGENERATION

Although seed production is good, seedlings are not often found on the ground except, occasionally, one-year seedlings which do not often survive.

TIMBER

Corsican pine timber is in general similar to Scots pine but has a larger proportion of sapwood and is usually somewhat coarser in texture. The average weight of the seasoned timber is about 32 lb. per cubic foot; in the green condition (130 per cent moisture content) it is about 58 lb. per cubic foot.

The timber air seasons rapidly, but during the early stages of seasoning it is particularly liable to become discoloured by blue stain fungi. (The staining of freshly felled logs, especially at the ends and in the vicinity of whorls of trimmed branches, has been especially severe in East Anglia during spells of mild weather in recent winters.) When kiln dried, the timber often becomes severely distorted and some checking may occur. The heavy degrade that occurs during the drying is partly accounted for by the whorls of knots resulting from persistent branches.

Corsican pine timber is not resistant to decay. The sapwood, of which there is a high proportion, is very susceptible to fungal attack though the heartwood is moderately resistant. The heartwood is

CORSICAN PINE (PINUS NIGRA VAR. CALABRICA): TIMBER STRENGTH

TABLE 38

	Modulus of Elasticity	*Bending Strength*	*Compression Parallel to the Grain*	*Shear*
Corsican pine (*Pinus nigra* var. *calabrica*)	1,000,000 lb. sq. in.	1,300 lb. sq. in.	1,100 lb. sq. in.	200 lb. sq. in.
Scots pine (*Pinus sylvestris*)	1,200,000 lb. sq. in.	1,600 lb. sq. in.	1,200 lb. sq. in.	200 lb. sq. in.

moderately resistant to penetration by preservatives, but the sapwood is very permeable; it is said that Corsican pine retains more preservative, and is therefore more expensive to treat, than is Scots pine.

Tests carried out on thinnings from the Forest of Bere and also on mature timber indicate that it is not as strong as native Scots pine. Sunley (1956) gives the comparative figures set out in Table 38.

Its resistance to impact is only about two-thirds of that of Scots pine. This and the occurrence of large knot clusters may account for reports of brittleness in the timber.

The timber, when seasoned, works well with machine and hand tools. The knots are softer and hold better than those of Scots pine. Corsican pine has been used mainly for estate purposes and for mining timber. Thinnings are in regular use for fibreboard manufacture. It has been suggested that if pruned it would be more suitable for plywood manufacture than most other home-grown softwoods.

POTENTIALITIES OF THE SPECIES IN THE NATIONAL ECONOMY

In the south and east of England, Corsican pine is a species of great importance for use on light sandy soils as it produces much more timber than Scots pine and is less liable to attack by insects. Where atmospheric pollution is a consideration, it has a place; while experience has shown that it is also well suited for planting on coastal sand dunes where exposure is not too severe.

On the other hand, there are limits to its wider use and it should not be planted in situations where die-back is likely to occur.

Pinus peuce Grisebach

This tree, which occurs naturally in three small areas in the mountains in Bulgaria, Macedonia and Montenegro, was introduced in 1863. It is hardy and specimens have been recorded in all parts of Britain. The two tallest trees recorded have both reached 90 ft. One, 89 years old was measured at Dropmore, Buckinghamshire, in 1930, and the other a tree of unknown age at Stourhead, Wiltshire, in 1956 by Maynard Greville.

Within recent years *P. peuce* has been planted experimentally in different districts and some of the results so far obtained are distinctly encouraging. For example, in a trial of species at Kielder, on a *Molinia* flush type of peat, *P. peuce* averaged 6 ft. in height after 8 years, and had grown better than *Abies grandis*, *Chamaecyparis lawsoniana*, *Thuja plicata* and *Tsuga heterophylla*. At 16 years, the pine had grown to 14½ ft.; it had a healthy appearance and seemed unaffected by exposure. At Beddgelert, also on an exposed site, this species promises well.

At Bedgebury, there is a good plot, growing in an acid soil, which reached 17 ft. in 17 years.

Pinus peuce is high on the list of five-needled pines showing resistance to the blister-rust. The tree grows slowly in the nursery and, in the forest, moves very slowly for a number of years after planting. It is too soon to make any forecast of the place it may occupy in British forestry but it is worth persevering with, and it may prove to have uses in exposed, higher-lying sites, and also in breeding White pine hybrids resistant to blister rust.

Pinus pinaster Aiton (*P. maritima* Poiret)

Maritime pine is both the common English name and the standard timber name.

COUNTRY OF ORIGIN AND PROVENANCE

Maritime pine is native to the coastal regions and islands of the Mediterranean, and reaches the Atlantic coast of France and Portugal, where it has also been extensively planted. There is no information on the origin of the early introductions to Britain.

The large quantities of seed which the Forestry Commission imported in 1925-29 almost all originated in the Landes. From 1930-34 all the seed was sent from Portugal (Leiria) while in 1935 most of the seed came from Corsica. Since then, only small quantities of seed have been required and enough has often been available from existing stands in Britain to meet our needs.

An experiment comparing growth of trees grown from seed originating from the Landes, France, from Leiria, Portugal and from Wareham, Dorset, was laid down in 1949 (Wood and Pinchin, 1951). The most recent assessment shows that in rate of growth

there is little to choose between them. However, plants of Portuguese origin grew very rapidly in their first year and were less wind firm than trees of French and English origins.

HISTORY AND EXTENT OF PLANTING

The date of the first introduction of the maritime pine is not certain. Elwes and Henry (1910) attribute its introduction to Gerard sometime before 1610 but Loudon (1838) gives 1596 as the year. The species was used to some extent during the 17th and 18th centuries and was established on a moderate scale in the south and east of Britain but it failed in the north. A little later, J. B. Petre planted upwards of 500 acres at Westwick, Norfolk, in 1809, using seed from trees planted in 1702 on his estate (Elwes and Henry). However, in plantings at Westwick at the beginning of the twentieth century, *P. pinaster* had given way to Douglas fir. At Holkham, also in Norfolk, *P. pinaster* had given way to Austrian pine at this time (Orde-Powlett, 1926).

In the south of England, the species became well known largely because of extensive plantings in and around Bournemouth, in particular at Talbot Woods. However, this area was built over as Bournemouth expanded and all that remains of these woods is a number of small blocks, none exceeding ten acres, which are retained primarily for amenity.

The first Maritime pine crops to be established by the Forestry Commission in the early 1920's were direct sown and were quite successful. However, subsequent large scale sowings in the south and east of the country were, in some cases, carried on to unsuitable land with poor results, although on good soil there was no difficulty. From 1925 until 1936 between 100 and 400 lb. of seed were imported annually, but most of the seed was direct sown and thus restocked a far smaller area than if it had been sown in the nursery to raise stock for planting in the forest. Since 1936, the species has seldom been used.

The 1947-49 Census of Woodlands revealed about 100 acres of *P. pinaster* in England (including the amenity woodland areas around Bournemouth), 12 acres in Wales and 1 in Scotland. There are, in addition, in the south and east of England some two or three hundred acres of Scots pine or Corsican pine which were put in to replace failed direct sowings, and which contain a scattering of trees of Maritime pine.

CLIMATIC AND SITE REQUIREMENTS

In the south at least of England, Maritime pine has generally been confined to the lighter sandy soils where it grows well. However on the very poorest Eocene sands, special preparation of the ground is necessary if it is to be established

ESTABLISHMENT TECHNIQUE

Direct sowing is an easy way of raising a crop of this species in the forest, and if soil conditions are right very little need be done beyond preparing patches and sowing a few seeds on each. On poorer heathland, it has been found necessary to cultivate to a depth of about eight inches before sowing and to apply a phosphatic fertiliser. It is best to reduce the seedlings on each patch down to one plant, two or three years after sowing.

Planting of one-year-old seedlings has also been practised successfully, seed being sown in the normal way in the nursery. Very little transplanting has been done and the scanty evidence available indicates that the transplant is an unbalanced plant with a large top and a strong tap root with few laterals.

Spacing of sowing patches, or of seedlings in plantation, is similar to that for other pines.

TENDING

When the proper technique for direct sowing has been followed Maritime pine grows quickly and little weeding is necessary.

OTHER SILVICULTURAL CHARACTERISTICS

In the first years of growth of maritime pine the crown develops rapidly; thus at Wareham, five years after sowing almost complete closure of canopy and suppression of ground vegetation has occurred. Such vigorous and large crowns also present a substantial barrier to the wind and put a severe strain on the young root system. At Wareham leaning trees have been found in exposed edges of plots as early as three years after sowing. The leading shoot of such trees grow vertically and so basal bends are formed. The formation of basal bends is a long-standing defect; Mitchell in 1827 commented that "the pinaster" was "getting into disgrace through deformity for want of shelter", and Loudon in 1838 said that "in the case of transplanted trees, from the weight of head produced by the dense mass of long foliage, the stem is generally inclined to one side; and when after two or three years, it begins to grow erect, a curvature appears above the root which remains visible even in old trees".

RATE OF GROWTH AND YIELD

Very little information is available about the yield of *P. pinaster*. There are no sample plots in any crop—the only records available are those of measurements of specimen trees and young forest plots. Early growth of Maritime pine is quite rapid. At Wareham, in direct sowing experiments, plants in

the best treatments averaged 3 feet in height 5 years after sowing, and 15.4 feet fifteen years after sowing. On the same site after 15 years, Scots pine had reached a height of 11.3 ft., lodgepole pine 14.4 ft., *P. radiata* 12.6 ft., and Corsican pine 10.1 ft.

The fastest grown and one of the tallest recorded Maritime pines was a specimen 100 ft. tall 80 years after planting, which grew at Scorrier House, Cornwall. The fastest growth in middle age is recorded for a tree at Westonbirt Arboretum which grew from 61 ft. in 1931 (Chittenden 1932) to 90 ft. in 1955. The tallest maritime pine recorded in England is a tree 109 ft. tall by 11 ft. 10 in. girth which grew at Foxley Park, Hereford, and was measured in 1931 (Chittenden 1932). The tallest tree measured recently is a specimen 100 ft. tall at Bolderwood, Hampshire.

PESTS AND DISEASES

Maritime pine is probably restricted by climate in Great Britain, and like Corsican pine, shows needle cast and dieback, accompanied by *Brunchorstia*, when planted in unsuitable places. But much less is known about its behaviour, because it has not been so widely planted.

No insect pest specific to *P. pinaster* has been reported.

OTHER FORMS OF DAMAGE

Windblow has been reported in a young pole crop on an exposed situation at Wareham, but here kaolin clay deposits below the soil surface had limited the depth of rooting. Elwes and Henry mention that most of the 500 acres of Maritime pine at Westwick was blown down when 85 years old. However, the species is usually considered windfirm.

SEED AND SEED BEARING

The tree seeds freely along the Dorset coast. Seed collected in Britain is usually quite as good as imported seed and may sometimes be better. The germination capacity of good quality seed averages about 70 per cent; up to 80 per cent of viable seeds may yield one-year-old seedlings. Germination is reasonably quick.

NATURAL REGENERATION

Not practised, though in Dorset self-sown plants are frequently seen.

TIMBER

In Norfolk at the beginning of this century the timber of *P. pinaster* was reported as being "inferior to Scots pine, rarely selling for more than 4d. per foot while the latter is readily saleable at 6d." (Elwes and Henry).

POTENTIALITIES OF THE SPECIES IN THE NATIONAL ECONOMY

Although the very early growth of Maritime pine seems to be faster than that of other pines, the species does not seem capable of producing high yields of timber in Britain. Its susceptibility to exposure and consequent stem deformation when very young, together with the fact that *P. radiata* or Corsican pine will probably thrive on sites suitable for *P. pinaster*, make it very unlikely that this species will find any real place in British forestry.

Pinus ponderosa Lawson (Plate 10)

There is no common name in Great Britain for this tree, which is known in America as the Western Yellow Pine. The standard name for imported timber is ponderosa pine (B.S.N.T. 1952).

COUNTRY OF ORIGIN, HISTORICAL NOTES AND PROVENANCE

P. ponderosa is a widespread species in Western North America, ranging from British Columbia to Mexico and from the Pacific Coast inland to Colorado, Nebraska and Texas.

It was first introduced in 1827 when David Douglas sent seed to the Horticultural Society of London. This seed probably came from trees near the Spokane River, Washington. *P. ponderosa* has been little planted. Specimen trees dating from the nineteenth century are not uncommon but plantations are rare and most of them recent in origin.

Little is known about the effect of provenance on growth in Great Britain, but two small experiments were laid down in 1930 at Thetford, Norfolk, and at Findon, Ross-shire, to compare *P. ponderosa* plants of six different origins. Unfortunately, all the trees came from a restricted area in British Columbia and the result is that all have grown at much the same rate. Growth, generally, is better at Thetford than at Findon.

EXTENT OF PLANTING

This is quite small, being restricted to a few experimental plantations.

CLIMATIC REQUIREMENTS

Elwes and Henry (1910) state that *P. ponderosa* grows better in southern and central England than in Scotland, and that the species does not do well in the west. The first part of this statement is supported by measurements of specimen trees, which are generally taller in the south than they are in Scotland.

TABLE 39 PINUS PONDEROSA: GROWTH AND PRODUCTION

Location	*Age yrs.*	*No. of stems per acre*	*Top Ht. ft.*	*Mean Girth in.*	*Basal Area Hoppus sq. ft.*	*Standing Volume Hoppus ft. O.B.*	*Total Volume Hoppus ft. over bark*
Olleys, Thetford	28	592	42	21½	117	2,060	2,742
Bedgebury, Kent	27	651	36	18	92	1,372	1,818
Laughton, Lincolnshire	24	476	39	19½	78	1,348	2,072

SITE REQUIREMENTS

P. ponderosa seems to prefer well-drained soils and grows satisfactorily on dry sites, while it has been found to survive in frosty localities where other conifers were damaged. It may not be a long-lived tree on shallow soils, for there are examples of die-back of the crown in tall trees in these situations.

ESTABLISHMENT TECHNIQUE

P. ponderosa is given standard treatment in the nursery. One-plus-one transplants are normally 6 to 9 in. in height and suitable for forest planting at this age. There is no advantage in raising older stock.

VEGETATIVE PROPAGATION. Grafting of this species is commonly practised in the United States, but in Britain the tree has neither been grafted nor propagated by cuttings.

PLANTING. Both pit and notch planting have been found satisfactory. Survival in the first year has generally been good—over 85 per cent, though cases of survival less than 40 per cent are on record. Losses in the second and third year after planting have been between 6 and 20 per cent.

SPACING. Plants have been put in at four to five foot spacing.

TENDING AND THINNING

Early growth is often irregular, and in the first thinning, 13 to 24 years after planting, when the mean height of the crop has reached 25 to 30 ft., the chief object has been the removal of coarse misshapen dominants and suppressed trees.

OTHER SILVICULTURAL CHARACTERISTICS

The species is a strong light demander and subdominant trees quickly become suppressed and die.

RATE OF GROWTH AND YIELD

Permanent sample plot data are available from three plots of *P. ponderosa*, all three having been established in 1948. The most recent measurements are given in Table 39.

The three plots compare favourably in height and volume production with Quality Class I/II Scots pine.

Data from three other stands are given in Table 40.

It will be seen that the plot in the Forest of Dean is growing faster than any of the permanent sample plots, while the trees at Barcaldine are growing more slowly.

Data for the rate of growth of older trees are available only from records of specimen trees. These show that several trees in the south of England have reached 100 ft. in 100 years, the fastest, a tree at Blackmoor, near Liss in Hampshire, having reached 105 feet in 85 years. No comparison can be made with trees growing in other parts of the British Isles as the relevant dates of planting are not known.

The tallest tree recorded is a specimen 132 feet tall at Scotney Castle, Kent. A tree, 118 feet tall at Redleaf, Kent, is the next tallest. The tallest tree recorded in Wales is one 110 feet tall at Powis Castle, Welshpool, while the tallest Scottish tree is one 92 feet tall at Rossdhu, Dunbartonshire.

DISEASES AND PESTS

No pests and diseases specific to *P. ponderosa* have been reported in Britain.

SEED

No data are available for home-collected seed. Imported seed sometimes has shown slight dormancy but no pre-treatment is considered necessary to

TABLE 40 PINUS PONDEROSA: GROWTH OF THREE STANDS

Location	*Soil/Vegn.*	*Age yrs.*	*No. of stems per acre*	*Ht. Ft.*	*Mean Girth in.*	*Notes*
Forest of Dean	Clay loam	18	720	34	16	—
Barcaldine, Argyll	Bracken/Grass/Heather	24	—	15–20	—	Plants made slow start
West Tofts, Thetford	Sand	24	600	31	18	Provenance Expt.

overcome this. The average number of seeds per pound is about 9,000.

SEED-BEARING. Cones have been reported on a 24-year-old tree at Bedgebury and on several 21-year-old trees at West Tofts, Thetford.

GENETICS AND BREEDING

Three 'plus' trees have been selected. No other breeding work has been done.

TIMBER

Little home grown *Pinus ponderosa* timber has been handled by the trade. However the scanty information available indicates that the timber air seasons well, is stable, and works well with machine and hand tools. It has been used for high class joinery.

POTENTIALITIES OF THE SPECIES IN THE NATIONAL ECONOMY

From the evidence available, it seems that *Pinus ponderosa* may have a range similar to Corsican pine in Britain. It is difficult to imagine it displacing this well-tried and productive species.

Pinus radiata D. Don (Plate 11).

Synonym:—*P. insignis* Douglas. The variety *binata* Hort. is distinguished by the prevalence of short shoots with two needles instead of the usual three.

The English name is Monterey pine.

COUNTRY OF ORIGIN, PROVENANCE AND HISTORICAL NOTES

P. radiata is native only to a narrow coastal belt in Monterey, California, and to a few islands off the coast. The tree was first introduced in 1833 from Monterey County by Douglas (Loudon, 1838). In 1850 and 1851 seed was sent to Messrs. Veitch by William Lobb (Elwes and Henry, 1910). Loudon mentions that five years after the first introduction, plants had grown to between 3 and 5 feet and it is possible, from such early promise, that the earliest small plantations were raised from Lobb's seed. *Pinus radiata* has been little planted during this century and scarcely any plantations have been made in the last twenty years. The plantations in Britain bear seed freely and small quantities of seed have been collected from them; small quantities of seed have also been imported from New Zealand plantations.

EXTENT OF PLANTING

Specimens and small groups of *P. radiata* have been planted fairly widely, but while good specimens may be seen in the milder parts of Scotland, it is in the south and south-west of England that the species is most commonly found.

The 1947-49 Census revealed a marked absence of young stands as shown in Table 41. 137 out of the total of 163 acres of plantation occur in Devon and Cornwall, and the other 26 acres in Sussex and Hampshire.

PINUS RADIATA: AGE-CLASS DISTRIBUTION, 1947

TABLE 41 Acres

Age-class, years					*Uneven Aged*	*Total*
1–20	21–40	41–60	61–80	*Over* 80		
2	13	7	41	21	79	163

CLIMATIC REQUIREMENTS

The limiting factor in the distribution of *P. radiata* in Britain appears to be temperature. The tree is not completely frost-hardy, and although it will survive short periods of low temperature and has not been killed by minimum temperatures between 0° and −5°F, periods of continuous freezing winds cause browning and death of foliage, and may kill the tree outright. Lack of summer warmth diminishes the vigour and growth of the tree; if the present distribution of plantations is plotted on a map showing accumulated temperatures, it is found that the species is almost entirely restricted to areas with high mean accumulated temperatures (2,500—3,000 day degrees) and is not found at all in areas with less than 2,000 day degrees.

Rainfall does not appear to limit the distribution of *P. radiata* except inasmuch as high rainfall areas coincide with those with low accumulated temperatures. The tree is quite at home in 25 to 45 inches mean annual rainfall and specimens can be found in areas with considerably higher rainfall.

SITE REQUIREMENTS

Dallimore and Jackson (1948) state that *P. radiata* grows well on light, moist, well-drained soils. Forestry Commission experience is that it will also grow extremely well by British standards on dry, infertile, sandy soils such as those at Wareham, Dorset. The species will withstand strong winds, though some diminution of height growth and increase in branchiness occurs on such sites. Salt winds are also tolerated and trees can safely be planted near the coast.

TECHNIQUE OF ESTABLISHMENT

Some difficulty is experienced in establishing *P. radiata* in England. Most success is obtained if plants are put out as one-year seedlings. Provided seed is sown towards the end of the usual

sowing period, at a density about half that for Scots pine, and is otherwise treated in the standard way, vigorous well-formed seedlings 4 to 6 inches high are obtained at the end of the year. Seedlings are best planted in the forest in late spring. If transplants are required, it is preferable to sow in very late spring (late May or early June) and so obtain smaller first year seedlings and better balanced transplants. At Wareham, *P. radiata* has been established successfully by direct sowing, trees growing very rapidly in the year after sowing.

Application of phosphate fertiliser is essential for direct sowings on soils such as those at Wareham, and is also very beneficial to planted seedlings.

The spacing in plantation of *P. radiata* has been similar to that of other pines i.e. 4½ ft. × 4½ ft. or 5 ft. × 5 ft.; but now that it is more generally appreciated how rapidly the species can grow, a wider spacing, e.g. 6 ft. × 6 ft. would be used and trees pruned early.

TENDING AND THINNING

WEEDING. The sites where *P. radiata* has been planted are seldom fertile, and weeding for the first two or possibly three years is all that has been necessary.

THINNING AND PRUNING. There are insufficient stands of *P. radiata* in Britain for any thinning recommendations to have been worked out, and existing stands are thinned in the same way as Corsican or Scots pine of similar height. The branch development in *P. radiata* is coarse with many branches per whorl, and sometimes two or three whorls per year. Internodes are, however, quite long and pruning can be expected to improve both the timber quality of final crop trees and the appearance of the stand.

OTHER SILVICULTURAL CHARACTERISTICS

The coarse branch habit of *P. radiata* is especially characteristic of open grown or exposed trees. A high proportion of the trees planted in Great Britain has been put in small groups or windbreaks, and this has led to a greater awareness of this coarse branching habit than otherwise might be.

Vegetation is rapidly suppressed in young *P. radiata* plantations; the species can therefore be used as a pioneer, giving way to a more valuable species later.

RATE OF GROWTH AND YIELD

Data from the few young plots and from measurements of individual trees taken together show that early height growth is very rapid and that in 25 to 30 years *P. radiata* reaches 55 to 70 feet. Thereafter, the rate of height growth decreases markedly, trees taking another 25 to 75 years to reach 100 feet. The maximum height to which the tree can grow in Britain is not known; the biggest recorded specimens include trees 138 ft. and 130 ft. in height at Cuffnells, Hampshire, and a tree 132 ft. in height at Killerton, Devon.

The only sample plot measurements available are from a privately owned plot in South Devon and are given in Table 42 below. (Note that volumes are under-bark).

DISEASES AND PESTS

In the plots at Wareham occasional trees lose their colour and needles and appear to be dying. This may be similar to what has recently been described as "rapid decline" (Bednall and Stoate, 1953), about the cause of which little is known. Not all trees eventually die however; some recover their health and regain their vigour.

No insect pests are specific to *P. radiata*, but the Pine Shoot Moth (*Evetria buoliana*) is frequently reported and is the cause of many malformed crowns.

OTHER FORMS OF DAMAGE

A little windthrow has been reported on sites where the root development of *P. radiata* had been restricted.

PINUS RADIATA: SAMPLE PLOT AT DARTINGTON, SOUTH DEVON

TABLE 42 — Plot Area 0.190 acres — Measurements per acre

Age of Crop yrs.	*Main Crop*					*Periodic Mean Annual Main Crop Increment*
	Av. Height of 100 largest trees ft.	*True Girth at 4 ft. 3 in. in.*	*Vol. per acre Hoppus ft. under bark*	*Bark Percentage*	*Total Crop Yield to date Hoppus ft. under bark*	*Vol. Hoppus ft. under bark*
10	30.0	14.6	1,193	10.3	1,492	—
13.5	43.0	18.6	1,409	10.3	2,230	211
15	47.0	22.9	1,858	10.3	2,901	447
16	49.0	24.9	2,120	10.3	3,273	372

SEED AND SEED-BEARING

Plantations of *P. radiata* usually commence to bear cones before they are 20 years old and thereafter in the south bear quite heavy crops. Small quantities of seed have been obtained from British stands.

GENETICS AND BREEDING

No work has yet been done in Britain on this species. However, the work that is in progress in South Africa, Australia and New Zealand on the breeding of Monterey pine suggests that it will be possible to improve the growth habit of this species; and careful choice of seed origin and the use of, say, selected New Zealand seed might do much to minimise coarseness of branching.

NATURAL REGENERATION

Natural seedlings have been reported, but nowhere has *P. radiata* been deliberately regenerated.

TIMBER

The timber of home-grown *P. radiata* is usually coarse and is considered inferior in quality to that of other conifers. However, this opinion is based largely on timber obtained from specimen trees. There has been no experience of timber from pruned trees.

POTENTIALITIES OF THE SPECIES IN THE NATIONAL ECONOMY

P. radiata, because of its rapid rate of growth, might have a small place in the extreme south and south-west of England. Any crops will require careful tending and early pruning.

Pinus resinosa Aiton

The Red pine, a native of eastern North America from Nova Scotia to Pennsylvania, was introduced into Great Britain in 1756. Elwes and Henry (1910) say the tree does not grow very well in Britain and while the tallest specimen was a tree 86 ft. tall recorded from Dorking, Surrey, in 1931, few other trees have reached even 50 ft. At Bedgebury, Kent, a plot of this species is vigorous and healthy. When last measured this plot was 19 years old and had a mean height of 18 ft. and a mean girth of 15 inches.

It is most unlikely that this species will have any place in British forestry, the main reason being that on sites in this country best suited to it, it is unlikely to approach Corsican pine in vigour of growth.

Pinus strobus Linnaeus

COMMON NAME

Weymouth pine (named after Lord Weymouth on whose estate at Longleat in Wiltshire many trees of one of the earliest introductions were grown. (Loudon, 1838).)

The timber is known in the trade as Yellow Pine (B.S.N.T., 1952).

COUNTRY OF ORIGIN AND PROVENANCE

This species has a wide range from Manitoba and Newfoundland in lat. 50°N to Iowa and Connecticut, lat. 42°N, penetrating along the Alleghany mountains into Alabama and Georgia lat. 34°N. There is no record of the origin of the first introduction of the species to Britain, though the seed is almost certain to have been collected by early settlers in New England. There is no record of any comparison of Weymouth pine provenances in Britain.

HISTORY AND EXTENT OF PLANTING

The precise date of introduction of Weymouth pine is not known. Loudon (1838) says that the tree was first cultivated at Badminton in 1705 by the Duchess of Beaufort, and that soon afterwards a large number of trees were planted at Longleat, Wilts., at Mersham Hatch, near Ashford in Kent and at Whitton, Middlesex. Seed collected from the Mersham Hatch trees was being sold by 1726, and not long afterwards the trees at Whitton were producing plenty of seed which was distributed "to all the curious". The tree continued to be used for planting on a small scale up to the end of the 18th century, and thereafter began to be propagated in plenty, chiefly from seed of the Mersham Hatch trees. American seed was regularly imported but on a small scale compared with the amount of seed produced by the trees at Mersham Hatch (Hunter, 1801). In 1765 and subsequent years, gold and silver medals were offered by the Society for the Encouragement of Arts for plantations of Weymouth pine (Elwes and Henry, 1910). Small plantations continued to be established at intervals through the late 18th and 19th century. For example in the Crown Woods at Windsor about six acres were planted with Weymouth pine in the 1850's (Adkin 1916). In 1892 the white pine blister rust (*Cronartium ribicola*) was first noted in Britain on Weymouth pine at Kings Lynn, Norfolk. It quickly spread and by 1909 was reported by Somerville to be causing devastation in a number of plantations, and he strongly recommended that the species be planted no more. Since 1909 the rust has spread and there are now few Weymouth pine stands without infected trees.

The Census of Woodlands, 1947-1949 showed 22 acres of *P. strobus* plantations in England and 19 in Scotland.

TABLE 43 PINUS STROBUS: GROWTH AND PRODUCTION

Location	*Age*	*No. of Stems per acre*	*Top Ht. ft.*	*Mean Girth in.*	*Standing Volume H. ft. Over Bark*	*Total Volume Hoppus Feet over bark*
Dunach	28	934	43	21	3,431	4,367
Alice Holt	48	164	60½	36	2,520	6,096

CLIMATIC AND SITE REQUIREMENTS

Elwes and Henry recommend deep sandy or sandy loam soils for this species, and many of the best trees are found on such soils. The tree grows well in parts of Scotland, but Elwes and Henry say that it thrives better in the south of Britain. The scanty evidence available suggests that the tree does not seed so freely in the north.

TECHNIQUE OF ESTABLISHMENT

Recent experience of establishing Weymouth pine is solely derived from raising plants for one or two small forest plots. In the nursery, seed was sown and covered in the normal way and seedlings were lifted after two years' growth for lining-out. Plants were pit planted or notched, as two-plus-one transplants and survived satisfactorily. Fisher (1907) mentions a plantation in which three-year-old seedlings were mattock planted satisfactorily.

Spacing of plants in the nineteenth and early twentieth century was 4 ft. × 4 ft. or 3 ft. × 5 ft. (Schlich, 1919, Fisher, 1907). There is no reason to think that the tendency in recent years for plants to be put in at wider spacings, e.g. 5 ft. × 5 ft. would not also be applied to *P. strobus*.

TENDING AND THINNING

In all the existing plots, thinning has had to be "sanitary", removing dead and dying trees.

RATE OF GROWTH AND YIELD

Data are available from two sample plots of *P. strobus*, one at Alice Holt, Hants., and one at Dunach in Argyll. Trees in the latter plot were blown over in 1937, while the plot at Alice Holt suffered severely from blister rust. However, measurements have continued to be taken at Alice Holt, and the plot has been underplanted with *Tsuga heterophylla*. Both plots were similar in rate of height growth to Scots pine of Quality Class I and II respectively, but their total volume production was much higher. The last recorded measurements are given in Table 43.

Other young forest plots exist at Lynford, Norfolk, and Bedgebury, Kent, both on sandy soils. There is a very young plot at Beddgelert, Caernarvonshire, on a shale soil on a moderately elevated exposed site, while at Lochgoilhead in Argyll there is a very vigorous stand on sandy boulder till in a sheltered site. The most recent measurements from these plots are shown in Table 44.

At Delamere, Cheshire, there are several acres of Weymouth pine in mixture with Corsican and Scots pine. Where Corsican pine is present it dominates both Scots and Weymouth pines, but Weymouth pine easily holds its own with Scots pine. In 1951 when the crop was 50 years old, the Weymouth pine was about 54 feet tall. The outstanding feature of these trees is their freedom from blister rust. The site is on glacial sands and gravels with a southerly aspect.

At Weasenham, Norfolk, a 48-year-old tree is 80 ft. high; Loudon mentions two trees, one 80 ft. at 60 years and another 53 ft. at 41 years. At Dropmore, Buckinghamshire, and Althorp, Northamptonshire, there are two trees both about 80 years old and measuring 85 and 89 ft. respectively. Elwes and Henry report a tree 122 feet high at 105 years (when it was blown down) and several trees about 150 years old and 100 ft. high.

The only final yield figures available are given by Adkin (1916) who describes a felling at Windsor of about 6 acres of 70-year-old Weymouth pine which yielded 4,000 Hoppus ft. per acre. (Volume to 6 in. top, under bark.) The height of the crop was 73 ft.

From these measurements it will be seen that on good sites vigorous stands or specimens can be expected to put on nearly two feet in height per year in their early growth, and that, given freedom from *Cronartium*, trees could be expected to reach dimensions similar to those of mature trees in their native country. On sites where other species have

PINUS STROBUS: PLOT DETAILS

TABLE 44

Location	*Age*	*Average Height ft.*	*Remarks*
Beddgelert	10	6.3	Some rust, otherwise vigorous and healthy.
Bedgebury	19	37.5	Some rust.
Lochgoilhead	25	44	Some rust, much natural regeneration.
Lynford	25	24.7	25% affected by rust, 22% damaged by vermin.

been planted, and comparisons of rate have been made, Weymouth pine is not among the leaders. At Bagley Wood, Berkshire, Schlich (1919) shows that its height growth was not so rapid as that of Douglas fir, *Tsuga heterophylla*, *Thuja plicata*, Sitka spruce, European larch, Japanese larch, or Corsican pine, but that in proportion to its height its girth was greatest. At Bedgebury a *P. strobus* plot is second in height growth only to *P. radiata*, and comparable to Corsican pine, Scots pine and *P. ponderosa*. However, all the pines here are considerably slower in growth than European larch, Japanese larch, Douglas fir or Norway spruce.

DISEASES AND PESTS

Weymouth pine, like most other five-needled pines, is subject to attack by White Pine Blister Rust, *Cronartium ribicola*, of which Boyce (1948) gives a full account. The chief alternate host in Great Britain is blackcurrant (*Ribes nigrum*). It is seldom possible to site plantations more than a mile from the nearest blackcurrants, and the probability of attack has prevented the extensive use of this pine. In most stands a few trees survive unattacked, but it is suspected that this is due to chance, rather than to natural resistance.

In addition to blister rust, damage by voles has occurred in the plot at Lynford, Norfolk; the animals appear particularly to like the thickened bark resulting from attack by blister rust.

SEED AND SEED-BEARING

From its earliest introduction, the Weymouth pine has produced seed freely.

There is no record of any recent home collection of Weymouth pine seed. Good quality imported seed has about 70 per cent germination capacity, with about 27,000 seeds per lb. The seed requires stratification for at least 90 days at 36°F. in order to overcome embryo dormancy and complete the process of after-ripening. Viability is maintained for up to five years if seed is stored properly.

GENETICS AND BREEDING

A small programme of breeding for resistance to *Cronartium ribicola* is in progress. Apparently resistant trees of the five-needled pine species are being selected in areas of severe *Cronartium* attack, and so far nineteen trees have been selected for observation and testing. Hybridization between *P. strobus* and *P. griffithii* or *P. peuce* was begun in 1955 and continued in 1956. Both British and American origins of *P. strobus* were used.

NATURAL REGENERATION

Natural seeding of Weymouth pine has occurred on several sites, but little is known about its possibilities.

TIMBER

Fisher (1907) mentions fellings at Windsor Forest in which Weymouth pine timber fetched 8d. per cu. ft. compared with 4d. per cu. ft. for Scots pine; Loudon mentions home-grown timber being used for flooring and cabinet work.

POTENTIALITIES OF THE SPECIES IN THE NATIONAL ECONOMY

The dominating factor in the future use of Weymouth pine is the blister rust. If trees which are both vigorous and resistant to the rust can be produced in quantity, then *P. strobus* would be a useful species for British foresters. Until such resistance is found, it is a waste of time to plant the tree.

Pinus thunbergii Parlatore

This Japanese species was first introduced to Britain by Veitch in 1861. The tree grows quite slowly; the tallest recorded specimen, only 55 ft. tall, is at Sevenoaks, Kent. A small plantation just over two acres in extent was made at St. Leonards, Kent, in 1925; and in 1952 when 27 years old had an average height of 36 ft., a mean girth of 19 inches and a volume per acre of 2,100 Hoppus ft.

At Bedgebury, specimen trees after growing well for a number of years, deteriorated in health.

This species is most unlikely to play any part in British forestry.

J.R.A.

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Podocarpus Persoon

Very few of the Podocarps can be grown in the open air in Great Britain and those which can tolerate the climate survive in sheltered places as bushes. The hardiest is *P. andinus* which used to be not uncommon in shubberies and gardens but is now less frequently planted. *P. totara* has survived out of doors in the south-west and west of the country in one or two sheltered gardens.

J.M.

Pseudolarix Gordon

Pseudolarix amabilis (Nelson) Rehder

This genus is represented by this species only, the Golden Larch of China, which was introduced in 1853 by Fortune. It is a rare tree with us, being found occasionally in collections in the south of England. It is fairly hardy but grows slowly. Little is known about its soil requirements It has no forest importance.

J.M.

Pseudotsuga Carrière

This genus consists of three species which occur in Asia and, according to some authorities, three in Western North America. In this account, however, the American forms have been put together into *P. taxifolia*. Of the Asian species, *P. wilsoniana* from Formosa and Yunnan, is too tender for use in Great Britain, *P. japonica*, from Japan, introduced in 1910, is rarely seen, while *P. sinensis* from Western China is almost unknown in cultivation.

Pseudotsuga taxifolia (Poiret) Britton (*P. douglasii* Carrière). Plate 9.

COMMON NAME

Douglas fir. In Britain this name covers both the tree and the timber, imported timber being also known by the American exporters' name "Oregon pine".

COUNTRY OF ORIGIN AND PROVENANCE

Western North America, from British Columbia to California, Montana, Colorado, Western Texas and Northern Mexico. This area includes the distribution of the species in a wide sense. *P. taxifolia* var. *glauca* or *P. glauca* of various authors, and *P. macrocarpa* Mayr or var. *macrocarpa* occur at the southern end of the range, in Colorado, etc., and have seldom grown satisfactorily in Britain. Although earlier recommended as being hardier in the winter, they were found to grow more slowly and suffered various forms of damage (Schlich, 1904 and 1919; Richardson, 1905). The Colorado Douglas has an attractive blue colour and is a decorative tree.

Douglas fir from the northern and middle parts of the range has also been divided into various varieties or forms, but these are here considered as different provenances of the species *P. taxifolia*, though they can be classified into several broad groups whose exact native boundaries are undefined. Thus coastal provenances from British Columbia, Washington and Oregon include the green Douglas or var. *viridis* and inland provenances include the intermediate, grey or *caesia* variety.

Few critical experiments on the provenance of Douglas fir have been planted in Britain. One in Radnor Forest planted in 1933 (by the University College of North Wales) and the experiment in the Forest of Dean described by Peace (1948) have suffered in various ways which make the interpretation of results difficult. So far it has not been possible to grade the different provenances either by vigour or any other characteristic. In general the coastal provenances grow fastest, though exceptions in early years have been noted (Lines, 1956) and sometimes the inland ones suffer from late frosts (Day, 1930), but they have also been noted for greater resistance to winter cold. A comprehensive study of the coastal form from U.S.A. was commenced in 1951 and stocks were planted at a number of sites in Britain in 1953 and 1954. There is as yet no good comparison with Canadian seed sources.

The majority of plantations in Britain have been raised from seed from Washington and the coastal parts of British Columbia around the lower Fraser River. Kay and Anderson (1928) had no doubt that Vancouver Island was the correct provenance for Britain. More recently it has been considered that the oceanic zone in Washington and the northern Cascade foothills seem to be the best sites for future seed collection, until further evidence is available (Wood, 1955).

HISTORICAL NOTES

Discovered about 1792 by Archibald Menzies at Nootka Sound, Vancouver Island, British Columbia. Introduced in 1826-7 by David Douglas, who sent seed to the (Royal) Horticultural Society, London, probably from the Washington-Oregon border, a few miles inland from Fort Vancouver, in the lowlands between the Cascade Mountains and the Coast Range (Harvey, 1947). In 1846-7 Hartweg sent seed from Santa Cruz, California, and in 1852-3 there were introductions by William Lobb and by John Jeffrey for the Oregon Association. Trees from the original introduction were distributed widely and many still exist. One at Dropmore, Buckinghamshire, was the first to fruit. In Perthshire there is one at Scone Palace and two at Lynedoch, on the same estate, of which one was extensively used as a seed source, giving rise both to the Taymount plantation of 1860 (McCorquodale, 1880; Schlich, 1888) and to many specimen trees, e.g. at

TABLE 45 PSEUDOTSUGA TAXIFOLIA (DOUGLAS FIR): DISTRIBUTION BY COUNTRIES, AND PERCENTAGES OF HIGH FOREST AREAS OCCUPIED, 1947

	England			*Scotland*			*Wales*			*Great Britain*		
	Area Acres	*Percentages of Conifers*	*Percentages of all species*	*Area Acres*	*Percentages of Conifers*	*Percentages of all species*	*Area Acres*	*Percentages of Conifers*	*Percentages of all species*	*Area Acres*	*Percentages of Conifers*	*Percentages of all species*
Private Woodlands	7,207	4	1	5,440	2	2	1,849	9	2	14,496	3	1
Forestry Commission	10,505	6	4	5,734	3	3	7,069	9	8	23,308	5	5
Total	17,712	5	2	11,174	2	2	8,918	9	5	37,804	4	2

TABLE 46 PSEUDOTSUGA TAXIFOLIA (DOUGLAS FIR): HIGH FOREST AREAS, PURE AND MIXED STANDS COMBINED, BY AGE-CLASSES, 1947 Acres

	Age-class, yrs.								*Uneven-aged*	*Total*
	1–10	11–20	21–30	31–40	41–60	61–80	81–120	*Over* 120		
Private Woodlands	1,374	2,060	5,279	2,447	1,208	515	223	—	1,390	14,496
Forestry Commission	2,156	10,407	9,668	210	202	201	141	—	323	23,308
Total	3,530	12,467	14,947	2,657	1,410	716	364	—	1,713	37,804

Strathallan and probably Murthly (despite a story of fresh import for these). Other trees from the original source are at Drumlanrig and Jardine Hall in Dumfriesshire; Corehouse, Lanarkshire; Dawyck in Peeblesshire, and other places. The excellent result at Taymount was an important factor in the extension of the planting of this species in Britain.

EXTENT OF PLANTING

Douglas fir is one of the most important exotics grown in Britain. Figures are given in Tables 45 and 46. Privately-owned woodlands contained, in 1947, approximately 14,500 acres (thirty-eight per cent); about 23,500 acres (sixty-two per cent) are in Forestry Commission plantations, making 38,000 acres in all. Over ninety per cent of the area of Douglas fir in Commission Forests is less than thirty years old. In privately-owned woodlands, however, only about sixty per cent of the area is less than thirty years old, while twenty-four per cent is between thirty-one and sixty years. The majority of the old woods are found in Scotland. The distribution of age-classes confirms that Douglas fir has been used as a forest tree longer than has Sitka spruce, and in spite of wartime fellings, there are still more than 2,000 acres of forest over forty years of age, and almost 2,000 acres of uneven-aged forest.

Although no exact figures are available for the area of Douglas fir planted since the Census of Woodlands in 1947-49, Annual Reports of the Forestry Commission (1951-1955) show that fourteen million trees have been planted, excluding those used for beating up. Expressed in terms of area, at least ten thousand acres have been added, in addition to that planted by private estates.

CLIMATIC REQUIREMENTS

The limits of temperature and rainfall for Douglas fir in Great Britain are not clearly defined, although it is considered that it might reasonably be expected to exhibit increasing sensitivity towards the colder end of its range (Wood, 1955). Day (1955) also concluded that Douglas fir will be favoured in the warmer parts of Britain, and associating this with its need for water (see p. 120), he concludes that it is best adapted to the "western and more humid parts of the country, or locally on specially favourable soils." However, Macdonald (1952) states that although "for rapid growth, the mild, moist conditions of the west appear to be essential, Douglas fir is capable of making a satisfactory but slower-growing crop in the low rainfall and the more continental climate of eastern and south-eastern England. In this it is more accommodating than some other trees from Western America". There are also many good crops of Douglas fir in the east of Scotland.

Douglas fir is a wind-sensitive species, and although the leaders of tall trees sometimes thrust themselves out above the level of the canopy, they suffer from the wind. The loss of the leading shoot

in exposed places, remarked by Webster (1886), is a common occurrence, and it is well illustrated in two sample plots at Tortworth, Gloucestershire, whose height growth was similar for the first forty years, but fell away suddenly in the plot which out-grew the shelter afforded by the hill behind (Christie, 1955). Thus Douglas fir is a tree for valley bottoms and sheltered sites, though not necessarily confined to low elevations, as there have been successful examples of its growth at a thousand feet or more, e.g. Balmoral (Macdonald, 1952) and in Wales (Bennett and Long, 1919).

Though Douglas fir is less tender to frost than Norway and even Sitka spruce, the establishment of plantations is often hindered by late spring frosts and these are sometimes serious in sites suitable for Douglas fir. Thus many plantations suffered most severely in their early years in the Breckland district of Norfolk, which is notoriously frosty in spring.

SITE REQUIREMENTS

Experience shows that a good root hold is essential for this large and long-lived species, and that a well-drained porous soil is of especial importance for Douglas fir. This was noted by Hutchison as early as 1873 and emphasised by Kay and Anderson (1928) in their detailed comparison of Canadian and British stands of Douglas fir, both from considerations of good growth and good form and also for resistance to windblow (see p. 123). In many cases Douglas fir has done well on rocky land where the roots could penetrate the interstices. "On fertile loams it grows rapidly and is sometimes condemned for its rank growth and heavy branching; these, however, are conditions which appear to be corrected by time, for many fine crops have been raised on such soils. On lighter sandy soils, the growth is naturally slower, but the stems are almost invariably straight and the branches light. At the same time, it appears to be able to persist on light soils without exhibiting signs of butt rot which affects spruces and other conifers on this kind of land." (Macdonald, 1952).

Day (1955) quoting American workers, considered that an adequate water supply is an important necessity and concluded that although Douglas fir appears to grow on poor dry sites, these have in reality a good supply of moisture in the soil at the beginning of the growing season. Chalk (1951) suggested that in Britain the amount of late wood formed is related to the presence of an adequate water supply.

A controversy on the possibility of growing Douglas fir on calcareous soils ended in the conclusion that the superficial soil had been leached and was not particularly alkaline (Lawson, 1916; 1917; Somerville, 1917). In the Breckland, Norfolk, very good growth has been obtained on a moderate depth of sand over chalk, under a rainfall of about twenty-five inches per annum (Wood and Nimmo, 1955). On deep peat variable early results have been obtained experimentally after intensive preparation of the ground and manuring (Zehetmayr, 1954). On the upland heaths, results have been somewhat similar, and while Douglas fir is obviously intolerant of heathland conditions at the start, with adequate ground preparation, and after the suppression of the vegetation, it may have a future. Thus it has done well on "tough peat knolls" (peat over glacial drift soils) (Macdonald, 1953); and raised on single-furrow ploughing, with a nurse crop of broom (*Sarothamnus scoparius*) and phosphate fertiliser, it has reached 10 to 14 ft. in ten years and forms a promising crop in experiments at Wykeham, in Allerston Forest, and at Broxa, in Langdale Forest, both on the North Yorkshire moors near Scarborough.

ESTABLISHMENT TECHNIQUE

NURSERY PRACTICE. In general, the treatment is similar to that for other conifers, with the following special recommendations:—The seed should be stratified, two parts of seed being mixed with three parts of coarse sand for sixty to seventy days prior to sowing (Macdonald, 1935). Moist pre-chilling is advantageous (Holmes and Buszewicz, 1955).

In growing one-year seedlings, about 800 viable seed per square yard are usually sown, aiming at about 500 plants. With seed of average size and germinative capacity (say 45,000 seeds per pound and eighty-five per cent germination) one pound of seed is sown per forty-five square yards of seed bed.

Douglas fir responds to partial soil sterilisation (Holmes and Faulkner, 1953) but this is not usually necessary as seedlings grow fast. In the well-manured heathland and woodland nurseries, Douglas fir one-year seedlings often become too large, and the species is usually confined to agricultural nurseries with normal fertilisation.

Mineral spirit weedkillers may be used, but the species is rather sensitive and not more than about two-and-a-half pints per 100 square yards (fifteen gallons per acre) of White Spirit should be used.

Douglas fir seedlings are susceptible to early frost and sometimes benefit from the use of covering screens in early autumn.

VEGETATIVE PROPAGATION. For tree-breeding work, grafting may be done in the open, the scions being collected in March and early April, and stored in a cool moist atmosphere. For small stocks of pencil thickness and 9 to 15 in. tall, small scions may be grafted by the "veneer side" method, in mid-April to early May. For stocks $\frac{1}{2}$ to $\frac{3}{4}$ in. diameter and over

18 in. tall, the "apical veneer" method is suitable in the early season and the "rind graft" method later on. Stocks which are over $\frac{3}{4}$ in. diameter and 6 in. above the ground can be "top-worked". The root stock is cut back when the scion is fully active and the original tie needs replacement by July. A support is necessary for the top-worked plants. Depending on the quality of the scion, from 60 to 90 per cent success is usual.

Cuttings from trees up to five years old can be rooted, using either summer wood cuttings taken in July, or dormant cuttings taken in April.

PLANTING. The size, age and type of plant used varies with the site, and as great use is made of Douglas fir on good soils with heavy weed growth, a fairly large transplant is commonly grown. On fertile sites they are notched into the ground. On poor sites, methods of ground preparation suitable to the site must be employed, such as ploughing, and smaller plants are desirable. Douglas fir is normally a quick-growing species in early years. Manuring is not necessary on the normal planting sites, but may be required, for example, on upland heaths. As Douglas fir is considered to be a more tender species than the commonly planted pines, larches and spruces, it is usually planted late in the season, to avoid the droughts and cold winds of spring. It is especially sensitive on wet, cold soils.

SPACING. The question of spacing in the plantations has been more controversial with Douglas fir than most species. The possibility of restricting the coarse branching of some plantations, by closer spacing of the plants, has been argued with those who consider the coarseness due to unsuitable seed provenance, too rich a soil, and those who would eliminate it by pruning The problem of stability, and the desirability of wide spacing to permit adequate root-growth, influence the answer. And questions of the ultimate quality of the timber, and of the difficulties of disposing of the small thinnings resulting from closely-spaced crops, have all been considered. Little evidence is available from spacing experiments, of which few have been established. As a result, the usual spacing has been five to six feet, with a recent tendency, in common with all species, to economise by widening the spacing to seven or even eight feet.

In underplanting or planting in scrub, irregular or group planting is usual.

TENDING AND THINNING

WEEDING. Vigorous weeds must be cut back, but Douglas fir grows quickly and is able to stand considerable side shade, so that it is more able to overcome weed competition than most species.

THINNING. Thinnings commonly commence when the top height of the crop is about thirty feet, and this may be at an age of ten to twenty years or more, depending upon the rate of growth. There may be a tendency for a number of very coarsely branched, vigorous dominants to develop, to the detriment of surrounding trees. Early thinnings aim at the removal of these wolf trees and are usually made on a three-year cycle, this period being extended in more mature crops. The crowns of Douglas fir respond rapidly to thinning and on most sites height growth is very fast. Delay in thinning in the early life of a plantation may have serious consequences, and part of the reputation of Douglas fir for windblow must be attributed to the opening up of unthinned woods (Forestry Commission, 1951).

PRUNING. Many of the writers on spacing, who conclude in recent years that wider spacings (six feet or more) are on the whole advantageous, also recommend high pruning. Scott (1931) states that pruning is "necessary" but in fact it is usually not done. Some pruning experiments have been carried out, but are as yet incomplete. So far, they have shown that pruning has usually been started too late to ensure that the unpruned core is kept narrow, which means that pruning should be started very early, that it must reach up to almost half the height of the tree to keep the core small, and that pruning to this height probably does not affect the vigour of the tree. On the basis of these experiments, Zehetmayr (1954a), writing of conifers in general, proposed pruning to a height of 10 to 12 feet when the dominant trees are 22 to 24 ft. high, and a second pruning to 18 ft. when the trees reach 34 to 36 feet. In the case of fast-growing Douglas fir it may be appropriate to prune when the trees are rather taller.

One of the difficulties is to determine the minimum necessary number of stems to be pruned, which must be sufficient to ensure that the crop eventually consists of pruned trees; a further difficulty is to select the correct ones. Crown thinning is necessary to ensure that pruned stems are favoured. Pruning a higher proportion of stems would obviate part of the difficulties, but is objectionable on economic grounds, as pruning is costly. If the pruning of trees removed subsequently as thinnings made peeling easier, the economic objections would be reduced, but Zehetmayr (1952) found that this was not the case.

Pruning by disbudding has been tried experimentally, and though it has shown some signs of being successful for some species, it is not so for Douglas fir, which is much too sensitive to the loss of branches (Zehetmayr and Farquhar, 1956).

OTHER SILVICULTURAL CHARACTERISTICS

"The shade-bearing qualities of Douglas fir make it an excellent choice for underplanting, and it has been much used for re-stocking poor scrub areas

of oak and birch; its value for this work is enhanced by its relatively high resistance to honey fungus" (Macdonald, 1952). As a result, the distribution of the species is to some extent governed by the situation of oak scrub which has been converted to high forest, e.g. in Inverness-shire, Perthshire, Argyll, Kirkcudbrightshire, Caernarvonshire, Merioneth, Radnor, Somerset and Devon (Forestry Commission, 1952). Restocking has been carried out by various means, ranging from heavy fellings in over-wood or coppice, or even complete clearance in some cases, to the removal of only a small number of trees and the planting of Douglas fir wide apart or in small scattered groups.

In an experiment in Quantock Forest, Somerset, Douglas fir was planted in lines 6 feet apart at about 800 to the acre on three different kinds of site: (a) under oak coppice 30 to 35 feet high; (b) under similar coppice in which 400 of the largest stems per acre had been girdled, and (c) on a clear-felled area intended as a control. Only the planting under the thinned coppice gave a satisfactory result (Miller, 1951).

Douglas fir is also a good species for planting in derelict woodlands after partial cutting back of rhododendrons, because its dense shade and its quick early growth can suppress rhododendron regrowth (Murray, 1950)

Scott (1931) described methods of planting in birch or oak scrub which have advantages over planting on bare ground. In planting under birch scrub it was found sufficient to girdle the birch stems in the year of planting; losses after planting were less than on bare sites. Many successful Douglas plantations have been raised by this method.

Its success when underplanted amid scrub is due partly to its shade-bearing capacity, and partly to its need for protection against exposure and frost; Douglas fir does well when it can get away through the competing vegetation. It is not successful as a lower storey to another economic crop, and for such cases some more tolerant shade-bearer such as *Abies grandis* or *Tsuga heterophylla* is to be preferred.

A peculiarity of Douglas fir is its tendency to suffer from a late form of "check" when the plants appear to be well established and before they close canopy.

Douglas fir is somewhat difficult to manage in mixture, but Douglas fir and *Thuja plicata* at Gairletter, Argyll, grew satisfactorily, and attracted favourable comment (M'Beath, 1914).

RATE OF GROWTH AND YIELD

The current Douglas fir yield tables (Hummel and Christie, 1953) are based on records from 73 permanent sample plots. Quality Class I Douglas fir reaches a top height of 110 feet in fifty years, while the poorest Quality Class (V), reaches a top height of seventy feet in the same period. There are, however, one or two examples of it having been grown in mixture on still poorer sites. At Culbin Forest, Moray, for instance, Douglas fir in mixture with Corsican pine has only reached a top height of sixty-one feet in forty-eight years, the pine having a top height of fifty-five feet.

The total volume production per acre for Quality Class I at fifty years is 12,300 Hoppus feet, over bark, and that of Quality Class V is 5,700 Hoppus feet, a difference of 6,600 Hoppus feet In Quality Class I the periodic annual increment culminates at about eighteen years, from which point it falls off rapidly; it culminates at successively later years in the lower Quality Classes. The point of maximum volume production is reached at forty years in Quality Class I, at about fifty-three years in Quality Class III and at about sixty-two years for Quality Class V. The American yield tables (McArdle, 1949) show Douglas fir to have a slower rate of height growth for the first twenty years than in Britain, thereafter, it is as fast or faster. The point of maximum volume production for McArdle's Site Class II, the site class nearest to our Quality Class I, occurs between sixty and seventy years. The rapid early height growth of plantation-grown Douglas fir in Britain, compared with the slower early growth of the mainly naturally-regenerated Douglas fir in America, together with the effects of exposure discussed above, may to some extent explain why the point of maximum volume production is reached at an earlier age in this country than in America.

The British yield tables show that between forty-one per cent and thirty-six per cent of the total volume production will, by fifty years, have been removed in thinnings, depending on the Quality Class of the crop. The fastest-growing sample plots of Douglas fir have averaged 2.3 feet a year in height since they were planted. These plots are at Dunster, in Somerset and at Beaufort, Inverness-shire. Unfortunately, the latter plots were blown in the severe winter gales of 1952 and 1953, but their development to 1949 has been described by Mackenzie (1950). Christie (1955) discussed the two plots at Tortworth which at eighty-two and sixty-eight years had standing volumes per acre of 11,000 and 6,000 Hoppus feet over bark, and a total volume production of 12,800 and 7,200 Hoppus feet, respectively.

As there are only eight permanent sample plots older than fifty years, the data provided by these plots were not considered adequate to justify the extension of the yield tables beyond fifty years. There are, however, records of growth for several small stands of old Douglas fir, which give an in-

dication of the possibilities of this species in Britain, and trees with heights of over 120 feet are now becoming common, heights of over 160 feet having been attained in certain areas. A tree at Duncraig, Wester Ross, measured 180 feet high, with a breast-height girth of seven feet eight inches, in 1956, and one at Powis Castle, Montgomeryshire, had a height of 176 feet and a girth of thirteen feet four inches in 1954. One of the fastest-growing single trees, measured at Dunkeld, Perthshire, in 1955, had reached a height of 164 feet and a girth of nine feet one inch in sixty-seven years. There is a concentration of tall Douglas at Inveraray, Argyll, with many groups of trees mostly over 150 feet, while in Puck Pits Inclosure in the New Forest, Hampshire, the largest tree had a breast height girth of fourteen feet three inches, when measured in 1953.

In 1914, the stand at Taymount, Perthshire (Scott, 1913; Robinson, 1914) at fifty-two years of age had a top height of eighty-eight feet, 149 stems per acre, and a standing volume per acre of 6,640 Hoppus feet over bark. Thomson (1913) gave details of a fifty-eight-year-old plantation at Cochwillan, Caernarvonshire, which had a top height of 101 feet, and 119 stems per acre with a standing volume of 11,080 Hoppus feet over bark.

DISEASES AND PESTS

Douglas fir in Great Britain can generally be regarded as a healthy tree, for although it is subject to a considerable number of diseases, none of them has proved to be a limiting factor on its cultivation. The best-known fungal diseases of Douglas fir are the two needle casts, *Rhabdocline pseudotsugae* Syd. and *Phaeocryptopus gäumannii* (Rhode) Pet. The former was long thought to be confined to the Colorado and intermediate forms of Douglas fir in Great Britain, but has recently been reported on the green form as well. Colorado Douglas fir trees are attacked severely by *Rhabdocline*, and the proportion remaining free from attack is almost negligible. With coastal or green Douglas fir the proportion of trees severely attacked is very low, and the number that escape entirely is substantial.

The position with regard to *Phaeocryptopus* is very different. This fungus is generally present in the west of England, in Wales and in Western Scotland, and in those areas is far commoner than *Rhabdocline*. *Phaeocryptopus* occurs on all provenances, though on Colorado, and to some extent on intermediate forms, its presence is often masked by the more efficient defoliation caused by *Rhabdocline*. But the effect of *Phaeocryptopus* is only occasionally severe, and in many cases no appreciable defoliation results, the only indication of the presence of the fungus being that the trees are faintly yellow-green instead of deep green in colour. Thus, at present, neither of these needle diseases seriously affects the cultivation of Douglas fir in Great Britain (Forestry Commission, 1956).

On young Douglas fir, the stem fungus *Phomopsis pseudotsugae* Wilson, is occasionally troublesome, both in nurseries and in plantations which have not yet closed canopy. It causes shallow cankers and die-back. It is often associated with frost, extending the damage caused by that agency. (Forestry Commission, 1948).

Pole stage plantations in several parts of the country have suffered from resin bleeding, associated with cracks at the base of the lower live branches of the crown, and with dead patches of bark tissue. The cause of this trouble has not yet been found, but drought has been suggested as a possible explanation. Douglas fir is not seriously subject to drought crack, despite its frequently rapid growth. This is of interest, since with trees such as Sitka spruce or species of *Abies*, where drought crack often occurs, there is a distinct association between crack and growth rapidity.

In nurseries fast-grown seedlings are sometimes attacked by Grey mould (*Botrytis cinerea*). This causes die-back of the tips, and resultant bushy plants. It often follows autumn frost injury.

Douglas fir can be regarded as above average in resistance to our two principal root fungi, *Armillaria mellea* and *Fomes annosus*, the former killing young plants in the forest, the latter occasionally doing the same, but more often causing butt rot. Little is known yet about decay in older trees, but *Polyporus schweinitzii* has been recorded, causing red cuboidal rot.

Only two insect species are of common occurrence on Douglas firs in Britain. One of these, the Chalcid seedfly *Megastigmus spermotrophus* Wachtl., can be responsible for very serious seed losses, infestation figures of up to 100 per cent having been recorded. Control by spraying the forest floor with an insecticide such as D.D.T. has been suggested for seed orchards when the insects are emerging (Hussey, 1954). The aphid, *Adelges cooleyi* Gill., is very numerous and widespread. Although its sap-sucking activities produce leaf discoloration and distortion, general experience shows that the attacks have no serious repercussions on the crops. It is interesting to note that the Colorado Douglas fir is much more resistant to infestation than are the coastal provenances. (Forestry Commission, 1947).

OTHER FORMS OF DAMAGE

WINDBLOW. Douglas fir has long had a bad reputation for blowing down in storms, and after the hurricane of 1953, Andersen (1954) found it to be the most unstable of five species of conifers which he

was able to compare. Its susceptibility to windblow may be due less to any inherent instability than to the fact that it is one of the fastest growing conifers planted in Britain, and consequently it often outgrows surrounding plantations of other species, thus losing the benefit provided by their shelter. The exposure to wind is aggravated by the fact that the areas of Douglas fir are usually comparatively small, because conditions suitable for it do not often occur in large blocks (Lines, 1953). It is also often due to the fact that Douglas fir has been planted on soils too soft or too shallow to support it. Formerly, too, it was planted too closely, and sometimes the resulting stems would even bend over as a result of wind, and remain capable of being pushed upright again.

Of the ninety-five permanent sample plots of Douglas fir established since 1920, twenty-six have been windblown. Several others have been severely damaged, but are being retained for studies on the increment and subsequent development of crops damaged, but not completely destroyed, by wind. The majority of the plots that were blown were established prior to 1926.

ATMOSPHERIC POLLUTION. Scott (1931) remarked "It is damaged by smoke and fumes to a greater extent than any conifer at present in general use for planting, and is consequently quite unsuitable for industrial areas." Later experience confirms this conclusion.

SEED AND SEED-BEARING

American seed ranges from about 20,000 to 68,000 per pound, with a mean of 42,000, and the number per pound increases from south to north according to the provenance of the seed. (Dep. Agric., U.S.A., 1948.) In Britain, seed is smaller still, 46,000 to 120,000 per pound, with a mean of 69,000. Data are variable and are probably insufficient to give a reliable picture as yet. The yield of seed per bushel varies from 4 to 30 oz. (mean 14½ oz.); the purity of the seed, from 65 to 99 per cent (mean 87 per cent) and the germination percentage from 5 to 70, with a mean of 22 per cent. Generally the main source of loss is damage by *Megastigmus* flies, as noted above.

Douglas fir flowers in April, and seed should be collected in September. The first flowers appear at fifteen to twenty years of age and the first good seed-crop at thirty to thirty-five. The maximum seed production begins between the ages of fifty and sixty years, while good cone crops occur at intervals of five to seven years (Matthews, 1955).

GENETICS AND BREEDING

Registered seed sources comprise 26 "plus" and "almost plus" stands of about 122 acres, and 7 "normal" stands of about 40 acres. A total of 299 plus trees have been selected, 211 in Scotland, 72 in England and 16 in Wales.

Seed orchards are being established, and it is proposed to plant fifty acres between 1954 and 1963. These, it is estimated, may give 500 lb. of seed per annum after an age of fifteen years, which is about one-quarter of the total annual seed requirement in Britain.

NATURAL REGENERATION

Natural regeneration occurs sporadically from time to time, and was studied in detail by Jones (1945) in the New Forest. Examples are given by Guillebaud (1936) in Norfolk, where, in company with Scots pine and other species, good natural crops have been obtained, and there are many other similar cases. Natural regeneration is not, however, employed in the systematic management of woods in Britain.

TIMBER

The weight of the seasoned material is usually between 31 and 34 lb. per cubic foot. The heartwood is moderately resistant to decay, and there is evidence to suggest that fast-grown wood is less durable than slow grown. It is resistant to impregnation with wood preservatives and, as far as present experience goes, satisfactory penetration (even under pressure) can only be obtained by making incisions into the heartwood.

Strength tests have so far been carried out on mature timber and on three consignments of thinnings. It appears that home-grown Douglas fir is less strong than Canadian grown, but is still our strongest species in rigidity—an important property for structural timbers. It is compared in Table 47 below with Scots pine, which has roughly the same weight per cubic foot.

TABLE 47 STRENGTH PROPERTIES OF DOUGLAS FIR (PSEUDOTSUGA TAXIFOLIA) AND SCOTS PINE (PINUS SYLVESTRIS) lb. per square inch

	Modulus of Elasticity	*Bending Strength*	*Compression parallel to the grain*	*Shear*
Douglas fir (*Pseudotsuga taxifolia*)	1,300,000	2,100	1,500	200
Scots pine (*Pinus sylvestris*)	1,200,000	1,600	1,200	200

Formerly the timber did not find favour in Britain but "the second World War effectively removed the prejudice against this timber, which was difficult to sell during the inter-war years" (Macdonald, 1952). Opinions expressed by the home-timber trade and users indicate that it seasons and works well but dulls saws more rapidly than most softwoods and "picks up" when planed on a flat-sawn surface. It cleaves well. It kiln dries well, with some tendency to distort and for the appearance to be spoiled by resin exudation.

It has been used mainly for pitwood, estate work, but also for fibreboard manufacture, box making and in place of sweet chestnut for cleft fencing. It has also been used for joists in house building.

At present its status is only that of a general purpose softwood, but when more timber is available in sawmill sizes it may achieve a special place in structural work on account of its high strength-weight ratio.

POTENTIALITIES OF THE SPECIES IN THE NATIONAL ECONOMY

Douglas fir was one of the first western American exotics to be used as a forest tree in Britain, and its cultivation became very popular towards the end of the last century. Its use subsequently became less fashionable as its deficiencies became known; but in the great expansion of planting after the 1914-18 War it was again extensively planted. In recent years its popularity has diminished, though there is again a tendency to use it to an increasing degree on suitable sites.

For the future, "the tendency will be to use it with more discretion on the richer soils, and, by paying close attention to its silviculture, to reduce the risk of damage by wind. It will continue to be used in scrub areas, and, to some degree, in enriching poorly stocked hardwood crops. It may also find increasing employment in the afforestation of the drier *Calluna* heaths in the eastern part of the country where, in mixture with pine, it holds out some hope of promise" (Macdonald, (1952).

The timber has considerable possibilities and probably would be even more useful if the trees were pruned.

M.V.E.

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Saxegothaea Lindley

Saxegothaea conspicua Lindley. Prince Albert's Yew.

This species has been included in this list because it forms a tree, though a small one, in its native country —Chile and Patagonia. Under British conditions it is rarely more than a shrub occurring in gardens and shrubberies in various parts of the country and it is probably less common than it once was. Its yew-like foliage is not particularly attractive and, lacking decorative qualities, it is not likely to be used much in future. Individual small trees of over thirty feet have been recorded but, generally the plant is rarely more than five or six feet high. It thrives better in the milder parts of the country.

J.M.

Sciadopitys Siebold and Zuccarini

Sciadopitys verticillata (Thunberg) Siebold and Zuccarini

The Japanese Umbrella Pine, introduced in 1861, is a familiar object in arboreta and gardens, where it is always of interest. It is extremely slow growing and has no place in forestry. The tallest trees recorded in Great Britain are only 44 ft. in height, one at the Royal Horticultural Society's Garden at Wisley, Surrey, and one at Eastnor Castle, Herefordshire.

J.M.

Sequoia Endlicher

This genus contained two species *S. sempervirens* and *S. gigantea* but, following Rehder, we have placed the latter in the genus *Sequoiadendron*, leaving only one species in *Sequoia*.

Sequoia sempervirens (Lambert) Endlicher (Plate 17)

COMMON NAME

Redwood.

COUNTRY OF ORIGIN AND PROVENANCE

Sequoia sempervirens occurs naturally in a limited region near the Pacific Coast of the United States, mainly in California, but with a small extension into Oregon. It is found in a territory which is some 450 miles long and 20 miles broad.

Nothing is known about provenance differences in Great Britain.

HISTORICAL NOTES

This tree was discovered in 1795 by Archibald Menzies and rediscovered by David Douglas in 1831. The general opinion is that the redwood was introduced into Great Britain by Hartweg in 1846 although it is maintained by Elwes and Henry that the introduction actually took place in 1843 when seed was sent to Messrs. Knight and Perry by Dr. Fischer of St. Petersburg, who had received supplies from America. The first plantation of which we have knowledge is that at Leighton Park, Montgomery, which was formed in 1856, it is believed with plants which had been brought from America in pots.

EXTENT OF PLANTING

Although the redwood has been much planted as a specimen tree in parks, gardens, avenues, etc., it has been little used in forestry and there is only a very small area under this tree, mostly in small plots and clumps. In some places, *Sequoias* have been planted in broadleaved woodland but this use has not been extensive.

CLIMATIC REQUIREMENTS

One would say that this tree does best in the moister western districts of Britain but the existence of numerous tall and fine specimens in the south-east make one hesitate before making too firm a pronouncement. On the other hand, good specimen trees are usually found to be growing in particularly favourable sites and the quality of the site may make up, in many instances, for deficiencies in climate. From the evidence of specimen trees, it is apparent that this species generally grows better in the south although, again, there are several large and tall trees in Scotland. What little evidence we possess from plantations indicates that the rate of growth in the east is much slower than in the west, and experience has shown that the susceptibility to frost damage exhibited by this tree makes it difficult to establish in a plantation, except in relatively frost-free districts. It failed completely, for example, when planted in the open at Thetford in Norfolk.

SITE REQUIREMENTS

A sheltered site is necessary for the best growth because *Sequoia sempervirens* dislikes exposed conditions and flourishes only where it has adequate protection from the prevailing winds. In an extreme case, it suffered very badly from exposure when planted at an elevation of 1,200 ft. at Beddgelert, Caernarvonshire, and began to grow only when adjoining hardier crops developed sufficiently to give it shelter.

It does not like very acid soils and has failed altogether on *Molinia* peat. It seems to require a moist, though well-drained soil, and is at its best on fertile soils of the brown earth type.

ESTABLISHMENT TECHNIQUE

NURSERY PRACTICE. Standard nursery practice is adequate for sowing, but the seed is often of low quality and this must be allowed for. The percentage of empty seed is often as high as 80, and the number of seedlings is usually no more than 10 per cent of the viable seed. There is often difficulty in the autumn, because the seedlings are liable to be severely injured by frost, and most foresters find it necessary to cover their seedbeds to protect the seedlings at that time.

VEGETATIVE PROPAGATION. This is of some importance because of the difficulty of obtaining seed and its poor quality. Redwood can be propagated by cuttings but this method is not easy and occasionally leads to disappointment. The best practice is to take large cuttings, from 5 to 7 inches long, from first and second order shoots, and consisting of current years wood or wood one year old. Cuttings of this type, which are hard to find on mature trees, may be obtained by pruning 'stock' plants or using material from 'coppice' shoots. Insertion of cuttings in July gives the best results, but this can also be done in March and April. The speed of rooting has been increased by the use of electrical soil warming and by indolyl butyric acid (1 mg. per c.c. of 50 per cent alcohol).

PLANTING. Standard methods are adequate on the sites which are suitable for *Sequoia*.

SPACING. There is little information. On a good site where growth is likely to be rapid, wide spacings can be employed.

TENDING

WEEDING. Thorough weeding is advisable until the young trees start to grow rapidly. In old coppice, where *Sequoia* is sometimes used, the plants like the side shelter but their tops and leading shoots must be kept well clear of competing vegetation. No information is available on thinning or pruning.

OTHER SILVICULTURAL CHARACTERISTICS

Sequoia sempervirens is a good shade-bearer, and in suitable localities may be used for enriching old broadleaved woodland or coppice.

RATE OF GROWTH AND YIELD

On really favourable sites, the redwood makes remarkable growth and produces a greater volume in a shorter time than any other conifer. Table 48 gives details of the few plots which have been measured recently.

TABLE 48 SEQUOIA SEMPERVIRENS: GROWTH AND PRODUCTION

Location	*Age* yrs.	*Top Height* ft.	*Girth at breast height* in.	*Volume per Acre Hoppus ft. over bark*	*Total Production per Acre Hoppus ft., over bark*
Leighton, Montgomery	19	55	25	3,700	5,110
Dartington, Devon	20	61	33	4,195	7,145
Forest of Dean, Glos.	21	52½	26	3,665	4,527
Bedgebury, Kent	24	37	18½	1,610	1,995
Novar, Ross-shire	45	58	36	—	—
Leighton, Montgomery	94	111½	132	24,155	—

Certain features stand out in this table. In the first place, there is the remarkable growth of young crops on good sites at Leighton and Dartington, the latter in particular being one of the most striking plantations in the country. A good account of it has been given by Hiley and Lehtpere (1954). The plot at Bedgebury and the measurements from the clump of trees at Novar give an indication of the moderate performance of *Sequoia* on unsuitable sites. Lastly, the record of the old plantation at Leighton shows what this species can do on a good site as it grows older. Here the volume standing on the ground is greater than that of any other forest growth in Great Britain.

Of the numerous specimen trees in the country mention may be made of some of the tallest for which recent measurements are available. They include a tree of 141 ft. by 18 ft. 2 in. at Stourhead, Wiltshire, and another at the same place of 129 ft. by 16 ft. 7 in. At Leighton Knolls, Shropshire, there is a tree 138 ft. by 14 ft. 10 in. and elsewhere in the south of the country there are other specimens between 120 and 130 ft. in height. Heights are generally lower in the north.

OTHER FORMS OF DAMAGE

WINDBLOW. This tree is generally windfirm.

ATMOSPHERIC POLLUTION. *Sequoia sempervirens* is sensitive to pollution and cannot be used where this is at all pronounced.

SEED AND SEED-BEARING

Fertile seed is rarely produced in Great Britain and this may be due to lack of pollination as the male flowers are susceptible to frost damage. They are clearly visible in December and pollen is normally shed in February.

NATURAL REGENERATION

Regeneration by seed is highly unlikely, but this tree sprouts readily from the base after the stem has been cut, and it might be possible to renew the crop in favourable situations by these coppice shoots.

TIMBER

There is very little experience of the timber qualities of this tree. Hiley and Lehtpere say that thinnings of *Sequoia* have been used for sawn lattice hurdles for which they find are better than any other thinnings tried by the authors. They say that the timber is light in weight and saws easily without subsequent warping or splitting.

POTENTIALITIES OF THE SPECIES IN THE NATIONAL ECONOMY

These are limited but there is scope for the use of *Sequoia* on carefully chosen sites in view of its rapid growth and high yields.

J.M.

Sequoiadendron Buchholz

Sequoiadendron giganteum (Lindley) Buchholz (Plate 17)

COMMON NAME

This tree is generally known by the name of wellingtonia.

COUNTRY OF ORIGIN

It occurs locally in groves in Central California on the Western slopes of the Sierra Nevada, from Placer County to Tulare County.

HISTORICAL NOTES

The wellingtonia was introduced in 1853 by William Lobb who collected seed in the Calaveras Grove in California (Kent, 1900). A small quantity of seed was also sent home by Mr. J. D. Matthew in 1853 (Elwes and Henry 1906-13). In 1859, six to eight pounds of seed were collected in the Mariposa Grove by William Murray who sent it to Edinburgh (Murray 1860). Brown (1882) stated that "seeds are now obtainable in considerable quantities from time to time. Cuttings of this tree root freely and make very good plants".

Wellingtonia rapidly became popular as an ornamental tree and was planted all over the country, singly or in clumps or in avenues. Of the avenues, perhaps the most famous is that at Stratfieldsaye, Hampshire, the residence of the Duke of Wellington, planted in 1867-8, with plants raised from cuttings from a parent tree on the same estate, which must then have been quite young (Profit 1931).

EXTENT OF PLANTING

This tree has scarcely been used in the forest, only a few acres of plantation having been recorded.

CLIMATIC REQUIREMENTS

Based solely on the growth of avenue and specimen trees, the impression is that *Sequoiadendron giganteum* is much less restricted than *Sequoia sempervirens* by climate and seems to grow well in most districts of Great Britain. Notably, it grows much better in Scotland than the redwood.

SITE REQUIREMENTS

From the same evidence, wellingtonia is much less affected by exposure than the redwood and it stands out in the open in many situations where redwood would be damaged.

TABLE 49 SEQUOIADENDRON GIGANTEUM: GROWTH AND PRODUCTION

Locality	*Age yrs.*	*Top Height ft.*	*Mean Girth, Breast Height, in.*	*Volume per acre Hoppus ft. over bark*	*Total Crop Hoppus ft. over bark*
Bedgebury, Kent	20	28½	16	1,613	1,894
Novar, Ross	45	56	63½	—	—
Faversham, Kent	70	110	—	18,600	—

It seems to be fairly tolerant of soil conditions and will grow on most soils with the exception of wet acid peats. It is better suited to dry soils than is the redwood, and will grow to a good size on the sandy soils of the Bunter, the Eocene sands of the London basin and Hampshire, and the dry sands over the chalk in the Breckland district of Norfolk.

ESTABLISHMENT TECHNIQUE

NURSERY PRACTICE. Its behaviour is similar to that of redwood save that it is less likely to be damaged by autumn frosts.

VEGETATIVE PROPAGATION. It can be grown from cuttings by standard methods.

PLANTING. Wellingtonia is not an easy tree to establish in plantations and losses are frequently high after planting. It suffers badly if planting is followed by a spell of dry weather while it is frequently injured by the fungus *Botrytis* in the first year or two in the forest. No special techniques are required in planting.

SPACING. There is little experience to serve as a guide. It can be treated like the redwood.

TENDING

WEEDING. This must be thoroughly done because the tree suffers if close competition from weeds arises. It grows very slowly to begin with, often only a few inches a year, and weeding may have to continue over a lengthy period. No information is available on thinning or pruning.

OTHER SILVICULTURAL CHARACTERISTICS

The wellingtonia is less tolerant of shade than the redwood, and this limits its usefulness in undergrowth or in the enrichment of existing crops, for which otherwise it is suited.

RATE OF GROWTH AND YIELD

There is less information about this species than there is for the redwood and Table 49 gives what fragmentary data are available.

At Bedgebury and at Novar the growth of wellingtonia does not differ greatly from that of redwood while the crop at Faversham (Le Sueur 1945) shows that wellingtonia can produce extremely high volumes. At Leighton Park, Montgomery, there is a small stand in which 94-year-old wellingtonias are mixed with *Abies grandis* 30 years younger. Here the former have a mean height of 122 ft. and a mean breast height girth of 139½ inches, whereas the *grandis* at 64 years of age are 146½ ft. tall with a mean breast-height girth of 104½ inches. The volume per acre, both species combined, is 17,340 Hoppus feet.

Among the best specimens of wellingtonia are trees at Fonthill Abbey, Wiltshire, 165 feet in height by 24 feet in girth at breast height; 145 feet by 20 feet 11 inches in the New Forest; 138 feet by 20 feet 11 inches at Westonbirt, Gloucestershire. In Scotland there is a tree 151 feet by 22 feet 8 inches at Glenlee, Kirkcudbrightshire; one of 143 feet by 15 feet 10 inches at Murthly, Perthshire, and one of 138 feet by 20 feet 9 inches at Dunkeld. Specimen trees of wellingtonia seem to run to a greater height than those of redwood, and there is almost no difference in general height growth in wellingtonia between trees growing in Scotland and those in the south of England.

DISEASES AND PESTS

OTHER FORMS OF DAMAGE

WINDBLOW. Wellingtonia has a good record for wind firmness.

ATMOSPHERIC POLLUTION. Though it does not like a polluted atmosphere, wellingtonia is more tolerant than redwood and is not so easily injured by pollution.

SEED AND SEED-BEARING

Little seed is known to have been produced, but there is no obvious reason why trees in groups and avenues should not produce seed occasionally. The male flowers appear in December and the pollen is usually shed in April.

GENETICS AND BREEDING

Two possible seed sources have been registered and five "plus" trees have been selected and recorded.

NATURAL REGENERATION

There is no likelihood of natural regeneration in Britain.

TIMBER

There is no published information about the timber of wellingtonia in Great Britain.

POTENTIALITIES OF THE SPECIES IN THE NATIONAL ECONOMY

These are limited but there may be a place for this tree in old woodland areas where the growing stock requires to be built up. On really good sheltered sites it would probably be better to use the redwood, if trees of this type are wanted, but in less generous sites the wellingtonia would serve. Its custom of growing slowly for six or seven years after planting is a disadvantage in weedy places.

J.M.

SEQUOIA AND SEQUOIADENDRON: REFERENCES

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Taiwania Hayata

Taiwania cryptomerioides Hayata

A native of Formosa, introduced in 1920, this tree is too tender for general use. It has survived, with some protection, for thirty years in the National Pinetum at Bedgebury in Kent, but has made little growth.

J.M.

Taxodium Richard

Of the three species of *Taxodium* which are generally recognised, *T. ascendens*, *T. distichum* and *T. mucronatum*, only *T. distichum* will be mentioned here. None has been used in forestry, but *T. distichum* can reach a considerable size whereas *T. ascendens* is a slower growing tree much damaged by frost, and *T. mucronatum* is a rare and tender species.

Taxodium distichum (Linnaeus) Richard

The deciduous cypress from the Southern United States has a long history in Great Britain, having been introduced by Tradescant about the year 1640. It has been planted for ornament over a long period and has thriven well in the southern part of the country especially on the edges of lakes in parks and on the banks of streams. Many of the best specimens are found in the neighbourhood of London. Good examples are found at Syon House, Brentford; Burwood Park, Surrey; Wimbledon and elsewhere. Further afield there are large trees at Broadlands, Hampshire; Fairlawn, Tonbridge, Kent; Cobham, Kent, and Brocket Park, Hertfordshire. Several of these trees are more than 100 ft. in height and are of substantial dimensions; one of the trees at Burwood Park is almost 100 ft. high and has a girth at breast height of 16 ft. 8 in.

J.M.

Taxus Linnaeus

Yew, *Taxus baccata* Linnaeus, is one of our three native conifers of Great Britain and is familiar in most parts of the country, particularly in its numerous forms and varieties which are frequently used in churchyards, gardens and parks. One of the commonest of these is the variety *fastigiata*, the Irish or Florence Court Yew. The yew grows wild in woodlands on the chalk and limestone, particularly in Southern England.

Of the exotic species, *T. cuspidata* from Japan is not uncommon, but neither this tree nor any other species is as good as the native yew.

J.M.

Thuja Linnaeus

The genus *Thuja* is composed of six species, natives of the northern hemisphere and occurring in China, Formosa, Korea, Japan and North America. They include one tree of forest importance —*T. plicata*, and two species *T. occidentalis* and *T. orientalis*, mainly of arboricultural and horticultural interest, which are widely used for such purposes, but the others are of little account. *T. koraiensis*, a native of Korea, is rarely met with, although it is in cultivation; *T. sutchuenensis*, from China, has not been grown so far as we know; while *T. standishii*, a Japanese species, though of some interest, is not a common tree.

Thuja occidentalis, *T. orientalis*, and to a less extent *T. plicata*, vary in cultivation, and the first two species in particular have yielded a large number of horticultural varieties.

Thuja occidentalis Linnaeus

This tree is of some interest because it was possibly the first conifer to be brought in from North America. It was introduced in 1596. *T. occidentalis* has a wide range in eastern North America from Nova Scotia and New Brunswick, in the north, to Virginia and Tennessee, in the south, and extending westward into Michigan, Illinois, Minnesota and Manitoba. Although it has been in Great Britain for so long, it does not seem to have been used in the forest, and any prospect which it may have had in silviculture vanished when *Thuja plicata* appeared on the scene.

It is, nevertheless, a common ornamental and garden tree, either as the type or as one or other of its numerous varieties, and though none of these reach any great size they are mostly attractive specimens in cultivation. The tallest tree of which there is a recent record is one of 64 ft. in height in the New Forest and there is another specimen of 55 ft. at Burghclere, Newbury, Berkshire. In recent years one or two experimental plantations of *Thuja occidentalis* have been made in different parts of the country. At Bedgebury, Kent, a plot of this species 18 years old had reached 18 ft. in height, a satisfactory rate of growth but one which is greatly exceeded at the same place by *T. plicata.* which has grown nearly twice as fast. On a strongly podzolized sandy soil, at Wareham Forest in Dorset, in an area of moderate rainfall and relatively high summer temperatures, *T. occidentalis* was planted in mistake for *T. plicata* and with the help of a nurse of broom (*Sarothamnus scoparius*) grew quite well to reach a height of 14 ft. in 15 years. Now, however, growth seems to be falling off. On a thin rendzina soil over the chalk at Friston, Sussex, it grew slowly, about 7 ft. in 15 years, a height only half of that made by an adjoining plot of *T. plicata.* On another chalk site at Queen Elizabeth Forest, Buriton, Hampshire, growth was better on a slightly deeper soil over chalk, and a height of 12 ft. was attained in 15 years. In view of its frequent occurrence on swampy ground in its native country, it was tried on a wettish site at Beddgelert, Caernarvonshire, with a thin acid peat. Here it has grown irregularly but slowly. On an upland site, in some exposure, at Clocaenog, Denbighshire, *T. occidentalis* is only 7 ft. high after 14 years' growth and its foliage is thin and weak.

Thuja orientalis Linnaeus

This species is often distinguished by the name *Biota*, one of the divisions of the genus *Thuja*, characterised by cone scales which are fleshy when young and woody and hooked when mature, by the wingless seeds and by erect branching. A native of China, it was introduced into England early in the eighteenth century. Along with its varieties, it is grown solely for ornament and though, in many cases, decorative, it nowhere reaches any size. It has been tried in the forest both at Bedgebury and at Beddgelert and has been unsatisfactory at both places.

Thuja plicata Lambert (Plate 12)

COMMON NAME

Western red cedar is a name which is now gaining currency, having displaced the older soubriquet of arbor-vitae. Among foresters the tree is generally referred to as "thuja". The accepted name for the timber is western red cedar.

COUNTRY OF ORIGIN AND PROVENANCE

This tree has a wide distribution in Western North America, extending from Alaska southwards through British Columbia, Oregon and Washington into California. It occurs down to the sea on the Pacific Coast and extends inland as far as Idaho and Montana. The provenance of *Thuja plicata* has not been studied in Great Britain. Imported seed has come mainly from British Columbia, but much of our requirements are collected at home as there are usually good supplies of seed.

HISTORICAL NOTES

Née, who accompanied Malespina on his voyage round the world in 1789-94, brought back a specimen which was described by Don. Archibald Menzies also gathered specimens at Nootka Sound in 1795.

The first introduction was not made until 1853 when William Lobb sent a consignment of seed to Messrs. Veitch of Exeter. This seed had been collected in 1852 during a journey to Oregon and the Columbia River (Veitch 1906). *Thuja plicata* seems to have been used for ornamental planting soon after its introduction and it has never lost favour for this purpose. Probably the first occasion on which it was used in forestry was in the planting of a wood at Benmore, Argyll, in 1876-77 (McBeath 1914). Between then and 1919 it was used as a forest tree to a limited extent, generally in small plots, but it was not infrequently employed as an edge tree to plantations of other species. It was used in formal avenues and became quite popular as a hedging plant.

TABLE 50 THUJA PLICATA: AREAS BY AGE-CLASSES AND OWNERSHIP, 1947 Acres

	Age Class, Yrs.							*Uneven-aged*	*Total*
	1–10	11–20	21–30	31–40	41–60	61–80	81–120		
Private Woodlands	65	27	63	99	31	21	9	88	403
Forestry Commission	72	97	72	30	3	—	—	19	293
Total	137	124	135	129	34	21	9	107	696

EXTENT OF PLANTING

Thuja plicata has not been widely planted in Great Britain, for the Census of Woodlands 1947-9 revealed only about 700 acres, analysed by age-class in Table 50.

Recent years have shown an increasing use of *Thuja plicata* by the Forestry Commission, the annual reports of which show that in the years 1951-55 approximately half a million plants per annum were used for new planting and beating up.

CLIMATIC REQUIREMENTS

Nothing clearly emerges from a study of the growth of *Thuja plicata* in Great Britain to suggest any limitation imposed by our climate, at least within the range of sites where tree growth is possible. The general impression is that in the milder, moister districts of the west and south-west this tree shows greater vigour than in the drier south-eastern counties, although there the effect of climate may be offset locally by peculiarly favourable site conditions. *Thuja plicata* grows well quite far north in Scotland.

This species has not been used in exposed situations and we have little evidence as to its capacity to resist exposure.

In its youth, *Thuja plicata* is apt to suffer from frost but it is not one of the most susceptible of the conifers in common use in this respect.

SITE REQUIREMENTS

Thuja plicata has been planted on a wide range of soils in Britain, including the extremes of acid peat and the highly calcareous soils of the chalk, and it is clear that it is a tolerant species although its performance naturally varies according to the character of the soil. On peat, it has been tried experimentally (Zehetmayr 1954), largely because it is known to tolerate muskeg conditions in its native country, and though the results have not been spectacular, there is promise enough to justify further trials. On chalk, at Friston in Sussex, *Thuja plicata* has grown at the rate of a foot a year for the first fifteen years and seems to be maintaining its growth on a thin rendzina soil; at Buriton, also on chalk, it has grown rather less well, but it is on a more exposed site. One cannot expect trees of any great dimensions on these dry sites but it is interesting, nevertheless, to know that at least a pole crop is possible on chalk. On heavy clays, such as those in the midlands of England, it grows slowly but appears healthy. In Rockingham Forest, Northamptonshire, on an old woodland site, it reached 20 ft. in 23 years; planted on abandoned arable land nearby, it did not grow so well and it is 3 ft. shorter. At Thetford, in Norfolk, in a low rainfall and on a dry sand over the chalk, it failed completely when planted in the open, but is now establishing itself where it has been replanted under the shade of birch and alder (Wood and Nimmo 1955). In the same district, at Weasenham, *Thuja plicata* has been successful (Guillebaud 1936). Heavy losses after planting have been reported on very dry sites and also where the ground has been waterlogged, and it is probable that on the more extreme sites establishment may be difficult, although, once established, the trees may grow reasonably well. It appears that *Thuja plicata* requires for its best development sheltered sites with a deep, freely-drained yet moist soil, and that these sites are more likely to be found in the west of the country.

ESTABLISHMENT TECHNIQUES

NURSERY PRACTICE. *Thuja plicata* responds well to standard treatment in the nursery and no special precautions are necessary. It is usually sown broadcast, 1 lb. seed covering 45 sq. yd. of seedbed, and the seedlings are usually fit for lifting at the end of the first growing season. One-plus-one transplants, or one-plus-two when larger plants are wanted, are usually satisfactory. The fungus *Keithia thujina* causes severe damage in the seedbeds and transplant lines and has made it nearly impossible to raise *Thuja plicata* in many nurseries.

VEGETATIVE PROPAGATION. Grafting is not normally used as *Thuja plicata* is easily propagated by cuttings. Although this method of reproduction is not normally used in nursery practice, a limited amount of vegetative propagation is being undertaken because summer wood cuttings, taken in July, afford a means of reproducing individuals with resistance to *Keithia thujina*. For this purpose, cuttings should be free from disease and should consist of current year's wood from four to six inches long, taken with a heel of older wood. Good results, up to 70 or 80 per cent of success, can be obtained in unheated frames and without using growth-promoting substances, but the use of low voltage electrical soil warming, and of applications of indolyl butyric acid in alcohol at the rate of one milligram per cubic centimetre of 50 per cent spirit, has increased the speed of rooting and raised the proportion of cuttings actually taking root. Many of the cuttings, inserted in July, should be rooted by mid-September, and these should be lined out into well prepared nursery soil in the autumn. The remaining cuttings will root during the following spring and can be lined out in late April and May.

PLANTING. Standard methods are adequate and no special techniques are required.

SPACING. If spacing is too wide, it is apt to delay the formation of canopy for an inordinately long time because the tree has a narrow pyramidal shape and does not spread outwards very rapidly. Wide

spacing should therefore be avoided. Normally it is planted at spacings of 4½ or 5 feet.

TENDING AND THINNING

WEEDING. There are no special features. *Thuja plicata* withstands shade but it must be kept clear of weeds in its early stages.

THINNING. Not enough experience is yet available to enable foresters in Great Britain to have worked out any special thinning regime for *Thuja plicata*, if, indeed, that is necessary. Moderate low thinnings are usually carried out because a really heavy thinning would delay the re-forming of canopy for a long time, although this species is not slow as, say, Lawson cypress, to respond.

PRUNING. Pruning is not usually practised although it might be used with advantage if it could be done cheaply. *Thuja plicata* retains its branches for a long time and knots have been found to be troublesome when the timber comes to be worked.

OTHER SILVICULTURAL CHARACTERISTICS

Thuja plicata is tolerant of shade and is therefore suitable for use in underplanting old oak and birch coppice and scrub. It has also been used successfully for underplanting European larch and there are good examples of this at Dymock, Gloucestershire (Plate 12) and Haldon, Devon.

It is also a good 'mixer' because its habit of growth does not lead it to interfere with its neighbours, and also because its rate of growth permits it to keep pace with several other species without outgrowing or suppressing them, while its shade-bearing capacity allows it to live with faster-growing trees. In the old plantation at Benmore, already referred to, it grew in mixture with Douglas fir, the Douglas being 70 ft. high and the *Thuja plicata* 60 ft., while more recently Evans (1950) has drawn attention to a mixture of *Thuja plicata* and European larch. It may be suitable for 'enriching' understocked broadleaved woodlands.

TABLE 51 THUJA PLICATA: GROWTH AND PRODUCTION

Location	*Age of Crop*	*Main Crop*			*Total Crop Vol. per acre Hoppus ft., O.B.*
		Top height	*Mean Girth*	*Vol. per acre Hoppus ft. O.B.*	
	yrs.	*ft.*	*in.*		
Dunster, Somerset	20	55	24½	2,381	3,436
Corris, Montgomery	23	47½	18½	3,080	4,325
Gwydyr, Caernarvonshire	25	41½	20	2,170	3,001
Bedgebury, Kent	26	45	18½	1,539	1,993
Monaughty, Moray	27	50	21	3,543	—
Barcaldine, Argyll	28	51	20	2,572	—
Dunster, Somerset	34	59½	29	2,629	—
Caerphilly, Glamorgan	34	52½	22	2,873	—
Haggerston, Northumberland	34	55½	25	3,753	5,478
Dunster, Somerset	35	78	35½	7,708	—
Dunach, Argyll	35	47	26½	3,761	—
Caerphilly, Glamorgan	36	51½	20	3,561	—
Stanage Park, Radnor	37	66	35½	7,378	—
Ffrwdgrech, Brecknockshire	37	62	26½	4,331	—
Forest of Dean, Gloucestershire	38	59½	29	3,400	—
Forest of Dean, Gloucestershire	38	70	32	3,376	—
" " " "	39	69½	31	3,874	5,602
Caerphilly, Glamorgan	40	58½	22½	2,740	—
Darnaway, Morayshire	41	61½	28	4,348	—
Wintringham, Yorkshire	42	47	24½	4,876	—
Essendene, Lincolnshire	43	51½	19	4,862	—
Novar, Ross-shire	43	79½	38½	4,830	12,388
Dalbeattie, Kirkcudbright	44	63½	22	4,006	6,714
Dunterton, Cornwall	46	72	33	5,248	—
Alice Holt, Hampshire	48	65½	35	4,180	7,161
Novar, Ross-shire	51	79	30½	6,521	11,130
Inveraray, Argyll	66	103½	46	9,810	—

As a 'nurse', and as a tree for mixing with oak in young plantations, *Thuja plicata* has certain merits, not the least of which is the shape of its crown which does not spread out and damage young oak trees in its immediate neighbourhood. In view of its growth on some of the calcareous soils, it may have a use as a species for mixing with beech in the early years of the rotation.

One other point, though scarcely silvicultural, which may be mentioned is the habit which this tree has, when grown as a single specimen in the open, of layering when the lower branches touch the ground. This may be repeated once and even twice.

RATE OF GROWTH AND YIELD

No yield tables have yet been prepared for *Thuja plicata* and the rates of growth have not yet been grouped into Quality Classes. From the evidence in our possession, it is clear that though it grows rapidly in many places *Thuja plicata* is not one of the fastest growing exotics in Great Britain, and is easily surpassed by Douglas fir, Sitka spruce and *Abies grandis*. Although its height-growth is not exceptionally fast, it seems to be able to make rapid diameter growth on favourable sites and this, together with its capacity to stand in dense crop without serious detriment, produces occasionally some exceptionally high-yielding stands. For example, a plot at Stanage, Radnor, 37 years old, growing in a sheltered site on a shallow rich loam over the Devonian, had a top height of 66 ft., which in itself is not exceptional; but with 620 trees to the acre and a mean breast-height girth of 35½ in., it had a standing volume of 7,380 Hoppus ft. per acre. The basal area per acre reached the extremely high figure of 335 sq. ft. (Hoppus). Table 51 gives details of a number of sample plots of *Thuja plicata* which have been measured recently.

COMPARISON OF FOUR NORTH-WEST AMERICAN SPECIES IN THE FOREST OF DEAN

TABLE 52

Species	*Mean Height 1953 ft.*	*Mean Height 1956 ft.*
Thuja plicata	14.9	20.5
Tsuga heterophylla....	15.5	20.5
Douglas fir (*Pseudotsuga taxifolia*)	11.9	17.5
Sitka spruce (*Picea sitchensis*)	9.7	15.0

As an example of the early growth of *Thuja plicata* compared with that of other Pacific coast species, *Tsuga heterophylla*, Douglas fir and Sitka spruce, the figures in Table 52 may be of interest. They relate to an experimental plantation set out in the Forest of Dean in 1942 in which a 'north-west American mixture' was used; it was made up of these four species planted in staggered groups of 16 trees each, the object being to secure eventually an intimate mixture of all four:

There are numerous fine specimens of *Thuja plicata* in many parts of the country; among these the following may be mentioned—Bicton, Devon, 129 ft. by 17 ft. 6 in. girth at breast height; West Dean, Sussex, 117 ft. by 10 ft. 6 in.; Benmore, Argyll, 118 ft. by 10 ft. 8 in.; New Forest, 115 ft. by 13 ft. 3 in.

DISEASES AND PESTS

Thuja plicata is very severely affected by the fungus *Keithia thujina* in the nursery, and the heavy damage caused by this fungus has seriously restricted the production of stocks for planting. Young crops in the forest are also damaged from time to time. Research is proceeding at present on the life history of *Keithia* and it is hoped that this will enable us to make an attack on the fungus which has, so far, proved difficult to control by spraying. Attempts which have been made to keep isolated nurseries free from the disease have been only partially successful.

There is no specific insect pest on *Thuja plicata* in Great Britain and, generally, the tree is remarkably free from injury from this source.

OTHER FORMS OF DAMAGE

WINDBLOW. *Thuja plicata* does not have a bad reputation for windblow and in most situations it stands up well. It is not often broken by strong winds. Plantations have been overthrown by severe gales but this species has suffered no worse than many others on those occasions.

ATMOSPHERIC POLLUTION. This tree is sensitive to atmospheric pollution and is unsuitable for use in a polluted atmosphere.

FROST. The glazed frost of 1940 (Sanzen Baker and Nimmo 1941) did not damage *Thuja plicata* seriously, except where the tree was growing at high elevation.

DEER. *Thuja plicata* is occasionally damaged by deer which select it for rubbing.

SEED AND SEED-BEARING

Thuja plicata is a free seed bearer in Great Britain, giving some seed almost every year, with good seed crops occurring approximately at three-year intervals. First flowering takes place between ten and fifteen years of age, and seed crops worth collecting are obtainable after twenty years. Maximum seed production probably takes place between the ages of 40 and 60 years (Matthews 1955).

Flowering takes place in late March or early April. Seed can be collected in an early year in August, and in October in a late year. Normally it is gathered in September.

Home-grown seed of *Thuja plicata* averages about 350,000 per lb., with a range for 53 samples of 170,000 to 580,000. The average germination capacity is 40 per cent.

GENETICS AND BREEDING

The following seed sources have been recorded up to the present time in Great Britain: 'Plus' and 'Almost Plus': seven stands extending to twelve acres; 'Normal': six stands, totalling fourteen acres.

Twelve 'plus' trees have been selected and recorded, two of which are being tested for resistance to *Keithia*.

NATURAL REGENERATION

Natural regeneration is not practised. Seedlings of *Thuja plicata* are not infrequent in our plantations and eventually it may be possible to regenerate some of our *Thuja* crops naturally.

TIMBER

The timber of *Thuja plicata* has been used in Great Britain mainly for estate purposes and some users have referred to its suitability for gate-making on account of its lightness and durability in the open. Some timber merchants have reported that they have used it to a limited extent for the framework of portable buildings and for roof boarding. It is also used, like other conifers, for fencing and mining timber.

Within recent years, a small number of tests has been carried out at Princes Risborough on the timber of *Thuja plicata* grown in this country in which one or two consignments of thinnings, as well as some mature timber, were examined (Anon. 1955). It was found that air seasoning takes place slowly without any serious defect and that the timber kiln seasons well with a slight tendency to collapse. The timber of *Thuja plicata* is the lightest of all the home-grown softwoods so far tested, as it weighs only 24 lb. per cubic foot. The outer heartwood is highly resistant to decay, but the timber, as a whole, is difficult to treat with preservatives, even under pressure. Cartwright (1941) has reported that the resistance to decay of home-grown western red cedar wood is of the same order as that of the imported timber.

Strength tests, carried out so far, indicate that home-grown *Thuja plicata* timber is probably stronger than timber grown in Canada. It works well with thin-edged hand and machine tools, provided they are kept sharp, but dead knots may be troublesome and spring wood is apt to crumble. The timber cleaves well, but bruises easily.

It is a good softwood for use outdoors where durability and low weight are primary considerations.

POTENTIALITIES OF THE SPECIES IN THE NATIONAL ECONOMY

Thuja plicata is undoubtedly a tree which deserves wider use than it is now possible to give it, for it has many qualities which make it suitable for our conditions and requirements. If it became possible once more to raise it in quantity without the ravages of *Keithia*, it would be planted more freely.

Thuja standishii (Gordon) Carrière.

This tree, introduced from Japan about the year 1860, does not grow with any rapidity in Great Britain and is not common. It has not been tried in the forest.

A hybrid between this species and *T. plicata* produced in Denmark is reported to be resistant to attacks of the fungus *Keithia thujina*.

J.M.

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Thujopsis Siebold and Zuccarini

Thujopsis dolabrata (Linnaeus filius) Siebold and Zuccarini

One of the most important coniferous trees of Japan, *T. dolabrata*, or Hiba, was not introduced into Great Britain until 1853, although it had been first collected by Kaempfer as long ago as 1712. It quickly became popular as an ornamental evergreen

and that popularity it has not lost, for it is still being planted; it makes a handsome and decorative shrub or small tree, which grows well on a wide variety of soils, except those rich in lime. According to Dallimore and Jackson (1948) it is best raised from cuttings which give more uniform and faster growing stock than can be obtained by sowing. It has no future as a forest tree in Great Britain. Individual trees of *Thujopsis* have reached a height of 50 feet or more and, among the tallest specimens recently measured, the following may be mentioned: Westonbirt, Gloucestershire, 56 feet tall by 3 ft. 2 in. in girth at breast height; Stratfieldsaye, Hampshire, 52 feet by 2 ft. 10 in.; Benmore, Argyll, 50 ft. by 3 ft. 4 in.; West Dean, Sussex, 50 ft.; Eastnor Castle, Hereford, 48 ft. and Inveraray, Argyll, 47 ft.

J.M.

Torreya Arnott

Various introduced species of *Torreya* are found in parks and gardens in Great Britain, the commonest being *T. californica*, and *T. nucifera*. These two species occasionally form small trees, but generally *Torreya* occurs with us as a bush and that only in the milder districts.

J.M.

Tsuga Carrière

The genus *Tsuga*, the hemlocks, includes ten known species and one natural hybrid which are found in temperate North America, Japan, Formosa, China and the Himalaya (Dallimore and Jackson, 1948). Only *T. heterophylla*, the western hemlock from north-west America, is of economic importance in Great Britain. No other species is of forest importance with us, and few are found commonly as individual trees in gardens. With the possible exception of *T. mertensiana* there seems no likelihood of any extension of their use.

T. canadensis (Linnaeus) Carrière

This, the Eastern hemlock, which has a wide distribution in Canada east of the Rocky Mountains and in the eastern United States, was introduced to Britain by Collinson in 1736. It was the first species of the genus to arrive in this country and it has been widely planted as an ornamental tree. Although it is an important forest tree in its native country, eastern hemlock has not been successful as such in Britain, mainly on account of its forking habit and because it is always round-headed when grown here (Jackson, 1946). One of the largest specimens is at Leaton Knolls, Salop, which measured 105 feet and had a girth of nine feet; another specimen at Hardwick, Bury St. Edmunds, Suffolk, was 114 feet tall with a girth of eight feet two inches. Both trees were measured in 1954.

T. caroliniana Engelmann

This is a tree of limited natural distribution in the mountains of south-west Virginia and Georgia in the United States of America. It was introduced in 1886, but only grows slowly in this country and there are no large trees. Probably the tallest tree is at Grayswood Hill, Surrey, which was fifty-three feet tall in 1955. In a small plot at Crarae, Argyll, the trees have a mean height of just under three feet at twelve years of age.

T. chinensis (Franchet) Pritzel

Introduced by Wilson in 1900, this hemlock from central and west China has made slow growth as a specimen tree, and only occasionally are small examples found. It suffers from spring frosts.

T. diversifolia (Maximowicz) Masters

This northern Japanese hemlock was introduced in 1861 and has rarely formed more than a shrub in Britain. There is a small plot at Crarae with a mean height of six feet at eighteen years of age. Two of the largest specimen trees are at St. Clere, Kent, and Glamis, Angus. In 1955 the St. Clere tree was 33 feet in height and had a girth of three feet eight inches, while the Glamis tree was forty-four feet tall.

T. dumosa (D. Don) Eichler

This hemlock was introduced in 1838 from the Himalaya but it does well only in the milder parts of the country. A specimen sixty-eight feet tall was recorded at Boconnoc, Cornwall, in 1931. There is a small plot at Crarae which measured less than three feet at eighteen years of age.

Tsuga heterophylla (Rafinesque) Sargent (Plate 13)

COMMON NAME

Western hemlock. Both the timber and the tree are known by this name in Britain.

COUNTRY OF ORIGIN AND PROVENANCE

The Western hemlock comes from western North America and has a natural range from approximately latitude 63°N in Alaska to 40°N in California. It occurs on the islands and seaward slopes of the coastal mountain ranges in Alaska and northern and central British Columbia, penetrating inland along river valleys to the limit of abundant rainfall, from sea level to an elevation of 2,000 to 3,000 feet. It is found extensively throughout southern British Columbia and also appears in south-west Alberta, north Idaho and western Montana. In Washington and Oregon it occurs over the whole of the western areas up to elevations of 5,000 feet, and extends to the east of the Cascade mountains. In California it occurs in the fog belt west of the Coast Range (Sudworth, 1908; Galoux, 1951).

The provenance of Western hemlock has not been studied in detail in Britain and no experiments to compare different provenances have yet been established. Wood (1955) suggests that the climax species of north-west America (including *T. heterophylla*) will probably not vary so much as the early succession species, and that seed from the Queen Charlotte Islands should prove a suitable source for most planting sites, with Alaskan material for colder and more exposed places. Although Wood reports that he found no evidence of stem fluting based on regional distribution, Heintzleman (1949), writing about the Alaskan forests, points out that "on the whole the quality of the hemlock and spruce timber on the south (Alaskan) coast is poorer than that of Washington and Oregon . . . more of the hemlocks have a 'fluted' base that extends upwards. . . . However, there are many stands of excellent trees and good individuals in the poorer stands". This emphasises the need for careful selection of parents and of suitable localities in collecting seed of this species. Hiley (1950) suggests that seed procured from near the mouth of the Fraser River in British Columbia would be fairly suitable for Britain as a whole.

HISTORICAL NOTES

The Western hemlock was discovered in 1826 by David Douglas. It was not introduced to Britain until 1851, when seed was sent by Jeffrey and distributed to members of the Oregon Association. Ten years later, a collection of seed was sent by Brown from the British Columbian expedition (Hutchison, 1880). The plants raised from these seeds were planted as individual trees and many grew fast and remained healthy. Hutchison records many of these trees, and singles out for special mention a tree raised from the 1851 seed introduction and planted by Mr. Patton at The Cairnies, Perthshire, as being twenty feet tall in 1861 and forty-six feet in 1879. The tree was not affected by the severe winter of the "memorable year" of 1860 although other young stock was killed.

After its introduction, the demand for western hemlock became great, and plants were scarce, but in 1882 Brown stated that the "plants are now comparatively plentiful in the country". It had to wait rather longer before it was used as a forest tree than most other new trees introduced in the nineteenth century, and Anderson (1950) suggests that its "deceptive air of delicacy" may have kept it from being used earlier in the forest. The first plantation was probably at Blantyre Wood, Inveraray, Argyll, where thirty trees were planted in 1888.

EXTENT OF PLANTING

The total area of Western hemlock in Britain is relatively small and the 1947-49 Census of Woodlands revealed 1,076 acres of woodlands over five acres in extent. Of this total 198 acres were in England, 548 acres in Scotland, and 330 acres in Wales; approximately fifteen per cent of the area was privately owned. Table 53 below gives details of the age-classes:

No accurate data are available for areas planted with Western hemlock since 1949, but it is estimated that from 1950 to 1955, about 1,800 acres have been planted by the Forestry Commission. There are no figures available for the area planted by private estates during this period, but the acreage is probably not large.

CLIMATIC REQUIREMENTS

Wood (1955) reports on Western hemlock that "for this species as a whole it is not possible to suggest any broad climatic limitation which is likely to operate in Britain. Plainly its "abundance distribution" shows that moisture is a big factor with it but the climatic moisture limit is probably not found in our conditions. No doubt its sensitivity to moisture in the site might be more noticeable in our drier east". This agrees with Macdonald (1952) who states that it prefers the oceanic climates of northern and western districts of Britain and that it differs from Douglas fir in being less suited to the climate of the dry eastern and south-eastern regions.

Western hemlock withstands low temperatures but is susceptible to spring frosts. Damage is usually confined to the tips of side shoots and the leaders, but the species shows excellent powers of recovery.

TABLE 53 TSUGA HETEROPHYLLA: HIGH FOREST AREAS, PURE AND MIXED STANDS COMBINED, BY AGE-CLASSES, 1947 Acres

Ownership	*Age-class*						*Uneven aged*	*Total*
	1–10	11–20	21–30	31–40	41–80	80+		
Privately owned woodlands	18	32	60	14	22	—	24	170
Forestry Commission	464	178	19	—	2	—	243	906
Total	482	210	79	14	24	—	267	1,076

In its early stages it does not withstand exposure and can suffer defoliation, but there are examples of plantations in Wales and Scotland affected in this way, which have recovered in recent years; thus the tree may be more resistant to exposure than originally thought (Macdonald, 1952; Zehetmayr, 1954). It appears to withstand the effects of salt sea winds, as occasional plantations are to be found along the west coast of Scotland within a few hundred yards of the sea there being a good example on Cumlodden Estate, Argyll. The species is resistant to snow damage.

SITE REQUIREMENTS

Western hemlock appears to grow well on a wide variety of sites but it thrives best on the lower, moist but well-drained sites, as for example, the sides of sheltered valleys, and in this respect it resembles its native associate Douglas fir. Anderson says that "it prefers deep fresh soils but seems to be able to grow well on wet sites and even on very dry ones if they are not too loose, as well as on somewhat infertile soils provided it has the benefit of shade and of moisture in the atmosphere". Trials made on deep peat show promise, and where canopy has closed, growth has increased rapidly (Zehetmayr). On the poorer dry heaths, western hemlock has not done well when planted pure, but with a broom (*Sarothamnus scoparius*) nurse and the use of phosphate, early growth has been satisfactory (Nimmo, 1953). It also responds to nursing by pine, and on a dry heath on the infertile Bagshot Sands at Ringwood, Hants., it is now growing through a Scots pine nurse after the usual slow start. This is on a site where *Pinus contorta* is growing very slowly and looking unhealthy. Like many other conifers it does not tolerate limestone soils, but it grows well on slightly acid sites where the danger of heart rot (*Fomes annosus*) may also be less. At Bedgebury, Kent, a plot of Quality Class I western hemlock is growing on an acid silty soil where the mean annual rainfall is thirty-one inches.

ESTABLISHMENT TECHNIQUE

NURSERY PRACTICE. Treatment is similar to that for other conifers. Seed sowing is carried out in spring and as the seedlings produce their best development in well-manured humose sandy soils, most of the sowing now takes place in heathland or woodland nurseries. As growth is slow, sowing should be completed before the end of March to ensure the production of usable one-year seedlings. A broadcast sowing density of sixty square yards of seedbed per pound of seed, of sixty per cent germination, is recommended. It is essential to cover the seed with a very light $\frac{1}{8}$ to $\frac{3}{16}$ inch covering of coarse angular sand to ensure maximum seedling production. Overhead covers of laths are used in the south of England to prevent sun scorch and autumn covers are also needed in most nurseries to prevent early frost damage.

The usual spacing when lining-out is nine inches by two inches, and the customary ages for planting stock are one-year-one-year and two-year-one-year.

DIRECT SOWING. This method is not used in practice. Experimental work on a heathland area at Allerston, Yorkshire, was unsuccessful.

PLANTING. The use of large plants is generally restricted to the fertile weedy sites, or for underplanting, and smaller plants are preferred for ploughed ground. Planting under a light shade of, for example, birch, appears to be beneficial but not essential. Manuring is used only on the poorer heaths and wet peats where the species shows a slight response to phosphate (Zehetmayr).

SPACING. The usual spacing for western hemlock is five feet although on poor quality sites the spacing is often reduced to four-and-one-half feet. On very fertile sites the spacing can be increased to six feet but should not be extended beyond this limit.

TENDING AND THINNING

WEEDING. Normal precautions against weeds need to be taken.

THINNING. Hemlock is a fast growing tree in Britain and on Quality Class II sites reaches thirty-eight feet in twenty years. Most of the thinning done has been low thinning carried out to a moderately heavy grade and this has proved satisfactory. In view of the shade-bearing abilities of the tree, it is surprising, however, that more crown thinning has not been practised. Thinning has usually begun when the crop is about thirty to thirty-five feet tall and has continued at intervals of three to five years.

PRUNING. Brashing practice is normal, but the operation is made difficult by the numerous fine springy branches which are not easy to saw. Pruning for the improvement of timber quality has not so far been undertaken, but a recent report from the Forest Products Research Laboratory (1955) indicates that it may well be worthwhile.

OTHER SILVICULTURAL CHARACTERISTICS

One of the most important features of western hemlock is its tolerance of heavy shade. This makes it very suitable for underplanting and for the group regeneration of woods where the gaps are small. It has been used successfully for filling up areas of cankered European larch which have been drastically opened out; the hemlock has grown well under the partial shade of the remaining larch. It is also a valuable enrichment species for use in bringing scrub and coppice areas back into productive forest. Its pliant, pendulous leading shoot is not easily

whipped or damaged, and the young trees possess strong powers of recovery after being suppressed. Western hemlock has grown well in mixture with both conifers and hardwoods, and may prove most useful for an intermediate yield when grown with the latter. Stem fluting is fairly common in many plantations and trees sometimes fork at an early age and maintain double leaders until mature. When planted on infertile sites, western hemlock often grows slowly for a number of years and in doing so develops a characteristic bushy habit; once the canopy closes the height growth is then rapid.

RATE OF GROWTH AND YIELD

Yield tables have not yet been published in Britain but a provisional yield table has been prepared (Evans 1957), based on measurements which have been made in thirty-two sample plots; only two of these are over fifty years of age and most are under thirty. Four Quality Classes have been distinguished and these show top heights, at fifty years of age, of one hundred feet, ninety feet, eighty feet and seventy feet respectively for Quality Classes I to IV. Practically all the plots are at elevations of less than 1,000 feet. Just over half the plots are in areas where the annual rainfall is less than forty inches, but only one plot in this rainfall range is of Quality Class I. Total volume production is heavy, and at fifty years of age on Quality Class I sites it is 12,450 hoppus feet overbark; on sites II, III and IV it is respectively 10,730, 8,690 and 6,800 hoppus feet. Evans concludes that hemlock in Britain "will produce yields only slightly less than the known big volume producers—Douglas fir and Sitka spruce. . . ."

Some very tall individual trees have been recorded, the tallest being at Benmore, Argyll, which was 154 feet in height in 1956 at the age of ninety years; its girth at breast height was ten feet six inches. An adjacent tree, ten years younger, was 133 feet tall with a girth of nine feet four inches.

DISEASES AND PESTS

In the nursery, Western hemlock is liable to attack by *Botrytis cinerea* (Grey mould), but with proper management of the seedbeds no severe damage is caused. It is suspected of being more than usually susceptible to the butt rot fungus *Fomes annosus*, but it is possible that this belief has arisen from its being planted frequently in the past on old woodland sites. *Armillaria mellea*, the honey fungus, can also cause some damage.

There are no serious insect pests on western hemlock.

OTHER FORMS OF DAMAGE

WINDBLOW. The scanty evidence suggests that hemlock may be fairly windfirm.

ATMOSPHERIC POLLUTION. Little is known about Western hemlock's tolerance to pollution but it is not thought to be high.

SEED AND SEED-BEARING

Flowering usually begins about the twentieth year, and the first crop which is economic to collect is produced between thirty and thirty-five years of age. Good seed crops occur at intervals of about three years and maximum cone production is reached between forty and sixty years. Flowering takes place in April and the cones should be collected in September or early October (Matthews, 1955). As the cones are near the tips of the branches, collection is difficult but recently a method has been evolved using a triangular net, the apex of which is hung from near the top of the tree and stretched over the outside of the crown; the collector then clambers over the net collecting the cones from the branch tips. This method is practicable only on trees with deep crowns (Forestry Commission 1956).

The average number of seeds per pound is 250,000 but ranges from 100,000 to 700,000. Seed stores well at 34°F and at a moisture content of eight per cent. The average germination is fifty per cent.

GENETICS AND BREEDING

Five stands of plus or almost plus trees, and seven stands of 'normal' trees, totalling eleven acres, had been registered by the end of 1956. In addition, twenty-five plus trees had been selected and recorded but no seed orchards have yet been established.

NATURAL REGENERATION

Natural seeding of western hemlock has occurred abundantly in many parts of the country. The seedlings have appeared in the open and also under dense shade, both of other species and of hemlock itself. The young plants are able to persist, and it may be practicable to obtain the regeneration of woods in this way.

TIMBER

Western hemlock did not have a good reputation in its native country until it began to be used more widely during the period of the 1939-45 war and since then its value has been appreciated. Hiley has suggested that this poor opinion, formerly held of the timber in America, militated against the planting of the tree in Britain.

There is little evidence regarding the properties of large size saw timber in this country, but tests have been carried out on two consignments of thinnings. These tests showed that the timber kiln seasons well but with some distortion and loosening of knots. Seasoned material weighs about 30 lb. per cubic

foot. It works easily with machine and hand tools and takes nails well. Tested material was slightly less strong than Canadian-grown timber, but the home-grown material was only fifty-four or fifty-five years old.

No information is available on resistance to decay, or resistance to impregnation by wood preservatives. Hemlock has so far been used mainly for pitwood and estate purposes. It may be regarded as a general purpose softwood.

POTENTIALITIES OF THE SPECIES IN THE NATIONAL ECONOMY

Western hemlock is similar in many of its characters to some of the other North American introductions and it has had to compete for favour with these for available ground. This factor, along with doubt in the past as to the value of the timber, probably accounts for the small area of hemlock in Britain. The species has some valuable silvicultural features, however, principally the ability to stand dense shade and its powers of regenerating naturally. It seems likely that western hemlock is likely to maintain its present position in afforestation in Britain and even to expand it; while its use in the regeneration of existing woods is likely to increase, especially if the present trend towards using more mixtures of species persists.

× **Tsuga jeffreyi** (Henry) Henry

This tree is said to have been first raised at Edinburgh in 1851 from seed collected in British Columbia by Jeffrey. It was known only as a cultivated tree until recently, when seedlings found in Vancouver were identified as × *T. jeffreyi* (Dallimore and Jackson 1948). It is considered to be a hybrid between *T. mertensiana* and *T. heterophylla*. The few trees which are found in this country are all small, but some are thought to be of considerable age. The young specimen at Bedgebury, Kent, was twenty-three feet in height when measured in 1954.

Tsuga mertensiana (Bongard) Carrière

Mountain hemlock from north-west America was introduced by W. Murray in 1854. A high elevation species in its native land, it has grown slowly in this country, and is found occasionally in parks and gardens. A specimen at Murthly, Perthshire, was eighty-eight feet in height and had a girth of six feet eleven inches in 1955; it is probably the tallest in Britain. A second large specimen is at Methven Castle, Perthshire; this was seventy-one feet tall and had a girth of nine feet three inches in 1955. With a suitable provenance it is possible that this tree might find a limited use at high elevations.

Tsuga sieboldii Carrière

This tree from southern Japan was introduced to Europe in 1850 and is found occasionally in Britain as a small tree. There is a plot at Crarae, Argyll, eighteen years of age and nine feet tall, and one of the largest specimens, which is at Murthly Castle, measured forty-four feet in 1954.

T. yunnanensis (Franchet) Masters

This is a tree from west China, uncommon in Britain, which is closely related to *T. chinensis*. It suffers severely from spring frosts. A specimen at Westonbirt, Gloucestershire, was twelve feet in height and had a girth of seven inches in 1956.

R.F. and G.G.S.

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Widdringtonia Endlicher

The widdringtonias are too tender generally for use in the United Kingdom, although individuals can be grown out of doors in the warmer parts of the country. Specimen trees of *W. whytei* are found in Cornwall and other mild districts, but they are not common and do not reach any size.

J.M.

PART III

Exotic Broadleaved Trees in Great Britain

It has not been possible to treat the broadleaved trees in the same way as the conifers and mention most of the genera, species of which have grown in the open air in this country, for two reasons. The first, and weightiest, is the enormous number of genera which, to a greater or less extent, have found their way into cultivation and the treatment of which, individually, would expand this report to an inordinate length. The second is the fact, already commented on, that no exotic broadleaved tree is of much importance in British silviculture and, as far as can be seen, none is likely to achieve any degree of prominence in the near future. We have, therefore, picked out for treatment in the following pages, those genera on which there is some information, derived chiefly from their use in experimental work, and have tried to assess their value as we see it at the present time. The result is naturally uneven, but unless widespread surveys could be carried out to collect all the information available from our forests and woodlands, no account of the broadleaved exotics could be other than incomplete, and even if it were complete, it would still be uneven.

Acer Linnaeus

The maples are widely distributed throughout deciduous forests in the northern hemisphere, over one hundred species being known. *Acer* is represented in Britain by *Acer campestre*, the field maple, a small tree common in hedgerows and coppices in the south, and by the long naturalised *Acer pseudoplatanus*, the sycamore, which is an important forest tree. A fellow European, *Acer platanoides*, the Norway maple, an introduction of less antiquity, has been planted on a minor scale and will receive separate mention. The only other maple which has received attention as a forest tree is the north-western American species *A. macrophyllum*, and a brief note on this is given below.

The maples are chiefly of arboricultural interest, many of them being of great value for their autumn colour. In Britain it is chiefly the Japanese species (notably the many forms of *A. palmatum*) which are planted for decorative effect.

The eastern North American species, which include a number of important forest trees, are on the whole disappointing in Britain. The sugar maple, *A. saccharum*, was introduced as early as 1735, but is rarely seen. A tree at Kew was 78 ft. tall with a breast height girth of 9 ft. 9 ins. in 1955. There are few larger.

Acer saccharinum is rather more successful, though few specimens over seventy feet in height have been recorded. *A. rubrum* is rare in cultivation and reaches no great size. *A. pennsylvanicum* grows very vigorously as a young tree but none of the eastern North American species has any apparent future as a forest tree in Britain.

Numerous Asian maples are in cultivation. The finest collection of maples in Britain is at Westonbirt, Gloucestershire.

Acer macrophyllum Pursh

One of the few large broadleaved trees of the north-west American coast, *A. macrophyllum* was introduced by Douglas in 1825. It has been little planted, though it seems to have been greatly admired in the early years after its introduction (Loudon 1842). However, it has made no mark, presumably because it compares unfavourably in performance with the common sycamore, nor has it any particular beauty of form or colour to commend it. It has plainly no chance of displacing native broadleaved trees.

A few trial plots have been planted. At Bedgebury, Kent, the tree was slow to establish; planted in 1929 it only averaged 15 ft. in height by 1951, and the plot is irregular and even now has scarcely closed canopy. Much of the irregularity here is due to trees

dying back to the ground (from no recognised cause); they subsequently send up vigorous coppice shoots. At Bedgebury the tree fruits and sets fertile seed.

At Benmore, Argyll, *Acer macrophyllum* does rather better, and in one large group has a top height of 35 ft. at 22 years of age, the tallest tree being 37 ft. high.

Few large specimens are known. At Kew, there is a tree 83 feet tall with girth at breast height of 7 ft. 6 in. At Westonbirt, a tree 78 feet tall has a girth of 9 ft. 9 in.

Acer platanoides Linnaeus

The Norway maple was introduced in 1683. Its range covers much of Europe, Jones (1944) giving its northern boundary as:—Central France, Southern Norway and Sweden, Lake Ladoga, and the Urals; and its southern as—Northern Spain, Northern Italy, the Balkans, Asia Minor and Northern Persia.

It has been much less planted than *Acer pseudoplatanus*, but according to Jones it "would only need more extensive planting to become as fully naturalised".

Acer platanoides, according to that author, has very similar requirements to those of sycamore, namely, moist free rooting soils of high base status with free nitrification. But there is some evidence that it is rather less demanding than sycamore, as it can grow fairly well on sites which are by no means ideal. At Bedgebury, on an acid infertile silt, a trial plot reached a height of 23½ feet in twenty-two years, while an adjacent plot of sycamore of similar age had failed to close canopy and remained in a state of check, averaging only 6½ ft. in height.

On better sites, there is less difference in early performance between the two species, but *Acer platanoides* usually makes the faster growth in the first thirty years or so. At Coopers Hill near Windsor, the trial plots established by Schlich in 1891-2, a mixed hardwood plot contained sycamore and Norway maple, in addition to other species, on a deep sandy loam of fair fertility overlying London Clay. At 18 years of age, Norway maple had attained 38 ft. in height as compared with 28 ft. for sycamore (Fisher 1909).

There are few plot measurements for Norway maple. James (1951) gives figures for a plot at Cirencester and four temporary sample plots have been measured by the Forestry Commission. Table 54 summarises the available data.

The Cirencester plot is interesting as it was originally planted with more beech than Norway maple. In intimate mixture, Norway maple is likely to suppress beech, unless considerable care is taken in thinning. Norway maple is a distinctly fast growing hardwood at least for forty years. It is extremely unlikely that it will prove as productive as beech after fifty years of age.

Norway maple does not seem to reach such large dimensions as sycamore, nor is it probably so long lived. Trees over 80 ft. in height are rare. Mitchell records a specimen 81 ft. in height with a breast height girth of 9 ft. 2 in. (1952 measurement) at Pampisford Hall, Cambridge.

It fruits at an early age; Wylie (1936), mentions a plantation at Tintern, Monmouth, which produced much fertile seed at the age of 25. Natural seeding frequently occurs and there are a few managed stands which have been established by this means. There is a good example at Westbury, Wiltshire.

The seed runs about 5,000 to the pound, and normally has a germination capacity of 70 per cent. It is best kept stratified in moist sand after collection

TABLE 54 ACER PLATANOIDES: GROWTH AND PRODUCTION

Site	*Age yrs.*	*Mean Height ft.*	*Mean Girth in.*	*Vol. per acre Hoppus ft. over bark*	*Total Production per acre Hoppus ft. over bark*	*No. of stems per acre*
Gravetye Forest, Sussex	42	62½	27	2,247	2,920	260
Manby Woods, Lincoln	38	58	30	1,081	—	176
Dunkirk Wood, Kent	40	46	28	954	—	142
Cirencester, Gloucestershire	46	Beech 53	18	350	—	211
		Norway Maple 59	23	1,269	—	354
Betteshanger, Kent	40	Norway Maple 49	25½	1,431	—	270
		Beech 39	16½	24½	—	102

until it is sown in the following spring. The rate of sowing is approximately one pound to 10 square yards. Norway maple presents no nursery difficulties. The timber resembles sycamore in most respects and has been used for the same purposes; most of the small quantities produced have been used for turnery.

Norway maple is a useful minor hardwood which is being planted to an increasing extent in the south, but nowhere on any scale. It has a good autumn colour and is valued for this where amenity considerations are important. It is not likely to be of any great economic importance, but may be a desirable enough constituent of broadleaved woodland, particularly where there are good markets for turnery.

R.F.W.

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Aesculus Linnaeus

Several species of *Aesculus* are in cultivation in Britain; *A. hippocastanum* is however by far the most commonly planted of the genus, and the only one which has received any consideration as a forest tree.

The American *A. octandra* is occasionally seen in the south of England, and though it makes a handsome specimen, rarely exceeds sixty feet in height. Other species in cultivation are *A. indica* and *A. turbinata*. The red flowered hybrid × *A. carnea* is commonly planted as an ornamental tree.

Aesculus hippocastanum Linnaeus

The horse chestnut (from Northern Greece) has been in cultivation in Britain since the seventeenth century and is planted throughout the country as a park or shade tree. It reaches its best development in the warmer parts of the country, and does not bear fruit with any regularity in the north.

It has not been considered a suitable tree for forestry mainly because of its soft weak timber, but its rapid diameter increment on suitable sites has suggested that it might have possibilities for pulp or other purposes for which inherent strength is not essential.

Few plantations of the tree exist, though one or two trial plots have been established in recent years. A few small plantations or large groups have however been measured and offer some idea of the potentialities of the tree. Table 55 summarises the available data.

It seems that the yield of horse chestnut might be expected to be of the same order as that of beech; about 50 to 60 hoppus feet per acre per annum. The plot at Speen is of interest, as it is a well stocked coppice, with some 930 stools and about 4,500 stool shoots per acre exceeding four in. in girth at breast height.

Horse chestnut appears to be a rather demanding species with a preference for base-rich soils and it does very well on the deeper soils overlying the chalk. It is not normally a long-lived tree, and is often in decline after a hundred years.

It rarely exceeds 100 ft. in height, but often grows to very considerable girth. Specimen trees 80 ft. in height with breast-height girths of 15 ft. or more are on record for most parts of the country.

Seed is produced freely every two or three seasons. It runs about 40 to the pound, and should either be sown immediately after collection or kept stratified in moist sand or peat over the winter.

Nursery treatment presents no difficulties, and one-year-one-year transplants are usually of suitable size for planting.

Horse chestnut seems unlikely to play any considerable part in British forestry, though it is conceivable that it might be grown on a coppice rotation for pulping.

R.F.W.

TABLE 55 AESCULUS HIPPOCASTANUM: GROWTH AND PRODUCTION

Site	*Age Yrs.*	*Mean Height ft.*	*Mean breast height girth in. over bark*	*Volume Hoppus ft. over bark*
Gatton Park, Redhill, Surrey	120 (approx.)	84	90	9,585
Lee Estate, Buckinghamshire	40	56	20	2,684
Hambleden, Oxford	27	47½	42	1,111
Speen, Berkshire	20 (approx.)	36	11½	722

Ailanthus Desfontaines

Ailanthus altissima (Miller) Swingle

The "Tree of Heaven" from China, which was introduced in 1751 by Peter Collinson, has been fairly commonly planted in towns, particularly in the south. Efforts have been made to establish trial plots of it, but without success. It has failed twice in the Forest Plots at Bedgebury, Kent, the young plants dying back to the ground each winter. *Ailanthus altissima* is almost certainly a climatic misfit due to lack of adequate summer warmth, and can only thrive when conditions are made specially favourable for it. It has no prospects in British forestry. A number of specimens over 70 ft. tall are on record, all in the southern counties.

R.F.W.

Alnus B. Ehrhart

The alders are widely distributed in the northern hemisphere, some thirty species being recognised Only one species is indigenous to Britain, *Alnus glutinosa*, a tree which frequents river banks, basic fen peats, and other moist sites of high fertility. It is too demanding a species to be other than of local importance.

The chief interest in alders has been as nurse trees or soil improvers rather than as timber producers in their own right, the nitrogen-fixing capability of many *Alnus* species having encouraged foresters to consider them especially for these roles. Three exotic alders have been tried under forest conditions, namely *A. cordata*, *A. incana* and *A. rubra*. A number of others are in cultivation, but few if any compare in stature with the native *A. glutinosa* or the three exotics mentioned above. The Asian *A. hirsuta* and the related species *A. matsumurae* from Japan may have possibilities. A specimen of the latter, planted in October 1952 reached a height of 20 ft. by September 1956 at Alice Holt. *Alnus rugosa* has been tried on chalk at Buriton, Hampshire, but it is a poor thing. *A. viridis* and *A. sinuata* have been tried on peat without success (Zehetmayr, 1954).

Hybridization between *A. rubra* and *A. cordata* has been recorded in Britain, and there are some particularly vigorous young trees of this parentage under observation at Alice Holt.

A. cordata Desfontaines

This species is said to have been introduced in 1820. It is a native of southern Italy and Corsica, and appears to be less confined to riparian sites than most species of *Alnus*.

It has received much less attention than *A. incana* and *A. rubra*, in spite of the good growth of arboretum specimens on various soils (Elwes and Henry 1909). It has been used in France for some time as a pioneer species in reafforestation, and its most valuable characteristic, a tolerance of comparatively dry soils, is noticed by Rol (1951).

There are a few trial plantations. At Queen Elizabeth Forest near Buriton, Hampshire, a plot of *A. cordata* was established in 1935, being one of a number of species tried at that time as nurses or pioneer crops for the later establishment of beech. The site is an exposed down, altitude 650 ft., with about 18 in. of loamy soil overlying the Upper Chalk. The annual rainfall is about 35 in. Growth of the alder has been very rapid, by 1956 (i.e. in 22 yrs.) the crop averaged 45 ft. in height, with a mean breast height girth of 17 in., and a total yield of 1,921 Hoppus ft. per acre. It is very noticeable that a number of nitrophilous plants have come into the plantation.

Alnus cordata has also been tried on a heavy calcareous boulder clay in Rockingham Forest, Northamptonshire. Here it has reached 24 ft. in height at 21 yrs. of age, and is vigorous and healthy, but many of the stems are bent and leaning. At Rockingham, both *A. incana* and *A. rubra* have so far grown rather faster than *A. cordata*.

A small plot of *A. cordata* at Benmore in Argyll has grown extremely fast, the tallest trees averaging 53 ft. in height at 31 yrs. of age. Here it is markedly faster than *A. incana* and *A. rubra* which are 31 and 29 ft. tall respectively at 25 yrs. At Bedgebury in Kent, *A. cordata* gave rather disappointing results on an acid silty soil. It has been planted experimentally on peat but with little success (Zehetmayr, 1954). It does not appear to be a species for the more acid sites.

A. cordata fruits at an early age and produces fertile seed. Home collections have averaged 220,000 seed to the pound, with a germination capacity of 25 per cent. The seed stores poorly, and should be sown in the first season after collection. Normal nursery methods are suitable, and one-year-one-year transplants are fit for planting.

More experience of *Alnus cordata* will be required before estimating its place in Britain. At least it has shown that it can grow rapidly on calcareous soils, and some role might be found for it on chalk.

Alnus incana (Linnaeus) Moench

The European Grey alder was introduced to Britain in 1780. It has been more widely planted than the previous species, but has no regular place in British silviculture today.

One of its first uses was as a nurse for oak and other broadleaved species; Carr (1866) makes an early reference to the planting of *A. incana* for this purpose. Elwes (1909) used Grey alder on frosty sites as a nurse for *Thuja*, and planted the two species

TABLE 56 ALNUS INCANA: GROWTH AND PRODUCTION

Site	Age Yrs.	Mean Height ft.	Mean Girth Breast Height in.	Volume Per Acre Hoppus ft. O.B.	Total Yield Per Acre Hoppus ft. O.B.
Drummond Hill, Perth	24	57	29	1,139	3,183
Thetford, Suffolk	23	42½	20	1,138	1,481

simultaneously, the faster early growth of the alder providing cover for the conifer.

Alnus incana was planted experimentally as a nurse for oak on a number of sites in the late 1920's. Unfortunately, however, it was usually planted much too close to the oak groups which it was designed to benefit, and had to be removed too soon to be of much service. The prolific crop of suckers which it threw up was also found to be a nuisance.

Grey alder has also been considered as a nurse for beech on open downland sites. Experimental plantations at Buriton, Hampshire, on a downland site with a fair depth of clay-with-flints overlying the chalk, achieved a fair measure of success. Grey alder planted in 1930 reached about 15 ft. in 7 growing seasons, and 30 ft. in 20 yrs. Certain experimental plots of Grey alder at Buriton have been interplanted with beech with considerable success. *A. incana* was subsequently planted on some scale at Buriton on much shallower soils with a view to the provision of advance shelter, but unfortunately it failed on these less favourable sites.

There are a few cases where there is a suggestion that a nursed species has benefited from extra nitrogen in the presence of Grey alder. At Friston Forest, Sussex, an ash plantation exhibited the typical checked condition due to the dense chalk downland sward. Invasion of Grey alder suckers from an adjacent plot was accompanied by the onset of quite vigorous growth by the ash.

Grey alder has been tried on peat soils, on heaths and mountain grasslands, but on the whole has proved a failure on these sites, where we should like to have some broadleaved species to diversify our coniferous plantations. On the best *Molinia* peats and on *Juncus* flushes, Grey alder has occasionally done quite well, and it has made the best showing of the various alders tried (Zehetmayr). It has not succeeded on heaths.

There are few crop measurements available for Grey alder. Table 56 summarises the data from two sample plots.

The Drummond Hill plot is on a deep, fresh, loamy soil, a particularly favourable site. The Thetford plot is on sand overlying chalk, a much poorer and drier soil. The growth is good in the circumstances; the much lower yield is due to the open stocking of the plot at establishment.

A small plantation at Nith Bridge, Dumfriesshire, contains some of the tallest recorded specimens of *A. incana*. Planted in 1916, a number of these trees exceeded 74 ft. in height when measured in 1954, and the tallest was 81 ft., with a breast height girth of 3 ft. 1 in.

Alnus incana seeds freely in Britain. Home collected seed has averaged 650,000 to the pound with a germination capacity of 30 per cent. It presents no special nursery problems.

The Grey alder will probably not be used in Britain to any great extent, since the sites on which it will thrive are not those for which we most require a nurse or pioneer for more valuable species. On the drier sites, *A. cordata* is probably the better alder.

Alnus rubra Bongard

The Oregon alder was introduced into Britain in the latter part of the nineteenth century. It has an extensive latitudinal range on the north-west American coast. In Britain, *A. rubra* has proved a most disappointing species. It has been tried on a wide variety of sites, and has frequently grown extremely well for some ten to fifteen years. In the great majority of cases, it then declines rapidly and dies back. The cause is unknown, and hardly seems explicable in terms of site. No provenance experiments have been undertaken, but dieback has been observed in *A. rubra* from seed sources as far apart as the Queen Charlotte Islands and the lower Fraser valley, both in British Columbia.

A small plantation at Buriton, Hampshire, situated on clay-with-flints on an exposed chalk down, has so far escaped trouble. At 26 years of age, the trees averaged 47 ft. in height with a breast height girth of 28 in., the performance of Oregon alder on this site being markedly superior to that of grey alder. Oregon alder has also done quite well on the calcareous boulder clay at Rockingham, Northamptonshire, the tallest trees averaging 31 ft. in 21 yrs. Here also it shows no signs of dieback, and grows faster than *A. incana* and *A. cordata*. But these are exceptional performances.

Alnus rubra was one of the alders tried on peat (Zehetmayr, 1954), and early growth was very fast in a number of cases, but nearly all the plantations subsequently failed. There are a number of reports of the susceptibility of Oregon alder (as a young

plant) to spring frost. (Brown, P.; Thomson, G. J., 1936), and it appears to be more frequently injured than *A. cordata* or *A. incana*. Guillebaud (1932) discusses the nursery treatment of Oregon alder, and mentions the (deceptively) good growth of some of the first trial plantations. Oregon alder produces fertile seed in Britain; home collected seed averages 700,000 to the pound with a germinative capacity of 40 per cent. Nursery treatment presents no special difficulty.

Alnus rubra is unlikely to receive much further attention in Britain, except possibly as a parent of hybrids.

R.F.W.

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Betula Linnaeus

The birches occur throughout the higher latitudes of the northern hemisphere, some forty species being recognised. Two European species are indigenous also to Britain, *Betula pubescens* Ehrhart, and *B. pendula* Roth. They are trees of the lighter acid soils and, like most birches, pioneer cut-over or devastated forest sites. Birch is not an important tree in Britain, though natural stands are often of silvicultural value in providing suitable conditions for the introduction of more valuable species. Birch timber is used for turnery, but in Britain few trees come up to the standard required for rotary veneering, which is an important market for the much superior birch (of the same species) in Finland and Sweden. The improvement of the native species by selection or by the introduction of better provenances is now receiving some attention; and a few trials of the more important exotics species have been undertaken.

The birches offer excellent opportunities for hybridization and this may well be a profitable line of study to follow in Britain. A considerable number of species are already in cultivation in arboreta, etc., and some of them are especially valued for their graceful habits and distinctive bark colouring. There are young trial plots of a few species, and a number of others are represented by small groups at Alice Holt, Benmore and other forest gardens. Mention can only be made of the species which have been planted in forest plots, or which appear to be worth further attention on other evidence.

Betula ermani Chamisso

From north-east Asia and Japan. A plot at Bedgebury was planted in 1951 and has started quite well. It is also on trial at Kielder, Northumberland. There are few really good specimens of this species, as it is by no means outstanding in arboreta.

Betula jacquemontiana Spach

A Himalayan birch allied to *B. utilis* and, according to Bean, a hardier species than the latter. A small group, planted at Alice Holt in 1952, shows excellent early growth and stem form; in 1956 the best trees were 17 feet tall. It has also started well at Benmore. It is rare in cultivation, but appears to warrant further trial.

Betula lenta Linnaeus

The north-east American Cherry birch has been in cultivation since 1759, according to Loudon. However, it has been little planted and does not seem to reach very large dimensions. Elwes and Henry (1909) mention a tree sixty feet tall with a breast height girth of four foot nine inches, but this seems to be exceptional. A plot at Bedgebury, Kent, planted in 1935, had a height of 30 feet in 1955. Recent trials at Kielder, have however proved a failure.

The tree has a pleasing appearance and good stem form, though there is a tendency to fork. It sets fertile seed in quantity, which average some 600,000 to the pound. Germination capacity of home-collected seed rarely exceeds thirty per cent.

The impression is that *Betula lenta* will prove rather too slow-growing to be worth planting.

Betula lutea Michaux

The yellow birch, also from the east of North America, was introduced, according to Loudon, in 1767. Since it has one of the most valuable timbers amongst the birches, it is a tree which we should like to grow, but its performance has not been encouraging. It is possible that its requirements have been underestimated, as it is one of the most demanding of birch species. A plot planted at Bedgebury in 1950 is growing very slowly, and a small group at Alice Holt is doing rather better, but the trees are very bushy in appearance. Trial plots at Kielder are even less satisfactory.

Betula lutea failed completely when planted at Cirencester in 1905 in mixture with *Castanea sativa* and *Prunus serotina* (Macdonald 1931). There appear to be very few good specimen trees, the largest known to Elwes (1909) was a tree fifty feet tall with a breast height girth of four feet, growing at Tortworth, Gloucestershire.

It is very unlikely the *Betula lutea* will prove of any value in Britain.

Betula mandshurica (Regel) Nakai

This name covers a complex of geographic varieties, in Japan. China and North-east Asia. A number of birches in cultivation can probably be ascribed to *Betula mandshurica*, though introduced under different names. None appears to have done particularly well.

A small group of *B. mandshurica* var *szechuanica* in the Speech House arboretum, Forest of Dean, reached thirty-two feet in height at the age of thirty-six years. A plot (assumed to be also var. *szechuanica*) planted at Bedgebury in 1950 has started quite well.

Betula maximowicziana Regel

This is said to be the largest of the birches native to Japan. It is still rare in cultivation, and plots were planted for the first time in the spring of 1957. It was observed that a large number of one-year-one-year transplants died back to the collar during the winter in the nursery. The cause is not known. *B. maximowicziana* is reputedly hardy, and a few good specimen trees are recorded. At Grayswood, Surrey, there is a tree sixty feet in height.

Betula papyrifera Marshall

The paper birch was introduced in 1750. It is the most widely distributed North American birch, and several geographic varieties have been described. The type (the tree of the east) and the important variety *B. papyrifera* var. *occidentalis* (Hooker) Sargent, from western North America are both in cultivation, though no comparisons seem to have been made.

A plot at Bedgebury, planted in 1948, is growing with considerable vigour, and at Benmore a small group is 30 ft. tall at 22 years of age. The largest specimen known to Elwes (1909) was a tree 82 feet in height near Reading, Berkshire.

Betula papyrifera appears to warrant further trial.

Betula populifolia Marshall

The Grey birch of eastern North America is an ephemeral species of no great stature, unlikely to be of any value in Britain. A plot at Bedgebury is very unprepossessing in appearance, and is only 19 feet tall at 16 years of age. It plainly compares very unfavourably with our native birches.

R.F.W.

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Carya Nuttall

Several of the American hickories are in cultivation in Britain, but none is likely to be of any importance as a forest exotic. They are comparatively slow growing under our conditions, very particular as to soils, and difficult to establish. So far as is known, there are no successful plantations.

There are, however, good specimens of several species in arboreta, mainly in the south of England, and *Carya ovalis*, *C. tomentosa*, *C. laciniosa*, *C. cordiformis and C. ovata* are all recorded as attaining heights of seventy feet or more. Dallimore discusses the cultivation of *Carya* at some length, in his article on "American Broadleaved Trees" in the *Kew Bulletin* for 1911.

R.F.W.

Castanea Miller

The genus is represented in Britain by the long-naturalised *C. sativa* of Europe, introduced (according to tradition) by the Romans.

Our only interest in exotic chestnuts is to have a second string in case the fungus *Endothia parasitica* should arrive in Britain.

The Asian chestnuts *C. mollissima* and *C. crenata*, which are resistant to *Endothia*, have recently been tried at Bedgebury, Kent, but both unfortunately suffered severely from winter cold. Neither appears likely to be a suitable subject for cultivation in Britain.

R.F.W.

Eucalyptus L'Héritier
(Plates 14 and 17)

The importance of the eucalypts in British forestry is small, and they might be dismissed quite cursorily but for the fact that the genus provides many valuable exotics throughout the world. Britain is a useful testing ground, and the behaviour of the Eucalypts here may provide evidence of climatic adaptability of value to planters in other countries.

It is not practicable however to deal with the eucalypts in Britain species by species; they will rather be treated as a group.

Eucalypts in Britain have had a considerable amount of attention in the literature; they have on the whole been objects of arboricultural rather than silvicultural interest. A most useful general account of the behaviour of the genus in Britain has been given by Martin (1948); the present statement draws heavily on this. Since Martin's article was written, there have been other introductions of eucalypts; a few more small collections have been planted and further evidence on hardiness obtained. During the early part of 1956, an Australian Forest Officer, R. G. Green, visited a

number of sites in Britain where eucalypts have been planted, and he also studied the meteorological records relating to such sites. His observations provide the main additions to Martin's account.

A list (not claimed to be exhaustive) of the eucalypts in cultivation in Britain, or which have been tried in Britain, appears opposite. It is more than likely that some of the nomenclature is faulty; the list is not critical, and in many cases of purely ephemeral introductions all that is implied is that the growing of Eucalypts so named has been attempted. Authorities for specific names have been intentionally omitted to avoid the appearance of greater botanical exactitude than in fact exists.

COUNTRY OF ORIGIN AND SEED SOURCES

The eucalypts which have succeeded in Britain are natives of the cooler mountain regions of southern Australia and Tasmania. Introductions in the past have been very much on a "hit-and-miss" basis. It has however become abundantly clear that the number of species likely to prosper in Britain for any length of time is quite small, and the more recent introductions have been restricted to species which, on the grounds of climate of origin, appear to have some chance under British conditions. Such introductions are mainly due to the interest of certain Australians who happen to be conversant with British conditions.

It is not possible to list reliable or proven sources for any species. Little provenance work has been attempted. Sir George Campbell recently arranged a provenance experiment in *Eucalyptus obliqua*; and a few comparisons of seed origins are available for other species. At St. Clement Forest, Cornwall, *E. johnstoni*, *E. urnigera* and *E. coccifera* are represented by young plants of two different provenances; and at Benmore, Argyll, there are provenance comparisons of *E. coccifera* and *E. subcrenulata*.

It is becoming possible to compare home and native seed of a number of species.

HISTORY

The first successful introduction seems to have been *E. gunnii* "*whittingehamensis*" by James Balfour of Whittingehame in 1846. One of his original seedlings still exists, and is now a large tree with a well distributed progeny in Britain. Eucalypts became fashionable objects in the 70's and 80's of the last century, and many of the famous collections date from then. It is probable that over thirty species had been introduced before 1900.

It was appreciated at an early stage that most of the eucalypts had a very limited range in Britain, and all the notable collections grew up in coastal regions or in Ireland. Martin (1948) mentions the following 19th century collections: Castlewellan, Co. Down; Loch Hourn, Inverness-shire; Menabilly, Cornwall; Rostrevor, Co. Down; Corrie, Isle of Arran. The best collection observed by Martin, that at Mt. Usher, Co. Wicklow, dates from about the turn of the century, as do the collections at Tresco, Scilly Isles; Poole, Dorset, and Borde Hill, Sussex.

Martin mentions a number of other gardens where eucalypts have been grown. A considerable collection which has been made quite recently is that at Crarae, Argyll, where Sir George Campbell has raised over twenty species in the last few years.

The Forestry Commission has not regarded the eucalypts as a probable source of exotics for timber production; it has however been realised that there is a remote possibility that one or two species worth growing for their timber might succeed in a quite limited range in the milder parts of the country. Hence the views of visiting Australian foresters have been sought and opportunities taken to introduce a few species from time to time. Martin's survey provided a stimulus, and seed sent by him after his tour in Britain was raised at the Royal Botanic Garden, Edinburgh, and the stocks planted out at the Benmore Forest Garden, Argyll. A few of these plants were also established at the Forestry Commission's Research Station, Alice Holt, Hampshire, where they have experienced a much more rigorous winter climate. Martin's view was that there might be possibilities in natural or artificial hybrids between *E. gigantea* (according to him the best timber tree of the near-hardy species) and certain hardier eucalypts from higher elevations. His introductions included the hybrids *E. salicifolia* × *coccifera*, *E. salicifolia* × *gigantea and E. pauciflora* × *salicifolia*. Fielding, following his visit to Britain in 1949, sent seed of a number of Tasmanian species already showing promise in this country, selecting provenances which he considered should have the best chance of success.

These included reintroductions of *E. johnstoni*, *E. urnigera*, *E. gigantea*, *E. subcrenulata*, *E. coccifera* and *E. pauciflora;* these eucalypts were planted at St. Clement, Cornwall, and Benmore, Argyll in 1953.

A few other small lots have been raised from Australian or home seed from time to time.

The John Innes Horticultural Institute (Bayfordbury, Hertfordshire) received a considerable collection of some thirty species in 1954—this was, however, reduced to eight species after the first winter in the open.

PRESENT EXTENT OF PLANTING

This remains purely experimental, on the arboretum or small forest plot scale.

CLIMATE

The eucalypts afford one of the best examples in Britain of exotic species limited by low temperatures. Indeed winter minimum temperature, if not the only important factor, is by so much the most important that the consideration of others is somewhat academic. The picture is fairly clear, though it might be slightly modified by better provenance work. The absolute minimum temperatures recorded in the period 1901-1940 are shown in Fig. 1, page 7.

It will be seen that over practically the whole of the British mainland temperatures fall at least once in 40 years to 20°F., and over by far the greater part of the country to 10°F. Quite a high proportion of the British mainland may experience zero F. temperatures at least once in 40 years. The much milder Irish winter is well illustrated by this map. The behaviour of the eucalypts in Britain is in close accord with this temperature distribution, the numbers of species which will survive falling off rapidly from the most favoured districts inland; and equally, the length of time a particular species is likely to live is related to the actuarial risk of experiencing frost of the degree to which it is susceptible. As Martin remarks, the history of eucalypts in Britain is punctuated by the occurrence of exceptionally severe winters, during which trees which have grown normally for years are killed or cut back severely. A considerable number of records of 'killing' frosts have been collected from a variety of sources. These are not all of equal value, sometimes owing to the distance between the planting site and the recording station, but perhaps also to confusion between screen and grass minimum temperatures. A further source of difficulty is the age of the tree; this is not always stated when recording a fatality. However an attempt has been made, in Table 57, to summarise the available data, and where there is special reason to doubt the record it has been shown with a query. Equally important are records of low temperatures survived, and a rather lesser number of these are also given.

TABLE 57 EUCALYPTS WHICH HAVE BEEN TRIED IN BRITAIN WITH SOME RECORDS OF FAILURE AND SURVIVAL AT LOW TEMPERATURES

Species of Eucalyptus	*Temperatures (screen minimum °F)*		*Location and Remarks*
	Killed	*Survived*	
amygdalina	22°	—	Mt. Usher, Co. Wicklow, Ireland.
angustifolia	—	17° ?	Loch Hourn, Inverness-shire.
acervula (scabra ?)	—	—	Recorded at Menabilly, Cornwall prior to 1911.
alpina	—	—	Arran, 1894/5 (Glasgow 7° Feb. 1895).
barrenleni	—	—	Kennington 1939, killed in first winter as seedlings.
biangularis .... (globulus × urnigera ?)	—	19°	Rostrevor, Co. Down, Ireland.
bicostata	—	—	Knapdale, Argyll, 1939, failed early.
blakelyi	—	—	Knapdale, Argyll, 1939, failed early.
botryoides	16°	—	Abbotsbury, Dorset, 1908.
calophylla	28°	—	Scilly Isles, 1946/7.
,, ...	20°	—	Bayfordbury, Herts., 1955/6, killed in first winter after planting.
cambageana	17°	—	Londonderry, Ireland.
capitellata	20°	—	Bayfordbury, Herts., 1955/6, killed in first winter after planting.
cinerea	—	—	Kennington, Oxford, 1939, killed first winter as seedlings.
,, ...	17°	—	Londonderry, Ireland.
,, ...	17°	—	Winchester, 1940/41.
citriodora	—	—	Menabilly, Cornwall. Killed at early stage.
coccifera	17°	—	Londonderry, Ireland.
,, ...	15°	—	Arran, 1894/5.
,, ...	0° ?	—	Kilmarnock, 1894/5 (Glasgow 7°).
,, ...	15°	—	Royal Bot. Garden, Edinburgh, 1946/7 (seedlings).
,, ...	10°–13°	—	Wisley, Surrey, 1946/7.
(var. parvifolia)	17°	—	Winchester, Hants., 1940/1.
,, ,, ...	—	0° ?	Loch Hourn, Inverness-shire, 1894/5.
,, ,, ...	—	9°	Colesborne, Glos.. 1879.
,, ,, ...	—	15°	Alice Holt, Hants., 1952.
coccifera × salicifolia	15°	—	Alice Holt, Hants., 1953/4.
,, ,, ...	—	9°	Benmore, Argyll, 1954/5.
cordata	12°	—	Exeter, Devon.
,, ...	—	16°	Abbotsbury, Dorset, 1908/9 (thrives at Loch Hourn, Inverness).

TABLE 57—*contd.*

	Killed	*Survived*	
coriacea	—	—	Kennington, 1939, killed first winter as seedlings.
crucis	17°	—	Winchester, 1940/41.
,,	—	—	Kennington, 1939, killed first winter as seedlings.
dalrympleana	14°	—	Willaston, Cheshire, 1954.
,,	—	22°	Willaston, Cheshire, 1940/41.
,,	—	18°	Willaston, Cheshire, 1946/47.
deanei	—	—	Reported as hardy in Cornwall.
delegatensis	—	6°	Mt. Usher, Co. Wicklow, Ireland.
dives	—	—	Kennington, 1939, killed first winter as seedlings.
,,	20°	—	Bayfordbury, Herts., 1955/6, killed first winter planted.
,,	17°	—	Winchester, 1940/41.
eximia	20°	—	Bayfordbury, Herts., 1955/6, killed first winter planted.
fastigata	—	—	Crarae, Argyll, 1953, seedlings killed first winter (Benmore 15°).
ficifolia	—	—	Bayfordbury, Herts., failed early.
gigantea	16°	—	Royal Bot. Garden, Edinburgh, 1946/7, killed as seedlings.
,,	15°	—	St. Clement, Cornwall, 1954, younger plants severely cut back.
,,	14°	—	Willaston, Cheshire, 1954.
,,	—	22°	Willaston, Cheshire, 1940/1.
,,	—	18°	Willaston, Cheshire, 1946/7.
gomphocephala	—	—	Menabilly, Cornwall. Survived to 1899 but has died since.
globulus	17°	—	Loch Hourn, Inverness-shire, 1895.
,,	24°	—	Arran, 1880/1.
,,	24°	—	Bournemouth, 1890/1.
,,	—	15° ?	Stranraer, 1898.
gunnii	0°	—	Bedgebury, Kent, 1946/7.
,,	—	0°	Kettering, Northants., 1946/7.
,,	—	0° ?	Loch Hourn, Inverness-shire, 1894/5.
,,	—	5°	Brightlingsea, Essex.
,,	—	0°	Colesborne, Glos., 1908/9.
,, whittingehamensis	—	—2° ?	Whittingehame, East Lothian, 1895 (doubtful record).
haemastoma	17°	—	Loch Hourn, Inverness-shire, and Arran, 1894/5.
,,	20°	—	Bayfordbury, Herts., 1955/6, killed first winter after planting.
johnstoni	18°	—	Lizard, Cornwall, 1954. Killed first winter after planting.
,,	—	6° ?	Mt. Usher, Co. Wicklow, Ireland. 1939/40 (slightly damaged).
,,	—	0° ?	Loch Hourn, Inverness-shire, 1894/5.
,,	—	9°	Benmore, Argyll, 1955.
leucoxylon	16°	—	Abbotsbury, Dorset, 1908.
ligustrina	—	—	Kennington, 1939, killed first winter as seedlings.
macarthuri	—	6° ?	Mt. Usher, Co. Wicklow, 1939/40, but recorded killed at Winchester and Willaston at 15°.
,,	15°	—	
macrorrhyncha	20°	—	Bayfordbury, Herts., 1955/6. Killed first winter after planting.
maculata	20°	—	Bayfordbury, Herts., 1955/6. Killed first winter after planting.
melliodora	—	20°	Bayfordbury, Herts. Survived this temperature in first winter after planting.
micrantha	20°	—	Bayfordbury, Herts., 1955/6. Killed first winter after planting.
mitchelliana	17°	—	Winchester, 1940/41.
multiflora	20°	—	Bayfordbury, Herts., 1955/6, killed first winter after planting.
nicholi	—	—	Knapdale, Argyll. Failed early.
niphophila	—	—	Crarae, Argyll. Survived several winters.
,,	—	15°	Royal Bot. Gardens, Edinburgh, 1946/7.
nitens	—	—	Crarae, Argyll, 1956. Survived first winter. (Benmore temperature 13°).
,,	—	20°	Bayfordbury, Herts., 1955/6. Survived this temperature in first winter after planting.
numercosa	20°	—	Bayfordbury, Herts., 1955/56, killed first winter after planting.
obliqua	15°	—	Alice Holt, Hants. Killed as one-year seedlings.
,,	22°	—	Mt. Usher, Co. Wicklow, Ireland.
ovata	17°	—	Winchester, 1940/41.
,,	—	—	Kennington, 1939. Killed first winter as seedlings.
paniculata	20°	—	Bayfordbury, Herts., 1955/6, killed first winter after planting.
parvifolia	0°	—	Kettering, Northants, 1946/7.
,,	—	6° ?	Borde Hill, Sussex.
,,	—	12°	Winchester, 1946/7.
pauciflora	16°	—	Abbotsbury, Dorset, 1908.
,,	17°	—	Londonderry, Ireland.
,,	2°	—	Kettering, Northants, 1946/7.
,,	—	9°	Benmore, Argyll, 1955.
,,	—	9°	Alice Holt, Hampshire, 1953/4.
,,	—	11°	Arran, 1894/5.

TABLE 57—*contd.*

	Killed	*Survived*	
pauciflora × salicifolia....	—	9°	Alice Holt, Hants., 1953/4.
perriniana	17°	—	Londonderry, Ireland.
,, ...	19°	—	Benmore, Argyll, 1949/50 (seedlings).
,, ...	—	9°	Benmore, Argyll, 1954/55.
pilularis	20°	—	Bayfordbury, Herts, 1955/6, killed first winter after planting.
piperita	20°	—	Bayfordbury, Herts., 1955/6, killed first winter after planting.
polyanthemos	22°	—	Mt. Usher Co. Wicklow, Ireland.
pulverulenta	—	6°	Mt. Usher, Co. Wicklow, Ireland, but damaged.
,, ...	17°	—	Londonderry, Ireland, and Loch Hourn, Inverness-shire.
,, ...	—	16°	Abbotsbury, Dorset.
punctata	20°	—	Bayfordbury, Herts., 1955/6, killed first winter after planting.
radiata	—	20°	Bayfordbury, Herts., 1955/6. Survived this temperature in first winter after planting.
regnans	6°	—	Mt. Usher, Co. Wicklow, Ireland.
,, ...	15°	—	Crarae, Argyll, 1954.
resinifera....	17°	—	Loch Hourn, Inverness-shire.
,, ...	20°	—	Bayfordbury, Herts., 1955/6, killed first winter after planting.
risdoni	19°	—	Benmore, Argyll, 1949/50.
rudis	16°	—	Abbotsbury, Dorset.
,, ...	17°	—	Loch Hourn, Inverness-shire, and Arran.
rostrata	18°	—	Mt. Usher, Co. Wicklow, Ireland.
salicifolia × gigantea	18°	9°	Benmore, Argyll, 1950/51, and Alice Holt, 1952/53. But one tree at Alice Holt has survived 9°, 1953.
salicifolia × pauciflora....	—	9°	Alice Holt, Hants., 1953/4. Benmore, Argyll, 1954/5.
saligna	20°	—	Bayfordbury, Herts., 1955/6, killed first winter after planting. Mt. Usher, Co. Wicklow, 1899, said to be "fairly hardy".
sieberiana	20°	—	Bayfordbury, Herts., 1955/6, killed first winter after planting.
stuartiana	—	6° ?	Mt. Usher, Co. Wicklow, Ireland, 1939/40.
,, ...	—	8°	Wisley, Surrey, 1908/9.
subcrenulata	—	16°	Abbotsbury, Dorset, 1908/9.
,, ...	—	9°	Benmore, Argyll, 1955.
subviridis	—	20°	Bayfordbury, Herts., 1955/6, survived this temperature in first winter after planting.
tasmanica	18°	—	Benmore, Argyll, 1950/1.
triantha	20°	—	Bayfordbury, Herts., 1955/6, killed first winter after planting.
urceolaris	17°	—	Winchester, 1940/41.
urnigera	—	6° ?	Mt. Usher, Co. Wicklow, 1939/40.
,, ...	—	0° ?	Loch Hourn, Inverness-shire, 1894/5.
,, ...	17°	—	Londonderry, Ireland.
,, ...	—	16°	Abbotsbury, Dorset, 1908.
,, ...	18°	—	Benmore, Argyll, 1950/51, killed as seedlings.
,, ...	17°	—	Royal Bot. Garden, Edinburgh, 1940/1.
vernicosa	—	—2° ?	Whittingehame, East Lothian, 1894/5.
,, ...	—	0° ?	Loch Hourn, Inverness-shire, 1894/5. Silverton, Devon, recorded as hardy.
viminalis	17°	—	Londonderry, Ireland.
,, ...	22°	—	Arran.
,, ...	—	20°	Bayfordbury, Herts., 1955/6; survived this temperature in first winter after planting.
virgata	6°	—	Mt. Usher, Co. Wicklow, Ireland, 1939/40.

Martin (1948) attempted to classify the eucalypts in Britain according to the minimum temperatures they might be expected to withstand. His order for the less tender species is:—

0°F. *E. vernicosa, parvifolia, niphophila* and the hardier polymorphs of *E. gunnii.* (The inclusion of *E. niphophila* is not entirely on British evidence.)

5°F. *E. coccifera, subcrenulata, johnstoni, urnigera.*

10°-15°F. *E. pauciflora, gigantea, rubida, aggregata, cordata, dalrympleana, ovata, viminalis, macarthuri, pulverulenta, resinifera.*

15°-20°F. *E. globulus, obliqua, regnans, perriniana, cambageana, linearis, amygdalina, rostrata, saligna, risdoni, tasmanica, sieberiana.*

Martin emphasises that temperature alone is not the whole story, and that a given eucalypt may withstand lower temperatures on a well-drained site than on a poorly drained one. It may be added here that prolonged easterly winds in winter will defoliate eucalypts severely even although temperatures do not fall to a level fatal to them. There is no doubt that the length of cold spells is of importance. Eucalypts in western coastal districts are favoured

by the relative shortness of cold spells and often by the shelter from easterly winds, as well as by the infrequency of severe winter frosts. Spring frosts do not appear to be a factor of importance—they do not further limit the distribution of Eucalypts in Britain.

Martin's order of hardiness might be amended by promoting *E. pauciflora* into a first group with his hardiest subjects:—eucalypts which may be expected to make some showing in most districts at low elevations. The second and third groups require progressively milder districts. It is rather doubtful whether we have enough evidence to support any very definite temperature limits, though it is fairly clear that the 10°F. absolute minimum isotherm bounds the regions in which there is any *reasonable* prospect of growing eucalypts. For the less hardy species the area is much more circumscribed. It is a horticultural commonplace that the severity of winter frost increases extremely rapidly inland from the coast, and that while it is possible to grow a tender species such as *E. globulus* within a stone's throw of the sea in Cornwall, it may fail five miles inland. Little is known about the heat or moisture requirements of Eucalypt species in Britain.

SOILS AND SITES PREFERRED

There is little evidence concerning the soil preferences of eucalypts in Britain, though the impression may be obtained that their nutrient requirements are more easily met than those of our native hardwoods. Free drainage appears to be of importance; Martin thinks that *E. gunnii* is less particular in this respect than most species.

One hardy species, *E. parvifolia*, has done quite well on shallow soils over the chalk.

Local shelter from easterly winds in winter is very desirable; some of the best sites are found in sheltered western inlets close to tidal water.

TECHNIQUES OF ESTABLISHMENT

No developments of any importance have occurred in Britain. Eucalypts have normally been raised on horticultural lines, i.e. sown in boxes, pans or specially prepared beds and pricked out into pots or tubes. It is not usually possible to raise one-year stock fit for planting in Britain—but Eucalypts have often been planted successfully from pots during the second summer after sowing.

Young eucalypts are often found to be most unstable after planting, and staking has often been necessary for the first few years.

GROWTH, ETC.

Several species have commonly exhibited very rapid rates of growth in the early stages (that is by British standards). Heights of 20 ft. in four years from planting are not unusual with the faster species in suitable environments. Height growth has been well sustained under the most favourable circumstances. In Ireland at least half a dozen species (*E. johnstoni, urnigera, globulus, stuartiana, angustifolia, dalrympleana*) have been recorded as attaining 100 ft. in height, in some cases (O'Beirne 1945) inside 40 years from date of planting. Records from the British mainland are less impressive, but there are many instances of trees exceeding 80 ft. in height, mainly in the south-western counties, and in the west of Scotland. Special mention must be made of the famous specimen of *Eucalyptus gunnii* at Whittingehame. (Plate 14).

A few other measurements of individual trees are given in Table 58, it being emphasised however that they are not comparative figures, nor necessarily typical of the behaviour of a particular species.

Under favourable conditions eucalypts can equal the rates of height growth expected of the better poplars in Britain, and they can, by British standards, reach very large dimensions.

No volume figures for regular stands are available.

DISEASES, PESTS AND OTHER FORMS OF DAMAGE

The Eucalypts have needed little pathological study in Britain.

SEED-BEARING IN BRITAIN

A number of species have produced viable seed in Britain, one at least *E. gunnii* "*whittingehamensis*", a variant of *gunnii* with *urnigera* affiliations, is represented by third generation offspring. There is some evidence (Martin) that the progeny vary in hardiness.

TABLE 58 EUCALYPTUS: GROWTH RECORDS

Species of Eucalyptus	*Age (where known) yrs.*	*Height (feet)*	*Girth at breast height (inches)*	*Site*
urnigera	50 approx.	73	84	Crarae, Argyll
johnstoni	46	82	63	Loch Hourn, Inverness-shire
coccifera	40 approx.	92	61	Loch Hourn, Inverness-shire
globulus	31	105	—	Avondale, Ireland
gunnii	—	65	105	Brightlingsea, Essex

The following eucalypts are known to have produced viable seed in Britain: *E. coccifera, gunnii, gunnii "whittingehamensis", urnigera, vernicosa, cordata, globulus, johnstoni, parvifolia.*

TIMBER QUALITY. Timber has not been produced in sufficient quantity to warrant testing.

The prospects are not good since few of the best reputed species are hardy in Britain.

POTENTIALITIES IN THE NATIONAL ECONOMY

As previously mentioned, these are extremely slight. Plainly the main drawback to their usefulness in Britain is the extremely restricted area in which they can be expected to succeed.

R.F.W.

EUCALYPTUS: REFERENCES

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Fagus Linnaeus

The European beech, *Fagus sylvatica*, a most important forest tree, is indigenous to Britain. Since it is the finest species in the genus, it is understandable that little attention has been paid to exotic beeches. The American *Fagus grandifolia*, Ehrhart, though introduced as early as 1766, is very rare in Britain. A tree at Wakehurst Place, Sussex, is seventy feet tall with a breast-height girth of 8 ft., but this is exceptional, and *Fagus grandifolia* may be considered a failure in cultivation here.

Fagus orientalis Lipsky seems to have been ignored till quite recently, when it was introduced for comparison with a number of European provenances of *F. sylvatica*. There is apparently some doubt whether it should be considered a separate species as it appears to grade into *F. sylvatica* in the Balkan peninsula.

Small plots planted at Alice Holt and Buriton, Hampshire, in 1954, appear to be healthy, and are growing at about the same rate as European beech. *Fagus sieboldii* Endlicher was planted at Wendover Forest, Buckinghamshire, at the same time, but failed to survive.

R.F.W.

Fraxinus Linnaeus

A large north-temperate genus containing several important timber trees. The European ash, *F. excelsior* Linnaeus, is native to Britain. It is an extremely demanding species, yielding valuable timber only when grown on first-class sites. A somewhat less fastidious ash might have some small place in British forestry.

A number of *Fraxinus* species are in cultivation in Britain and thriving. Perhaps the most popular ornamental ash is *Fraxinus ornus*, the Manna, or Flowering ash, from south-east Europe. Another south European ash, *Fraxinus angustifolia*, does well in the south of England, and some large specimens are recorded. Henry (1909) notes a tree 72 ft. tall at Hardwick, Bury St. Edmunds, Suffolk; the Hon. Maynard Greville has recently (1956) measured a tree at Hardwick 99 ft. tall, which is presumably the same specimen.

Some little attention has been paid to the American ashes as potential forest trees, and of these only *F. americana* Linnaeus can be said to have any prospects. Only two plantations are known. *F. americana, F. oregona*, and *F. viridis* were planted at Cirencester, Glos., in mixture with beech in 1905. The two latter species failed early, but *F. americana* was able to hold a place in the canopy (Macdonald, 1931). The soil at Cirencester is a shallow loam over Oolitic limestone, and the site would be regarded as too dry for the common ash.

At Bedgebury, Kent, a plot planted in 1931 has grown very slowly, and few trees exceed 20 ft. in height after 25 years. However, this showing is quite respectable, as the soil is acid and silty and the site very prone to spring frost, conditions which would render the establishment of common ash most difficult.

There are some good specimen trees at Kew, and Dallimore (1911) remarks that *F. americana* grows faster than the common ash under the adverse soil conditions there. He mentions trees 80 ft. tall with girths of 8 ft. at breast height. What little evidence there is suggests that *Fraxinus americana* is worth further attention.

R.F.W.

FRAXINUS: REFERENCES

Macdonald, J. 1931. Forest Gardens. *For. Comm. Bull.* No. 12. H.M.S.O.

Dallimore, W. 1911. "Notes on Trees Suitable for Experimental Forestry". *Kew Bull.* No. 11. 211-223.

Gleditsia Linnaeus

The American Honey Locust *Gleditsia triacanthos* Linnaeus, is comparatively rare in cultivation, though introduced as long ago as 1700. An unsuccessful effort was made to establish a plot of it at Bedgebury in 1951, the young trees dying in the two subsequent seasons. Our summer temperatures are too low for it. There are, however, some quite good specimens in the south of England. Trees seventy feet tall have been recorded from Kew, and Pampisford Hall, Cambridgeshire.

R.F.W.

Juglans Linnaeus

A number of walnuts are in cultivation in Britain, but only two rank as timber trees. *Juglans regia* has been cultivated since antiquity, and *J. nigra* has been in Britain since the seventeenth century. Neither has been planted to any extent as a forest tree, though many unsuccessful attempts and a lesser number of successful ones have been made.

Juglans nigra Linnaeus

The Black walnut of the eastern United States has been widely planted as an ornamental or park tree, though it is much less planted at the present time. Many very large specimens are recorded, some exceeding 80 ft. in height with breast-height girth of over 12 ft. Particularly fine trees exist at Kew, Surrey; Syon House, Middlesex; Takeley, Essex; Marble Hill, Twickenham; and Hartnell House, Aylesbury, Bucks. It has not done nearly so well in the north, and it may be assumed that its requirements for summer warmth are high.

Black walnut was one of William Cobbett's enthusiasms, but he does not appear to have 'sold' the tree as successfully as *Robinia pseudoacacia*, probably because the walnut is much more difficult to cultivate.

One of the few recorded plantations of Black walnut, at Quidenham, Norfolk, was described by Beevor (1913). This was a mixture of walnut (14 per acre), oak (20 per acre) with smaller numbers of larch and *Robinia*. At 80 years of age the walnut accounted for the same volume per acre as the oak, viz. 500 to 570 hoppus ft. The walnuts appear to have averaged over sixty inches in girth at breast height, and at this age were still mainly sound and healthy. The soil was a sand a foot or more deep overlying chalky boulder till.

The only recent investigations of Black walnut have been concerned with the raising of the tree in the nursery, type of stock and methods of planting, etc. As common walnut (*J. regia*) was the principal experimental subject, the results will be mentioned under that species. The behaviour of *J. nigra* did not differ significantly.

J. nigra has been planted alongside *J. regia* in several establishment experiments at Ffosydd Orles, Tintern Forest, Monmouthshire, in the years 1937 to 1940. It has not proved any easier to establish, and is neither faster in growth nor better in form than the common walnut on this site. As the elevation at Ffosydd Orles is about 400 ft. and the aspect north-westerly, it may be the site is rather too cool for *J. nigra*.

Very small quantities of home-grown timber have been handled by the trade, mainly for furniture making.

Juglans regia Linnaeus

The common walnut is indigenous to south-east Europe and Asia Minor. The date of its introduction is unknown, but it is certainly ancient. The timber of the common walnut, though very valuable, is really a by-product, since the tree has been planted primarily for its nuts. Walnut is much less planted nowadays than it used to be.

Since it is a tree which demands the most fertile soils and has a wide spreading crown intolerant of competition, it is likely to do best if cultivated on 'orchard' lines rather than in a more conventional type of plantation.

It is not an easy tree to raise or establish. It has been found (Gray 1939) that the most suitable stock for planting is produced by lifting and cutting back both the shoot and the tap root of stout two-year-old seedlings; the 'stumped' plants are then lined out for a further two years. A number of efforts to establish plantations of *J. regia* were made in the 1930's, and most proved totally unsuccessful. The chief errors seem to have been the siting of the tree on soils which were too heavy, and failure to realise that a tree of such demanding nature required extremely careful tending; in fact arboricultural rather than silvicultural attention.

One plantation has succeeded. At Ffosydd Orles, Monmouthshire, a few acres of walnut were planted between 1937 and 1940 in groups amongst coppice, the soil being a deep rich loam over Old Red Sandstone. Various experimental treatments—planting methods, mulching, manuring, etc. were tried here, with indifferent results, the early growth of the trees being disappointing. However, it was found that the coppice shelter, which had been retained as frost protection, did more harm than good, and a vigorous and continuous weeding programme has resulted in a high proportion of the walnut getting away. The best trees are now some 28 ft. tall.

Season of pruning experiments carried out at Ffosydd Orles, showed that only in the months of July and August could green branches be removed without profuse sap flow.

Walnut reaches very large dimensions on suitable sites, particularly in girth. Specimens girthing 15 ft. at breast height are not rare, and much larger girths have been recorded (Elwes 1909). It does not often exceed 70 ft. in height. It is probable that walnut is best grown as an orchard tree, and it is possible to select cultivars which are suited to both fruit and timber production (Witt, 1939). R.F.W.

JUGLANS: REFERENCES

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Liriodendron Linnaeus

Of the two species in this genus, *L. chinense* is rarely seen and we are thus only concerned with the American *L. tulipifera.*

Liriodendron tulipifera Linnaeus

This tree, which has a wide distribution in North America, from Canada to Florida, Alabama and Mississippi, is said to have been introduced by Tradescant in the seventeenth century. It was certainly in cultivation in London before 1700.

For a considerable time it was a favourite tree for planting in parks on account of its handsome appearance and, though for a time it was little used, it appears to have come back into favour to some extent. When planted on a suitable site, with a moist, deep soil, it can reach an impressive size, but it seems definitely to be a tree for southern England because all the large specimens occur south of the Midlands although the tree can be grown in the extreme north of Scotland. The tallest is a tree 110 ft. in height with a girth of 22 ft. 2 in. at Killerton, Devon, and there is a tree 105 ft. high and 14 ft. 10 in. at breast height at Albury Park in Surrey. In this county, too, at Esher Place, there is probably the largest of the *Liriodendrons* in England, a specimen 90 to 100 ft. high and 25 ft. 9 in. in girth (Gardner, 1948).

Liriodendron does not seem to have been used as a forest tree in Great Britain and the only available record is from the plot at Bedgebury in Kent, which was planted in 1931. The trees started slowly and after 20 years growth had reached only 12 ft. in height, but the tree is obviously unsuited to the site. If carefully chosen sites, such as those which grow the best ash, were given to this tree, it might make an excellent crop either by itself or in mixture with other species.

J.M.

LIRIODENDRON: REFERENCE

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Nothofagus Blume

The "Southern beeches" are amongst the most recent introductions to Britain. The performance of the genus here is very uneven, and the only really successful representatives are certain Chilean species. Two of these, *N. obliqua* and *N. procera*, have attracted attention as forest species, and are considered in some detail below.

The New Zealand and Australian members are all plainly unsuited to our climate and have no prospects in British forestry. Specimens of *N. fusca* and *N. cliffortioides* are occasionally seen in arboreta; there are some quite good trees, between 50 and 60 ft. tall, of *N. fusca* at Exbury House, Hampshire. The remaining Antipodean species are rare in cultivation.

Nothofagus obliqua (Mirbel) Blume

Nothofagus obliqua grows in Chile between latitudes 35° and 43° south. It is a species of the drier regions, inland from the coastal evergreen rain forest. Its range is considerable, but so far its provenance attributes have not been studied, though plans are in hand to do this.

N. obliqua was introduced in 1902 by H. J. Elwes (Bean, 1906). A number of trees raised from Elwes's seed still exist. One specimen at Kew had attained 68 ft. in height by 1927 (Anon, 1927), a rate of growth which was considered most unusual for a broadleaved species in these gardens. In 1951, the tree was 79 ft. in height, with a girth of 5 ft. 4 in.

A further important introduction dates from H. F. Comber's Andean expeditions of 1925-6 and 1926-7, the seed collected being distributed to a considerable list of subscribers throughout the country. Perhaps the most notable specimens from this introduction are at Muncaster Castle, Cumberland, where Sir John Ramsden has a most interesting collection of *Nothofagus* species. A quarter-acre plot at Muncaster, planted about 1932 at wide spacing, is one of the first plantations of the species. In 1953 (i.e. at 21 years of age) the trees were about 60 ft. in height, with a mean breast-height girth of 48 in., and a standing volume of approximately 2,800 Hoppus ft. per acre. A plot was planted at Bedgebury, Kent, between 1930 and 1934. In 1953 this had a top height of 45½ feet., a mean girth of 13 in., and a standing volume of 1,215 Hoppus ft.; in addition 720 Hoppus ft. had been removed in thinning.

A small plot at Lael, Ross-shire, averaged 31.6 ft. in height at 17 years of age, and appears healthy and vigorous. An interesting plantation in Windsor Forest, Berkshire, has grown nearly 20 ft. in 10 years since planting. The *Nothofagus* is mixed with larch, and is considerably taller than that species. The plants used were natural seedlings found round an old tree growing in an abandoned nursery.

The difficulty of obtaining seed has always hampered trials, though small quantities of stock have been raised from home-collected seed for some years. A considerable importation of seed from Chile in 1954, however, allowed an extensive series of trial plantations to be established in 1956. But in general the planting of *N. obliqua* remains on a purely experimental scale.

The climatic and site requirements of *N. obliqua* can only be estimated on somewhat inadequate evidence. The tree does not (so far) appear to be

limited in Britain by winter cold. Dallimore (1909) noted that young trees at Kew were unharmed by the particularly difficult winter of 1908-9.

The Bedgebury plot withstood about 41 degrees F. of frost (grass min.) in January 1940, without injury. However, occasional trees in this plot show slight cambial injuries on the lower stem, which appear attributable to frost damage.

N. obliqua does not seem to require heavy rainfall. The rainfall at Bedgebury is approximately 31 in. per annum. This species has also done well at King's Forest in Suffolk on a dry sandy soil overlying the chalk, with an annual rainfall of not more than 25 in. However, its growth is noticeably faster in the moister west.

It appears to have quite low site requirements for a broadleaved tree. At Bedgebury, the soil is an acid silt of low base status not suited to the more demanding broadleaved subjects; but *N. obliqua* has so far grown faster than would be expected of beech on a good site. It tolerates calcareous soils (Anon,1925) and appears healthy, though slow growing, on a heavy boulder clay in Rockingham Forest, Northamptonshire.

N. obliqua is an easy species in the nursery. The standard treatments for coniferous seedbeds appear to suit it well enough. Sowing rates of 30 sq. yd. per lb. of seed, at 30 per cent germination capacity, equivalent to 500 viable seed per square yard, are suitable. One-year seedlings are usually big enough for lifting and transplanting, after which one year in transplant lines is usually sufficient to produce plantable stock. Seedlings frequently die back several inches after transplanting, but usually recover satisfactorily.

No special planting techniques have been developed. Survival has usually been fair to good, though large numbers of plants have in certain seasons died back almost to ground level; most however recover well. The cause of this trouble is not clear.

N. obliqua grows quickly after establishment, and no special tending problems have arisen. What little experience of thinning is available suggests that *N. obliqua* should be thinned a good deal more heavily than beech (*Fagus sylvatica*), since the crowns diminish quickly in competition and do not appear to recover readily. Stem form is moderate, and self pruning rather slow. *N. obliqua* is understood to be a light demanding dominant in its native habitat (Kalela, 1941) and appears to behave as such in Britain.

N. obliqua produces viable seed quite freely in Britain; the Bedgebury plot began to fruit in 1953 at 23 years of age. Home-grown seed is of fair quality, and has averaged 50,000 to the pound with a mean germination percentage of 30. It has proved easy to store dry at a temperature of 35°F.; and prior to sowing, stratification for two months in moist sand has proved beneficial.

Quite profuse natural seeding has been noted at Bedgebury in the 27-year-old plot ; and large numbers of seedlings have survived one or more seasons without any measures being taken to husband this (unwanted) regeneration. Natural seedlings have also been observed in some quantity at Tortworth, Gloucestershire, below one of the original "Elwes" trees.

It is too early to assign any place to *Nothofagus obliqua* in British forestry. It shows some promise of filling a gap in our range of broadleaved species, as it appears to grow rapidly on soils of rather low nutrient status on which most of our broadleaved species are unproductive. Little is known of its timber quality in Britain, though examination of young material has been mildly encouraging. Should it approach the standard of the imported material, and should the tree confirm its early silvicultural promise, there seems little doubt that *N. obliqua* would prove a useful acquisition.

Nothofagus procera (Poeppig and Endlicher) Oersted (Plate 15).

The range of *N. procera* in Chile is contained by the rather larger one of *N. obliqua*. *N. procera* was also introduced by Elwes in 1902, and its history closely parallels that of *N. obliqua*. It has been tried on a very similar scale, but on the whole appears to be a much less promising species for general cultivation in Britain since it has not shown the same degree of winter hardiness as *N. obliqua*.

As with *N. obliqua*, extremely fast growth has been recorded in a number of localities. At Muncaster Castle, Cumberland, a tree planted in 1923 was 74 ft. in height with breast height girth 5 ft. 11 in. in 1955, at an age of 33 yrs. Individuals of similar dimensions are also recorded at Westonbirt, Gloucestershire, and at Castle Kennedy, Wigtown. Plainly the best trees are in the west.

There are a few small trial plantations dating from the 1930's. At Bedgebury, Kent, a trial plot planted in 1930 made good early growth, but was almost completely destroyed by the severe cold of January, 1940, when 41 degrees of frost (grass minimum) were recorded nearby. Only a few trees survived.

An interesting example of cold injury to *N. procera* has been noticed at Alice Holt, Hampshire, where rapidly growing four-year-old trees developed curious swellings at the base of the stem following severe conditions in the winter of 1953-1954; a number subsequently died back to this point.

Further west, experience has been more favourable. A plot at Haldon, Devon, established in 1937 by underplanting a stand of European larch, has exhibited extremely fast growth. In 1956 (i.e. at 19

yrs. of age) the *Nothofagus* averaged 39 ft. in height with a mean breast height girth of 15 in. Several trees however suffered damage during the winter of 1955-6, die back (apparently due to cold injury) being observed in the crowns. Promising early growth has also been experienced in trial plantations at Herodsfoot, Cornwall, and Dovey, Merioneth. The latter plot has been of particular interest, since it was established at approximately 1,000 ft. elevation towards the highest level considered advisable for Japanese larch in view of the exposure. At 19 years of age, the *Nothofagus* had a top height of 45 ft., being slightly in advance of the adjacent Japanese larch. The total yield so far has been 1,700 Hoppus ft. per acre.

An extensive series of trial plots was planted in 1956 following the importation of substantial quantities of seed from Chile in 1954. Planting remains on a purely experimental scale.

The stem form of *N. procera* appears much superior to that of *N. obliqua* under British conditions; indeed in young plantations the trees appear as regular as poplars. *N. procera* produces viable seed quite freely; the remaining trees in the plot at Bedgebury began to fruit in 1953, and several plantations have been raised from their progeny. Home-produced seed appears as good as imported, averaging some 45,000 to the pound with mean germination capacity of 30 per cent. It is stored and treated much as *N. obliqua*, but a shorter period of stratification (4 weeks) prior to sowing appears sufficient. One-year seedlings are often a foot or more in height.

N. procera is understood to be a more shade-tolerant species than *N. obliqua* in the Chilean forests (Kalela). Little comparative experience is available in Britain, but the success of the underplanting at Haldon has been noted.

No clear separation of the site requirements of the two species is yet possible in this country, save for the overriding climatic factor of winter cold. There is some suggestion that *N. procera* responds to a greater degree to increasing moisture than does *N. obliqua*.

The imported timber of *Nothofagus procera* has a considerable reputation, and the tree plainly has very desirable silvicultural characters. Unless a provenance remedy can be found for its lack of winter hardiness, planting outside the milder localities appears to be hazardous.

R.F.W.

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Platanus Linnaeus

The planes require brief mention for the sake of *P. acerifolia*, the London plane. The oriental plane, *P. orientalis* Linnaeus, appears to have been in cultivation from about the middle of the sixteenth century (Loudon, 1854). The introduction of the occidental plane, *P. occidentalis* Linnaeus, is credited to John Tradescant about the year 1630. Oriental plane is hardy in Britain, and grows to large dimensions in the south, forming a massive crown with spreading branches which often reach the ground. Occidental plane, on the other hand, is a failure in cultivation, though curiously enough it seems to have grown successfully for many years after its introduction, till (according to Loudon) severe spring frosts in 1809 and the hard winter of 1813-14 combined to destroy a large proportion of the trees in England. Subsequent introductions have often failed to survive the first winters in the nursery, and there do not appear to be any good specimens in the country at the present time.

Platanus acerifolia (Aiton) Willdenow

This, the London plane, is considered to be a hybrid between the oriental and occidental planes. Henry and Flood (1919) suggest that it originated in the Oxford Botanic Gardens about the year 1670. It has been propagated vegetatively and widely distributed; it is the commonest and best street tree of London and is extensively planted on the Continent.

In Britain, its best performance is in the south. It combines the hardiness of *P. orientalis* with the fine stature and stem form of *P. occidentalis*, and is a tree of considerable longevity. There are many specimens of London plane exceeding 100 ft. in height with girths of 15 ft. and more. One of the largest trees is at the Bishop's Palace, Ely, Cambridgeshire; in 1950 this tree was 114 ft. tall with a girth at breast height of 26 ft. 4 in.

Most of the best trees appear to be growing on light soils of good fertility. Few efforts appear to have been made to make plantations. A plot of London plane failed at Bedgebury, Kent, on a poor silty soil, but there seems little reason why the tree should not succeed on really good broadleaved sites in the south. The timber is sometimes used for furniture or interior panelling and has a very pleasant figure.

R.F.W.

PLATANUS: REFERENCES

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Populus Linnaeus

Varieties Cultivated

There are three species of poplar native to Britain, namely *Populus alba* Linnaeus, the White poplar; *P. nigra* Linnaeus, the Black poplar; and *P. tremula* Linnaeus, the Aspen. In addition, *P. canescens* Smith, the Grey poplar, which is probably *P. alba* × *tremula*, also occurs wild. None of these are of much commercial importance, though *P. canescens* grows to a large size and selected clones may prove valuable for woodland sites.

Thus we are largely dependent on exotic species, or on hybrids with at least one exotic parent, for our main poplar plantings. A very large number of species, varieties and hybrids occur in gardens and arboreta, and an even larger number are being tested for timber production under varying conditions in different parts of Britain. The list of exotic or semi-exotic poplars below comprises only those varieties which have been long enough under test for some useful information on their behaviour to have come to light.

SECTION LEUCE: WHITE POPLARS

P. grandidentata Michaux, North America
P. tremuloides Michaux, North America
X *P. tremula* × *tremuloides*. Mainly imported as seedlings from Denmark, but also raised in Britain, using imported *P. tremuloides* pollen.

SECTION AIGEIROS: BLACK POPLARS

P. deltoides Marshall, North America
P. freemontii Watson, North America
P. sargentii Dode, North America
P. wislizenii Sargent, North America
X *P. euramericana* (Dode) Guinier so-called, Hybrid Black poplars, all basically *P. deltoides* × *nigra*
X *P. 'serotina'*
X *P. 'robusta'*
X *P. 'eugenei'*
and many others.

SECTION TACAMAHACA: BALSAM POPLARS

P. koreana Rehder, Eastern Asia
P. laurifolia Ledebour, Eastern Asia
P. maximowiczii Henry, Eastern Asia
P. simonii Carrière, Eastern Asia
P. tacamahaca Miller, North America
P. trichocarpa Hooker, North America
P. yunnanensis Dode, Eastern Asia,
X *P. koreana* × *trichocarpa*
X *P. maximowiczii* × *trichocarpa* (including P. 'Androscoggin')
X *P. tacamahaca* × *trichocarpa*

TACAMAHACA × AIGEIROS HYBRIDS

X *P. berolinensis* Dippel group. (*P. nigra* × *laurifolia*?)
X *P. 'generosa'* Henry (including P. 'McKee') (*P. deltoides angulata* × *trichocarpa*)
X *P. candicans* Aiton (*P. gileadensis* Roul.)
X *P. maximowiczii* × *nigra* (including *P.* 'Rochester')
X *P. deltoides angulata* × *simonii*
X *P. nigra* × *trichocarpa*

SECTION LEUCOIDES

P. lasiocarpa Oliver
P. wilsonii Schneider

SECTION TURANGA

P. euphratica Oliver

General Discussion

Before considering the separate groups, a few general notes may be of value. Poplars are still a minor species in Britain's forest economy, and despite considerable opportunities for further planting, they will never rank in importance with the major genera. However, their suitability for hedgerows, roadsides, and small spinneys on sufficiently moist fertile soils, and their comparatively rapid return, are leading to a steadily increasing interest, and considerable extensions to the very small acreage at present under poplar.

Though all poplars tend to be rather demanding, if satisfactory growth is to be achieved, the climatic and soil requirements of the different groups vary considerably and will be considered separately.

For all groups except *Leuce* and *Leucoides* propagation from nine-inch hardwood cuttings, inserted in the nursery in early spring, is standard. Sometimes these can be planted out after one year in the nursery, but normally thay are transplanted and stumped, being used for planting with a one-year shoot and a two-year root. Plants with stout shoots four to nine feet in length are considered desirable. On good sites the use of unrooted sets, consisting of eight to twelve foot shoots, usually two years old and cut from special stools, is feasible. But on all but the best sites rooted plants give better establishment.

Planting is normally by the pit method, using large pits; mulching for several years, until establishment is complete and rapid growth has commenced, is highly desirable, though not always practised.

No weeding of herbaceous plants is required, due to the suppression of weed growth by the mulches, but coppice competition has to be restrained. With the comparatively low light values found in Britain, poplars will not tolerate competition for light. For the same reason poplars prefer free crown growth, and therefore grow particularly well as individuals or in lines. In plantation some crown competition is unavoidable, but it must be kept to the minimum or growth will fall off. In the absence of a good market for small sizes of poplar, wide spacings, from 24 × 24 ft. to 28 × 28 ft., are often advocated. A good general market for poplar pulpwood would make closer planting much more economical. Little information is yet available on pruning, but it is now considered that it should be kept at a minimum until the trees are fully established and growing rapidly. Thereafter about half the stem should be kept clear of branches until an economic height, probably 20 to 25 feet of clear stem, is reached.

By far the most serious disease of poplars in Great Britain is bacterial canker caused by *Pseudomonas syringae* forma *populea*. There are very big differences in varietal resistance to this bacterium, and in practice no great difficulty has been experienced in finding sufficient resistant clones for commercial use. Nevertheless it has a major effect on the selection of varieties for planting, and will be considered again below. The fungal canker caused by *Dothichiza populea*, which is so serious on the continent of Europe, is seldom more than a nuisance in Britain, being strictly confined to plants weakened by close spacing in the nursery and by other adverse factors, such as drought, after transference to the field. The very prevalent leaf rust, caused by *Melampsora* species, has the same status. It does not prevent the successful cultivation of even the most susceptible clones.

Poplars have a very large insect population, as they are attractive to leaf feeders, sucking insects and wood borers, but none of these are sufficiently destructive to have any serious effect on poplar cultivation.

No organised poplar breeding is in progress in Britain, though preparation is being made for a very limited programme of work on the cross *P. maximowiczii* × *trichocarpa*, which appears to have especially good possibilities in this country.

There is a steady demand for poplar timber for matches, for chip baskets for fruit, and for a few other specialised purposes. Much of the poplar grown hitherto was not properly pruned and hence was not acceptable for the veneering which these products involve. Apart from this, poplar is acceptable in the general timber market, being comparable to softwood for uses such as box making. No general outlet yet exists for poplar as pulpwood.

Most of the information about poplars in Britain is available in two Forestry Commission publications: Bulletin No. 19 *Poplars* and Leaflet No. 27 *Poplar Planting*. In addition, a mimeographed *List of Poplars in the Possession of the Forestry Commission Research Branch*, is prepared annually for limited circulation.

Section Leuce

Populus tremuloides and *P. grandidentata*, the two American aspens, have not been fully tested in Great Britain, but so far they show no particular promise. The information below applies mainly therefore to *P. tremula* × *tremuloides*, which is now raised on a commercial scale in several Scandinavian countries.

This hybrid has only been planted in Britain on a trial scale, but on a fairly wide range of sites. It appears, like native *P. tremula*, to be more tolerant of acid soils and woodland conditions than most other poplars.

It is almost impossible to raise this hybrid from hardwood cuttings, and laborious and expensive to raise it from softwood cuttings in the summer, so that seed is the best method of propagation. For this reason, it cannot be dealt with on a clonal basis like most other poplars. The necessity of producing hybrid seed has limited even its trial use in Britain, and most of the plants used have been imported as seedlings from Denmark. The very small seeds require a very fine, shaded and moist seedbed. Evidence so far suggests that rather smaller plants, two to three feet high, are more easily established than plants of the size favoured for most other poplars. Stumping and growing on in the nursery for a year before planting out, is probably beneficial and certainly produces a straighter shoot.

It is assumed that being naturally trees of close woodland, aspens would stand closer spacing than other poplars, but no evidence is yet available on the later stages of their growth.

Early growth rates of the hybrid aspen, on some sites, are markedly superior to the best achieved by the native *P. tremula*; but establishment has always proved more difficult than with most other poplars. On the best sites height, but not diameter growth, is comparable with that of the Black and Balsam poplars.

Unfortunately all the plants of *P. tremula* × *tremuloides* so far tested have proved extremely susceptible to the bacterial canker *Pseudomonas syringae* forma *populea*. For this reason, despite its early promise, this hybrid aspen cannot be used on a commercial scale in Britain, unless resistant strains can be discovered.

Section Aigeiros

Populus deltoides, which has a vast range in North America, and is in consequence extremely variable, was never planted in the past outside botanical collections. Recent trials of a number of promising clones bear no suggestion that pure *P. deltoides* is likely to rival the *P. euramericana* hybrids under British conditions. *P. sargentii*, *P. wislizenii* and *P. freemontii* generally come from further south and west in the United States than *P. deltoides*, and as might be expected, they are less suited climatically to the British Isles. Some clones are very subject to winter injury. It is most unlikely that any of them will be used for timber production. The remarks below therefore can be taken as applying in the main to the Black hybrids, *P. euramericana*.

All the Black poplar hybrids are now properly classified as horticultural varieties of *P. euramericana*. *P.* '*serotina*', the first to appear, has been in cultivation in Britain for about 100 years, and individual trees have reached very large sizes. Trees containing over 1,000 Hoppus Feet of timber in the trunk and main limbs have been recorded. Most of the other Black hybrids have only been in cultivation for 40 to 50 years or less, and have not yet had an opportunity to reach their full size. A number of varieties, in particular *P.* '*pseudo-eugenei*', are very susceptible to bacterial canker, but most of them are reasonably resistant. Five varieties have been recommended for general planting, and officially certified clonal stocks are maintained for distribution to private landowners and to the nursery trade. The trees originally selected were:—*P.* '*robusta*', *P.* '*serotina*', *P.* '*gelrica*', *P.* '*eugenei*', *P.* '*serotina erecta*' so-called. The last of these has been discarded recently and *P.* '*laevigiata*' substituted. These varieties, and particularly *P.* '*serotina*' and *P.* '*robusta*', have provided the bulk of the poplars planted in Britain during the last ten years. Two other of the older hybrids have done quite well, they are *P.* '*marilandica*', which has not been generally recommended because it is slower and less straight than the others, and *P.* '*regenerata*', some clones of which are canker-susceptible. A number of more recent Black hybrids are on trial, some of which may eventually replace or be added to the present recommended varieties. Even within a supposedly uniform hybrid such as *P.* '*robusta*', there are appreciable clonal differences in rate of growth, crown form, etc., so that further selection is not only possible, but desirable.

One interesting group consists of the selections made in Italy from a semi-natural population of Black hybrids growing in the Po valley. Some of these are of very rapid growth, but they appear better adapted to a longer growing season than we experience, and in Britain late cessation of growth in the autumn has led to frost injury.

It is clearly evident as one moves south in Europe that the Black poplars are essentially trees requiring long, hot summers and high light intensities. The hotter the temperature and the brighter the light the faster they grow and the closer they can be planted. The British Isles appears to be on the edge of their commercial range. The further north one goes in Britain the better the site must be if poplars are to be grown satisfactorily. Most of the commercial planting of Hybrid Black poplars is likely to remain in the southern half of England, though very good sites further north will yield satisfactory returns on a slightly longer rotation. The very best sites in the south may produce timber for match veneering in 20 to 23 years, though 25 to 30 years is likely to be more general, and in the north 30 to 35 years is to be expected. The Balsam poplars of the section *Tacamahaca*, in particular *P. trichocarpa* and its hybrids, appear more suited for the regions of Britain with low summer temperatures.

Volumes on these rotations are likely to range from 2,500 to 3,000 Hoppus feet per acre. This is not a high volume, but it must be remembered that the rotation is very short compared with that accepted for other timber trees in Britain.

Section Tacamahaca

Most of the Asian Balsam poplars can be ruled out on account of their high susceptibility to bacterial canker. Several, for instance *P. koreana* and *P. yunnanensis*, are not winter-hardy in Britain. Only *P. maximowiczii* appears to have any possibilities, and then rather as a parent than in its own right. Most of the *P. tacamahaca* planted in Britain in the past appear to be of a single, very free-suckering clone. It is probably a bad clone, and has grown very poorly, seldom reaching timber size. However, more recent importations of the same species from a wide range of sites in North America have done little better.

In the same way nearly all the *P. trichocarpa* in Britain appears to have originated from a single clonal introduction. As far as rapidity of growth is concerned it is a very good clone; where it has not been attacked by bacterial canker some very fine trees have been grown, but unfortunately it rapidly falls victim to canker whenever it becomes infected.

Recently a number of fresh importations have been made both of *P. trichocarpa* and of *P. tacamahaca* × *trichocarpa* hybrids. Some of these appear to be highly resistant to canker, and their early growth is equal or superior to that of the established clone. Despite the fact that they have not been fully tested, two of them have now been issued as approved varieties.

A clone of the hybrid *P. koreana* × *trichocarpa* has proved the fastest poplar in the nursery under English conditions, shoots eleven feet tall having been produced in a single season; but in the field, this variety, which in any case is not fully hardy, yields pride of place to *P.* '*Androscoggin*' a *P. maximowiczii* × *trichocarpa* hybrid raised originally in the United States by Stout and Schreiner. On a very favourable site this tree has reached 50 ft. in six years, which is extremely rapid growth for English conditions. Unfortunately it is too susceptible to bacterial canker to be put into general use. Several other clones of the same cross appear promising, and it is hoped later, by using canker-resistant parents, to repeat the cross with more hope of getting a fully resistant Hybrid.

The importance of the Balsam poplars, particularly of *P. trichocarpa* and its hybrids, rests on their suitability for those parts of the British Isles, especially the west and north, where the summer temperatures are lower, the rainfall higher, and the soils rather more acid than in the south. Under these conditions, but still only on the better sites, the Balsam poplars grow much better than the Black hybrids. Canker-resistant Balsam poplars of good growth would therefore substantially increase the available site range for the genus.

Balsam poplars also appear to be more adapted to woodland conditions than the Black Hybrids, standing competition with other trees or among themselves rather better. Poplars, because of their rapid growth, and because they can be planted at wide spacings, have suggested themselves for derelict woodland sites, where the cost of clearance is often the main bar to re-afforestation. Except on the best sites the Black hybrids have proved unable to cope with coppice competition, but the Balsam poplars may prove rather more suitable for the reclamation of derelict woodland sites on reasonably good soils.

Tacamahaca × Aigeiros Hybrids

The large and confused *P. berolinensis* group provides some clones of very good form and unusually dense foliage, which may, despite their relatively slow growth, be valuable as roadside trees in Britain, combining good appearance with eventual utilisation value.

P. '*generosa*', which was the first deliberately-produced hybrid poplar, made by Professor Henry at Kew in 1914, is too canker-susceptible to be of any practical value. In any case, though initial growth is very rapid, it normally falls behind *P. trichocarpa* before it has reached veneering size. The 'McKee' poplar, patented in America, is the same cross and is equally canker-susceptible.

P. candicans, which is probably *P. deltoides* × *tacamahaca*, was planted widely in Britain as an ornamental under the name of Ontario poplar, mainly because of the Balsam odour of the breaking buds in the spring. It is extremely susceptible to bacterial canker and is tending gradually to die out.

A number of other Balsam × Black hybrids are under test, but it is too early yet to say much of their behaviour. Some are certainly canker-susceptible, but others may play a part in British poplar cultivation in the future.

In general the climatic and soil requirements of this group seem to be nearer that of the pure Balsams than that of the Black parent. Most of them do reasonably well in the north in conditions of low sunshine, and on slightly acid soils. Like the Balsam poplars they will tolerate semi-woodland conditions.

Section Leucoides

P. lasiocarpa and *P. wilsonii* have been planted fairly widely in arboreta mainly on account of their very large leaves. It is evident from these trees that they have no future for timber production. Some other members of this group are being grown at the Forest Research Station, but propagation difficulties have limited their use, and in any case none of them appear potential timber trees under British conditions.

Section Turanga

P. euphratica, which is really a sub-tropical poplar, is certainly not hardy in Britain. It has been grown as grafts for a single season, but perished during the winter.

T.R.P.

Prunus Linnaeus

The genus is represented in Britain by the native *Prunus avium*, the gean, and several other shrubby species of no importance. *Prunus avium* is an occasional constituent of beech woods and can reach large dimensions. There is little need to look elsewhere for a *Prunus* of good stature and timber quality, but two exotic species have been tried.

Prunus serotina Ehrhart

This tree from eastern North America was planted at Cirencester in 1905. James (1951) considers the crop "of no value". More recently, (1953) a plot has been established at Bedgebury. It is healthy but the young trees are very bushy. *P. serotina* has been used in Holland as a shelterbelt tree; it has however been found that it is an alternate host of *Myzus persicae*, an aphid carrier of a virus disease of sugar beet. Hence its planting in Britain is to be discouraged.

Prunus sargentii Rehder

This species, which comes from Japan, was planted at Bedgebury in 1949. It is almost certainly of more value as a decorative species than as a forest tree.

R.F.W.

Quercus Linnaeus

This important north temperate genus of some 200 species is represented in Britain by *Quercus robur* Linnaeus and *Quercus petraea* (Mattuschka) Lieblein, the pedunculate and sessile oaks.

Oak forest is the most important broadleaved type in Britain, though all existing oak woodland has been greatly modified by centuries of management. Exotic oaks have so far been of no significance in British forestry, and are not likely to become of any great importance. A large number of species are in cultivation, and many are of value in arboriculture.

A few have been tried under forest conditions, but only two seem likely to find any place in our silviculture, these are the American Red oak, *Q. borealis* and the Turkey oak, *Q. cerris*.

Quercus borealis Michaux filius Plate 16

The Red oak of eastern North America was introduced by Miller in 1739, and is the most successful of the American oaks. Although so long in this country, there seems to have been little interest in the Red oak as a forest tree till the twentieth century. The history of the tree as a forest exotic in western Europe is a good deal longer, and in parts of Belgium, Holland and France it is more or less naturalised. Although Elwes (1909) mentions that Red oak ripens seed in the south of England, it frequently fails to carry its acorns to the second year and it is probable that the more plentiful production of seed on the Continent has been a big factor in the development of the tree there.

Red oak may have a place in Britain on sandy soils which are insufficiently fertile for the native oaks. It is unlikely to be as productive as our native oaks on the better sites over rotations aiming at large dimensions; but will probably grow faster on any site for thirty years or so.

Red oak has been tried on lowland *Calluna* heath, often in mixture with pines, in the hope that its litter will effect an improvement in the soil. Few plantations on heathland sites have however reached any age. A great deal of Red oak is planted simply to provide autumn colour.

There are few crop measurements yet available; data from three permanent plots are summarised in Table 59.

Red oak is not a long-lived tree and need not be expected to compare in ultimate dimensions with our native species. It does not commonly exceed 12 ft. in girth at breast height; it reaches good heights however, and many trees between 80 and 100 feet tall are recorded.

There is little information on the timber properties of Red oak grown in Britain. It has however proved very easy to cleave, and as it absorbs preservatives freely it can be rendered durable and so should be useful for fencing and estate work. It has been used successfully in the manufacture of pallets for fork-lift trucks. It may be regarded as a general purpose hardwood, but not as a substitute for English oak in its more specialised uses.

It is unlikely that Red oak will ever be extensively planted, but it may well find a small place on marginal broadleaved sites in the south.

R.F.W.

Quercus cerris Linnaeus

The Turkey oak, of which the date of introduction is unknown, was in cultivation and being planted in England in the eighteenth century. It is a native of south-eastern Europe, Asia Minor and Syria.

The Turkey oak, at least in the southern parts of Great Britain, is the most vigorous oak we have, and one of the best-formed, growing better than either *Q. petraea* or *Q. robur* particularly on light soils. It is a pity, therefore, that its timber is in such ill-repute. It bears seed regularly and natural seedlings are frequently seen, often occurring in adjoining plantations of other species, and there is no doubt that if the tree were more abundant in the country it would speedily naturalise itself and spread by natural seeding as the sycamore is doing.

TABLE 59 QUERCUS BOREALIS: GROWTH AND PRODUCTION

	Age yrs.	*Top Height ft.*	*Mean Girth Breast Height in.*	*Standing Volume Per Acre, Hoppus ft. O.B.*	*Total Yield, Hoppus ft. O.B.*
Sutton Bottom, Forest of Dean	22	42½	11	478	689
Bedgebury, Kent	26	36	12	439	610
Herriard Park, Hampshire	51	73½	30½	1,969	—

Individual trees reach a considerable size and several have been recorded over a hundred feet in height. There are some excellent specimens in the suburbs of London which indicate that the Turkey oak is at least moderately tolerant of atmospheric pollution.

This oak has been little used in the forest and, indeed, if it appears, it is usually promptly cut out; but there is one record of a plot of plantation-grown Turkey oak at Knutsford in Cheshire which, at 110 years of age, had a top height of 95½ ft., a mean girth of 87 in. and a volume per acre of 3,055 Hoppus feet.

The timber suffers from lack of durability which makes it unsuitable for outdoor use, while the heartwood is resistant to impregnation with preservatives. Its strength properties are said to be inferior to those of the native oaks but it is a good bending timber and works well with hand and machine tools.

It seasons slowly with considerable degrade. When seasoned it weighs between 50 and 55 lb. per cubic foot.

If some continuing use could be found for the timber of this tree, it would have a future in British forestry.

Quercus coccinea Münchhausen

The Scarlet oak is a native of North America where it occurs in southern Canada, in the north-eastern United States and westwards as far as Nebraska. It has long been known in Great Britain for it was introduced in the seventeenth century, and a tree is said to have been growing in Bishop Compton's garden at Fulham in 1691. Elwes and Henry give it as their opinion that this tree does not grow so large in England or reach so great an age as *Q. borealis*.

Although a number of moderately tall trees have been recorded, none of them has any great girth, and it is possible that *Q. coccinea* may be a relatively short-lived tree in Britain. One of the best trees recently measured is a specimen at Westonbirt, Gloucestershire, 81 ft. tall by 4 ft. 10 in. girth at breast height. A tree at Terling Place, Essex, which measured 50 ft. in height in 1953, was 25 ft. high in 1909. As it was planted in 1885, the rate of growth has been poor. In its native country, the Scarlet oak grows on dry, sandy and gravelly soils. At Bedgebury, on a rather acid, silty soil, *Q. coccinea* planted in 1933 had reached a height of 22½ ft. at 19 years of age. This growth was a little better than that of the native species, but not so good as that of *Q. borealis*.

J.M.

Quercus frainetto Tenore (*Q. conferta* Kitaibel)

A native of south-eastern Europe, *Q. frainetto* was introduced shortly before 1838. It has not been commonly planted, though it makes a very handsome tree. One of the largest specimens known is in the grounds of Westonbirt School, in Gloucestershire, and is 90 ft. tall by 10 ft. in girth at breast height.

A plot was planted at Bedgebury, Kent, in 1943, but has not yet closed canopy. It is much handicapped by spring frost susceptibility.

Quercus hispanica lucombeana (Sweet) Rehder

The Lucombe oak is a hybrid between *Q. cerris* and *Q. suber*, discovered amongst seedlings of the former by William Lucombe at Exeter in 1765 (Hadfield 1955). It has been extensively propagated by grafting and is quite a common ornamental tree in the south of England. There are also numerous second and later generation seedlings, exhibiting varying degrees of segregation.

Except in the more severe winters, it remains evergreen. It may reach quite considerable dimensions; trees 80 ft. tall are known. No plantations of this interesting hybrid appear to have been made.

Quercus ilex Linnaeus

The holm oak, which is native to the Mediterranean region, has been in cultivation since the sixteenth century, and is by far the commonest of the evergreen oaks planted in Britain. It has not been planted in the forest, but is a particularly useful tree for exposed coastal districts as it withstands sea winds very well. Considerable use has been made of it at Holkham on the Norfolk coast for ornamental effect and shelter, *Quercus ilex* having been planted on the estate since 1740 (Munroe, 1911). The plantations of *Q. ilex* at Osborne on the Isle of Wight, laid out by the Prince Consort, are also noteworthy.

Quercus ilex is a slow-growing tree, which rarely exceeds 70 ft. in height, though breast-height girths of 12 ft. or more are not uncommon. It ripens seed in the south of England.

Quercus mirbeckii Durieu

This interesting tree is native to southern Portugal, Morocco, Algeria and Tunisia. It was introduced in 1844 or 1845, when King Louis Philippe sent some acorns as a present to Queen Victoria. Under British conditions it is semi-evergreen.

A plot planted between 1930 and 1934 at Bedgebury has grown quite well, reaching 19 ft. in height in 22 years. It is much less susceptible to spring frost than *Q. frainetto*. So far, its rate of growth at Bedgebury is very similar to that of *Q. palustris;* it is a little slower than the native oaks, and distinctly slower than *Q. borealis* and *Q. coccinea*.

R.F.W.

Quercus palustris Münchhausen

The Pin oak of eastern North America is not a common tree in Great Britain, though it has been in cultivation since about 1800, when it was first introduced. It has been planted as a specimen tree but, apart from the plot at Bedgebury, no plantations have been recorded.

Like all the American oaks, it does not rival the native oaks for size or vigour, but there are several good specimens known, nearly all in the southern part of England; it does not grow well in the north nor in Scotland. Among those which have recently been measured by Maynard Greville, the following may be mentioned—a tree at Powis Castle, Montgomery, 81 ft. by 8 ft. at breast height; in Kew Gardens, 75 ft. by 7 ft. 11 in.; at Osterley Park, Middlesex, 74 ft. by 6 ft. 3 in.; at Syon House, Middlesex, 70 ft. by 7 ft. 11 in.

In the plot at Bedgebury, which was planted between 1933 and 1935, this species had reached 17½ feet in height in 18 years, its growth being slightly inferior to that of *Q. coccinea* and considerably less than that of the Red oak, *Q. borealis*. The site at Bedgebury is not the best for an oak like *Q. palustris* which is said to prefer deep moist sandy soils, but its early growth, nevertheless, is not discouraging.

J.M.

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Robinia Linnaeus

Of this small genus of leguminous trees and shrubs, only one species need be considered.

Robinia pseudoacacia Linnaeus

The locust or false acacia was introduced from America some time prior to 1640 (Henry, 1909). To quote Henry, "it only came prominently into vogue by the vigorous advocacy of Cobbett". William Cobbett returned from his political exile in America in 1819, and began to raise the tree in quantity in 1823. He is said to have distributed over a million plants. Henry may be quoted again: "Cobbett devoted many pages . . . (in *Woodlands*) . . . to an account of this species, which he considered was going to supplant all other trees in England; but Cobbett's enthusiasm in arboriculture, as in politics, often outran his discretion, and though many of his trees remain, mostly long past their prime, and in a more or less decayed condition, the *Robinia* has never realised his predictions". This is the history of *Robinia* in Britain in a nutshell.

Certain of Cobbett's claims were undoubtedly justified, and the tree has been found profitable and cultivated on a few estates till fairly recent times. Sir Hugh Beevor (1908) thought its tolerance of poor sandy soils and the extreme durability of its timber sufficient arguments to justify its continued cultivation at Hargham, Norfolk.

One factor which seems to have played a large part in the decline of the locust is the rabbit, which seems to have a particular liking for the young sucker shoots. Another, without doubt, is the strong dislike of the woodman for its fearsome thorns.

Today the tree is scarcely planted at all. A plot at Bedgebury, Kent, planted in 1931, is quite a good example of *Robinia* in plantation. Early growth has been quite good, the trees averaging 31 ft. tall in 20 years, but the form is ugly, and plainly the yield must be very small.

An experiment with *Robinia* in Wareham forest, Dorset, has demonstrated the nursing value of the tree. Sitka spruce interplanted with *Robinia* remained green and grew satisfactorily, while control trees soon lapsed into the typical checked condition of spruce on *Calluna* heath.

Robinia might still have some place on light sandy soils as a nurse for more yielding species, though the benefits might well be cancelled by the nuisance value of the suckers. The extreme durability of fencing timber (which appears to be well proven) is a less cogent argument for growing the tree in view of the advances made in preservative treatment.

R.F.W.

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Beevor, Sir Hugh. 1908. Notes. *Quart. Journ. For.*, Vol. 2. 301.

Sorbus Linnaeus

There are several native species: *Sorbus aria*, the whitebeam, a common small tree of the chalk; *Sorbus aucuparia*, the rowan or mountain ash, and *Sorbus torminalis*, the wild service, which sometimes reaches considerable dimensions in the south of England.

One exotic has been tried, *Sorbus intermedia* (Ehrhart) Persoon, from northern Europe. It has been planted experimentally as a broadleaved pioneer species under very diverse conditions, on chalk downland in the south of England, on *Calluna* heathland in North Wales, and on peat in Northumberland (Zehetmayr 1954), and has given quite a good account of itself on all these sites. It has taken 9 years to reach 10 ft. at Clocaenog, North Wales, on *Calluna* heath, but is healthy and has suppressed the heather. At Buriton, Hampshire, on an exposed chalk down, it has reached 12½ feet in 17 years.

R.F.W.

Tilia Linnaeus

Two species of lime are considered indigenous to Britain, *T. cordata* Miller, the small-leaved lime, and *T. platyphyllos* Scopoli, the large-leaved lime. *Tilia europea* Linnaeus, which is considered to be the hybrid between them, is often planted as an avenue tree.

A number of exotic limes are of arboricultural value, but few, if any, appear to have been tried under forest conditions. The most successful introductions appear to be from eastern Europe and western Asia, and of these mention might be made of *T. petiolaris* and *T. tomentosa* since very fine specimens of both are frequently seen. A small group of *T. japonica* (Miquel) Simonkai, was planted at Buriton in Hampshire, on chalk downland, and in 20 yrs. reached a height of 25 ft.; this rate of growth is similar to that of *T. cordata.*

R.F.W.

Ulmus Linnaeus

Three major species are found in Britain, *U. glabra*, *U. carpinifolia* and *U. procera;* there are, besides, a number of intermediates. The elms are of importance as they provide a considerable proportion of our hedgerow timber. Exotic elms are very unlikely to be of any value in Britain; none appears likely to equal our own trees in stature. There are few records of exotic elms in plantation.

Ulmus americana Linnaeus

The American elm was planted at Cirencester in 1905, and has done very well. James (1951) notes that this plot, at 46 years of age, had a top height of 51 ft., a mean girth of 23 in. and a standing volume of 3,172 Hoppus ft. per acre. It is more susceptible than most native elms to Elm Disease (*Ceratostomella ulmi*), though this particular plot has so far escaped.

Ulmus parvifolia Jacquin

This elm from East Asia was planted at Bedgebury, Kent, in 1934, but has failed. Like other Asian elms, it is resistant to Elm Disease.

R.F.W.

APPENDIX: QUESTIONNAIRE DETAILS

STANDING COMMITTEE ON BRITISH COMMONWEALTH FORESTRY

Office of the Forestry Commission,
25, Savile Row,
London, W.1.

Dear .....,

At the Sixth British Commonwealth Conference, the Report of the Committee on Forest Management, Silviculture and Forest Protection was adopted. In this report the following recommendation was made:—

"A detailed account of the use of exotic species in the Commonwealth based partly on information supplied to the Third British Empire Conference, was given by the late Professor R. S. Troup in his book "Exotic Forest Trees in the British Empire" (1932). Much experience has been gained since that date and it is recommended that the Standing Committee should arrange for its collection in a standardised form for presentation to the next Commonwealth Forestry Conference."

The Standing Committee has appointed a small Sub-Committee, under the chairmanship of Mr. M. V. Laurie, to give effect to this resolution, and as a result of their deliberations, the attached pro-forma has been drafted in which information on exotic species introduced into your country can be assembled under standardised heads.

It is appreciated that the amount of information available for different species will be very variable indeed. Some species may only have been tried on the scale of small experimental plots, in which case many of the heads will remain blank, while others may be extensively planted and may make an appreciable contribution to the country's timber resources. In the latter case, it is hoped that as full and complete information as possible will be furnished.

Limitations of the work—It will obviously be impossible to think of dealing with every exotic tree that has been tried in the country, and the return should be restricted to exotic trees which are either grown as economic crops or which are being tried as potential economic crops. Trees which have only been planted as single-tree arboretum specimens should not be included.

Definition of an exotic—The definition in the *British Commonwealth Forest Terminology* is:—"Exotic: Not native to the area in question". There may sometimes be some difficulty in deciding whether a tree is native to the country and in determining the limits of the area under consideration. For instance sycamore and sweet chestnut in Britain, which were believed to have been introduced in Roman times, would be classed as indigenous; while European larch would be considered exotic. Norway spruce, introduced over four centuries ago, would be a border-line case. It is suggested that if the species has grown in the country for several centuries, and has become part of the natural forest associations of the country it can, for the purpose of this review, be regarded as indigenous.

Regarding geographical elements, it is suggested that if, within a large country like Australia or Canada or within a sub-continent like India a species is planted well outside its natural range, it might in such circumstances be regarded as an exotic (e.g. teak planted in the United Provinces in India).

The decision as to whether a species should be considered an exotic or not in respect of the above two criteria must be left to the judgment of the country concerned.

Exotic species which have been tried and failed should also be briefly reported upon, the reasons for failure, when known, being given under the appropriate sections of the questionnaire. Such information can be very valuable in preventing repetition of trials of species that have proved unsuitable for any particular locality.

The resolution passed at the Sixth British Commonwealth Conference recommends that this information be collected for presentation at the next Commonwealth Conference to be held in Australia and New Zealand in 1957, and it is hoped that all the countries in the British Commonwealth will assist by completing a report on Part I General, and reports on Part II for each species in draft form ready for presentation in 1957. It will be decided at the 1957 Conference how the information so collected will be collated and published and through what agency this will be done.

Yours faithfully,

C. D. BEGLEY
Secretary,
Standing Committee.

EXOTIC FOREST TREES IN THE BRITISH COMMONWEALTH

QUESTIONNAIRE ON EXOTIC PLANTING

I. GENERAL—FOR THE PARTICULAR REGION OR COUNTRY.

(a) General statement regarding the extent to which indigenous species fulfil requirements and the place and usefulness of exotic species in the country's economy. The general policy that is being followed in the use of exotics should be stated.

(b) General account of the climate of the country with references to published climatic data. If country is large or has a varied climate, division into climatic zones (as was done for Australia in Troup's book) would be useful. Any particular features of the climate (e.g. prevalence of late spring frosts for Britain), that affect the selection of exotics should be mentioned.

(c) General note on soils in the areas available for forestry—again with special reference to particular limiting features (e.g. laterisation in certain conditions in the tropics). References to published information on soils to be given where available.

(d) Techniques of establishment—When, in any locality, techniques of establishment are standardised, it will save repetition under each species if they can be described in detail here and only divergences from standard practice, or special points to be discussed, are described under Section II para. 8 for individual species.

II. STATEMENT BY SPECIES

(1) Scientific name (with botanical authority).

(2) Local names and trade names.

(3) Country of origin, with general notes on seed supply position and on provenance (e.g. "*Pinus pinaster* in South Africa—strains of Portuguese origin are the most suitable. Those from the Landes in France and the Mediterranean regions are of poorer form and slow growing"). Give references to any published results on provenance.

(4) Historical—date of first introduction, by whom introduced—if known. Outline history of extension of planting.

(5) Present extent of planting, i.e. whether merely experimental on a small scale, or whether in crops of some size. In the latter case state:—

(a) approximate total area already planted and rate of extension planned.

(b) approximate age distribution.

(6) Climatic zones in which planted, with notes on those in which it does best and those where climatic factors appear to be limiting. Notes on any special requirements in the matter of rainfall, humidity, shelter from wind, freedom from frosts (both winter and late) etc. Tolerance of, or susceptibility to, the various climatic factors should be mentioned.

(7) Soils and sites preferred (including vegetation types). Sites to be avoided. (Geological formations, soils, altitudinal limits, latitudinal limits, etc.)

(8) Techniques of establishment (*see* also I (d) above)—(a) Direct Sowing or (b) Planting.

If (a)—give brief notes on—ground preparation, method of sowing (patches, bands etc.), seed pre-treatment, quantity of seed used per acre, method of seed covering, protection against vermin—any special measures required for this particular species.

If (b)—give notes on nursery procedure, age and type of plant used, spacing and any other special points of technique adopted. For both the above, mention any particular measures peculiar to the species that may be necessary to secure establishment (e.g. special tending, manuring, use of nurses, irrigation, etc.). Note—Where suitable for the region concerned a general note on techniques of establishment may be given in Section I (d) and only divergences from it reported for each species here.

(9) Notes on early crop development (height only), tending and thinning.

(10) Notes on any particular silvicultural characteristics of importance.

(11) Rate of growth and yield. Give references to any published yield tables. If none, give any information available from sample plot measurements to indicate the sizes attained and the volume produced in a given time. If no sample plots or crop measurements are available, indications of the size (height and girth) attained at a specified age should be given. An indication of density of stocking should be given.

(12) Diseases and pests—Brief mention of diseases and pests that do sufficient damage to be of economic importance.

(13) Other damage to which the species is particularly susceptible in the country of introduction.

(14) Note on seed-bearing in introduced country.

(15) Notes on natural regeneration and the techniques for obtaining it.

(16) Timber or poles, quality and uses. Other uses (e.g. fuel, minor forest produce, etc.).

(17) Potentialities of the species in the national economy.

(18) References to published information.

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