BRITISH FOREST TREES

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BRITISH FOREST TREES

AND THEIR

SYLVICULTURAL CHARACTERISTICS AND TREATMENT

BY

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TRANSLATOR OF FÜRST'S "PROTECTION OF WOODLANDS."

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TO

THE HIGHLAND AND AGRICULTURAL SOCIETY
OF SCOTLAND,

THROUGH WHOSE EFFORTS SO MUCH HAS BEEN DONE

TO PROMOTE THE STUDY

AND THE

BETTER KNOWLEDGE OF WOODCRAFT THROUGHOUT BRITAIN

THIS CONTRIBUTION

TO THE LITERATURE OF THE

SCIENCE AND PRACTICE OF FORESTRY

IS,

BY PERMISSION,

Dedicated.

PREFACE

"Truly, the *waste* and *destruction* of our *woods*, has been so universal, that I conceive nothing less than an *universal Plantation of all the sorts of Trees* will supply, and well encounter the defect ; and therefore I shall here adventure to speak something in general of them all ; though I chiefly insist upon the propagation of *such* only as seem to be the most wanting, and serviceable to the end proposed."—EVELYN'S *Silva*, 4th *Edit.*, 1706, *v. Introduction.*

CONSIDERING the amount of attention which, especially during the last six or seven years, has been given to forestry in Britain, the appearance of a small work embodying the leading principles of sylviculture as applied to the principal species of forest trees should hardly require any apology.

In the following pages are set forth in as short and concise a manner as seemed to the author intelligible and practically useful, the chief sylvicultural characteristics of our timber trees according to the present advanced state of the knowledge of forest science in Germany. This makes no pretension of being a work of original research or of observation based on long experience in the treatment of forests in Britain. It is, and only professes to be, to a considerable extent, a compilation from the best German sources ; but the author can at any rate vouch for the correctness of the scientific principles enunciated, from his personal observations made here, and also during fifteen years' active service in the teak forests of tropical Burma.

The works which have been chiefly utilised in the compilation are :—

Burckhardt's *Säen und Pflanzen*, 5th Edit., 1880.
Ney's . . . *Lehre vom Waldbau*, 1885.
Gayer's . . *Waldbau*, 3rd Edit., 1889.

Numerous other works have been consulted and utilised, and wherever it has seemed desirable to quote the authority for any assertion, this has been done in a footnote.

Whilst embodying the principles of sylviculture, it has been the author's care to omit any lengthened or unnecessary details as to the practical operations of sowing and planting, which are as well understood by arboriculturists in Britain as by sylviculturists on the Continent. Throughout the English literature on arboriculture many very valuable observations and facts have been recorded in the works of Evelyn, Loudon, Gilpin, Selby, Lindley, Monteith, Grigor, Brown, Veitch, Curtis, Michie, &c., and in the *Transactions* of the Highland and Agricultural, and the Arboricultural Societies of Scotland. But they often fall short of their full practical value sylviculturally, because they have not usually been based on a systematic and scientific knowledge of the fundamental principles which ought to underlie all sylvicultural operations, and which even on the Continent—where throughout the whole of the present century they have undoubtedly been far ahead of us in forest science—were not quite consistently, scientifically, and logically explained until the issue of the first edition of Gayer's great work in 1880.

The same remarks do not apply to Hough's American works, or to Schlich's *Manual of Forestry*, recently published under the auspices of the Indian Government as a text-book for the use of the students at Cooper's Hill, who now undergo their period of training there instead of in Germany or France as formerly. Though also compiled chiefly from German sources, that work differs essentially from this in its more didactic aim, in its detailed descriptions of the various operations of sowing, planting, tending, &c., necessary for students without any previous knowledge of woodland craft, and in its merely alluding in the briefest possible manner to the sylvicultural characteristics and treatment of each of our British forest trees.

Even despite the increased use of substitutes like iron, and the fact that owing to improvements in communication and transport the streets of London are partly paved with wood from Australia, whilst practically the only timber now used in the construction of the *wooden walls of England* is teak from Burma, the demands for timber utilised in the building and other trades are constantly increasing, so that wherever good timber can be produced in our home forests there is little likelihood of it failing to find a fair market. It is not at all likely, however, that landowners will put fresh land under forest, which, except in the case of osier-beds cut over annually, always involves a certain amount of outlay without immediate return as in agriculture, unless it can be shown to be a remunerative operation ; but the more thoroughly the principles of sylviculture are understood, and the deductions therefrom are given effect to, the more probable it is that fair returns will be obtained from land not quite good enough for agriculture.

In an interesting article on "Woodlands" in the *Nineteenth Century* for July 1891, page 33, Sir Herbert Maxwell, Bart., says:—

"One chief hindrance to our woodlands being remunerative may be stated at once—we are arboriculturists and sportsmen, not foresters. A large portion of the land returned as woodland is really pleasure-ground and game-cover. Thousands of landowners follow on a smaller scale the example set by the State on a larger in the New Forest and Windsor Forest. *Mixed planting is generally practised, in sharp contrast to what Continental foresters call 'pure forest'—that is, a woodland composed of one species of tree. This is in itself a hindrance to profitable management, because pure forest is much more easily tended than mixed plantation, and the timber is more readily marketable.*"

This view is entirely wrong, and of itself shows the urgent need for some properly qualified instruction in forest science, when one of the more intelligent owners of woodlands can hold and disseminate such incorrect ideas concerning the true nature of forest growth, and the natural requirements of the various species of our forest trees. Here is what Professor Gayer of Munich, the greatest living authority on sylviculture, says on the subject at page 386 of the *Zeitschrift für Forst- und Jagdwesen* for June 1892:—

"One can say that during the last thirty to forty years it has been a consistently emphasised leading principle of the Bavarian State Forest Department to recommend as much as possible the extension and maintenance of mixed forests in all localities in any way suitable for their growth; and the principle, too, has been acted on in many places. In many other localities, however, and especially in the spruce tracts, mercantile considerations gained influence and took precedence, and the thought of a suitable admixture of species was to a certain extent pushed into the background, rendering it now very difficult to effect with satisfactory results a re-transformation to the former state of things. All the more emphasis is consequently now being laid on the retention of mixed growth, especially in regard to retaining it in all older crops which are still classifiable as mixed forest, and endeavours are in general being made to prepare the way for a return to mixed woods in all suitable localities. And that, face to face with the late fearful devastations in the spruce forests of southern Bavaria, these principles should be even more strongly insisted on, can easily be understood."

At page 387 he also adds advice of good practical value, as follows :—

"Considering the circumstances of the timber market in general nowadays and of local demands, and also having regard to their incontestably thriving growth, no argument is required to show that the Conifers, and in particular spruce, must nearly everywhere claim the lion's share in the composition of the mixed forests of the future."

Mixed woods have the great advantages of denser growth, larger and finer production of timber both as regards quantity and technical quality, lessened danger from storms, snow, ice, insects, fire, and fungoid diseases, against all of which inestimable and solid advantages the only drawback that can be named is, that the tending of such woods is much more difficult, and requires considerably greater knowledge of sylviculture, than is requisite for the treatment of pure forests.

In France about 70 per cent. of the wooded area is under mixed forests, and although not such scientific foresters as the Germans, the French are good practical sylviculturists, who would long ere now have found out if any great advantages lay in pure forests.

Any one who has travelled through the better-wooded tracts of Britain after having undergone a lengthened practical and scientific course of study of forestry in Germany, cannot fail to be impressed with two main facts: *firstly*, that in general the plantations are not quite so dense as they should be in order to attain the utmost outturn and the best development producible by the soil; and *secondly*, that the importance of underplanting for the protection and improvement of the productive capacity of the soil is either not recognised, or at any rate not practically given effect to. Even Thomas Carlyle, who, as a shrewd country-bred youth with good powers of observation, probably knew as much about forestry as the average forester in Britain, makes the following rather depreciatory remark in regard to the normal density of the forests through which he happened to pass in his *Excursion* [*futile enough*] *to Paris*, published in the *New Review*, for October 1891, " *Wood enough still, but twice or even thrice as thick as we allow it to be*,' an unfavourable criticism which is certainly terse enough in its disposal of the question of density in plantations.

Even taking into consideration the damper insular climate of Britain, in which the soil is not so likely to deteriorate as on the inland forest tracts of the Continent, there can be no doubt that a greater degree of density and a better protection of soil against insolation, either by the maintenance of close canopy in high forest, or by underplanting wherever the canopy naturally begins to get interrupted and broken in the case of light-loving species like oak, ash, maple, pine, or larch, cannot fail to be productive of marked improvement in the quality of the timber, and in the total outturn both from the preliminary and from the final yield of forest crops. In particular, some of the larch forests seen by the author formed the finest possible examples of how woods should not be reared, and exhibited a total misconception of the requirements of forest crops in general, and of this species in particular.

Whilst adhering consistently to the principle that sylviculture in Britain should be engaged in by private owners only when it can be shown to rest in all reasonable probability on a sound financial basis, it is only necessary to point out that the percentage of interest on capital outlay represented by soil plus growing stock should be calculated somewhat lower than that obtainable from agriculture—in Germany it is about 3 to 4 per cent. for the latter, and 2½ to 3½ per cent. for the former in the State forests, but greater in private forests, and for oak and osier coppice—as the rate of interest is of enormous influence in all actuarial calculations concerning forestry. Owing to dangers and the long periods that elapse before the crops are mature it should be higher were the soil equally good.

Irrespective of the commons and heaths mostly only covered with heather, there are throughout Britain thousands of acres of land, perfectly able to yield remunerative returns if planted up, which are now practically lying waste, stale, unprofitable, and unproductive. There are thousands of acres of culturable, but uncultivated, land enclosed within the fencing of railway lines which might very easily, without prejudice to the railway traffic, without any danger to the public or the railway employees, but with considerable profit to the railway companies, be made to yield crops of apples or pears, filberts, &c., or be put under coppice for the production of oak-bark, osiers, hazel, black alder, fuel, &c., thus providing employment for thousands of people, and home-grown produce for many industries which have at present to supply their requirements to a great extent from the Continent. The objections to the pasturage of cattle or the growth of lofty trees on such land are of course at once self-evident, but the annual harvesting of osier-withes, or the collection of oak-bark and fuel from coppices formed on suitable soil would entail no wanton exposure of human life, and would surely be more profitable than the present casual and unremunerative growth of rank grasses, furze, broom, brambles and other weeds. Throughout Mecklenburg the bermes along the railway lines are thus utilised, and that similar operations are quite feasible in England can easily be seen at many places between Brentwood and Colchester on the Great Eastern Railway, where a fair and probably spontaneous growth of willows may often be noticed.

In consequence of the continuous depression in the value of agricultural holdings, many tracts hitherto under tillage or pasture have sunk to such low rentals that it is a question well worthy of consideration, if they might not now be more profitably cultivated as woodlands for the production of a portion of the timber for which many millions of pounds are annually expended by the building and other trades in the purchase of timber imported from the Continent, that might quite easily be grown here.

Whilst this little work is specially intended for the use of landowners and of those already engaged in practical forestry, it is hoped that at the same time it may perhaps assist in stimulating a little interest in sylviculture through Britain, where even among the more intelligent classes all that is known about our beautiful forest trees seldom goes further than the casual (and often rather doubtful) recognition of the various species in parks and ornamental woods.

J. Nisbet.

8th December, 1892.

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INTRODUCTION

HISTORICAL SKETCH OF FORESTS IN BRITAIN

In early times Continental Europe had a covering of tree vegetation over the greater part of its area. Cæsar described the country between the Seine and the Rhine as being a dense mass of woodlands; in another place he stated that the forests in Britain were practically the same, and complained that the ancient Britons found shelter in the woods. Scotland and Ireland had likewise their woodland covering, principally Scots pine, over large areas since transformed into open agricultural land, pasturage, and moorland.

Of our now common forest trees it is most probable that the species forming vast forests at the time of the Roman invasion were comparatively limited in number. The uplands of central and southern England, and all tracts with limy or chalky soil, bore dense woods of beech, whilst all the richer alluvial tracts with deeper soil were covered with a stately growth of oak. The higher land and the hills situated to the far north were mainly covered with Scots pine, birch and mountain ash, whilst oaks, ash, Scots elm, willows, aspen, alder and yew were confined generally to the coombs, the valleys, and the low-lying localities; beech was not indigenous to Scotland.

When one considers the unnatural difficulty about producing germinable seed freely in England, there seems little doubt that the chestnut, English elm, lime and poplar were not indigenous to Britain, but were introduced by the Romans along with a number of ornamental and fruiting trees, which never developed into trees of true forest growth, such as the plane, walnut, mulberry, service, hazel, box, medlar, apple, pear, prune, cherry, peach, apricot, quince, and rose. Many of these established themselves, and were regarded as indigenous by the monkish historians of the Norman Conquest, but some died out, and had to be re-introduced at later periods.[1]

The chronology of our forest trees appears to be as follows :—

Indigenous in prehistoric times :—Oak, beech,[2] Scots pine, birch, ash, mountain ash, Scots elm, sallow (saugh), aspen, alder, yew, hawthorn.

Introduced by the Romans :—Plane, chestnut, walnut, English elm, lime, alder, poplar, box, together with many ornamental and fruit-trees that have never attained true forest growth.

Introduced before the end of the fifteenth century :—Hornbeam, sycamore, willows (white and crack), poplars (white and grey).

Introduced during the sixteenth century :—Spruce, walnut, laburnum, juniper, holly, holm oak, stone or cluster pine, alderberry, viburnum, mulberry.

Introduced during the seventeenth century :—Silver fir, maple, plane, horse-chestnut, larch (England, 1629), robinia, buckthorn.

Introduced during the eighteenth century :—Weymouth, maritime, cembran, and pitch pines, larch (Scotland, 1727), service, cedar.

Introduced during the nineteenth century :—Austrian, yellow, and Jeffrey pines, Nordmann's and Douglas firs, deodar, eucalyptus.

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[1] Some interesting details concerning the above matters may be found in Loudon's *Arboretum et Fruticetum Britannicum*, 1838, vol. i. p. 15 *et seq.*

[2] Cæsar states that he did not find the *Fagus* in England, but he probably meant the chestnut (*Castanea vesca*), or *Fagus castanea*, as it is absolutely certain that the beech was indigenous to central England.

At the earliest periods the woodlands yielded not only food supplies and other necessaries of life in the shape of game, fish, fruits, honey, &c. for men, grazing for cattle, and pannage for swine, but were the only source from which could be drawn materials for providing light and warmth, for the erection of huts and sheds, construction of canoes, and of the various tools and implements in daily use. As time rolled on population gradually increased, and simultaneously therewith the demands for woodland produce rose. Nomadic tribes, living principally from their herds and by the chase, first took to shifting cultivation of cereal crops, and then gradually settled down to permanent tillage, but in either case the woods had to be cleared of timber before the soil could be rendered cultivable. At the same time a gradual advance was being made towards a higher state of civilization ; canoes gave place to boats, and boats to ships capable of performing voyages on the sea ; huts were improved into houses, and furniture became at first a luxury and then a necessity ; the desire for improved communications led to the construction of bridges, &c. In every case the upward civilizing tendency increased the demands on the timber stores provided by nature. These same processes can be seen at the present day in many parts of India, in the backwoods of Canada and the United States, in Australia, and in fact wherever influx or increase of population takes place in hitherto uncultivated territory. At first, what seemed the more favourable localities were cleared and brought under cultivation, generally those with good soil near river banks, where communication was easy. Slowly but surely what was considered the best ground for agriculture was denuded of its woodland covering, and brought under permanent cultivation.

In their undisturbed condition the reproductive power of the woodlands was perfect, but after human interference with their produce began this gradually diminished, until such lessened capability of reproduction, coupled with the growing restriction of woodland area consequent on the increase of agriculture and of the agricultural population, and the increasing demands for timber, gave serious cause for reflection, and necessitated the adoption of measures for the protection of the remaining woodlands.

In different countries varying local circumstances called for the adoption of protective measures, which differed of course in detail, but in general the methods adopted had a considerable degree of similarity. A beginning was usually made by the reigning power laying tracts of country—not necessarily woodlands, but generally including extensive wooded areas—under ban in order to preserve them as hunting grounds. Thus [1] at the end of the eighth century the old German word *Forst*,[2] corrupted through the old Norman form *Forêt* into the legal Latin *forestare*, to place under ban, became *foresta*, *forestis*, which up till then had merely denoted *a royal hunting ground*, but henceforth was applied to all such other lands as were proscribed or laid under ban as regards cultivation, the right of chase being vested in the king, or in those specially permitted by him to exercise it. Both in England and Scotland the early forest laws had reference principally to the protection of game.

In England, in its original and strictly legal sense therefore a FOREST *was an area* (*not necessarily woodland*) *for the sake of the chase placed under the royal ban with regard to cultivation, and subject to forest law in place of the common*

[1] Schwappach's *Forstgeschichte* in Lorey's *Handbuch der Forstwissenschaft*, 1886, vol. i., p. 147.

[2] According to Grimm, *Forst* was derived from the old High German *Foraha* = Anglo-Saxon *Fuhr* = modern German *Föhre* = *Scots Fir*, the principal tree throughout the great north German plain. See also Max Müller's *Chips from a German Workshop*, 1875, vol. iv., p. 518.

law. The addition of areas to the already existing forests was termed ***afforestation***, whilst later on the release of areas from the ban, and the determination of the rights belonging to the crown and those belonging to the commonalty, were known as ***disafforestation***, ***disforestation***, or ***deforestation***. Ancient records state that at the time of the Norman invasion there existed sixty-nine large forests in England covering the greater portion of the country. Milton says (*A Complete History of England*, Lond. 1706, vol. i., page 110, note *b*) that William the Conqueror *destroyed thirty-six parish churches, with the houses and possessions of so many townships, to make them habitations for wild beasts* in forming the New Forest. The monkish records from which this information is derived are, however, to be read with caution, for the writers naturally did not love the royal house that hustled them out of their churches, and can hardly be trusted to have chronicled a dispassionate and unbiased statement of the actual events. Such royal *forests* consisted of *vert* (timber, underwood and turf) and *venison* (including all animals and game). Manwood's *History of Forest Laws* and Holinshed's *Description of Britaine* (chap. ii,) give good descriptions of the ancient woods and forests.

The principal forests in England about that time were Rothbury and Lowes (Northumberland), Nicol, Knaredale, Westwood, Inglewood, and Copeland (Cumberland), Milburn, Whinfield, Martindale and Thornthwaite (Westmor land), Langden or Teesdale, and Weardale (Durham), Wiresdale and Bowland (Lancashire), Knaresborough, Pickering, and Hardwicke (York), Delamere and Macclesfield (Cheshire), Sherwood (Nottingham), Clune (Shropshire), Needwood (Stafford), Charnwood (Leicester), Lyfield or Leafield (Rutland), Wire, Malvern and Feckingham (Worcester), Arden or Ardennes (Warwick), Rockingham, Whittlebury, and Salcey (Northampton), Wabridge (Huntingdon), Dean, Micklewood, and Kingswood (Gloucester), Whichwood (Oxford), Bernwood and Clitern (Bucks), Hainault and Epping (Essex), Savernake, Blakemore, Bradon, and Pevisham (Wilts), Nerohe, Selwood and Mendip (Somerset), Chute, Alice Holt, Bere, and New Forest or Ytene (Hants), Gillingham, Cranbourne, and Blackmore (Dorset), Dartmoor and Exmoor (Devon), Windsor (Berks), Enfield (Middlesex), and the Weald of Kent, Andreas Wald, or Coit Andred, comprising Norwood (Surrey), Tunbridge (Kent), and Ashdown (Sussex). The only forest of considerable extent in Wales appears to have been the Radnor Great Forest in South Wales.

After *Magna Charta* was drawn up, the *Charta de foresta* (1216) removed some of the most glaring oppressions of the forest laws, but they still remained very harsh and unjust till a much later date. In Scotland the royal forests included large tracts subject to the *leges forestarum* which, though severe in themselves, were not quite so savage as those in force in England.

The destruction of woodlands went on more rapidly in Britain than on the Continent. By the time of Henry VII. only about one-third of the area of England remained under forest, while, according to Holinshed, plantations for the growth of timber for technical purposes were begun as early as Henry VIII.'s time, when a statute (c. 35) enjoined *re-plantations of Forest Trees to cure the spoils and devastations that have been made in the woods.* By offering rewards for the transformation of woodlands into arable land James I. in the early part of the seventeenth century gave an immense impulse to the national movement in this direction, whilst subsequently Charles I.'s chronic want of money led to his alienating by grant large portions of the royal woods, and later on Cromwell's agricultural policy, the repeal of the *Charta de foresta*, and the abolition of the *forest courts*, gave fresh impetus to clearing, and were the cause of large areas being denuded of timber, some being transformed into arable land and pasturage, but many of them being left to drift into barren moorland. The great Caledonian Forest, formerly occupying the bulk of the central portion of Scotland north of the Forth and Clyde, and formed principally of oak on the lowlands and Scots pine on the uplands (the only species of the pine or the fir tribe indigenous to Britain), covered also extensive tracts of which too often little is now left but the memory and the name. Thus to the south of the Forth and Clyde lay the forests of Ettrick, Lauderdale, Wedale, Romanach, and Jedwood on the east side, and those of Cadzow and Hamilton on the west. The principal forests to the north of that were Torwood (Stirling), Rannoch and Birnam (Perth), Glentanner, Invercauld and Braemar (Aberdeen), Tarnawa and Drummyne (Moray), Abernethy, Rothiemurchus, Glengarry, Glenmoriston, Strathglass, Strathfarrer, and Glenmore (Inverness), Coygach (Ross), Derrymore and Derrymonach (Sutherland).

Large extents of woodland were felled in Scotland at the time of the wars of Edward I., as they afforded cover to the patriotic bands opposing his army, and John of Ghent, Duke of Lancaster, is said [1] to have employed 24,000 men in the task of clearing away the timber and destroying the forests in order to punish an incursion. Similar measures were also adopted by Cromwell's army under Monk about the middle of the seventeenth century, and the destruction of the woods on the highland hills was continued into the present century. The pine forests covering many counties, those known as Glenmore, Rothiemurchus, and Rannoch, along with many others, were cleared and destroyed towards the

[1] Gilpin's *Forest Scenery*, Lauder's edition, 1834, vol. ii., p. 5.

end of the last, and the beginning of the present century, although fortunately others, such as those of Abernethy, Athole, Duthal, Braemar, and Invercauld, escaped with somewhat more rational treatment. Unfenced and unprotected, the natural reproduction from seed could not have any fair chance of outgrowing the damage done by cattle and sheep browsing on the young seedlings and shoots, and in this mutilated condition the light-loving pine would easily be choked and killed by rank casual growth of heather, heath, broom, and furze. To these historically authenticated clearances of the natural forests there must also be added the unrecorded enormous destruction of the aboriginal woodlands from conflagrations and fires intentionally kindled or accidentally caused, the vast extent of which cannot now be estimated. Most of the pine stems found in mosses exhibit signs of fire. As the pine is unable to reproduce itself by suckers, or coppice shoots, or from dormant buds along the stem, the destruction of these forests practically put an end to forest growth in the hilly tracts, and gave up the soil a prey to heath, and heather, and other lowlier forms of vegetation, without any possibility of natural reproduction of pine growth. Ireland, too, shows a similar record, the colonization schemes (*plantations*) of James I., Charles I., and Cromwell in the seventeenth century having given a great impetus to the work of timber clearance all throughout Ulster, Connaught, Leinster, and Munster.

That this work of destruction could without climatic and economic disaster be permitted to a much greater degree in Great Britain and Ireland than on the Continent was, and is, due mainly to our insular position with its moist and comparatively equable climate, and to the enormous supplies of coal,—mineralised forest produce,—which have been our heritage. What we owe in Britain to our forests of previous geological ages we may learn from the following :—[1]

"For the production of an equivalent in wood to the 115 million tons of coal worked out of mines during 1878 in England and Wales—the countries richest in coal in the whole world—there would be requisite an area of 359,375 square miles of pine forests; that is to say, rather more than six times their total area."

In France and Germany the principal domestic fuel even now is wood, that of the beech standing highest in repute. Considering the difficulties in former times of transporting timber and fuel to any great distances away from the natural water channels, it can easily be understood how at a comparatively early date repressive measures were necessitated in order to restrict the clearance of woodlands, and to maintain under timber a due proportion of the total area, conveniently spread over the length and breadth of every duchy. Thus in Germany an edict had to be issued as early as 1304 forbidding fresh clearances in a part of Alsace, and ordering land illegally brought under agriculture to be given up again to the production of timber. By the sixteenth century such edicts had become general throughout most of the states then forming the German empire. In France, too, similar edicts were issued during the sixteenth century by Charles IX. and Henry IV., but the most important and best known one was Colbert's *Ordonnance sur le fait des forêts* issued by Louis XIV. in 1669, upon the lines of which forest administration was mainly conducted until the Revolution, and whose influence is still to a certain extent traceable in the *code forestier* of the present day. In 1789 the forests, hitherto under the protection of the state, were cut down in the most reckless manner, being looked upon more or less as common property, whilst private owners of wood-

[1] V. Helferich, *Die Forstwirthschaft* in Schönberg's *Handbuch der politischen Oekonomie*, 1882, p. 713.

lands were enabled by a decree of 1790, repealing the *régime forêtier*, to transform the same into agricultural lands. These devastations went on at such a rate, and to such an extent, that it was found necessary to issue a prohibition from the Consulate with regard to further clearances, and to establish a regular administration of the national and communal forests.

In comparison with the forests of the three chief countries of the continent of Europe our woodlands have been cleared to an extent which, but for our damp insular climate, might have long ere now proved disastrously excessive, as may be seen from the following abstract :—[1]

	Extent of Woodlands.			Percentage of Woodlands owned by		
	Acres.	Per Cent. of Total Area.	Acres per head of Population.	State and Crown.	Communes, Corporations, Religious Bodies, &c.	Private Proprietors.
German Empire .	34,334,511	26	0·76	33	19	48
Austria & Hungary	46,833,682	30	1·26	11	26	63
France	20,740,913	16	0·57	11	23	66
Great Britain and Ireland	3,007,569[2]	4	0·07	2[3]	—	98
Total for Europe .	768,224,774	31½	2·49	—	—	—

As compared with the other methods of economic utilisation of the soil in these countries the following approximate

[1] Weber, *Die Aufgaben der Forstwirthschaft in* Lorey's *Handbuch der Forstwissenschaft*, 1886, vol. i., pp. 14–17.

[2] Board of Agriculture's Returns for 1891, p. x.

[3] Return to House of Commons in 1863 gives 112,376 acres as total of Crown forests. From the Report on *Woods and Forests and Land*

percentages of cultivated soil to the total area of the country may be of more than passing interest :—

	Percentage of Total Area of Country, under			
	Forest.	Tillage.	Pasturage.	Vineyards.
German Empire . . .	26	48	20	0·25
Austria and Hungary .	30	38	26	0·95
France	16	50	14	4·9
Great Britain & Ireland[1]	$3\frac{4}{5}$	$25\frac{1}{2}$	$35\frac{1}{2}$	—

In no country is arboriculture better understood or practised than in Britain, but in sylviculture, and indeed as regards forestry altogether, we have much to learn from Continental countries, from Germany in particular. In no other country than Britain is there such apathy shown by Government with respect to the provision from national funds of technical education concerning forestry, and as regards timber production and utilisation in general.

Of late years there has, however, been a decided consensus of opinion that the destruction of woodlands

Revenues of the Crown submitted to House of Commons on 26 July, 1889, the total forest area appears to be 109,139 acres, of which only 57,304 acres are actually under timber crops (*vide* Minutes of Evidence, pp. 4, 5, and 42).

[1] *Vide* Board of Agriculture's Statistical Returns for 1891 and 1892. The actual figures therein given for the United Kingdom according to the latest data are :—

Total acreage of	1891.	1892.
Land and Water . . .	77,799,793	77,642,099
Arable Land	20,611,810	19,769,272
Permanent Pasture . .	27,567,663	27,533,326
Woodlands	3,007,569	3,005,670

throughout Britain has been carried somewhat too far, and measures have in many parts of the country been taken to rectify the errors of the past by means of planting on an extensive scale. But, thanks to our insular position with its moist climate, and to the equalising influence of the Gulf Stream on the latter, in modifying the heat of summer and the rigour of winter as compared with the extremes of Continental countries situated within the same degrees of latitude, the destruction of the British woodlands has not been followed by such disastrous climatic changes as followed the denudation of forests in the Landes, Greece, Syria, Asia Minor, and Russia.

In the Greater Britain formed by the colonies and dependencies of the empire—Canada, Australia, New Zealand, the Cape, Natal, &c., and especially India—we still own the most extensive and the most valuable timber-producing tracts in the world, and thanks to the advances in maritime and inland communications, are able to supply easily all the demands that have hitherto arisen in regard to timber.

Considerations regarding timber production in Britain must, therefore, in general be determined mainly by the degree in which such operations can be shown to rest on a secure and remunerative financial basis. Arboriculture will still be necessary in parks and open spaces, for the residential portions of large estates, and under similar conditions where æsthetic aims are comparatively untrammelled by economic considerations; but the sylvicultural operations of private proprietors on a large scale must usually be guided by coldly calculating estimates regarding attainable revenue and necessary expenditure, and a preference will naturally be given to such species of trees, systems of rotation, and methods of treatment, as—whilst duly protecting the productive capacity of the soil—hold out fair promise of yielding the most profitable nett results.

The Forest Trees of Britain.

Principal Species.—The chief trees to be found in northern Europe forming, or under certain circumstances capable of forming, pure forests without an admixture of other species are :—

Coniferous trees—

1. Scots or common pine, or Scots fir (*Pinus sylvestris*, L.).
2. Spruce, spruce fir, or Norway spruce (*Picea excelsa*, Link.).
3. Silver fir (*Abies pectinata*, D.C.).
4. Larch (*Larix europæa*, D.C.).

Broad-leaved trees—

(A) *Hardwoods.*

1. Beech (*Fagus sylvatica*, L.).
2. Oak (*Quercus pedunculata*, Ehrh., and *sessiliflora*, Sm.).

(B) *Softwoods.*

1. Birch (*Betula alba*, L.).
2. Alder (*Alnus glutinosa*, Gaert.).

Minor Species.—Other trees, usually found in Britain only mixed in forests of the above principal species, are :—

Coniferous trees (all quite capable in themselves of forming pure forest)—

(A) *Indigenous to Europe*—

1. Black, Austrian, or Corsican pine (*Pinus laricio*, Poir = *Austriaca*, Höss).
2. Maritime pine (*Pinus maritima*, Lam.).
3. Mountain pine (*Pinus montana*, Mill).
4. Cembran pine (*Pinus cembra*, L.).
5. Nordmann's fir (*Abies Nordmanniana*, Link.).

(B) *Introduced from North America*—

1. Weymouth pine (*Pinus strobus*, L.).
2. Pitch pine (*Pinus rigida*, Mill).
3. Yellow pine (*Pinus ponderosa*, Mill).
4. Jeffrey's pine (*Pinus Jeffreyi*, Murr.).
5. Douglas fir (*Pseudotsuga Douglasii*, Carr).

Broad-leaved species.

(A) *Hardwoods*—

1. Ash (*Fraxinus excelsior*, L.).
2. Maple or Norway maple (*Acer platanoides*, L.).
3. Sycamore or great maple (*Acer pseudoplatanus*, L.).
4. Elms, viz.:—
   Common, English, or small-leaved elm (*Ulmus campestris*, Sm.).
   Scots wych, or mountain elm (*Ulmus montana*, Sm.).
5. Hornbeam (*Carpinus betulus*).
6. Sweet or Spanish chestnut (*Castanea vesca*, Gaert.).
7. Mountain ash, Rowan, or Fowler's service tree (*Sorbus aucuparia*, L.).

(B) *Softwoods*—

1. White alder (*Alnus incana*, Willd.).
2. Lime (*Tilia parvifolia* and *grandifolia*, Ehrh.).
3. Horse-chestnut (*Æsculus hippocastanum*, L.).
4. Aspen (*Populus tremula*, L.), and other poplars (*Populus species*).
5. Willows (*Salix species*).

(C) *Smaller trees, and shrubs in coppice.*

Forest Growth in Relation to Soil.

During growth, trees exact certain supplies of nutriment from the soil, which would be restored to it if they were left to fall as they grow. If, however, the timber be utilised, with the removal of each crop the soil is left poorer than before, unless the influence of the agents active in decomposing the mineral and organic constituents of the soil has been protected, for if these chemical changes be not called into action the soil must gradually become exhausted and deteriorate. In agriculture the larger supplies of nutriment extracted from the soil are returned in the shape of manure, which not only helps to restore the deficit, but also stimulates to nitrification and decomposition of the soil; in sylviculture the only recompense that can practically be made is found in the fall of leaves after fulfilling their function, flowers, fruits, twigs, and the like, whilst the leaf canopy also assists mechanically by preserving the soil-moisture from being evaporated by the sun's rays and by winds, thereby allowing the moisture more opportunity of rendering soluble the mineral constituents of the soil. Under the shade of the forest trees lowlier forms of vegetation thrive, and these in turn die, decompose, and aid in the great work of forming *humus* or leaf-mould which, being strongly hygroscopic, absorbs and retains the atmospheric moisture and precipitations, and regulates the motion of moisture within the soil. The roots of trees also in ramifying penetrate the soil in every direction, first of all cleaving and breaking up the rocks mechanically, and then on decaying assist indirectly in the subsequent chemical changes.

Retention of soil-moisture and formation of humus or vegetable mould, by which is meant all organic matter in process of decomposition—two of the important factors in determining the quality of soils from a sylvicultural point of view—are therefore the principal benefits conferred by tree-growth on the soil. Without considering the exceptional cases of very fertile or very moist soils, whose mineral strength or supply of moisture is not likely to be affected, these objects are most satisfactorily attained by maintaining growth in closed canopy—although the crowns of the trees need not necessarily be all at the same level, as in plantations—so that the soil should not be exposed to the disturbing and inimical influences of sun and wind, blowing away the dead leaves, evaporating the moisture, and otherwise interfering with the gradual process of decomposition of the humus. If the canopy be too light or broken, rank growth of grasses and weeds gains a foothold, and consumes the nutriment unprofitably, so that the crops best adapted for the protection of the soil are such as have a dense crown of foliage, and maintain their growth in close canopy through long stages of their development.

All species of forest trees are not endowed alike with the qualities requisite for maintaining or improving the productive capacity of the soil. Among deciduous trees they are conspicuous in the beech, with its close canopy, dense foliage, and heavy fall of leaves rich in potash, and slowly decomposing under the shade of the parent trees into strongly hygroscopic humus of excellent quality. Hornbeam foliage is thinner, decomposes more rapidly, and is less in quantity; the thickly-foliaged lime shades the soil well, but yields only a small amount of humus; the chestnut has a somewhat full crown of good mould-producing foliage; but none of these trees occur forming large pure forests in Britain. Oak, elm, ash, maple, sycamore, and the other more valuable and remunerative broad-leaved trees are unfortunately not naturally adapted on the whole for protecting, far less for increasing, the productive power of the soil, except when grown in admixture with species endowed with such capacity in a higher degree than themselves. Among the conifers, spruce and silver fir especially, and in a less degree the Weymouth, Austrian, and maritime pines, are gifted with soil-improving qualities, which are increased by the fine growth of moss beneath them acting like humus in its sponge-like absorption and retention of soil-moisture. The less thickly foliaged conifers, Scots pine and larch, are least of all endowed in this respect, though during the earlier stages of growth a layer of moss (principally species of *Hypnum*) is produced under them, which protects the soil from sun and wind. But as this covering of moss is apt to disappear when the opening up of the canopy reaches a certain degree, such pure forests cannot be worked with long periods of rotation without endangering the quality of the soil, unless underwood is sown or planted. Exceptionally, pure forests may be formed by trees of sparse foliage, when the soil runs no risk of becoming deteriorated through want of protection. Marshes planted up with alders, birch, aspen, and poplars are examples of this, but in such cases wind and sun often act beneficially by stimulating evaporation, and thereby decreasing the superfluous amount of soil-moisture.

In the vegetable kingdom, as in the animal, a constant strife is being waged between species, and in the different species between family groups, and in these again between individual plants—a definite struggle for existence in perfect accordance with the laws of nature regarding the survival of the fittest. There is, however, this great difference between the animal and the vegetable worlds, that the struggle carried on by forest trees in the temperate climate of central and northern Europe[1] is one which tends to produce a more or less pronounced, though perhaps never absolute, domination of the principal species over large areas limited only by the conditions best suited to the growth and development of each individual species.

If the whole continent of Europe were to be planted up quite regularly with an equal number of seedlings of each species of indigenous forest tree, we should find in course of time that a segregation of species would take place, and that, just as has happened in the ethnographic distribution of human races, they would also have their places more or less definitely allocated to them. Certain kinds of trees would be predominant over larger areas[2] in

[1] This is not the case in the tropical forests of equatorial regions, with the exception of the almost pure forests of *Dipterocarpus tuberculatus*, formed on tracts of Laterite, where soil is the principal factor limiting the growth of species.

[2] This gregarious tendency was already noted in Evelyn's *Sylva*. Gilpin (*Forest Scenery*, Lauder's edition, 1834, vol. ii., p. 113) says:—

which the most suitable of the other species would occur merely as subordinate clumps, or groups, or patches, or individuals, in situations for which they were either naturally better adapted than the ruling species, or to which the seed had been carried by some such fortuitous agency as birds, animals, &c. There would, too, always be a sort of debatable land between the domain of each, where the two neighbouring kinds of ruling species existed in more or less constant warfare and rivalry, each striving to gain an advantage over the other as far as possible; the more insinuating and hardy slowly, perhaps, but surely gaining advantages until it reached the limits of its proving more suitable and hardy than its rival. Nature would ascribe to each of the different forest trees the soils and situations best suited for it, and for which it was best suited.

Before man commenced to interfere with the work of nature by felling trees prematurely, and clearing, or sowing, or planting, as it pleased him, Scotland had its vastly predominating growth of Scots pine, and scantier growth of birch and rowan on the mountains; oaks, ashes, Scots elms, alders, and willows, together with the less important hazel, holly, and yew, were abundant on the better soils throughout all Scotland and northern England; central and southern England bore their enormous stretches of beech growth forming dense and more or less pure forests on the limy and chalky soils of the midland counties, where also a goodly growth of oak flourished on the richer alluvial tracts and lower uplands, used principally as coverts for innumerable wild boar, roe, and red deer, and constituting the grazing grounds into which large herds of swine were driven for pannage and mast. Norway and Sweden had their pine and spruce forests, whilst hundreds of thousands of acres of

"Mr. Evelyn remarks that every forest in which oak and beech grow promiscuously will, in a course of ages, become entirely beechen."

the low sandy land south of the Baltic bore Scots pine as the predominating forest growth; the lower hills of central and north-western Germany were clothed with beech, and the higher central mountains bore dark, dense woods of spruce, whilst the warmer tracts of southern Germany and eastern France were divided between spruce and silver fir, with beech at the lower elevations; further south, the Alps had their extensive forests of beech, silver fir, spruce, pine and larch, each more or less distinct, though of course overlapping at the edges. Austria in the same way had, and still has, its tracts of black pine and larch, and Russia its pines, firs, hornbeams, alder, aspen, and birch. In the richer alluvial tracts oaks, ash, elms, maples, and other prized timber trees happily found localities where they were able to assert themselves, whilst moist and low-lying situations, where winters were hard and late, and early frosts frequent and severe, were left to be the abiding place of alders, birch, aspen, poplars, willows, and such hardy denizens as failed to show themselves the fittest or most self-asserting in milder localities.

Such was the actual condition of affairs before man exerted himself in making demands on forest growth, and began interfering with the course of events being worked out by Nature in her own sure though gradual way; and it is certain that such would again be the state of affairs throughout Europe in a comparatively short space of time if all human interference with the course of nature were now to cease. Even now on the Continent the domain of the oak and the beech is being encroached on by pine and spruce, which are more easily satisfied as to soil and situation, and these in turn have to struggle with birch and willow for the maintenance of their own areas.

Growth of Timber Crops in General.

Under *timber* is comprised all wood used for technical purposes.

Timber trees differ essentially from *shrubs* in the production of a *bole*, *trunk* or *stem* to a greater or less height above the ground before ramifying to form their crown, and as a rule the length of the bole is dependent to a considerable degree on the density of the crop. Under *timber crop* is understood the quantity of material growing on any particular area, whilst under *growing stock* is comprised all the crops growing on the total area for which a *working plan* has been constructed ; under normal circumstances, when a fall of timber takes place annually, it includes all the timber crops ranging from the very youngest up to that now mature, the area covered by each of the annual crops being equal to the total area divided by the number of years included within the full period of rotation, and the total number of annual crops included within the growing stock being of course equal to the number of years included in the *period of rotation* or *turnus ;* it includes, in short, the various timber crops growing on each of the annual *falls* or *clearances.*

The timber crop may be a *pure forest* consisting of a homogeneous *wood*, *grove*, or *holt* formed of one species of tree only, or it may be a *mixed forest* made up of some *principal or ruling species* with one or more *subordinate or minor species* scattered throughout it in *hursts or clumps*, in *groups or clusters*, in *patches or knots*, in *rows or lines*, and *individually or singly.*

When the timber crop is allowed to attain its full maturity and attainable dimensions in height and girth, it is said to be treated as *high forest or high timber forest*, but when cut back to the stool so as to force it to reproduce itself by means of *stool shoots*, and of *stoles or suckers* from the roots, the method of treatment is termed *coppicing*; an amalgamation of the two systems, in which at each periodic fall or clearance of the coppice-growth a certain proportion of trees remains of ages varying according to the number of falls through which they have been left standing, is termed *copse*,[1] *coppice under standards*, *or stored coppice*, the poles and trees that are allowed to remain being *standards* and the coppice-growth forming the *underwood or undergrowth*.

Timber crops are either regenerated by *natural reproduction* through self-sown seed and by means of coppice-shoots or root-suckers, or by *artificial reproduction* through the sowing of seed, or the planting out of *seedlings* from seed-beds, or of *transplants*, as seedlings are named when they have been transferred once or oftener from the seed-beds to nursery beds, or by *layering* of living branches by means of bringing them partially under soil and allowing them to develop rootlets from the dormant buds and small shoots, or, finally, by the planting of *slips or cuttings* of species that form roots easily through the continuance of cambial activity.

In order fully to utilise the productive capacity of the soil, it is necessary that the stock should be sufficiently dense to form a *full or close canopy*, as the more the complete *canopy or normal density* is *broken or interrupted*, the less able is the crop to improve the productive capacity of the soil, or to safeguard it against deterioration through insolation and dry winds. The number of plants per acre necessary to

[1] *Copse* is the proper English term identical with the *Mittelwald*, or composition forest of Germany, and the *Taillis sous futaie* of France. *Vide* Gilpin's *Forest Scenery*, edited by Dick Lauder, 1834, vol. i. p. 301:—"The copse is a species of scenery composed commonly of forest trees intermixed with brushwood, which latter is periodically cut down in twelve, thirteen, or fourteen years."

attain this normal degree of density varies with the age of the crop and the nature of the species of trees;[1] thus on the Harz mountains Th. Hartig found the following results with regard to spruce:—

Age.	No. of stems per acre.	Average area for individual growths in square feet.	Total number of stems that were dominated or suppressed.
Years.			Per cent.
20	9,265	4·6	49
40	1,249	34·5	42
60	604	70·0	32
80	388	111·0	21
100	282	152·0	11
120	238	182·2	4

The natural tendency of forests to thin themselves depends on the fertility of the soil; on good soils density is maintained for a longer time than on inferior soils, and the process of elimination of suppressed and dominated individual poles does not take place to any great extent until the development of the total length of bole is nearly completed.

The degree to which different species of trees are able to form close canopy varies greatly; thus a spruce forest can overshadow a soil to more than double the extent that Scots pine does.

In general, trees growing in the full enjoyment of light and air have a greater increment than such as are grown with only a restricted measure of these, for they are enabled to draw more nutriment from the soil, and have greater opportunities of assimilating these supplies. But in closed forest on soils of similar quality the total production per unit of area will be greater than in the more open forest with

[1] *Vide* comparative table on p. 43. Hartig's data refer however to sowings, which are very much denser than plantations during the thicket and pole-forest stages of growth.

larger individual trees. Where the distance between the individual trees is greater than necessary, a tendency towards development of the crown sets in at the expense of the bole, stem, or shaft. Hence in order to obtain ultimately a maximum of long, straight timber it is necessary not to allow the canopy to be interrupted until the chief growth in height has been attained. Experience also shows that when, after completion of the total growth in height, measures are taken to interrupt the canopy for the purpose of allowing freer supplies of warmth, light, and air to become available for the crown foliage, the increase of growth in girth takes place with great rapidity, tending to the maximum possible yield obtainable. Growth in length is most lively whilst the trees are still poles below two feet in girth, but this varies according to species, situation, and nature of the forest. The young crop, whether formed of *seedling growth* spontaneously by natural regeneration or artificially through sowing or planting, or of *stool-shoots* and *stoles* or *suckers* through coppicing, consists of *saplings*, and up till the time that a forest in close canopy begins the natural process of clearing itself of dead branches it is termed a *thicket*; from then till the boles have attained a girth of about two feet at breast-height it is a *pole-forest*; after that it is a *tree-forest*, or *high forest*, or *high timber forest*.

Whilst the outturn in timber usually forms the *main produce* with a view to which sylviculture is carried on either in high forest (*e.g.* oak, pine) or in coppice (*e.g.* osiers, alders), yet the harvesting of the *minor produce*, like resin in spruce or pines, and tanning bark in oaks and willows, can under certain circumstances (*e.g.* oak coppice) be of greater importance than the timber produced.

For statistical purposes and actuarial calculations it is important to distinguish between the *outturn or final yield* of the crop and the *preliminary or intermediate yield* given during thinnings out, &c. before the crops reach their normal maturity. In regard to the proportion which under normal circumstances the preliminary yield bears to the final outturn Grebe [1] wrote as follows :—

"Granted that the thinnings begin at the proper time,—in the case of beech about 25—35 years, spruce about 20—30 years, and Scots pine about 15—25 years,—that they are regularly conducted, that the yield therefrom is not reduced by any peculiar local circumstances (such as right of collection of windfall, or interruption of density in canopy due to snow accumulations, &c.), we may expect that on the average the proportion which the intermediate yield from thinnings bears to the final yield of the mature crop will be :—

In Beech Forests—

With rotation of	80	years,	from	12—20	per cent.
,, ,,	100	,,	,,	14—25	,,
,, ,,	120	,,	,,	16—30	,,

The lower percentage being on poor soils, the higher on the better classes of soil.

In Spruce Forests—

With rotation of	60	years,	from	15—17	per cent.
,, ,,	80	,,	,,	20—22	,,
,, ,,	100	,,	,,	23—26	,,

In Scots Pine Forests—

With rotation of	60	years,	from	18—24	per cent.
,, ,,	80	,,	,,	22—28	,,
,, ,,	100	,,	,,	about 25	,,

In spruce and pine woods the higher percentages are obtainable from the inferior classes of soil.

General Comparative Considerations Regarding Timber Trees.

1. *Requirements as to Climate* exhibit themselves locally in relation to atmospheric warmth, light, atmospheric moisture, and currents of air.

[1] *Die Betriebs- und Ertragsregelung der Forste.* 2nd edition, 1879, pp. 300, 301.

Experiments are being made to establish the absolute amount of warmth requisite at different localities to obtain the normal development of each of the principal species of forest trees, but no definite conclusions have yet been come to.

Gayer estimates the requirements as to warmth according to the following scale :—*Greatest*—elm, sweet chestnut, oak (pedunculate) ; *moderate*—silver fir, beech, Weymouth pine, oak (sessile), black or Austrian, and Scots pines ; *lower*—birch, maple and sycamore, ash, alder, spruce ; *least*—Cembran pine, larch, mountain pine. (*Waldbau*, 1889, p. 20).

The demands on warmth naturally limit the different species of trees to certain zones of elevation, which, however, are very much modified by quality of soil, exposure, and local climatic considerations. According to Angot, the vegetation is later by fourteen days for every 100 metres (333 feet) in vertical ascent above the sea level.

In the case of evergreen conifers, the limitation of growth towards the north, or on lofty mountainous tracts, is not so much due to the actual degree of cold to which they are exposed, but is principally caused through dry winds on sunny days in winter stimulating transpiration through the leaves at a time when the roots can draw no fresh supplies of moisture from the frost-bound soil. Owing to the loss of moisture contained in the tree, the foliage becomes yellow and sickly, the growth impaired, the spines or needles are shed, and finally the death of the tree ensues. This phenomenon is most distinctly noticeable after long dry winters with comparatively frequent sunshine.[1]

Whilst excess of light paralyses the action of chlorophyll, deprivation of the due intensity under which assimilation proceeds most actively also exerts an injurious influence. Between these extremes are various degrees which are most

[1] R. Hartig, *Lehrbuch der Baumkrankheiten*. 2nd edition. 1889, pp. 104, 261.

favourable to the development of the different species of forest trees. These normal relative demands on light, dependent on density of the crown foliage and the power of overshadowed twigs to retain life, are everywhere perceptible, but vary with soil and situation, so that no hard and fast classification is possible : concerning the absolute quantity of light requisite for any species we know as little as about the absolute amount of relative warmth. G. Heyer [1] was the first to classify the forest trees in this respect ; his classification (for central Germany) compared with Gayer's (for southern Germany) is as follows :—

<table>
<tr><th colspan="3">According to Heyer (Central Germany).</th><th colspan="2">According to Gayer (Southern Germany).</th></tr>
<tr><th colspan="3">Greatest demands made by</th><th colspan="2">Greatest demands made by</th></tr>
<tr><th></th><th>Conifers.</th><th>Broad-leaved deciduous trees.</th><th></th><th></th></tr>
<tr><td>Light demanding</td><td>Larch, Scots pine.
Cembran pine.
Austrian and Weymouth pines.</td><td>Aspen, birch.
Alder.
Maple, sycamore, elm, ash, oak.</td><td>Larch, birch.
Scots pine, aspen, willow.
Oak, ash, chestnut, mountain pine.</td><td>Light demanding.</td></tr>
<tr><td>Shade-bearing.</td><td>Spruce, silver fir</td><td>Hornbeam.
Beech.</td><td>Elm, alder, Austrian pine.
White alder, lime, Weymouth pine, maple and sycamore.</td><td>Occupying intermediate position.</td></tr>
<tr><td rowspan="2">Shade demanding.</td><td>Silver fir, spruce.</td><td>Beech.</td><td rowspan="2">Spruce, hornbeam.
Beech.
Silver fir.</td><td rowspan="2">Shade-bearing.</td></tr>
<tr><td colspan="2">In earliest youth (2—3 years) when formed by sowing on soil not specially prepared for the reception of the seed.</td></tr>
</table>

[1] G. Heyer, *Das Verhalten der Waldbäume gegen Licht und Schatten*, 1852, p. 3. In the fourth edition of C. Heyer's *Waldbau*, 1891, p. 41, lime, horse chestnut and sweet chestnut are ranged between hornbeam, and ash and oak, which latter two are placed below maple, sycamore, and elm in the scale.

Whilst woody plants suffer little from frosts during winter, the late frosts in spring and the early frosts in autumn often occasion very considerable damage, especially to young growth. Danger from frost is greater on plains than in hilly tracts; greater on south and south-eastern exposures than on northern and western; greater in valleys, and coombs, and basins, than on ridges and shoulders; greater in localities protected from the wind than in those where currents of air have free play; greater in a dry state of the atmosphere than in a moist; greater on fresh soil than on dry; greater on loose sandy soil than on stiffer loam.

With reference to their liability to suffer from frost Gayer classifies the forest trees as follows:—*Liable*—Ash, acacia, sweet chestnut, beech; *less liable*—oak, silver fir, maple and sycamore, spruce, and common alder; *hardy*—lime, hornbeam, elms, birch, larch, aspen, Austrian and Scots pines (*op. cit.* p. 21).

The liability to suffer depends, however, less on the species than on the stage of growth to which the young shoots have advanced; it is greater in weakly than in healthy and vigorous plants; greater too in plants suddenly exposed after having long had the shelter of standards than in those that have been gradually accustomed to the loss of shelter.

By comparison of the development of trees of the same species, growing on soils of nearly equal quality, but in localities known to differ greatly as to the relative humidity of the air, it has been concluded that spruce, alder, maple, sycamore, and ash, also in a less degree silver fir, beech, and birch, thrive best in localities where the air has a high degree of relative humidity. On the Continent the principal tree on the dry sandy North-German plain is the Scots pine, which though it thrives in the insular climate of Britain does not thrive in the damp climate of Schleswig-Holstein; whilst the spruce on the Harz, the beech on the Solling and Deister, and in a less marked degree the silver fir in Thuringia and on the highlands of Southern Germany, on account of their great transpiration through the leaves, thrive better in moist localities than in those exposed to summer drought, and can often be reproduced there by sowing in the open without requiring nurses as at lower elevations. In mountainous tracts snowfall is apt to cause branches to break off, so that brittle woods like Scots pine are not the species best adapted for forming forest trees. In localities exposed to violent winds shallow-rooted species, particularly spruce, are liable to be thrown as windfall.

2. *Requirements as to soil* may be estimated from three points of view, namely, as regards depth, soil-moisture, and mineral strength generally, and it must be borne in mind that under all circumstances a due admixture of good humus or mould is benefical to all classes of soil, and to the general development of forest growth.

The disintegration of the rocks must necessarily be carried to such an extent as will admit of the penetration of the root-system. The majority of trees require for their growth soils varying from 1 to 3 feet in depth, and 5 to 6 feet may be taken as the greatest depth ever actually required even by the oak. Depth of soil, however, is beneficial even to trees having shallow root-systems, as it enables their roots to ramify more easily, and thus tends to produce longer development of the bole or stem.

As to formation of the root-system, some species develop a tap-root, which is either permanently retained or becomes transformed into a deep heart-shaped root with strong ramifications as in the oak, elm, Scots pine, silver fir, maple and sycamore, ash, chestnut, lime, and larch; others have no pronounced tap-root, but develop strong side-roots which penetrate the soil to a moderate depth, as in beech, hornbeam, aspen, and birch; others, like the alder, throw out strong side-roots, whence proceed deep-reaching rootlets; and others again develop strong side-roots confining their whole root-system practically to the upper layers of the soil, as is especially the case with spruce.

The following table expresses, only however in general terms, the depth of soil necessary for the various species of forest trees to thrive:—

Up to 1 *ft.*—Spruce, aspen, mountain ash, birch, mountain pine.
1 *to* 2 *ft.*—Beech, hornbeam, alder, Austrian and Weymouth pines.
2 *to* 3 *ft.*—Scots pine, silver fir, Douglas fir, elm, maple and sycamore, ash, lime, chestnut.
3 *to* 4 *ft.*—Oak, larch.

Comparative data are not yet available to show the absolute quantities of soil-moisture necessary for the various species of forest trees to enable them to maintain throughout the annual period of vegetation the requisite evaporation and transpiration through the foliage. Experience however shows that the demands for soil-moisture practically vary as follows:—

Greatest—alder, ash, willow, maple, elm; *considerable*—oak (pedunculate), hornbeam, birch, aspen, larch, Weymouth pine, spruce; *moderate*—beech, oak (sessile), lime, silver fir; *least*—Scots, Austrian, maritime and Cembran pines.

On the whole the broad-leaved, deciduous trees demand more soil-moisture than the conifers. The absolute demands of the various species of forest trees on the nutrient strength of the soil has also not yet been determined, the difficulty being that the mineral constitution is not the only factor, but that all the physical qualities exert important influence under every circumstance and in the most complicated concrete conditions.

According to Hartig :—[1]

"The quantity of nutriment taken up from the soil depends chiefly on the species, for some plants extract greater supplies than others. Thus the spruce, for example, when growing along with the beech in forests forming close canopy, extracts more raw mineral substance for ashes than the latter. At fifty years of age the relative proportion of productions between the spruce and the beech is :—

As regards cubic contents..............	2·78 to 1
,, ,, dry woody substance......	1·80 to 1
,, ,, ashes (mineral substance).	1·28 to 1

"These figures prove that spruce not only withdraws more nutriment from the soil than beech, but that it also produces more timber than the beech with any given quantity of mineral substance. For the production of any given cubic quantity of beech timber more mineral matter is requisite than for the production of the same volume of spruce."

Experience however here again shows that the forest trees may be classified as follows in regard to the demands made on the general fertility and mineral strength of the soil :—

Heyer (for Central Germany).		Gayer (for Southern Germany).	
Greatest demands.	Elm, sycamore, ash.	Most exacting.	Elm, maple and sycamore, ash.
High demands.	Oak, beech, maple, sweet chestnut, silver fir.	Exacting.	Oak, beech, lime, silver fir, aspen, willow.
Moderate demands	Lime, larch, hornbeam, alders, coppice willows, mountain ash, horse-chestnut, spruce, Cembran pine.	Little exacting.	Sweet chestnut, larch hornbeam, birch, alder, spruce.
Lower demands.	Poplars and tree willows.	Less exacting.	Cembran and Weymouth pines.
Least demands.	Scots, Weymouth and Austrian pines, birch, acacia.	Least exacting.	Scots and Austrian pines

[1] *Anatomie und Physiologie der Pflanzen*, 1891, p. 227.

The power of accommodating themselves to situations not naturally suited to their growth and normal requirements is greatest in the Scots pine and birch, less pronounced in the oak, beech, spruce, silver fir, Austrian and Weymouth pines, and least of all in the ash, elm, maple and sycamore.

It is impossible to say that clayey, loamy, limy or sandy soils are necessary for any particular species of forest tree; extracts from the works of the most eminent German sylviculturists are often absolutely contradictory on such points. G. Heyer[1] on the other hand even went so far to the other extreme as to assert that almost any soil could produce any kind of timber, provided it were supplied with the necessary and suitable quantity of moisture. Ney[2] ably summarises as follows:—

"As regards chemical composition of the soil, even slightly sour marshy soils are unfavourable to all species of trees except alder, birch, and spruce, whilst sour soils liable to dry up at certain seasons are unsuited for all except birch, spruce, Scots and Weymouth pines. Only these last-named species thrive on pure peat, and not even the spruce when it is dry. Ash, maple, sycamore and elm require a moderate quantity of lime in the soil, and beech, hornbeam, oak, as also larch and Austrian pine, thrive best on soils that have at least some lime in their composition. The hardwoods—oak, ash, maple, sycamore, elm, chestnut, beech, and hornbeam—also appear to demand the presence of a considerable quantity of potash, whilst on the other hand spruce, silver fir, and especially Scots pine and birch, thrive on soils rich neither in lime nor potash."

It seems hardly open to question that the one factor in regard to the soil of greatest importance from the sylvicultural point of view is *humus;*[3] given a sufficiency of vegetable mould or humus, all the physical factors are affected, and soils otherwise unsuited for the growth of the more exacting species become perfectly well adaptable to their

[1] G. Heyer, *Forstliche Bodenkunde und Klimatologie*, 1856, p. 488.

[2] C. E. Ney, *Die Lehre vom Waldbau*, 1885, p. 64.

[3] By *humus* or leaf-mould is meant *all organic matter undergoing the process of decomposition* (Liebig).

requirements. The immense improvement which takes place in soils under dense forests of beech and spruce is a striking proof of the invaluable soil-improving qualities of mould.

3. *Differences of Forest Trees as to Shape.*—The essential characteristic of a tree as compared with a shrub is that a main stem, trunk, or bole is developed above the root-system, and branches are thrown out to form a crown only at some distance above the soil. Some species of forest trees tend more to the development of a long straight bole than others, as for example the conifers generally in comparison with broad-leaved deciduous trees. The individual tendencies of every species are further dependent on several factors influencing them, of which the principal are the growing space allowed to each individual, the age of the forest, and the nature and quality of the soil and situation.

The natural tendency to assume a certain, more or less constant, form has free indulgence only when the individual tree has full enjoyment of light, warmth, and air. Some, by means of the development of the terminal bud of the main axis always taking place with much greater rapidity than the shoots of side branches, assume long straight stems with a more or less conical disposition of foliage, and have a decidedly stronger tendency upwards than sidewards; whilst in regard to others the terminal shoots of the branches compete with that of the ascending axis, with the result that the stem remains short and stunted, the crown low, and the branch development relatively great.

According to the tendencies exhibited in one or other of these directions, the forest trees have been classified as follows by Gayer:—*Forming undivided stems*—Spruce, silver fir, larch, Weymouth pine; *more or less branching towards summit*—Scots pine, alder, beech, oak (sessile), black poplar, Cembran pine; *somewhat greater tendency to branching*—ash, maple, sycamore, elm; *decided tendency to branching at comparatively small height above soil*—oak (pedunculate), lime, chestnut, hornbeam, mountain pine (*op. cit.* pp. 36, 37).

Ney again classifies them more broadly thus :—

Developing long stems—All conifers except Cembran pine ; sessile oak, chestnut, ash, maple, sycamore, birch, alder, poplars, horse-chestnut; *developing short stems*—English oak, beech, hornbeam ; limes, willows, elms (*op. cit.* p. 60).

When the growing space for each individual is limited, however, these natural tendencies are checked ; the struggle upwards for light and air induces growth in height, and counteracts the propensity towards branching development. The less the individual growing-space, and the more light-demanding the species of tree, the greater the impulse towards growth in height. In averagely dense forests of larch, Scots pine, oak, birch, and aspen, the crown of foliage extends a very little way down the stem,—although in the insular climate of Britain the Scots pine has a better crown than on the hot, dry, sandy North-German plain,—in spruce, beech, and hornbeam it reaches down about one-third of the bole, whilst in silver fir it often descends to about half way to the ground. Thus in forests of normal density supplies of assimilated nourishment are available for the upper parts of the bole in place of being dissipated over a large branch-system, and are utilised in producing long, straight stems approaching the cylindrical form, and thereby adding to the value of the timber, both for technical purposes and from a monetary point of view.

The Age of the Crop is a factor of little moment in the earlier stages of growth, as all species of trees, when grown in forests of normal density, assume a more or less conical or spindle-shaped crown until they outgrow the pole stage, and become, with lessened growth in height, tree-forest, when their individual natural tendencies begin to assert their influence. Following their natural tendency, spruce, silver fir, and larch continue to develop more vigorously upwards than sidewards, thereby retaining their conical shape of crown; Scots pine, elm, beech, maple, sycamore, birch, sessile oak, ash, and alder assume a crown of oval shape; English oak, lime, chestnut, and hornbeam tend rather to the formation of a broad, obovate crown.

When the total growth in height is completed, with advancing age all trees, with the exception of the spruce and larch, assume a more or less rounded-off appearance varying in degree with the natural tendency towards side-branch development.

The obvious conclusion from these facts is that forests of shade-bearing species, content with limited growing space, *i.e.* beech, hornbeam, and more particularly spruce and silver fir, are able to maintain close canopy more completely, and for a much longer time, than forests formed of Scots pine, larch, ash, maple and sycamore. When further, as in the case of the oak, birch, and chestnut, a decided tendency to branching growth is combined simultaneously with strong demand for light, interruption of the leaf-canopy takes place early and to an injurious degree, and all the more when the situation generally, and in particular the amount of soil-moisture, varies from that best suited to the particular species.

The Quality of the Soil exerts its special influence on the growth of trees. Fresh, fertile loams stimulate to development of crown, and yield fine boles though somewhat at the expense of their length. Deep, fresh, light sandy soils induce length of stem, with thinner crown, sparser branch development, and consequently a less girth of bole. Shallow and rocky soils produce short-stemmed trees, with strong tendency to branching and crooked growth.

Situation. With increasing elevation the forest trees have a diminished tendency towards stem-development, and an increasing tendency towards branching growth, until finally, towards their limit of growth, they resemble shrubs rather than trees, as for example the Scots pine in Scotland at about 2,500 feet. Similar effects are produced in localities exposed to constant winds, especially those that are damp and cold.

4. *Differences of Forest Trees as to Growth in Height, Girth, and Cubic Contents.*

(*a*) *Growth in height* varies considerably according to species, age, soil and situation, method of formation of forest, and form of treatment accorded to it. It takes place by means of two shoots during the annual period of active vegetation, namely the shoot from the spring flush beginning in April or May, and that from the summer flush beginning in July. In broad-leaved trees the latter is usually longer than the former, as it falls in the warmer and more energetic period of vegetation, but in conifers this is not usually the case, and the later development of the spring growth is less easily traceable, as no regular whorls are formed except by the spring buds. In warm autumnal weather, as in 1886, some trees also throw out autumn shoots early in October, but this is rather a drawback than an advantage, as the shoots have not time to develop, to harden naturally, and to form fresh normal buds for the following spring, before the early frosts set in and close the active period of vegetation for the season.

The following table exhibits the maxima heights usually attainable in forests, according to Gayer (*op. cit.* pp. 38, 39):—

Height in feet.	Attainable by
110—140	Spruce, silver fir, larch, Scots and Weymouth pines.
100—130	Oak, ash, beech, lime maple and sycamore; less frequently elm, poplar and birch.
80—100	Black and Cembran pines, hornbeam, alder and willow.

These maxima heights are reached in different periods by different kinds of trees; thus the birch reaches its full attainable growth in height long before the Austrian pine, the oak, or the spruce. For sylvicultural purposes, especially for the formation of mixed forests, it is important to know and consider the relative rates of growth at different periods of their development, particularly during the earlier stages of growth.

Ney[1] gives as the results of the yield tables arranged by Baur for beech, Schuberg for silver fir, Lorey for spruce, and Weise for Scots pine, the following average heights at ten years of age :—

Quality of soil.	I.		II.		III.		IV.		V.	
Average height.	Feet.	Inches.	Feet.	Inches.	Feet.	Inches.	Feet.	Inches.	Feet.	Inches.
Beech thicket ...	5	4	4	4	3	6	2	8	1	8
Silver fir thicket..	5	8	4	4	3	4	2	4	1	8
Spruce thicket ...	5	0	3	4	2	0	1	8	1	4
Scots pine thicket	7	4	6	0	5	0	4	4	3	8

The same tables show that the *current annual increase in height* on soil of the I. (best) quality was :—

Period of growth.	Beech.		Silver fir.		Spruce.		Scots pine.	
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
From 6th— 10th year	0	8	0	8	0	8	0	9
,, 16th— 20th ,,	1	4	1	1	1	4	1	8
,, 26th— 30th ,,	1	8	1	8	1	6	1	3
,, 36th— 40th ,,	1	4	1	7	1	6	1	3
,, 46th— 50th ,,	1	2	1	5	1	5	1	2
,, 56th— 60th ,,	1	0	1	2	1	4	0	9
,, 66th— 70th ,,	0	8	1	1	1	1	0	7
,, 76th— 80th ,,	0	8	0	8	0	9	0	6
,, 86th— 90th ,,	0	8	0	6	0	7	0	5
,, 96th—100th ,,	0	6	0	4	0	7	0	3
,, 106th—110th ,,	0	4	0	2	0	5	0	2
,, 116th—120th ,,	0	4	0	1	0	3	0	2

[1] *Lehre vom Waldbau*, 1885, pp. 54—59.

It appears, therefore, from the carefully compiled tables from which the above abstract is made, that, on soils of the best quality usually found under forest, the current annual increase in height is :—

Forest of	Attains its maximum during	Has already decreased to below	
		Half of its maximum during	Quarter of its maximum during
Beech ...	26th—30th year	61st—65th year	101st—105th year
Silver fir.	26th—30th ,,	76th—80th ,,	96th—100th ,,
Spruce ...	26th—40th ,,	81st—85th ,,	111th—115th ,,
Scots pine	16th—20th ,,	56th—60th ,,	81st—85th ,,

On soils of inferior quality the current annual increase in height follows much the same curve, but usually takes somewhat longer to culminate. The years of culmination shown by these tables are approximately as follows :—

Quality of soil.	I.	II.	III.	IV.	V.
Beech	28th	30th	40th	40th	41st
Silver fir	28th	35th	40th	40th	40th
Spruce	33rd	40th	45th	60th	—
Scots pine...........	18th	19th	49th	20th	21st

The absolute average height of the trees forming the forest varies very considerably, however, according to the quality of the soil, as may be seen from the table on page 38 (in feet). Thus on poor soil the Scots pine at eighty years' growth has not attained the same average height as is reached on the best class of pine soil after forty years' growth ; up till about the fiftieth year it is of quicker growth than the other species, but is then overtopped by the spruce and silver fir, whilst it is hardly at any later period dominated by the beech.

Age of forest.	Beech.		Silver fir.		Spruce.		Scots pine.	
	Soil quality.		Soil quality.		Soil quality.		Soil quality.	
Years.	I.	V.	I.	V.	I.	IV.	I.	IV.
20	17	4	15	5	17	5	24	11
40	50	18	49	21	48	18	52	26
60	72	33	78	39	78	36	74	36
80	87	47	97	47	99	52	87	43
100	99	53	109	54	114	62	95	—
120	106	60	113	57	123	68	100	—

These changes in rate of growth in height at different ages are of great importance in regard to the formation and subsequent treatment of mixed forests.

The following classifications have been made as to general average rapidity of growth in height during the early periods of development :—

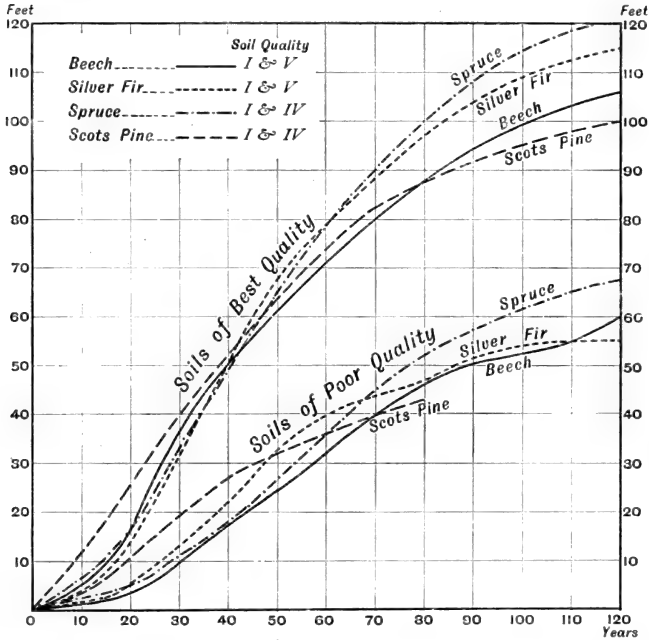
	Heyer (for Central Germany).	Gayer (for Southern Germany).
Most rapid of growth.	Alder, birch, poplar, willow, larch, Scots, maritime, and Weymouth pines.	Birch, larch. Aspen, alder, maple, sycamore, ash, lime, elm, willow, Weymouth and Scots pines.
Somewhat rapid of growth.	Chestnut, elm, maple and black or Austrian pine.	Oak. Black or Austrian pine, Hornbeam Beech.
Slow in growth.	Beech, hornbeam, oak, lime, sorbus-species, sycamore, ash, Cembran pine, spruce, silver fir, yew.	Spruce, Cembran pine. Silver fir.

A comparison of this table with that (on p. 26) exhibiting the requirements of the different species of forest trees as to light, shows that in a general way the light-loving trees are those also of quickest growth in height.

Some species, *e.g.* larch, and under favourable circumstances Scots and Weymouth pines and birch, maintain the advantage thus early won even after they have entered into the pole-forest stage, when growth in height is most active; other species, *e.g.* ash, maple, aspen, though still active in growth, do not maintain their early promise, but are overtaken and topped by species like the spruce, silver fir, beech and oak, which display increased vigour on reaching the pole-growth stage. Continuation of growth in height at the more advanced periods of life is dependent on the influences of soil and situation, but *cæteris paribus* is maintained longest by spruce, silver fir, and larch, which naturally incline towards growth in height rather than to branch development. Among the broad-leaved deciduous trees the sessile oak, elm, and beech retain the power of growth in height longer than other species, which early become rounded off in the crown on its cessation.

Adopting the graphic method, introduced by G. Heyer, the table on p. 38 showing the rate of growth in height can be represented by co-ordinates (see table on next page), the ordinate being the height attainable, and the absciss the age at which it is obtained.

Elevation, exposure to winds, and soil fertility all exercise influences on growth in height, which may be summed up in the short statement that the more suitable the soil and situation are for any particular species of tree, the more active and energetic will be its growth in height. Deep, fresh, light soil, rich in humus, is more favourable than binding soil of great mineral strength; high elevation above sea-level, or exposure to winds, interferes with the natural development in height. An uninterrupted leaf-canopy stimulates growth in height in such species as pines and most of the broad-leaved deciduous trees, which tend to branch development. Limitation of growing-space beyond the measure of density necessary to maintain an unbroken canopy acts



injuriously on the whole development, in place of stimulating beneficially to increased growth in height.

(*b*) *Growth in Girth* is in all species of forest trees more or less proportional to the growth in height, since the period in which the latter is greatest is also nearly coincident with that during which the trees are most active in increase of girth ; in fact, the energy displayed in both of these directions is merely the result of the trees having reached the most vigorous period of their growth, the stage of pole-forest. In the case of most of the light-loving species of trees it begins early, often reaches its maximum within the 20—30th year, maintains itself often without much diminution till about the 50—60th year, after which it diminishes. The period of most active increase in girth begins later in the case of oaks and in shade-bearing species, but often continues till the 70—90th year, and then begins gradually to decline.

The mean diameters at breast-height reckoned from the sources already named have been calculated to be as follows (in inches):—

Age of Forest.	Beech.		Silver fir.		Spruce.		Scots pine.	
	Soil quality.		Soil quality.		Soil quality.		Soil quality.	
Years.	I.	V.	I.	V.	I.	IV.	I.	IV.
40	4·0	...	5·2	2·0	5·6	Data not available.	6·4	2·8
60	7·6	3·2	9·2	4·0	9·2		9·6	4·4
80	10·0	4·8	12·8	6·4	12·0		12·0	5·6
100	11·6	6·8	15·6	8·0	14·0		17·2	...
120	13·6	8·4	17·6	9·6	15·2		18·0	...

From this it will be seen that the Scots pine increases rapidly in girth in comparison with these other trees, but that with advancing age it is almost equalled by the silver fir. But, as we shall presently see, on soils of the best quality there are on the average about 175 stems of silver fir per acre at 120 years, whilst there are only 141 of Scots pine, which makes a great difference to the proprietor as regards material and financial outturn.

Increase of growth in girth is of course to a great degree dependent on the situation and the quality of the soil, but factors of almost equal importance are the degree of light, and the measure to which the available light can be utilised, or in other words, to the extent of the development of foliage. In crowded forests, growth in girth is injuriously affected by diminution of the supply of light even more than growth in height; in according growing-space to the individual beyond a certain degree, however, growth in girth takes place somewhat at the expense of growth in length. When trees in the full vigour of growth are given an increase of growing-space after having been accustomed only to a limited space, the influence of the larger measure of enjoyment of light and air becomes marked in the rapid increase in girth. Even when the trees are advanced in age, and have already begun to decrease in the rate of girth increment—as for example in the case of beech or silver fir, during gradual clearances at the time of natural reproduction from seed under standards—a revival of vigorous increment can be induced by giving them free access to light and air. Such ability is, however, dependent on the trees not yet having completed their growth in height, as the energy employed in extending the foliage-bearing crown is really diverted from growth in height and utilised in branch development. Silver fir, spruce, larch, oak, and beech, endowed with long-continued capacity for growth in height, also retain longest the power of benefiting by increased supplies of light and air.

The largest girths are attainable by oak, elm, chestnut, lime, beech and black poplar among broad-leaved trees, and silver fir, spruce, Weymouth and Scots pines, Douglas fir, and larch among conifers.

(*c*) *Growth in Cubic Contents*, or *Total Increment*, is the complete result attained by the sums total of growth in height and growth in girth. It is a convenient measure of the general energy of growth, expressed either by the quantity of timber of a given species produced on a given area within a given period, or by the time necessary to produce a given quantity of timber of any particular species on a given area.

From the sources already mentioned on page 36 the average total number of stems per acre is calculated to be :—

Age of forest.	Beech.		Silver fir.		Spruce.		Scots pine.	
	Soil quality.		Soil quality.		Soil quality.		Soil quality.	
Years.	I.	V.	I.	V.	I.	IV.	I.	V.
20	...	...	2,981	...	2,560	Data not available.	...	...
40	1,360	...	1,375	4,472	1,053		727	1,814
60	504	1,480	529	1,783	509		377	1,040
80	328	736	316	890	317		244	731
100	256	456	223	561	240		171	...
120	192	352	175	409	224		141	...

The average cubic contents of the entire individual tree grown in pure forests and in close canopy have been found to be (in cubic feet) :—

Age of forest.	Beech.		Silver fir.		Spruce.		Scots pine.	
	Soil quality.		Soil quality,		Soil quality.		Soil quality.	
Years.	I.	V.	I.	V.	I.	IV.	I.	V.
40	2·52	...	4·68	0·36	6·12	Data not available.	6·48	1·08
60	11·88	1·08	19·44	2·16	18·36		18·00	2·52
80	25·20	3·60	41·04	5·76	42·12		33·48	4·32
100	40·68	7·56	64·44	11·88	61·92		54·00	...
120	63·00	12·24	87·48	18·72	70·56		70·20	...

Exclusive of timber extracted during thinnings, but including branches below 2·8 inches in diameter as well as timber, the total average production of pure forest per acre is (in cubic feet) approximately :—

Age of forest.	Beech.		Silver fir.		Spruce.		Scots pine.	
	Soil quality.		Soil quality.		Soil quality.		Soil quality.	
Years.	I.	V.	I.	V.	I.	IV.	I.	V.
20	1,160	246	1,015	174	2,204	507	2,349	826
40	3,596	928	6,742	1,508	6,467	1,856	4,872	1,928
60	6,119	1,628	10,498	3,552	10,773	3,813	6,844	2,711
80	8,410	2,624	12,934	5,365	13,398	5,321	8,250	3,233
100	10,454	3,494	14,442	6,728	14,920	6,336	9,236	...
120	12,194	4,304	15,370	7,656	15,950	7,250	9,918	...

A comparison of these various tables will show that although on poor soil there is frequently more than double the number of stems per acre that is to be found on soils of the best quality, yet the growth in height and the growth in girth are, up till near the eightieth year, each under the half of that exhibited on the more favourable localities, and though the proportion improves from the 80—120th year, its advance is only slightly in excess of one half, whilst the total production of wood exhibits very great differences up till the end of the pole-forest stage, and at no time amounts on inferior soil to half of that attained on soil of the best quality.

Great differences are exhibited according to soil and situation by the various species of trees in regard to current and average annual increment, as may be seen from the following table exhibiting the total production of wood (in cubic feet) :—

Age of forest.	Beech.		Silver fir.		Spruce.		Scots pine.	
Years.	Soil quality.		Soil quality.		Soil quality.		Soil quality.	
Current annual increment.	I.	V.	I.	V.	I.	IV.	I.	V.
At 20 years	97	26	188	38	203	49	**139**	**58**
,, 40 ,, ...	**130**	36	**217**	**96**	**229**	**93**	113	49
,, 60 ,, ...	117	43	145	**96**	174	**93**	93	35
,, 80 ,, ...	108	**58**	90	78	87	52	61	20
,, 100 ,, ...	94	43	58	55	61	46	43	—
,, 120 ,, ...	79	29	35	35	41	41	26	—
Average annual increment.								
Up till 20th year.	58	12	50	9	110	25	117	41
,, 40th ,,	89	23	168	38	161	46	**122**	**48**
,, 60th ,,	101	28	**174**	59	**179**	63	114	45
,, 80th ,,	**105**	32	161	**67**	167	**66**	103	40
,, 100th ,,	104	35	144	**67**	149	63	92	—
,, 120th ,,	101	**36**	128	63	133	60	82	—

From the above it will be seen that the Scots pine reaches its maximum annual and maximum average increment in cubic contents much earlier than the shade-bearing species that do not make great demands on increase of growing-space until the later stage of their development.

Comparing the average production of timber in forests growing on localities similar as to quality of soil, Gayer classifies the various species of trees in the following order as to general energy displayed in growth of cubic contents (*op. cit.* p. 43) :—

Spruce forest, silver fir forest.

Larch forest, Weymouth pine[1] forest, Scots pine forest.

[1] Burckhardt, *Säen und Pflanzen*, 5th edition, 1880, p. 426, says : —" In growth of cubic contents the Weymouth pine is surpassed by no other species of tree, except perhaps the poplar."

Beech forest.
Oak forest, ash forest, hornbeam forest.
Birch forest.

The conifers in general are more energetic in growth of cubic contents than the broad-leaved deciduous trees, and Gayer estimates that on the average the vital energy of crops of silver fir and spruce is about 100 per cent. and that of pine about 50 per cent. greater than beech, which is the broad-leaved species best endowed in this respect.

5. *Differences of forest trees as to reproductive power.*—In the vegetable as also in the animal world the effort made in reproducing and increasing the species is under certain circumstances even greater than that devoted to the maintenance of individual existence for the longest possible period. The tendency to reproduction is seen in all forest trees, as when treated in a natural manner they yield rich supplies of seed at short intervals during a great portion of their term of existence.

The natural process of reproduction takes place either from seed shed by the trees, or else by means of shoots from the stool, or stoles or suckers from the roots.

(*a*) *Reproduction from seed* is the chief method of propagation, and that in which the various forms of high forest are usually produced. The quantity of seed formed depends on many factors, the principal of which are the species of tree, the age of the trees, the nature of soil and situation, and the amount of light enjoyed.

The various species of trees show great differences in reproductive capacity as measured by the total quantity of germinable seed produced during a period of several decades; while again this total is dependent on the average quantity of good seed produced in each seed-year, and on the frequency with which seed-years recur. The monœcious species (*e.g.* oak, beech, conifers), in which pollination may be interfered with by rain, and the diœcious species (*e.g.* willows and poplars), bear seed on the whole less frequently than trees with hermaphrodite flowers (*e.g.* ash, elms, maples), whilst of the latter those bear seed less frequently which are liable to suffer from frost, or which, as is also the case with oak and beech, require a favourable preceding year's growth to enable them to form flower-buds. Whereas the seed of spruce, silver fir, and larch ripen in about six months after flowering, the seed of pines is not mature until the autumn of the following year, or about eighteen months after flowering.

As to average yield of good seed in each seed-year, the forest trees may be classed as follows :—*Good seed-producers*—Beech, oak, spruce Scots pine, birch, hornbeam, elm, alder, aspen, willow ; *indifferent seed-producers*—ash, maple, sycamore, silver fir, larch.

But as beech has on the average good seed-years only every 5—8 years, and as oak, spruce, Scots pine, alder, and ash have them only every 3—5 years, while the other species fructify in shorter intervals, they have been ranged by Gayer with regard to the total average annual production of seed as follows (*op. cit.* p. 47) :—

Producing most—Birch, aspen, willow.
then—Pines, spruce, elm, hornbeam, alder.
then—Maple and sycamore, silver fir, larch, lime, oak, alder, ash.
,, *least*—Beech.

In Britain, the English elm does not produce germinable seed, and the lime and chestnut only infrequently, but they compensate for this by their capacity of throwing out root-suckers.

Species having small, light, winged seeds produce more seed than others with heavy or with wingless seeds. It is worthy of note that the former, including birch, aspen, willows, Scots pine, and spruce, make more moderate demands as to soil and situation than the species with heavy seeds such as oak, beech, silver fir, maple, and sycamore. With their seed wafted to considerable distances by the wind, and easily satisfied as to soil and situation, they must be acknowledged to possess a considerably greater reproductive capacity than species with heavy seeds. In many parts of the Continent it may be observed how the domain of oak and beech is gradually being invaded by the Scots pine and the spruce, whilst in other localities these latter have themselves to maintain a struggle against the encroachments of the still more easily satisfied birch, aspen, and willow.

The germinative capacity of the different kinds of seed varies greatly. Ney gives the following as satisfactory percentages in experiments for testing the quality of deliveries by seedsmen (*op. cit.* p. 52).

Birch 10	Larch. ...35	Hornbeam 50	Oak 60	Scots pine 60
Alder ...15	Weymouth pine ...50	Silver fir. 50	Chestnut 60	Spruce .. 60
Elm......20	Ash 50	Maples ..50	Beech....60	Austrian pine ...70

The seed of most species germinates in the spring after it is shed, but that of birch, elm, aspen, and willows germinates in the spring in which it falls, and that of ash and hornbeam only in the second spring after its fall if it has been stored.

The Age of the Trees at which seed is produced in greatest quantity is generally that at which, having just completed the period when growth in height is most active, the individual tree begins to develop its crown, and to display greatest energy in increase of cubic contents. The power of seed-bearing is maintained up till near the close of life; the quality, however, of seed produced near both extremes of the reproductive period, but especially at the younger extreme, is poor, it being usually deficient in germinative capacity. Birch, alder, larch, and Scots pine begin to bear seed earliest, often from their 15–20th year, whilst oak and beech, the latest to enter the reproductive period, only commence to produce about the 60–70th year under normal conditions of forest growth.

Soil and Situation exhibit their influence mainly in regard to the amount of warmth afforded to the trees. At high elevations or at latitudes distant from their proper home, the seed-producing capacity of forest trees becomes weakened, and finally no longer possible. Warm southern and south-western aspects yield more seed than the colder northern and north-eastern exposures.

As an increased assimilation of mineral nutriment is necessitated for the formation of seed, judging by the comparatively high percentage of ashes contained in it, fresh soils, rich in mineral constituents, yield more and better germinating seed than those of inferior quality; the formation of flower-buds can only take place when towards the close of the period of vegetation a surplus of nourishment is available after the production of wood for the year is completed and the reserves of starchy matters for the commencement of next year's growth have already been provided for.

The Enjoyment of a large Amount of Light, by stimulating to increased assimilation of nutrients and to the production of reserves of starchy matter towards the close of the annual period of vegetation, has a beneficial effect in increasing the production of seed, as also a considerable influence on the quality of seed produced. Only trees with well-developed crowns are fully capable of utilizing the advantages to be gained from the free diffusion of sunshine and warmth throughout the foliage; dominated trees, or those whose crowns are deprived of free access to light and air, bear little or no seed, as also those non-indigenous forest trees, like the sweet chestnut, lime, and English elm, which have never been able to accommodate themselves thoroughly to the climate of Britain as regards reproduction by seed.

Ney[1] gives the following as about the usual amount of wingless and clean seed of fair average germinative capacity requisite per acre for the production of a crop of seedlings of average moderate density on soils of average quality:—

Species.	Broadcast sowing.		Sowing in rills or furrows.		Dibbling in.	
	Over whole area.	In strips or bands.	Over whole area.	In strips and patches.	Over whole area.	In strips and bands.
	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.
Oak	720	540	450	360	225	180
Beech	225	180	...	...	54	
Hornbeam	54	36				
Ash	54	$40\frac{1}{2}$				
Maple and sycamore	45	36				
Elm	$31\frac{1}{2}$	$22\frac{1}{2}$				
Alder	18	$13\frac{1}{2}$				
Birch	45	$31\frac{1}{2}$				
Sweet chestnut	...	...	630	...	180	180
Spruce	$10\frac{4}{5}$	$8\frac{1}{10}$				
Silver fir	63	54	45	36		
Scots pine	$6\frac{3}{10}$	$5\frac{2}{5}$	$5\frac{2}{5}$			
Black pine	$10\frac{4}{5}$	$8\frac{1}{10}$				
Larch	$13\frac{1}{2}$	$10\frac{4}{5}$				

[1] *Die Lehre vom Waldbau*, 1885, p. 181

(*b*) *Reproduction from Shoots and Suckers* is the method which usually takes place in coppice. It is the natural effort of young trees to replace the ascending axis or stem, when this has been removed by cutting, by means of calling into activity the dormant or adventitious buds situated either at the base of the stem just over the soil (*shoots*), or by stimulating those situated along the roots into growth towards the surface of the soil, and thence upwards to form fresh ascending axes, which may be detached from the parent plant and transplanted elsewhere (*stoles* or *suckers*). In both cases this natural effort is the result of the root-system remaining in activity, and drawing supplies of nutriment from the soil, which can only be duly utilised when a fresh stem, or stems, bear foliage to carry on the necessary work of assimilation.

The power of replacing the stem is greatest whilst the forest is in the full vigour of youth, and continues in general as long as the parent tree is in lively growth; a shallow soil produces more but less vigorous shoots than a deep soil; freshness of soil and mineral strength increase the number and vigour of the shoots; abundance of light is an essential condition for their production, as suppressed stools and roots develop at best but poor shoots and suckers.

The only trees suitable for reproduction in this manner are the broad-leaved species. Oak yields most shoots, while beech and birch after being coppiced several times weaken in reproductive power. Gayer makes the following classification :—

Producing shoots principally—Oak, hornbeam, beech, elm, chestnut, lime, black poplar, alder, ash, maple and sycamore, willow, birch; *producing suckers principally*—aspen, white alder, acacia (*op. cit.* p. 49).

Willow, poplar, lime, elm, and in a less degree chestnut, —the trees not originally indigenous to Britain,—have also considerable reproductive power by means of root-suckers in compensation for the natural disadvantages they are at in this country in regard to the production of abundant supplies of germinable seed. Of shrubs grown along with forest trees in coppice, hazel and hawthorn chiefly produce shoots from the stool, blackthorn mostly suckers, and field maple, and most shrubs, quantities of both. Chestnut, oak, hornbeam, elm, and alder retain the capacity for reproduction longest[1]: beech, birch, maple, sycamore and ash lose it soonest. Conifers have no reproductive power of this nature to speak of, or which can be utilised for practical sylvicultural purposes, although the larch in its period of youthful growth can throw out shoots, and also, but to a less extent, the three-needled species of pine,[2] none of which form forests in Britain.

Pollarding represents the same effort of nature to replace portions of the stem cut away at some height above the soil, by calling into activity the dormant buds situated below the parts removed.

6. *Difference as to Age attainable.*—In order that individual trees may reach the normal limit of life in healthy condition, the proper development of all the organs of nourishment is primarily essential; they must have the opportunity of extending their crowns and root-systems in accordance with the different demands made in this respect

[1] Recent experiments conducted by M. Bartet at Nancy show that oak and hornbeam are capable of producing stool shoots up to sixty or even eighty-five years of age.

[2] The leaves of pines in each sheath are divided as follows:

Whole leaf in each sheath divided into two needles in *P. sylvestris, Laricio, maritima, pumilio, pinea.*

Whole leaf in each sheath divided into three needles in *P. australis, Coulteri, taeda, longifolia.*

Whole leaf in each sheath divided into five needles in *P. strobus, Cembra, Lambertiana.*

by the various species when advancing in age. Light-loving species, like the Scots pine or the oak, have earlier and greater requirements as to growing-space than those with denser foliage, like the spruce or beech. Trees grown in the close canopy of high forest have not the same freedom and enjoyment of light and air, and in consequence are less vigorous than, and do not attain so high an age as, those grown in a more isolated position, or in the open. Unless due development of all assimilative organs takes place, full vigour and health are not attainable; but the capacity for regaining normal vigour on being admitted to larger growing-space differs considerably in the various species of trees, being greater in oak, lime, willow, elm and Cembran pine than in alder, aspen, maple, sycamore, beech, hornbeam and spruce (Gayer, *op. cit.* p. 44).

The second essential condition is that soil and situation must continue to supply the demands made by each species relative to its normal development. In general the locality where a certain species is indigenous affords it all the conditions necessary for the maintenance of healthy vigorous growth, and the attainment of sound old age. The longer the natural term of life, and the greater the demands of the species on the qualities of the soil, the more danger there is of its healthy development being interfered with, and at the same time the greater the risk of the soil deteriorating, and losing its moisture and power of decomposing humus. Localities differing from that in which the species is indigenous may offer too much or too little warmth of soil and air, considerable variations from the normal requirements being in either direction injurious; or the soil may offer more or less than the favourable degree of moisture, mineral strength, or depth,—richness of soil tending towards precocity and immature development beyond the limits of healthy vigour and power of resisting the action of conditions of growing-space, &c., unfavourable to the due extension and steady development of the assimilative organs, and thereby affecting the quality of the timber produced. Thus when larch and spruce, both indigenous to the cool, moist northern slopes of the Bavarian Alps, are grown in the dry warm climate of the lowlands, their growth and development are stimulated, but their period of life is considerably shortened, the timber yielded is inferior, their power of resisting injuries is weakened, and they are more liable to be attacked by insect enemies and by fungoid diseases.

As regards the attainable limits of healthy, vigorous age the following classification (mainly based on Gayer's) may be made :—

Attaining 500 *years and more*—yew, oak, lime, Scots elm, chestnut.
,, 300—400 *years*—English elm, silver fir, beech.
,, *about* 200 *years*—ash, maple, sycamore, spruce, larch, Scots pine, hornbeam.
Seldom attaining over 100 *years*—aspen, birch, alders, willows, poplars.

Many historical trees throughout Britain are known to be much older than any of the limits above assigned, but to attain the ages of the above classification presupposes that the individual trees have grown under circumstances unusually favourable to their development.

For trees grown in forests the attainment of an age even approaching these limits is out of the question, as being opposed to the economic and financial considerations which ought in general to form the basis of sylvicultural operations. In fixing the fall of the timber (the period of rotation or reproduction, the *Turnus*) the object of the proprietor may be to obtain the greatest quantity of timber generally, or the greatest outturn of certain dimensions, or the greatest returns for the capital represented by soil and growing stock of timber ; but under all circumstances the due protection of the soil from the deteriorating influences of sun and wind must always be one of the primary considerations in determining the period at which the forest can be most advantageously utilized and reproduced.

Special Individual Considerations regarding the Growth of Forest Trees

These are necessary in order to know under what conditions each species is likely to thrive. Trees like the acacia (*Robinia pseudoacacia*), the horse-chestnut (*Æsculus hippocastanum*), the plane tree (*Platanus occidentalis*), the walnut (*Juglans regia*), and coniferous exotics cultivated more for ornament than for profit are here left out of account, as belonging rather to the province of arboriculture than to that of sylviculture. The individual species are treated of in the order of enumeration on pages 13 and 14.

Chief Species, *forming, or capable of forming, Pure Forests.*

Conifers.

1. Scots or Common Pine, or Scots Fir (Pinus sylvestris, *L.*).

Distribution.[1]—Scots pine is the most widely distributed of all the European conifers, being found over nearly the whole of Europe and the greater part of northern Asia, from 70°N. latitude in Scandinavia, where it even

[1] The details as to distribution have generally been taken from Luerssen's *Forstbotanik* in Lorey's *Handbuch, &c.*, but such as refer to distribution throughout Great Britain and Ireland have been mostly extracted from Loudon's *Arboretum et Fruticetum Britannicum*, 1838, and Selby's *History of British Forest Trees*, 1842.

ascends to 900 ft. above sea-level, southwards to the Sierra Nevada and the Pyrenees, where it reaches an altitude of 5,400 ft. on the latter and 7,000 ft. on the former. No other forest tree covers such extensive tracts as the Scots pine. It covers more than 80 per cent. of the wooded area on the great North German plain, and forms forests of enormous extent in Russia. In Germany it is emphatically a tree of the plain, and not of the mountain, or even of the lower hills and uplands, as in Scotland. Towards the south the tree is not characterised by that straight growth which distinguishes it in its northern home.

In ancient times it was one of the three principal forest trees (oak, beech, pine) of Britain, occuping the hilly tracts of northern England, Scotland, and Ireland. It is the only species of the *Abietineæ* indigenous to Great Britain and Ireland. In the Scottish Highlands it attains an elevation of 2,700 ft. but is then, however, merely a shrub and no longer a forest tree.

On account of its exceedingly moderate demands as to soil and situation, its rich seed production, the cheapness of its cultivation, its ability to yield a fair monetary return in less time than most other forest trees, and the possibility of planting up waste areas with better species when once the soil has been improved by the Scots pine, its distribution has been considerably extended by artificial means.

Tree-form and Root-system are both to a greater extent dependent on the soil and situation than in the case of spruce or silver fir. On the better classes of soil it attains almost as straight growth as these, but always unfortunately deviates more than they do from the cylindrical form of bole, and in approaching more to the conical has diminished value for technical purposes requiring large-sized squares. The development of the crown is comparatively slight at all stages of its growth, but on favourable soils the leaves or needles (formerly called *spines* in old works on woodcraft) remain on for three years, whereas on the poorer localities often only one-year-old sprays bear foliage, short in growth.[1]

Scots pine is one of the deep-rooted species of trees, and develops a strong tap-root in good deep soil; where the latter is wanting in depth or strength the side-roots expand in growth, and when soil-moisture also fails, surface roots are extensively developed. On shallow lime, or coarse sand with unfavourable subsoil, and on moors, the otherwise deep-rooted Scots pine becomes a shallow-rooting tree like the spruce. When abnormal and excessive root-production is induced by poverty of soil, the crown still remains comparatively small, but ample for assimilating scanty food.

Requirements as to Soil and Situation.—Among the forest trees there is no species whose demands are so moderate as those of the Scots pine in regard to soil and situation, although for the natural development of its tap-root the deep, loose, sandy soil found on plains formerly forming the bed of the sea is that most favourable. On hard, binding soil the growth of a normal root-system is interfered with which often leads to fungoid disease; on stiff loam the growth in height suffers, and on shallow rocky soil there is decided tendency towards malformation of the bole. Between extremes, however, there are many gradations of

[1] Burckhardt, *Säen und Pflanzen*, 1880, p. 237, gives the following details as to defoliation:—Whilst the larch bears foliage only in summer, breaking into leaf, however, early in spring, the other conifers usually retain their needles for the following periods:—

Scots and Weymouth pines	2— 3	years.
Austrian and maritime pines	3— 4	,,
Cembran and mountain pines	4— 5	,,
Spruce; *Abies balsamea, alba and nigra*	5— 7	,,
Silver fir	6— 9	,,
Yew	7—12	,,
Spanish fir (*Abies pinsapo*)	10—15	,,

quality of soil to which this most useful tree readily accommodates itself.

The mineral quality of the soil finds its expression rather in the quality of the timber, and the duration of life of the tree, than in the cubic contents produced. The attainment of great height is with it, as with the other trees of the forest, one of the chief outward signs of the suitability of the situation. Its highest development and greatest production of resin take place on loamy sand, especially if humus be contained in it, and when the subsoil retains a constant moderate supply of moisture.

No other species is content with so little soil-moisture as the Scots pine, which can be made to form forests on dry, shifting sand, or on hot, southern slopes where even the very weeds find life difficult. In such unsuitable localities its growth is naturally not good, but by improving the soil through the shade and shelter of its foliage preventing insolation, and through the humus formed by the defoliated needles, it paves the way for a better subsequent growth or for other trees that could not be planted out in the first instance. It also, on the other hand, is capable of being grown on peat moors and bogs, and even endures stagnant water better than the spruce which demands soil-moisture; but under these unfavourable circumstances its growth is not vigorous. To the attainment of a long period of life, of large cubic contents, and of timber of first-rate quality a constant moderate degree of freshness in the soil is essential; dry soil yields good timber, but little of it; moist soil yields large cubic contents, but of inferior quality as timber. It is sensitive to changes in the quantity of soil-moisture, and when growing on a soil usually moist, suffers in growth if either inundations take place or the soil gets dried up in unusually hot seasons, or in consequence of neighbouring drainage, the root-system being unable in either case to accommodate itself all at once to the altered conditions.

In relation to warmth, however, it possesses great power of accommodation, thriving in localities where the summer heat and the winter cold are both very considerable. Whilst in Germany it prefers the dry air of the North German plain to damp hilly climates, and shows decided signs of falling off in development in the moist atmosphere of Schleswig-Holstein, yet it thrives well in damp localities in Scotland and north-western Norway, producing timber of excellent quality.

Except at high altitudes, where the greater dampness of these exposures would cause it naturally to seek the drier southern aspects, the northern and eastern slopes are best suited for the Scots pine on account of their better retention of soil-moisture, which compensates to a certain extent for the loss of light and warmth.

Requirements as to Light.—Decidedly a light-loving tree, the Scots pine is very sensitive to shade, whether from above or from the side,—more so, in fact, than any other conifer except the larch. On the poorer qualities of soil even a slight degree of over-shadowing affects the development of the leading shoot, whilst if the trees are cleared so as to enjoy free light and sunshine after having long stood in shade their recuperative power seems weak, and unable to induce a return to normal straight growth. Its ability to withstand the bad effects of shade is greater when the soil is deep, powerful, and fresh. Even in pure forests of Scots pine too close sowing or planting is unadvisable, especially on the poorer soils, as the individuals influence each other disadvantageously by side shade; on better soils, the dominating saplings assert themselves sooner above the others, which soon become suppressed and killed off.[1]

Attainment of Maturity and Reproductive Capacity.—No

[1] *Vide* note at foot of p. 57.

species of forest tree grown in high forest is subject to more different treatment as to its economic maturity as the Scots pine, the periods of rotation varying from sixty to one hundred years and more. Under average conditions as to soil, an eighty years' rotation frequently obtains, but where the larger dimensions of timber command high prices, higher rotations are fixed if the soil is not exposed to deteriorating influences. Good timber for ordinary building purposes is often produced by forests of seventy years of age. On poorer soils a rotation of fifty to sixty years is frequently more remunerative than one fixed at a later age, as increase in contents and value of the timber on such localities is very slow.

From about the fortieth to fiftieth year, and on indifferent soils much earlier, good seed years are frequent, six being expected in every ten years, and in addition there is generally some production of seed in the intervening years. The cones ripen in the second October after flowering, and in the succeeding spring the approach of warm weather causes them to open so that the seed may be wafted away by the wind. The germinative power of the seed is good, experimental tests generally yielding sixty to seventy per cent., although of course somewhat less favourable results must be expected when sowing is carried out in the open. The cones usually contain from forty to forty-five seeds, and one pound of seed without wings represents about 75,000 seeds,[2] which retain their germinative power for between two to three years.

[1] Burckhardt, *Saen und Pflanzen*, 1880, p. 418, gives the following comparative table for the relative number of seeds contained per unit of volume :—

Scots pine	100
Spruce	95
Larch	93
Austrian pine	56
Weymouth pine	28
Maritime pine	15
Silver fir	10

Liability to suffer from External Dangers is unfortunately characteristic of the Scots pine at all stages of its growth. In its earliest years it is apt to suffer seriously from the larvæ of species of *Agrotis* and *Gryllotalpa* at time of germinating, then of *Melolontha* gnawing the roots, whilst the bark is attacked by the fully developed weevils of *Hylobius* and *Pissodes* species. The cortex and sap-wood of young plantations suffer through the larvæ of *Hylurgus*, and those of poles and trees from *Bostrychus*, *Hylurgus*, *Hylastes* and *Polygraphus ; Gastropacha* and *Retinia* caterpillars often decimate the buds ; young shoots are badly damaged by species of *Hylurgus* and *Retinia ;* and finally the leaves form too often a favourite grazing ground for the caterpillars of *Gastropacha pini*, *Liparis monacha*, *Trachea piniperda*, *Fidonia piniaria*, *Lophyrus pini* and *Lyda pratensis.*

Leaf-shedding, or the loss of foliage, a fatal disease to which Scots pine is liable, and particularly so at the age of three to five years, is caused by drought (according to Ebermayer), or by frost (according to Nordlinger), or (according to R. Hartig), in many cases either by a process of drying up due to transpiration through the leaves on sunny days in winter whilst the frost-bound soil can yield no supplies of moisture to replace that evaporated, or else by a fungoid disease from infection with *Hysterium pinastri.*[1]

From fungoid diseases, too, the Scots pine has to bear somewhat more than its fair share. The leaves of young seedlings are attacked by *Hysterium pinastri*, and *Æcidium pini*, the branches and stems of poles and trees by *Trametes pini*, *Æcidium pini*, and *Cæoma pinitorquum*, and the roots and base of the stem by *Agaricus melleus* and *Trametes radiciperda*, whilst cotyledons and leaves of seedlings

[1] R. Hartig's *Lehrbuch der Baumkrankheiten*, 2nd edition, 1889, pp. 103—109.

become infected by *Phytophthora omnivora*. Red-rot [1] in the timber is caused by *Polyporus vaporarius* and *P. mollis*.

The above-mentioned insect enemies of the Scots pine also endanger to a greater or less extent the well being of the other species of pine—black or Austrian, Cembran, maritime, Weymouth,—but their attacks are usually neither so frequent nor so serious. A similar remark also obtains with reference to the fungoid diseases.

Accumulations of snow and ice on the branches, also heavy storms of wind and rain, often cause much damage, as during the sapling- and pole-stages of growth the wood of the branches is very brittle. In spite of the thin crown of foliage, on shallow-soiled, exposed localities the danger of trees being thrown altogether (*windfall*) is greater than on the sandy plains where the deep, strong tap-root lends security to the stem.

Very serious damage can be caused by forest fires in the dry months of summer, especially when the thicket age has not yet been passed; no tree suffers so much from this danger as the Scots pine, owing to its richness in resin. Protected by its rough bark it is not after the twentieth year liable to be much damaged by deer, but wounds occasioned by red-deer stripping the bark with their teeth, both in winter and summer, and rubbing the velvet from their antlers in early summer, heal better than those inflicted on

[1] Hess, *Der Forstschutz*, 1890, vol. ii. p. 185, says:—"*Red-rot* is occasioned by the solution of cellulose in a decomposing ferment formed in the protoplasm of the fungus and communicated by the mycelium to the surrounding cells; a resinous or tannic residuum is formed, which in oxidizing assumes a reddish-brown appearance. In *white-rot* the ferment of the mycelium dissolves the lignine, and leaves the bright-coloured cellulose untouched, hence the whitish colour of the diseased wood."

The details concerning insect enemies and fungoid diseases are mainly drawn from Hess's *Forstschutz*, 2nd Edit., 1887—1890.

other coniferous species, owing to its superior recuperative capacity in this respect.

Sylvicultural Treatment of Scots Pine.—As a light-loving species, hardy in respect to frost, Scots pine offers many contrasts to spruce and silver fir. Pure forests of pine are usually to be found only on the poorer classes of soil, where of course it does not attain anything like so good growth as on more favourable soils and situations. How great are the differences in average yield between the best and the poorest classes of pine soil may be seen from the table on page 44, the outturn on the latter at no time even approaching the half of that on the former, the average on soils of medium quality being, however, about 4,700 cubic feet per acre, at sixty years of age, and 5,700 cubic feet at eighty years.

The influences of soil and situation are apparent in every aspect of its development. The root-system is cramped, short, and branching on loam, and quite a contrast to the well-formed tap-root in deep, fresh, light sand, whilst moor-pan and poor, dry situations, as well as those which are too marshy and wet, cause the formation of long, thin strands that ramify in all directions throughout the surface-soil. Even in the foliage the quality of the soil and situation may at once be noted from the length of the needles and from their persistence, for whilst on the average and better situations they still depend from the two-year-old twigs, on the poorer sites they are mainly confined to the one-year-old sprays,—a circumstance of no little importance with regard to the sheltering of the soil and the retention of soil-moisture. The amount of resin contained in the timber, its length of bole, and its general quality, are all in like manner greatly dependent on the nature of the soil and situation, which also to a very great extent determine, or at any rate unmistakably indicate, the period at which the utilisation and reproduction of the growing crop can take place most advantageously and remuneratively.

In general the growth of the Scots pine is most vigorous throughout the thicket, and the pole-forest, and until after it enters the tree-forest stage of growth, in the latter two of which it also yields the largest returns from thinnings. But the poorer the soil, the sooner the average increment culminates and begins to diminish, the earlier the growth in height declines, and the rounding off of the crown begins. Along with the latter comes increased demand for growing-space, trees die off, and weevils, beetles, and caterpillars at once become attracted towards them as breeding places, frequently combined with simultaneous infection with fungoid disease, whilst the process of regular and judicious thinning out is somewhat interfered with, as the sickly and diseased stems must be removed first of all. Owing to the greater amount of light playing over the soil, this becomes covered with a growth of mosses, grasses, whortleberries, or heather according to its quality, and soon the canopy, from being at first merely interrupted, gradually becomes completely broken, the annual increment sinks, and the question of reproduction and clearance,—or too often merely its alternative, clearance and reproduction,—inevitably presents itself for consideration.

The poorer classes of pine soil exhibit these changes in so short a time that low periods of rotation are those most advantageous both in regard to outturn and with respect to the soil, but on the better classes the quantity of the outturn in timber, as well as its quality, points to the remunerative advantage offered by a fall fixed at from eighty to one-hundred and twenty years according to the circumstances of each case.

In comparison with spruce and silver fir, Scots pine has a rapid growth in early youth and often succeeds in forming canopy at about the age of five to six years, if it manages to escape the ailments peculiar to its species, which are unfortunately numerous. Should the young seedlings or transplants, before being able to develop their tap-root, suffer from long-continued drought, or should strong dry east winds dissipate the soil-moisture, the stock on the ground may be sadly diminished, or even decimated, especially when the quality of the soil is poor. A severe winter following a dry summer finds the young plants in a weakly condition and little able to withstand hard frosts, especially if following rapidly after heavy rain; for although pine is hardy as regards frost, the exposure of the roots after a sudden thaw kills the plant outright. Fungous disease (*Hysterium pinastri*) may then gain an easy foothold on the foliage in its sickly condition, and even perfectly healthy plants are liable to attacks from insects of various kinds, the most dangerous and destructive being cockchafer grubs (*Melolontha*) on light sandy soil, and various species of weevils (*Curculionidae*), particularly where the stumps of the old crop of trees have not been grubbed up, as some of the worst beetles have their breeding-places there. These youthful ailments of the pine often necessitate extensive planting operations in the filling up of blanks resulting from one or other of these causes, or from the browsing of sheep, which prefer pine sprays to heather and tough wiry mountain grass, when they can force a way through the fencing into plantations.

When once the young pine woods, however, have fairly established themselves, and have with close planting in about five to seven years attained the canopy usual in the thicket stage, their growth in height soon becomes vigorous. From heights varying at ten years of age from 3′8″ to 7′4″, according to the quality of the soil, it quickly shoots up to from ten to twenty-four feet at twenty years of age, and twenty-five to fifty-two feet at forty years of age, during which time of greatest energy of growth in height the pine surpasses most other trees of the forest, annual shoots of two feet in length throughout all the dominating poles being common enough on good situations. The energy of the Weymouth pine is even greater in this direction than that of the Scots pine, whilst that of the black or Austrian and maritime pines is somewhat less. At this stage of growth, unless the density of canopy be interfered with by accidents due to climate, such as breakage owing to accumulations of snow on the branches, or the foliage be eaten up by swarms of caterpillars, or the bark and sap-wood be destroyed by the larvæ of *Bostrichini*, the soil being well protected becomes greatly improved by the rich fall of needles annually, which on decomposition form good humus, and stimulate the soil to increased timber production. The impetus thus given to the general energy in growth favours, on the better classes of soil, the self-assertion of the dominating and predominating poles throughout the whole crop; but on soils of the poorer class the improvement thus brought about is apt to be frittered away and dissipated in prolonging the struggle between the dominating and the dominated classes, so that what on one situation may be gained by close planting in forcing up the poles and favouring the early development of a distinctly dominating class, may lead to exactly the opposite result on a poorer situation. Poles that have once stood in shade seldom develop into good normal stems.

The age at which a natural interruption of the canopy begins, and the rate at and extent to which it continues, are matters varying in general according to the quality of the soil, and the suitability of the situation for the pine. On shallow soils, or those which, like lime or poor sand, are easily heated, it begins to take place about the fortieth to the fiftieth year, whilst on deeper, fresher, more humose sands and loams, and milder soils generally, the tendency does not make itself so apparent until about the sixtieth to eightieth year. It is only under such circumstances as in the latter case that the pine gets fair play as a forest tree, and has the opportunity of developing normally into the fine and profitable timber tree that it unquestionably is. The characteristic reddening of the pine stems along the upper portion of the bole and near the crown takes place at the time when forests begin to thin themselves strongly.

With continued interruption of the canopy two points of interest press themselves on the attention of the owner; first, that in consequence of the diminution of the number of stems the total annual increment begins to fall below the average maximum that the soil can and should yield, and secondly, that insolation of the soil and its exposure to the wasting influence of dry winds must lead to deterioration and impoverishment. Both of these circumstances indicate the proper and prudent time for reproduction, which can then be most advantageously undertaken either before or after the crop on the ground has been utilised.

As already remarked, with no other species of high forest does the period of rotation or fall of the timber range between more varying limits than in the case of the Scots pine. Sometimes the indications above referred to recommend the utilisation of the crop at fifty to sixty years on the poorer situations, when the total average annual yield is often much greater than at a higher age, and where advancing years do not necessarily bring with them a finer development of large timber; on soils of such quality, however, the outturn yielded is more generally suitable for petty requirements than for building purposes, or works requiring large squares. Many pine forests give good useful building timber at seventy years of age, yielding at the same time fair returns for the capital represented by soil and growing-stock. For medium circumstances a rotation of seventy to eighty years is what is naturally indicated as the most remunerative, although, where large timber is well paid for and in good demand, the fall may often profitably be delayed till the hundredth, or even the hundred and twentieth year; for such long periods of rotation, however, favourable soils and situations are a *sine quâ non*, both from the sylvicultural and the monetary points of view.

Pure Forests of Scots Pine.—It cannot be denied that under certain circumstances pure forests of pine offer distinct advantages. They make little demand on the soil, are easily formed, tended, and worked, and yield both in the thinnings, and at the final harvesting of the crop, good useful kinds of timber generally saleable, and capable of supplying requirements of the most various descriptions. Where, however, accumulations of snow and ice are likely to occur in exposed localities, the formation of pure forests of Scots pine is not to be recommended; the interest of the owner will most probably be better served by the formation of mixed forests. But the greatest drawback of pure forests of equal age, which the usual system of total clearance with artificial reproduction entails, lies in the defective and only partial protection which the older woods are able to afford the soil; this is more especially the case on poor dry soils unsuited for the growth of other species along with the pine, and where it is not possible to regenerate the pinewoods naturally under parent standards.

For the production of large and valuable stems of Scots pine, prolongation of the fall of the whole crop would be a costly and unremunerative measure; but a choice always remains between retaining well-grown groups on good patches of soil, or the selection of healthy, well-developed trees as standards here and there over the area being reproduced.

In general the latter practice has most to recommend it, but the number of standards selected must be small, not exceeding ten to fifteen per acre, and for some time previous to the clearance of the crop they should gradually be accustomed to greater light and air, and prepared for standing isolated by being cut free from neighbouring trees. Even with such preliminary precautions, however, the standards often become windfall, and that too in localities not unduly exposed to heavy and violent storms, besides being liable to the attacks of insects and of fungous disease in the crown (*Peridermium pini*), whilst the young growth around such standards is always more or less interfered with. But where the standards maintain themselves healthy till the close of the second period of rotation, they yield a good return. The retention of standards is only advisable on the better classes of soil, where there is least danger of the younger generation of trees being too much retarded in growth by the light shadow cast around by the former. Without doubt the same object can perhaps be better attained by growing the pine in admixture with spruce or silver fir, and on the whole pure pine forests are only to be recommended on soils unsuited for the formation of mixed forests in which the shade-bearing conifers form the ruling species or matrix.

Mixed Forests with Scots Pine as the ruling Species.—Spruce is the tree most frequently grown in admixture with Scots pine, and even where it is not able to develop as well as the latter, it still performs good service as a subordinate species protecting the soil. In some localities it grows as quickly as the pine ; in others it is at first slower in growth, but ultimately succeeds in forming canopy along with the pine. When this begins to slacken in growth in height and gets overtaken at about thirty to fifty years of age, the spruce often threatens to crush out the pine unless the axe is freely used. On the poorer qualities of soil spruce never really ranks much higher than underwood, but is even then of great advantage to the pine in maintaining and stimulating the productive power of the soil, and in hindering the formation of a rank growth of whortleberry or heather.

When older forests of Scots pine have an admixture of spruce forming canopy along with them, they are usually characterised by a good cylindrical form of bole and large production of cubic contents per acre. They also suffer far less than pure forests from various dangers, and when the foliage of the pine has been stripped by the caterpillars of swarms of moths, the spruce can often take its place in the blanks formed, except when the 'Nun' moth (*Liparis monacha*) has been the cause, for then spruce is usually much more injured than pine. In such mixed forests breakage from snow is much less frequent than in woods of pure Scots pine. Although in general advantageous, there are however two cases in which an admixture of spruce is not advisable; namely, in the first instance, on the better class of pine soils, where the pine is of decidedly quicker growth than the spruce, and where the interests of the proprietor are best served by growing the pine pure and then later on under-planting with spruce, and in the second instance, on the poorer classes of pine soil where the spruce is unable to thrive. But on dry, impoverished mountain soil a mixture is often preferable, as in pure forests the pine soon thins itself and does not protect the soil sufficiently, whilst the spruce has only a sickly growth without any nurse. In such cases it depends on circumstances whether the treatment to be accorded will result in the mixed forest being pine with spruce, or spruce with pine. Many of the present middle-aged mixed crops of Scots pine and spruce in Germany arose from the malpractices of seedsmen formerly in mixing the cheaper spruce seed with that of the pine at a time when communications were not so good as they are now, and the errors could not conveniently be rectified immediately.

In what proportion the admixture of the spruce should take place is mainly dependent on the nature of the soil and situation. If the pine is towards the maturity of the crop to be unmistakably the chief or ruling species, then the spruce should not be introduced in greater quantity than from one-sixth to one-fourth. Where past experience, however, has shown that the pine can easily be protected from being overgrown and suppressed by the spruce about its fiftieth year, the latter can be planted in equal quantity in alternating squares or rows, in which case the spruce will at first require most attention, whilst later on measures will have to be taken to protect the pine against the other. Where spruce forms only a small proportion of the stock it is better to introduce it as individuals or in small patches than to plant it out in rows.

In mixed forests of pine and silver fir the latter is almost always the ruling species, so that this mixture will be considered later on (*vide* page 125).

In the Scottish highlands a mixture of birch with the pine seems a most natural one. They are both species with a considerable power of accommodation, and whose natural habitat ranges from moors to sandy soils; as the light winged seed is easily wafted into the pine woods, birch is very often found growing there. But in general the introduction of birch into pine forests has not much to recommend it, as it leads to interruption of the canopy and insolation of the soil. Even on poor soils birch is the more rapid in growth up till about the fifteenth to twentieth year, when it is outstripped in height by the pine; but until this has taken place the leading shoots of the latter are liable to be damaged by the whip-like twigs of the former. Under certain circumstances, however, the birch is a welcome guest in pine woods, only its stay must not be too prolonged. On soils of somewhat inferior quality, which suffice for the birch but are hardly good enough to ensure the thriving of other species, an admixture of birch protects the pine against insects, snow, and fire. Where, again, the pine is likely to find difficulty in establishing itself, an admixture of birch as a nurse often yields good results, as on very dry, almost shifting, sandy soils and on moors and marshes, on which experience shows that such mixed forests thrive better during the younger stages of growth. But in these cases the birch should be removed early in the way of thinning, especially on the more sandy varieties of soil.

The admixture of larch with Scots pine was formerly not at all infrequent, but has now pretty generally fallen into disrepute in most countries except Scotland, as might from the very first have been expected from the natural characteristics of the two species. Even on soils below the average in quality, the larch is the quicker in growth till between the tenth to the twentieth year, when it is caught up by the pine, and the one condition of its growth—absolute freedom of crown—can no longer be satisfied unless at the sacrifice of the surrounding pines; at such a stage of growth the almost inevitable measure to be adopted is the removal of the larch poles before they fall a prey to canker (*Peziza Willkommii*). But in any case the poorer classes of pine soil are no suitable situation for the larch, which requires a deep, fresh, and strong soil, such as will seldom be best utilised by being planted up with Scots pine. Where, however, the larch is desired in pine woods, it can better be reared and tended if planted in patches or groups than individually or in rows.

On peat-moors or sour boggy soils Scots pine has often aspen and alder mixed with it, but on the whole the appearance of crops of this kind is seldom satisfactory.

Scots pine woods are often the matrix throughout which other varieties of pine, in particular Weymouth and also black or Austrian pine, are grown with satisfactory results. The former often assists materially in maintaining the canopy, and both are less impatient of shade than our indigenous species. The Weymouth pine is, however, apt to overtop and crowd out the Scots pine, so that it should be introduced in clumps for more easy tending in favour of the latter. The black pine is notably backward in growth during its tenth to fifteenth year, but can bear a light shade well, and improves the soil considerably through its heavy fall of needles and its thicker foliage.

Formation and Reproduction of Pine Forests.—The methods of reproduction of pure pine forests are various. Natural regeneration under parent standard trees was long the rule, and is even now, in extensive pine tracts where low local timber rates, or a limited demand for timber, did and do not seem to call for or justify the outlay of large sums on artificial reproduction, although it cannot be denied that the latter leads to more regular and complete results. But wherever the whole crop can be profitably disposed of, natural reproduction of this species—and, indeed, of every species of forest tree except the beech and the silver fir, which are *shade-demanding* during the first two or three years of their existence—has come to be the exception in place of, as formerly, the rule, though some maintain that in many cases natural regeneration is the preferable method, and that better timber crops of pine can be raised from seed shed by parent standards, if blanks and unregenerated patches be promptly filled up artificially. Large pine forests on light sandy soil, where sudden clearance might render it a prey to the winds, ought certainly to be reproduced naturally, and in general such as show by self-sown seedlings a good capacity for regeneration, even if it be only in order to escape from the often serious damage caused in very young plantations by cockchafer grubs (*Melolontha*). From the actuarial point of view however—which must always be the principal one, and that most deserving of attention in the private forests of Britain—speedy artificial reproduction of regular, equal-aged crops holds out better promise of remunerative results than the doubtful success of naturally regenerated woodlands of a light-demanding species on any poor soil liable to deteriorate. And natural reproduction of our pine forests is seldom quite satisfactory; here the self-sown seedlings stand too thick, there too sparsely and irregularly, while in other places again they fail altogether, and the soil becomes covered with rank undergrowth, which effectually puts an end to all hope of future spontaneous growth; at best the results are generally such that expensive assistance has usually to be given by sowing or planting.

Natural Reproduction.—No protective standards are necessary for the natural reproduction of the Scots pine, for on the poorer classes of soil the seedling growth will not bear shade, and on the better situations it can thrive without shelter and soon demands, as a light-loving species, the removal of the parent trees. Natural reproduction under parent standards is therefore only possible on soils above the average in quality, and can be recommended only on the very best situations, as otherwise the increase in growth on the standards does not outweigh the damage done by overshadowing the younger generation. Where, however, a natural, self-sown growth is to be found with normally-formed leading shoots, the standing timber should be removed sooner than in other parts of the forest, so as to ensure the normal development of the young seedlings in groups or patches: for if once crippled in growth, or hindered in development, such seedlings never recover completely. Thus a young self-sown crop, which has stood for more than two or three years under the shade of close canopy, or older plants under more open cover which show a shortened and impaired growth of the leading shoot, do not yield suitable material for the formation of future crops, in addition to which the extraction of the parent trees can seldom be effected without causing a good deal of damage to the young undergrowth. The retention of self-sown seedlings occurring only singly here and there on areas that are intended to be stocked with pure forest of pine, is not advisable, as they are apt to break into undue branch development, do not form good boles, and generally interfere with the growth of their neighbours.

In mixed forests where the pine is grown along with thickly-foliaged trees, or in pine forests that have been underplanted with shade-bearing species, some soil preparation is necessary for the purpose of accelerating the decomposition of the layer of leaves on the ground, and the formation of humus. In pure forests of Scots pine, however, it is more often the case that reproduction is hindered by a heavy growth of grass and weeds, amongst which germination of the seed is difficult and the malformation of the seedling almost certain; for good development of the young plant can only be expected where the seed rests on the naked soil, and the rootlets can penetrate immediately into the earth. Even where the ground is only covered with weeds here and there, some soil preparation is requisite, otherwise the young crop is patchy, broken, and at best unequal in height, conditions not at all suitable for the formation of pure forests of a light-loving species like Scots pine, which only forms good stems when the density of the crop is sufficient to stimulate growth in height by interfering with and checking the natural, strongly-marked tendency to ramification and coronal development. Such soil-preparation need not take place over the whole area, but is at least advisable in bands or strips of twelve to twenty inches broad, occurring at intervals of three to four feet; the covering of weeds should be removed till the soil is reached, and this should if possible be broken up slightly early in spring, so that the seed may find a good bed for germination on being shed from the cones with the advent of somewhat warmer weather.

Where the quality of the soil is good enough to make natural reproduction advisable, twelve to twenty parent standards per acre, equally distributed over the area, will be found sufficient, especially if high forest of the same species be near the fall and assist in the distribution of seed. Where, however, it is desirable that the advantages of increased growth in girth, through freer exposure to light and air, should be attained by a greater number of stems before they are felled and extracted, this can be arranged for by reproducing in circles of forty to fifty yards diameter with very few standards surrounded by a belt or girdle of ten to twenty yards broad in which the seed-shedding parent trees are more numerous. The standards are first removed in three to four years from the central area, and those from the girdle gradually during the next ten to twelve years. If under the latter the germination and establishment of the Scots pine has not been successful other species can be sown, and thus at the end of the period of reproduction the area will be covered with circular groups, of about one-third of an acre each, consisting of pine of equal age, surrounded by belts, ten to twenty yards broad, of shade-bearing species like spruce or silver fir, in which patches of pine also occur, whereby to a certain extent the advantages of mixed forests over pure crops will be attained.

On the poorer classes of soil natural reproduction is not advisable, although where groups or large patches of well-developed self-sown seedlings have asserted themselves on blanks occasioned by windfall, &c., their retention is often advisable. Where a recent fall of timber has taken place, a natural growth can often be obtained if bands be prepared for the reception of seed whenever numerous cones on the neighbouring trees to the windward side show prospect of a large supply of seed being shed in the following spring in the direction of the area to be re-wooded. But such natural reproduction cannot be relied on for more than 100 to 120 yards, and is often extremely irregular and unsatisfactory, necessitating considerable outlay for the filling up of blanks. As germination can only be secured on dry soil when the seed has some soil-covering, it is advisable either to break up the soil before the time of seed-shedding, or to go over it lightly with the rake or harrow after the seed has fallen. A favourable germinating-bed is afforded by places where the stumps of the trees have been grubbed out to decrease the number of breeding-places available for such dangerous insect enemies as are found among the *Curculionidae* and *Bostrichini*.

In the enormous pine forests of northern Germany, natural reproduction over large areas has long been given up, and total clearance of the mature crop is at once followed by sowing or planting operations, except near the edge of next year's fall, where, for the distance of about 100 to 200 yards, there is sometimes a growth of self-sown seedlings from the seed shed during the last year, which is often capable of forming close canopy with more or less of artificial assistance.

Artificial Formation and Reproduction.—Whether the artificial formation or reproduction should take place by sowing or planting is a question dependent mainly on local circumstances in each case. In northern Germany, for example, it has received a practical answer in the fact that whilst about twenty or thirty years ago there was at least as much sowing as planting, the latter has now become the rule, except where want of available labour has settled the question in favour of sowing. No hard and fast rules can be framed for the pine more than for any other kind of forest tree, as in each case soil and situation and other circumstances must all be taken into consideration before any dictum can have genuine practical value; but in general the formation or the reproduction of pine forests is best undertaken by means of planting, as then the distances at which the plants shall stand, and the time at which the young crop shall form canopy, are most easily determinable by the owner. When the first and early thinnings are remunerative, tolerably close planting and dense plantations will naturally recommend themselves.

Sowing.—Under certain circumstances, however, sowing has its recommendations. The supply of seedlings may fail owing to grubs in the nurseries or other causes, the available supply of labour may not be securable, or the soil is perhaps not suitable for planting out young seedlings, whilst the necessarily higher costs of planting up with older transplants from nurseries may for one reason or another not be considered desirable.

Sowings are not always cheaper than planting, for a certain amount of preparation of the soil for the reception of seed is imperative to secure any fair measure of success; the filling up of blanks may at times be costly, and after all the results may show that it would have proved a saving both in time and money to have determined in favour of planting at the outset.

It is difficult to hit the happy medium in sowings of the pine; they are usually either too dense or too thin. In the latter case, even with some assistance in the way of planting, the crops often stand too open, and from the very first, branch-development is unduly great; in the former, even with the frequent assistance of the bill in the way of weeding and clearing, the individual struggle for predominance begins early and is long continued, especially on the poorer classes of soil, and in it is often dissipated the general energy in growth during the period when that vital energy is at its greatest.

Where pure forests of Scots pine are desired, sowing[1] in mountainous tracts usually takes place broadcast along lines cleared of weeds to a breadth of 1 to $1\frac{1}{2}$ feet and $3\frac{1}{2}$ to $4\frac{1}{2}$ feet apart. Where the soil is dry, hard, or covered with a thick layer of incompletely formed or inferior humus, some little soil-preparation is advisable in order to enable the rootlets to penetrate quickly into the ground, so that they may the better withstand drought. Where there is a strong growth of heath, heather or weeds, the area should be burned over before any soil-preparation takes place, but caution must be used to ensure that the fire does not spread into the forests. On level tracts the best soil-preparation can be effected by the plough during autumn, when sowing follows in spring, about 5 to 6 lbs. per acre being used, and germination assisted by the use of the rake or the harrow. On low-lying tracts where the soil is wet, or in localities with impermeable subsoil of moorpan or ironband, trenching with the subsoil plough is requisite, the seed being sown on the top and sides of the beds or mounds between the trenches.

Cones were often formerly sown out, but as in cold wet weather the scales did not open to let the seed issue, the results were at times very unsatisfactory.

Planting.—A great impetus was given to planting by the use of one, or at most two-year-old naked seedlings in districts with loose or mild soils, where notching could be carried out. Nursery costs, and the dangers incident to life in a nursery, were thereby reduced to a minimum, packing

[1] See table on p. 50.

and transport were rendered cheap and easy, the actual operation of planting was of the simplest and cheapest possible description, and the success was satisfactory, as good results could be achieved with the young material at a very reasonable outlay. And whenever possible, notching of naked seedlings has other advantages besides cheapness over planting with transplants having balls of earth attached, for in the loose or light soils where alone it is practicable, the seedlings maintain themselves better against drought than if planted out with earth around the roots,—a fact that has its explanation in the greater ease with which the comparatively undamaged and undiminished tender root-system can establish itself in the easily penetrable soil.

When notching is the method employed, as is usual on moist soils except those that are tenacious, the use of yearling seedlings has a decided advantage over older plants, as the roots are much less likely to get damaged during the planting operations. Yearling seedlings should be pricked out in rows not more than $4\frac{1}{2}$ feet apart, and should be set from $2\frac{1}{2}$ to $3\frac{1}{2}$ feet apart in the rows; but where trenching has been carried out, the rows are usually further apart, and the plants closer together in the lines. Long, thick, wedge-shaped notching spades should be used, so that the rootlets may not be damaged, and because planting too deep is in the case of the Scots pine less of a mistake than planting too shallow. On very dry or light soils, indeed, the seedlings are put in so far that only the top bud appears above the ground—a method that would of course not be applicable in moist localities or on stiff soils.

Planting with two-year-old plants is dearer, without being necessarily more successful, than when good yearling seedlings have been used. Transplants over two years old, and in unfavourable circumstances even two-year-old plants, are put out with balls of earth attached to the roots; but as this method is comparatively more expensive, it is usually adopted only on wet moors and other places where there is danger of the plants being lifted out of the ground by frost, or where, as in the case of shifting sand, the soil is extremely poor. The larger transplants are, however, to be recommended in the filling up of blanks,—a measure that should be promptly attended to in the formation of young pine woods, as can easily be understood when one considers their rapid growth in early years, and the tendency towards branch-development on any side offering the enjoyment of light and air. Young plants round blanks soon tend to assume branching and abnormal development, and if they have an advantage of two or three years in growth, they prevent younger plants from thriving. The filling up of blanks with transplants of four and five-year-old and older plants can only take place with large balls of earth, owing to the development of the tap-root, and is as a rule very expensive. But in such cases the filling up of blanks with Weymouth pine, black pine, spruce, or silver fir will generally recommend itself in preference to Scots pine, unless the soil and situation be distinctly unsuitable for any of these other species.

In its demand for light is explainable the mistake of too close planting of the pine. Thick sowing or dibbling in of many seeds in patches here and there is contrary to the natural habit of the species, more especially on the poorer classes of soil where the youthful energy of the pole stage of growth is squandered in an unprofitable struggle for individual supremacy. One or two-year-old seedlings should not be put out closer than 3 feet × 3 feet, three and four-year-old transplants with balls of earth attached not nearer than 4 feet × 4 feet., or in rows of 5 feet × 3 feet to make clearing and thinning out easier and cheaper.

When seedlings are to be used, they can be raised in temporary nurseries in any sheltered locality with good mild soil. The seed is sown in rills about one inch deep and 4 to $4\frac{1}{2}$ inches apart, and lightly covered with soil. If two-year-old seedlings are to be used, the rows are put six inches apart, the quantity of seed being of course reduced to $\frac{1}{2}$ to $\frac{2}{3}$ of what is found most suitable in the former case. When the seedlings are intended for very dry soil, bastard-trenching is advisable in order to loosen the soil and stimulate the young plants to the development of long roots; the work of trenching should be carried out as early as possible, so as to let the ground settle again before the seed is sown. If no sheltered locality be available, the nursery must have some artificial protection from the wind, such as dykes or hedges, whilst on poor soil manuring with leaf-mould or the ashes of weeds is advisable. Where such temporary nurseries have been well chosen, no covering or protection for the young seedlings is necessary, and in no case should twigs or sprays of Scots pine be used for such a purpose, as their needles are often infected with the fungous disease occasioned by *Hysterium pinastri*, which may only too easily be thus communicated to the seedlings.

In order to provide a supply of transplants for the filling up of blanks, or for the introduction of Scots pine as a subordinate tree in forests of other species, one must adopt the usual method of schooling the plants in nurseries, which should of course be located as near to the ultimate destination as practicable, in order to reduce to a minimum the costs of transport and the risk of damage during the final operations of planting out.

All planting operations with Scots pine on dry soils should be carried out as early as possible in spring, so that the young plants may have a fair chance of establishing themselves before the usual period of drought sets in. The better and the fresher the soil, the less danger is there of late operations proving unsuccessful.

2. Spruce, Norway Spruce, or Spruce fir (*Pinus abies*, L. = *Pinus picea*, Du Roi = *Pinus excelsa*, Lam. = *Abies excelsa*, D.C. = PICEA EXCELSA, Link).

Distribution.—In this respect the spruce is inferior only to the Scots pine. It extends from latitude 69° N. throughout the whole of northern and central Europe, southwards to the slopes of the Alps, Cevennes and Pyrenees. It forms extensive forests in Scandinavia, Finland, Lapland, and Russia, although its growth there is not to be compared with that attained on the hilly land and mountain masses in central Germany. It seems not to have been indigenous to Scotland or England, for no fossil traces of it have been found, and no historical record exists of it having ever formed forests on the hills of ancient Britain; it was probably only introduced toward the middle of the sixteenth century.

In France, as well as in Scotland on an altogether smaller scale, it has been cultivated to a much less extent than other conifers, and in Spain, Italy and Greece it is seldom met with forming forests. The eastern limit of the species is not easy to fix, as it gradually merges into another variety, the Siberian spruce (*Picea obovata*).

It ascends the Harz mountains to about 3,300 feet, the Black Forest and the mountains of Silesia to 3500–4000 feet, the Bavarian Alps to nearly 6,000 feet, and the central Alpine ranges to over 6,600 feet. In Germany and Switzerland the spruce is the principal forest tree on all mountain ranges and hilly tracts, often forming pure forests over large tracts of country, whilst below it there is a girdle of deciduous broad-leaved trees into whose domain it is always trying to extend its frontiers.

On the lower hills it is frequently found mixed with the silver fir and the beech, and at higher elevations in lower latitudes with the larch; in Silesia and East Prussia it forms extensive forests, often in company with the Scots pine. It is emphatically a tree of the upper hilly region, the more so in proportion as the hills and mountains are massive in formation, instead of consisting of a series of ridges and chains; it ascends to its greatest height when the general elevation of the surrounding country is considerably above the sea-level. Where the uplands fall away towards warm, dry, lowland tracts the spruce is not indigenous, and though pure forests of it are frequently to be found on indifferent soils in these localities, they are almost always the result of artificial production, and too often but poor in their production of timber.

Tree-form and Root-system of the spruce exhibit many differences from, and indeed direct contrasts to, those of the Scots pine. Its roots are mostly confined to the upper layer of the soil, and these of one tree often interlace with those of its nearest neighbours, thus obtaining some little protection during high winds. Its horizontal root-system, seldom going lower than 18–20 inches, and unprovided with any deep-reaching tap-root, stamps it indeed as the tree of shallow-soiled mountains, but offers it too often a sacrifice to the winds. It develops great numbers of rootlets, and as it also possesses the property of extending its roots to a great distance, it has a comparatively large area from which to draw supplies of nutriment, although owing to its density when forming pure forests the individual growing-space is limited beyond that of any other tree except perhaps the silver fir.

Although slower in growth during youth than the Scots pine, it maintains a much steadier rate of increase in height and grows up in dense canopy without much tendency to branch formation or interruption. In height, length of bole, straightness and full-woodedness of stem, freedom from branches, greatest quantitative production of wood and of useful timber per acre, it is rivalled only by the silver fir. Its crown is cone-shaped, and when grown in isolated positions the whole foliage is retained in more or less conical form from the summit downwards to near the ground; the short leaves or needles on the branches are retained for five to seven years.

Requirements as to Soil and Situation.—Shallow-rooted though the spruce undoubtedly be, yet it demands freshness in the soil, and cool, damp, mountain atmosphere is beneficial to its growth. Where other woods shelter it from the wind it also finds a suitable abode in the vicinity of the sea-coast, but its best development is attained in protected localities on mountain sides. In its true home the average temperature in July does not much exceed 66° Fahr.[1] and the total minimum warmth requisite during each annual period of active vegetation has been ascertained to be about 2,610° Fahr., which is about the annual average quantity of warmth developed at latitude 69° north. Its growth seems best when the enjoyment of the warmth, and thereby the period of active vegetation, is confined to a short summer season, during which there is daylight for the longest possible time, as in the north of Scotland and in Norway and Sweden. Drought is less easily borne by the spruce than by any other tree.

In regard to the quality of the soil, spruce shows a considerable degree of indifference, or at any rate adaptability; it makes greater demands on mineral strength than the Scots pine, but is content with less than the silver fir. Being at the same time one of the thickly-foliaged species of trees that improve the soil, and recruit such soils as have become impoverished, it is frequently found where broad-

[1] Willkomm, *Die forstliche Flora Deutschlands und Oesterreichs*, 887, p. 81.

leaved deciduous trees have previously allowed the soil to become deteriorated and impoverished.

Spruce thrives on soils of the most varied description, from the strong, friable mountain soil down through the binding varieties to the sandy-loamy, and the drained moors and bogs. Soils that show any good growth of weeds like *Epilobium*, *Senecio*, *Atropa*, or *Digitalis*, or of grasses like *Carex* are generally fresh and capable of producing good spruce forests, as also are those with high growth of whortleberry; but on tracts covered with heath and heather plantations should more frequently be made with spruce and Scots pine, than with spruce alone. It is not indifferent to mineral strength, but the chief factor in determining the suitability or non-suitability of any particular locality is certainly the equable distribution of a moderate quantity of moisture throughout the soil. The older sand formations, and loamy deposits resting on limy subsoil found in Alpine districts bear good spruce forests, but on limy soils it is apt to suffer from fungous diseases. On marls, loams, and rich clayey soils, deciduous broad-leaved trees find a more suitable home than the spruce. Low sandy plains with dry gravelly soil, soured undrained stretches with stagnant soil-moisture, moorpan with excess of sesquioxide of iron, or tracts liable to inundation are not the localities on which spruce can be expected to attain its normal development.

The most suitable aspect depends on the locality, and the elevation above the sea-level. Towards the lower limit of its proper region it prefers the cool, moist, north and north-east exposures, whilst towards the upper limit it seeks the southern and south-western aspects in order to obtain the requisite degree of warmth, and to escape from the drying-up influence of the east winds.

Requirements as to Light.—The ability to retain its branches in foliage for five to seven years, and the consequent density of its crown, give indication of the large capacity with which the spruce is endowed as regards bearing shade; but the extent to which the demand for some measure of enjoyment of light exists, is mainly dependent on how far any particular locality varies from the normal situations suitable to it. Where these various climatic changes are distinctly discernible, the demand for light becomes greater, and the capacity for bearing shade smaller. Where soils are wanting in moisture, young spruce cannot thrive under standards which intercept and partially retain the atmospheric precipitations. Excess of light on the other hand stimulates to increased assimilation of sap and too rapid growth in the earlier stages, which in consequence seriously affects the quality of the timber produced. In its true home, as, for example, on the fresh loamy soil of the Bavarian plateau, it frequently has to content itself for the first fifteen to twenty years of its existence with only a moderate supply of light under scattered standard parent trees, before being gradually admitted to the full enjoyment of unrestricted light and sunshine and the opportunity of normal development.

Attainment of Maturity and Reproductive Capacity.—Spruce is generally grown with a rotation of seventy to eighty years for ordinary timber, or one hundred to one hundred and twenty years for the production of larger assortments, but local market considerations must determine when the fall can most advantageously take place; higher periods of rotation are only advisable where the quality of the soil is above the average. Good money returns on the capital represented point decidedly towards the growth of spruce (and Douglas Fir) as being one of the most remunerative and profitable ways of utilising forest soils of about average quality.

Good seed years are less frequent with the spruce than the Scots pine, but are generally—reckoning from the fiftieth to sixtieth year—more productive when they occur ;

on the Harz mountains one good and one minor seed year are expected in every six years. Seed years can be foretold by the flower-buds, and the twigs showing these, broken off by squirrels and birds which feed on them. The ruddy-brown seed ripens in the October after the flowering, and is scattered from the cones in spring; it is somewhat larger and heavier than the greenish-black or brownish seed of Scots pine, and is reckoned good in quality when test experiments show a germinative power of seventy-five to eighty per cent. It thus has not only a greater germinative power than the Scots pine, but it retains this somewhat longer, especially when kept in the cone. Each cone has 200 to 250 seeds, and one pound contains from 55,000 to 60,000 seeds.

Liability to suffer from External Dangers.—As an offset against its many excellent qualities, spruce has unfortunately to contend with many external dangers at all periods of its existence, here of course to a greater extent, and there to a less, according to the soil and situation. Sharp, biting winds hinder reproduction at high elevations, except under the shelter of protective standards. Frost is only liable to damage the young growth at its earliest stage. Accumulations of snow, and of ice formed after rain on the heavy foliaged branches, bend down saplings in thickets, break the poles in young forests, snap off the tops of trees, and make large holes here and there in the canopy, especially at moderate elevations (on the Harz mountains, particularly those between 1700–2300 feet) where the snow is larger in flake than at high altitudes. Dense forests suffer most from snow, whilst a larger growing-space increases the danger from hanging ice.

No other species of forest tree is less able than the spruce to resist the violence of storms. Its shallow root-system, the long lever formed by the bole, and the purchase obtainable by the wind on the dense crown of foliage near the summit, all combine to weaken the resistance it is able to offer, especially in early spring and late autumn when strong winds are frequent just at the time when the foliage is often heavy with moisture and the soil sodden and softened by continuous rainfall. Whole forests are then often thrown down. The danger from wind is considerably lessened when other species are grown in admixture with it, or when natural reproduction takes place by the annual or periodical removal of the largest trees only.

Drought is injurious in the youngest stages of growth especially when accompanied by dry winds.

On unsuitable localities the mature stems are somewhat liable to die off, and old tree forests often suffer from fungous diseases, occasioned chiefly by *Trametes pini* and *Nectria cucurbitula* on the stem and branches, and by *Trametes radiciperda* and *Agaricus melleus* in and near the roots, which diminish the value of the timber. Cotyledons and leaves of seedlings are demolished by *Phytophthora omnivora.* In young plantations, and particularly in nurseries and young seedling crops, blanks are often caused after wet summers by *Pestalozzia Hartigii.* Red-rot in the timber is occasioned by *Polyporus vaporarius*, and white-rot by *Polyporus borealis* or, less frequently, *P. fulvus.*

But even the climatic dangers and fungous diseases combined are surpassed in importance by those to which spruce is exposed at all periods of its growth and development from the attacks of insect enemies. Extensive tracts of pure spruce forest have recently in Germany been severely damaged, partially destroyed, and even often killed outright by insects, the lower elevations suffering far more severely than those situated within the true mountainous region.

To enumerate merely the more important of such enemies, larvæ of *Melolontha vulgaris* and *hippocastani*, and *Gryllotalpa vulgaris*, and the full-grown *Hylastes cunicularis* and *Gryllotalpa* do great damage to the roots of seedlings and young plants, whilst the beetles *Hylobius abietis* and *pinastri* and *Hylastes cunicularis* gnaw the tender bark of their stems; later on the cortex and sap-wood suffer from both the larvæ and the fully-developed beetle of three varieties of *Bostrychus—amitinus*, *chalcographus*, and *typographus*, whilst the mature wood is damaged by both the active forms of *Xyloterus lineatus*. Buds and foliage are destroyed completely, and valuable forests utterly ruined over immense tracts of country, by that scourge of the coniferous forests of Germany, *Liparis monacha*, the voracity of whose caterpillars is only equalled by their almost unlimited numbers in bad years like 1889, 1890, 1891 in southern Bavaria, where alone the extent of forests devastated by the black arches, "nun," or spruce moth (*Liparis monacha*) is estimated to be about 42,500 acres or sixty-six square miles, of which by far the greatest portion was pure forest of spruce.[1] In the mixed forests attacked, the beech and Scots pine suffered comparatively much less than the spruce, although they were also badly injured; the spruce, however, was usually killed outright, owing to the much smaller reserves of starchy matters stored up by this species for subsequent constructive purposes.

In recuperative power with regard to injuries received, whether caused by insects or by deer, the thin-barked spruce is not well endowed. Where a strong head of game is maintained, red-deer do more damage in spruce forests than elsewhere, by stripping the bark with their teeth during summer, as well as for food during winter. The damage caused is often very serious, and is generally most widespread in pole-forests from twenty to forty years of age, although it is often done also in tree-forests up to sixty years of age. For the healing of the wounds thus caused,

[1] For a detailed account of this insect and its ravages, see the *Transactions of the Highland and Agricultural Society* for 1893.

spruce has unfortunately less recuperative power than the silver fir or even the Scots pine.

Sylvicultural Treatment of Spruce.—The economic value of spruce is by no means small, if its cultivation takes place under suitable circumstances. Moderate in its demands on soil, which it also protects and improves in quality, and seldom giving much trouble in the formation and reproduction of forests, spruce yields on favourable localities a larger outturn of timber than any other tree usually grown in pure-forests (*vide* table on page 44), without requiring a high period of rotation to attain marketable proportions. It remains long in close canopy, and forms lofty, cylindrical, straight stems, that are valuable and of great general utility. It also yields fair returns in the way of thinnings, and occasionally affords good grazing for cattle. From the actuarial point of view many advantages point towards the cultivation of spruce as one of the most remunerative orms of high forest; but the relatively high returns promised can only be realised on soils and situations which admit of the normal development of this species, and these are to be found chiefly in sheltered localities of mountainous regions having a moist and moderately good soil.

Misled by tempting actuarial calculations, it would be a mistake to transform existing crops into spruce woods without other definite reasons, for most other trees, and particularly the broad-leaved deciduous species, have undoubted advantages over spruce in respect to the greater security they afford against destruction of the crop from snow, storms, or insects. But in mountainous tracts, on undulating soil temporarily reduced by too open crops oı deciduous trees, or where timber prices are good, but fuel is little in demand, spruce forests generally as a matter of fact yield the most remunerative returns on soils of about the average quality.

Young crops of spruce do not form canopy so soon as those of Scots pine, though in plantations it is attained earlier than by sowing or with natural reproduction. On sunny localities the soil is apt to become overgrown with weeds like *Atropa*, *Digitalis*, *Epilobium*, *Rubus* and *Urtica*, with *Vaccinium*, *Carex*, *Scirpus* and *Juncus* on the moister patches, which usually interfere with the growth of the young plants and occasionally choke them altogether; but on dry and shallow soil the dangers arising from dry winds and direct insolation are greater. Frost in general does more damage, by lifting the young plants out of the ground, than is occasioned by the actual degree of cold to which they are exposed. Young growth, particularly in woods that have been formed by planting, is greatly exposed to danger from the large brown pine weevil (*Hylobius abietis*), which bores into the young shoots, and often ruins whole crops formed where the stumps of the mature crop have neither been grubbed up nor barked after the harvesting of the mature fall of timber.

Until the young crop forms canopy, the growth of the individual plants is rather towards lateral extension than in the direction of increase in height, but when once they have closed up (which usually occurs about the twelfth or twentieth year according to the quality of the soil), and the twig-shoots begin to interlace, the development of the leading shoot becomes vigorous, the more so in proportion to the density of the crop and the quality of the soil. As they are densely foliaged and make little demand on growing-space, young thickets of spruce generally stand very thick, and completely cover the soil. So much so is this the case, that, where sowings have been too thick, the development is greatly interfered with; but in general the natural selection of the predominating stems, to form the future crop, goes on normally and quickly, the current annual increase in height culminating with shoots averaging one and a half feet on soils of the best quality between the twenty-sixth and fortieth year, and later, with of course smaller averages, on those of merely average or inferior quality (*vide* tables on page 36—38). Throughout this period of energetic development, the natural suppression of dominated stems gradually progresses, but without any practical interruption of the canopy taking place, so that the boles are enabled to assume that full-wooded cylindrical shape which renders them so valuable. According to Baur this maximum of approach to the cylindrical is attained when the average height of the crop is from sixty-six to eighty feet, but with advancing age it sinks only gradually.

One decided drawback of the close canopy and even development of spruce woods at this stage of their life-history is the consequent danger from accumulations of snow, which often occasion serious damage—a danger however not so much to be feared in either Scotland or England as on the Continent with its severe winters. Later on the density of the crop also gradually diminishes without the continuity of the canopy being very seriously interrupted, whilst from the time that it has reached the tree-forest stage of development, a rich growth of mosses (*Hypnum*) covers the soil, which, however, gives place to whortleberry (*Vaccinium*) and similar weeds when self-thinning with consequent interruption of canopy has gone too far. It is at this stage of growth that pure forests of spruce of equal age are most exposed to the danger of windfall and to attacks of bark-beetles (*Bostrichini*). No species is so little able to resist the force of storms as the spruce, and when once violent winds succeed in breaking up the canopy, they seem to act in a concentrated and cyclonic manner, throwing down everything that offers resistance to their passage. According to Burckhardt,[1] in the Hanoverian portion of the Harz mountains, aggregating 134,350 acres, of which four-fifths, or 107,480 acres, are under spruce, during the present century (up till 1870) over two millions of mature spruce were thrown by wind, or the equivalent to full crops on about 10,500 acres, nearly 8 per cent. of the total area. He also estimates that wind and snow combined have during the present century destroyed at least four millions of stems in the tree-forest stage of growth, without including those that have been merely damaged by wind or snow, and have consequently fallen victims afterwards to bark-beetles, which first of all attack the sickly stems, breed there, and then attack sound and healthy trees, unless all unsound individuals are removed.

Pure Forests of Spruce.—Localities with a short period of vegetation being the natural home of spruce, its cultivation in pure forests in Scotland would seem advisable wherever the upper soil has the requisite moisture. In the generally damp climate of both the lowlands and highlands of Scotland with their comparatively short summer, the factors are given which hold out promise of the normal development of spruce, although its growth may perhaps not be so rapid as in warmer southern localities. At higher elevations or in the far north it takes perhaps a hundred to a hundred and twenty years to attain the same average dimensions in pure spruce forests that can be arrived at in lower or warmer localities in eighty to a hundred years, but this shortening is to a great extent counterbalanced by the better quality of the timber produced.

Tempted by the remunerative promises held out, spruce forests have often been formed on heavy loams and

[1] *Säen und Pflanzen*, 1880, p. 329. The introduction of the silver fir and the re-introduction of beech into these spruce forests has been occupying the attention of foresters there for many years past.

clays, or on sandy soils apt to suffer from want of moisture. When the climate is mild, and the period of vegetation prolonged through warm spring and autumn weather, plantations show rapid growth in youth, which, however, does not always continue throughout the whole period of rotation, but not infrequently shows signs of loss of energy about the fortieth to sixtieth year. The too rapid development during the youthful period produces soft wood of indifferent quality, which offers but little resistance to dangers threatened by snow, by the attacks of insects, through infection with fungous disease, or to diseases originating in other causes. Although of course this is by no means necessarily the case, it is not unusual to find such spruce woods early interrupted in canopy, and unable to afford sufficient protection to the soil, so much so in fact that their clearance may be advisable before they have attained sixty years of age. On such localities spruce is not necessarily out of place, but may, grown in patches along with a ruling species for which the soil and situation are more suitable, attain very satisfactory growth, and assist very materially in increasing the ultimate returns from the crop. The periods of rotation of spruce usually vary from seventy to eighty up to a hundred or a hundred and twenty years, the former supplying the ordinary assortments of timber requisite for building purposes, the latter yielding large squares. Local demands of course to a great extent determine the most remunerative period of rotation, but where the forests are extensive, fixing the fall at an early age is apt to swamp the market with small timber, whilst entailing the harvesting of large quantities of top-ends and small material of very little value. The postponement of the fall to a hundred and twenty or a hundred and forty years, for the production of large-girthed timber, can only be advisable in very sheltered localities, owing to the dangers to which the spruce then becomes exposed; and for the same reason the retention of standards, when mature crops are being cleared, is always combined with more risk than is prudent. Here again, however, the same end can be better attained by growing the spruce in admixture with other species, such as the beech, silver fir, or pine.

The thinning out of pure forests of spruce is usually confined to the removal of suppressed individuals, and of those likely to be immediately suppressed, and in localities where damage from snow is not improbable the operations must be conducted carefully. As the natural habit of spruce is to grow in close canopy, any premature removal of poles can only be an unnecessary diminution of the number of individual stems per acre. In the weedings and clearings which take place in young crops before thinnings are begun,[1] all soft woods and coppice shoots of trees forming part of the former crop should be removed in order to avoid the formation of blanks later on,—birches if left standing often do great damage by rubbing and chafing leading-shoots of the spruce,—and when the crop has been formed by thick sowing or planting in wisps of two or three on the poorer classes of spruce soil, these early protective measures for improving the growth of the young stock often occasion great trouble and considerable expense. In the thickets formed by planting in wisps on inferior soil, it is especially necessary to repeat the thinnings as frequently as possible, in order to assist nature in the selection of the predominating stems to form the future crop; the longer such operations are delayed the more difficult and expensive do they become

[1] Under *clearings and weedings* are classifiable all the operations in young woods which necessitate an outlay that cannot be covered by sale of the material cut out; when the costs involved are covered, or more than covered, by the proceeds obtained, the operations are then properly termed *thinnings*.

as the roots interlace and the lower portions of the stems grow into each other. Localities exposed to the danger of snow-accumulation require the most careful thinning, and even dominated individuals should be left standing, as reserves in case of accidents, if their crowns are still green; broken stems also should not be removed if three or four green whorls give hope of some side spray assuming the *rôle* of leading-shoot. Where a strong head of game is maintained, deer often do greatest damage by stripping the bark in woods directly they have been thinned, and in particular just after the first time of thinning out; from such wounds spruce suffers more serious permanent damage than Scots pine or silver fir, owing to its weaker recuperative power. For the same reason the removal of green branches with the bill or axe is not advisable; when it is desired to remove branches for the purpose of producing clean-stemmed timber free from knots, the operation should invariably be performed with the saw in the case of both living and of dead branches, and confined to those under $2\frac{1}{2}''$ diameter.

Soils that are somewhat inferior for the production of mixed forests of broad-leaved species, or areas where long-continued or badly managed copse, or coppice under standards, has allowed the soil to become more or less deteriorated, frequently afford good localities for the growth of spruce in pure forest, although it is not advisable to confine it to soils below the average in quality if the production of the larger, more valuable, and under certain circumstances more remunerative assortments of timber be desired. Where pure forests of spruce exist on an extensive scale over large tracts, it is exceedingly desirable to frame the working plan so that the annual fall should take place in several places apart from each other, instead of being combined in one large area annually, as it is to a great extent the latter method of procedure which causes so many of the drawbacks under which pure forests of spruce suffer. With the cessation of total clearances over large areas it is beyond all doubt that dangers from insects during the youthful period of growth, from snow during the pole-forest stage of development, and from wind when approaching maturity, would all be practically, and very considerably, lessened by the formation of several blocks, each with its growing stock of successive annual crops from one to eighty or a hundred years according to the period of rotation fixed on, in place of having the total area divided simply into eighty or a hundred compartments as the case may be, from the oldest of which a total clearance of the mature timber is annually made.

The usual method of regeneration of pure forests of spruce is, as above indicated, total clearance with artificial reproduction, except at very high altitudes where considerations of treatment are usually secondary to those relative to the general economic value of maintaining the higher mountains under forest in order to prevent landslips, and to regulate the flow of moisture through the soil and ensure the perennial feeding of the streams which have their sources there.

The unsuitability of the method of natural reproduction under parent standards that is customary in the case of the other two densely foliaged shade-bearing species, silver fir and beech, finds easy explanation in the indifferent resistance which the spruce is able to offer to the violence of storms, otherwise the diminished increment that is attained by the young crop during the earlier stage of growth would be amply compensated by the protection against various dangers which the parent trees would secure to their progeny during the first ten to twenty years. Experience has, however, shown that attempts at natural reproduction in this manner, except in very sheltered localities, usually lead to the parent standards being thrown by wind, when a rank growth of weeds soon covers the soil, and chokes a large proportion of the seedlings; and again, when the reproduction takes place by sowing or planting, the retention of standards is more likely to be injurious than beneficial.

Mixed Forests with Spruce as the Ruling Species.—Spruce is found forming pure forests over very extensive areas, as it is one of the species which can thrive and attain normal development without an admixture of other kinds of timber trees in the crop. At the same time there is hardly any other species of forest tree in Britain which gains so much as the spruce by the formation of mixed forests, both as regards the unquestionable protection thus afforded to it against dangers, whether of organic or inorganic nature, and in respect to the stimulus thereby secured for the total production of timber per acre, and the better quality of the timber produced.

In its Alpine home, the larch is frequently to be found naturally associated with spruce at the higher elevations, although artificial admixture of these two species in other localities has often been far from satisfactory. Throughout the mountainous tracts of eastern France, and of central and southern Germany, in particular in the Black Forest, mixed forests of spruce and silver fir are a favourite form of timber crop,—except on the Harz mountains, where the climatic factors do not seem to be favourable to the development of the latter. Beech is also often an associate of the spruce, and is to be found frequently in mixed forests of spruce and silver fir. Towards its northern and eastern limits, the species chiefly found growing along with spruce is undoubtedly the Scots pine. These are the trees which are usually found growing as subordinate species in mixed forests where spruce forms the ruling species or matrix, and although other mixtures have been tried artificially, the above-named are those which hold out the best sylvicultural and economical promises.

When the silver fir finds the soil and situation congenial, it is the most important associate of the spruce; and though during the earlier years of growth it must be granted some protection against the more rapidly developing spruce, it requires no special tending throughout the later stages of growth. In many respects it adapts itself better for admixture with the spruce than with any other ruling species of forest tree. In tree-form and natural development they have many close resemblances, but as silver fir is deeper-rooted than spruce, the two species, admixed, can develop unhindered a much larger aggregate of roots than if either species were grown in pure crop; and as this maximum of root-system has practically the opportunity of drawing the requisite supplies of nutriment from two different layers of soil, it follows naturally that the number of stems and the total production of timber per acre will under ordinary circumstances be considerably greater than can be shown by pure forests of either species. By interlacing of the two root-systems also, no inconsiderable support is given to the shallow-rooting spruce against windfall.

The main condition for the formation of mixed forests of spruce and silver fir is a good deep soil without excess of soil-moisture, as unless that essential condition be satisfied the latter is unable to maintain itself against the former. Even although developing slowly at first as compared with Scots pine, spruce has a more rapid early growth than the silver fir, and the advantage thus won it maintains throughout the pole-forest and into the tree-forest stage of development. Although the silver fir can thrive in the side-shade cast by the spruce, measures must be taken to prevent the latter shooting so far ahead as to form canopy above the silver fir in the thicket stage of growth, otherwise the latter dies off. Where the two species are planted out alternately in equal numbers, the silver fir soon gets defeated in the life-struggle, unless the soil is of better than average quality. Even when the admixture takes place by planting in alternate rows, the silver fir transplants should have the advantage of being older than those of the spruce. Where such mixed forests are formed or reproduced, it is advisable to allow the silver fir the advantage of five to ten years of growth in order to enable it to protect itself against the spruce without necessitating considerable outlay for tending,

Beech is not of so much importance as silver fir as a minor species in spruce forests, for though its root-system is heart-shaped like that of the former, its general habit of growth and development as a forest tree is greatly different from that of the latter; it requires to be grown in groups or patches in order to maintain itself at all against the much quicker growing spruce. Although it yields better fuel than any other species of forest tree, the wood of the beech is in poor demand as timber for technical purposes, so that in Britain it will usually only be found in forests on account of its soil-improving qualities.

Important though the considerations regarding increased annual production and better quality of timber be, yet the chief advantages to be gained through the introduction of silver fir and beech are beyond all question or doubt the greater security afforded to the spruce in respect to all the dangers and enemies to which this species is exposed. In localities where spruce can thrive safely till maturity, measures for increasing the production are hardly of the first importance, as the returns from pure forests of spruce are in themselves so good that further outlay for the introduction of a minor species might often seem uncalled for ; but where, as in most localities under spruce, storm, snow and ice-accumulations, attacks of insects, fungous diseases especially (*Trametes radiciperda* and *Agaricus melleus*), and other dangers cannot be left out of reckoning, an intermixture of one or other of these species—and on suitable soils and situations preferably the silver fir,—is in the highest degree advisable in the light of recent experience throughout Germany.

On many parts of the northern slopes of the Bavarian Alps, the larch also occurs as a subordinate species along with silver fir and beech in spruce forests. Its growth at first is much more rapid than that of the spruce, and on deep fresh soil the advantage thus early won is maintained till the sixtieth to seventieth year, or under favourable circumstances longer, although only too often it is caught up and overtopped by the spruce. Where the soil, however, is wanting in depth and strength, or where, as in Britain, both species are removed far from their natural homes, and cultivated under conditions in many respects dissimilar from their normal requirements, it not infrequently happens that the spruce, stimulated to lively growth in height, catches up the larch as early as the twentieth to thirtieth year, when nothing remains but to cut out the latter, and allow the spruce to form pure forest. Even when the larch has been introduced in patches among the spruce, little can be done in such cases to protect it, as its further growth is prejudiced by the side-shade, and it can no longer develop satisfactorily. As a rule, the larch should only be grown in spruce forests on parts where the soil is of better quality than the surrounding ground, and on such patches it generally thrives better in groups than when planted out alternately with spruce, or only simply here and there,—although it may be remarked here that Burckhardt recommends its being planted out singly only, except along the edges of compartments where it may form rows or belts. The groups should not, however, be too large, as otherwise there is the same tendency towards crooked, sabre-like growth as is characteristic of pure larch forest away from its Alpine home. Experience shows that when grown along with spruce, the larch is less liable to be attacked by fungous disease (*Peziza Willkommii*) than when it forms pure forest. As a rule large transplants should be used in introducing the larch into spruce woods, so as to assist in giving it the greatest possible advantage in growth,—but unfortunately where roe-deer are maintained, these are specially sought out by the bucks at the time of brushing the velvet from the horns in early summer, and much damage may be caused in this way.

Scots pine is seldom to be found as a minor species on the better classes of spruce soil, where the preference is usually given to those others already mentioned ; but it forms a valuable associate on the poorer qualities of soil, and wherever the satisfactory development of the spruce is likely to prove questionable. The *rôle* that it then plays is partly that of a purely subordinate species, partly that of a nurse or protector. In such cases the object in view is to raise the spruce in as large a quantity as possible, but at the same time to have the pine represented to as great an extent as can be grown along with the spruce, or as is necessary for the maintenance of closed forest. That, under such circumstances, what was originally intended as a spruce forest with the admixture of Scots pine, ultimately approaches maturity as a crop of pine with admixture of spruce, can easily be understood, as on such debatable land consideration must be duly given to the factors influencing the growth of both species at many critical periods of the life-history of the growing-stock. Any stencil-like regularity and uniformity of treatment of such mixed crops is out of the question, and it can only be expected that, with proper and prudent treatment, the mature fall will consist here and there of spruce with pine, and in other parts of pine with spruce intermixed. When there is doubt about the soil suiting the spruce, it is perhaps a good rule always to form the young crop by means of an equal admixture of both species in rows or bands proceeding later on with the clearings and thinnings as may seem advisable each time these operations are under consideration.

Such cases of doubtful success are just as frequent on the dry slopes of low hills and uplands, as on the more level tracts or plateaux. Pure pine forests are often just as much out of the question as pure forests of spruce, for whilst the latter is slow in closing up to form canopy, and inactive in growth generally, the former is apt to become interrupted in canopy at too early a stage of development, and to fail in affording to the ground the protection so specially requisite on soils of inferior quality. In mixed forests consisting equally of spruce and Scots pine,—or of spruce to half the number, and Scots, black and Weymouth pines forming the other half,—the best possible attainable results are perhaps achievable, the ultimate tending of the crop being dependent on the relative development of the different species. In Hanover it was usual, at the time when sowing stood in greater favour among sylviculturists than planting, to mix and sow spruce and Scots pine seed in the proportion of five to one, the pines being regarded solely as nurses, and cut out as soon as they began to inconvenience the spruce with their shade.

That, in equally mixed spruce and pine forest, the latter often becomes the dominant species, is due to inefficient tending more than anything else, for, unless some special attention be paid to the spruce during the clearings and thinnings, it either remains dwarfed as underwood, or at any rate has no fair chance of developing until the canopy of the pine becomes naturally interrupted. Many mixed woods of this description yield good returns if the pines are cleared away wherever the spruce shows need of freer enjoyment of light and air, and stems are left only here and there on the better patches to increase rapidly in girth over the well-protected soil.

The oak is not naturally a common associate with the spruce, from which it differs essentially in many sylvicultural characteristics. The oak is generally found on the milder situations on plains and uplands with a long warm period of vegetation, the spruce at higher elevations and on shallower soils. Still, in many parts of northern Germany such mixed forests do exist, and are often spoken well of. Even when oaks are given a few years' advantage at first, they are soon overtaken and topped in growth by the spruce, unless they are planted in clumps of considerable diameter. If planted in rows or small groups, though they may reach the pole-forest stage of growth evidently thriving and well above the spruce, they seldom maintain these advantages till maturity, but have usually to be cut out long before they attain good marketable dimensions.

Softwoods are often found associated with spruce, as nurses where the reproduction of the latter is difficult, or as protective standards in situations exposed to frost. But their artificial production is seldom necessary, as they usually occur self-sown, and if not, a more desirable substitute for parent shelter can generally be found in the pine. More frequently they in reality become weeds, whose coppice-shoots occasion much trouble and annoyance. This is particularly the case with coppice-growth of the birch, whose long whip-like twigs damage the leading-shoots of the young spruce growing around ; but where seedlings of birch occur merely scattered here and there individually throughout spruce woods in places where late and early frosts are to be feared, their retention till they are caught up in growth by the spruce, often yields good preliminary returns as well as useful aid sylviculturally.

Formation and Reproduction of Spruce Forests.—Except at high elevations, where the ordinary methods of reproduction of spruce forests cannot be carried out, and where their profitable working must be subordinated to the main object of maintaining the mountain-tops under woodland, there are three distinct forms of reproduction, all of which are practised in regular annual falls. These are :—

1. Natural reproduction under parent standards.

2. Total clearance in narrow strips, with natural reproduction from neighbouring woods.

3. Total clearance of annual fall, with artificial reproduction (usually by planting).

Natural reproduction under parent standards is especially practicable in respect to mixed crops of spruce with silver fir and beech, but is, however, also adopted in pure spruce forests on level soil, where late frosts or attacks of cockchafer grubs (*Melolontha vulgaris*) are to be feared on an extensive scale, and experience has further shown that in forests thus reproduced the dangers from *Curculionidae* are likewise diminished. Other local circumstances must of course be taken into consideration, and this method of reproduction will often recommend itself in outlying and sheltered localities, where the proprietor does not wish to incur the usually moderate costs of artificial regeneration. The results of natural reproduction under parent standards are varying. In some situations the parent standards are not much exposed to the violence of storms, but in most localities this is unfortunately not the case. The young crop often varies much in quality; in some situations a moist soil is favourable to germination and the seedlings stand too thick, whilst in other places reproduction is slow and unequal, resulting in thin patches of seedling growth of different ages, necessitating some artificial assistance, and adding considerably to the costs of tending later on.

The method of total clearance with natural reproduction from neighbouring woods, was formerly much more frequently adopted than is now the case. The fall for reproduction should not be more than 100–120 yards broad, and must of course be so located that the adjoining mature woods lie to the windward, in order that seed may be evenly shed over the area when the cones open with dry warm winds in late spring and early summer. Some measure of soil preparation for the reception of the seed is absolutely requisite, and when seed-years turn out disappointing, artificial reproduction or assistance becomes a necessity to a greater or less extent, as otherwise a rank growth of grasses and other weeds covers the soil and shuts out the hope of seedlings being subsequently able to force their way through these successfully.

The total clearance of the annual fall of the mature crop with artificial reproduction by planting, is now the usual method of treatment of spruce forests in Germany. Independent of seed-years, untrammelled by considerations regarding the protection of standard parent trees against the violence of storms, and far less threatened with danger from growth of weeds, reproduction can thus be carried out quickly and satisfactorily at a moderate cost, whilst the extraction of the mature timber is easier, and the grubbing-up of the roots less difficult in localities where there is any good market for fuel. This method has many advantages to recommend its adoption,—it is an easy system, involving the minimum outlay for supervision, tending, and ultimate harvesting of the crop, the annual fall of timber is regular, and varies little in quality or cubic contents, and the working plan is based on the simplest and safest of all foundations, *viz.* equality of the areas (modified according to their relative productive capacity) from which the mature crop is annually cleared; it has, however, drawbacks and disadvantages which have previously been referred to.

In whatever manner spruce forests are reproduced, a general principle should be followed of not making the annual fall comprise too large an area, as it is in every way of unquestionable advantage to have a series of self-contained blocks, each comprising within itself crops varying from one to eighty or a hundred years, instead of one large block simply divided into eighty or a hundred annual compartments or falls.

Natural Reproduction.—When reproduced naturally under parent standards, no preparatory fellings are necessary to stimulate the production of seed and prepare the soil for its reception. When a good seed-year seems favourable for reproductive fellings, they are made so as rather to resemble those in beech and silver fir, than in Scots pine forests; but on account of the danger from wind the number of trees left per acre is greater, only from $\frac{1}{4}$ to $\frac{1}{3}$ of the total number of trees forming close canopy being removed, so that during storms the crowns can afford each other some measure of support. On moist soil, a lighter disposal of the parent trees would also favour a rank growth of weeds, which is more prejudicial to young spruce than even a considerable degree of shade from lofty standards. The period of reproduction is much shorter than with beech or silver fir, as the seed-years are more frequent, and the amount of seed produced greater, besides which the young seedling growth is not so absolutely shade-demanding as with these other species. From the pine it also differs essentially, not only in the more abundant, though not more frequent, production of seed, but also in that the seed ripens in about six months, in place of being delayed till eighteen months after the flowering.

The shape that it is advisable to give the area to be reproduced is dependent on the extent of the danger from wind; the greater the danger, the more should reproduction take place in long narrow strips, on which the number of trees along the middle should be greater than towards the edges, so as to ensure speedier regeneration and earlier clearance of the parent trees, in order to minimise the damage caused to the seedling growth at the time of extraction. Where good patches of self-sown spruce occur they should be retained, but all other species of trees should be cut out. When practicable, large branches should be sawn off to decrease the leverage obtainable by the wind, but care should be taken to carry out this operation during winter, in order to prevent the outflow of sap from the wounds. Whatever soil-preparation can be conveniently undertaken yields its reward in easier and better growth of seedlings ; the layer of thick moss should at any rate be removed with the rake. In Prussia, breaking up of the soil roughly into clods in bands or strips one to one and a half feet broad and six feet apart has been found a judicious outlay, the operation being performed in the autumn of the seed-year.

The clearance of the standard parent trees commences in the winter of the year following the seed-shedding, and the extraction should take place, so far as possible, whilst snow lies on the ground, in order to minimise the injury done to the seedling crop ; clearance must be effected as speedily as possible, as the danger from wind increases greatly when once this operation has been begun ; even in sheltered localities the final clearance should be completed by the time the seedlings have attained a height of one foot. Where reproduction has not been equally and uniformly successful, it is not advisable to retain the standards ; blanks can easily be filled up by sowing or planting, or an excellent opportunity is thus given for introducing other species such as silver fir, beech, pine or larch, whose admixture along with spruce has been shown by experience to be so desirable for many good reasons. Douglas fir should also yield good results.

Artificial Reproduction and Formation.—During the last century, sowing was the usual method of forming or reproducing spruce forests artificially, but towards the beginning of the present century planting, in place of being confined merely to the filling up of blanks in sowings, became a rival of the older method, and for the last fifty years it has been the favourite system. Sowing, besides not always being so successful, is on the whole not so very much cheaper than planting that one can afford to overlook the difference of two to four years' growth won for the future crop when seedlings or transplants are utilised. But planting of spruce has other advantages over sowing. Plantations suffer less from rank growth of grass, run less risk of being lifted out of the ground by frost, and also suffer less where large herds of deer are maintained, whilst they can be opened earlier to grazing; they thrive as a rule better than young crops raised from seed, and can be formed in autumn as well as in spring.

The material for filling up the blanks in crops raised from seed was formerly usually taken from reserve plots or temporary nurseries prepared by sowing thickly in the proportion of about 150 lbs. of seed per acre actually sown. By the time the seedlings were four or five years old they could only be used in wisps of three to five, in place of individually, as they had grown quite entangled, a method that is even now intentionally practised under certain circumstances, but which is hardly recommendable, as it renders subsequent tending difficult, and interferes too often with the normal development and the early selection of predominating poles.

The distances at which seedlings and transplants were planted out in the great home of the spruce, the Harz mountains of central Germany, has varied at different times. At first plantations used to be made at $2\frac{1}{2}$ feet × $2\frac{1}{2}$ feet, but later on the plants were made to stand at from 3 feet × 3 feet to 5 feet × 5 feet, the wider distances being preferred where there was heavy snowfall; recent experience in Germany has shown, however, that 4 feet × 4 feet is preferable to any wider distance.

Sowing.—Although planting is now generally admitted to be preferable to sowing, yet under certain circumstances the latter method finds its proper uses, as, for example, where seedlings or transplants are not conveniently obtainable, or where the soil is too rocky or otherwise unsuitable for planting, or when a good market for small material like pea-sticks can be tapped early and remuneratively. More seed per acre is used for spruce than for Scots pine, for not only do fewer seeds go to the lb. (55,000 to 57,000), but a denser crop is also desirable. As a rule about 10 to 12 lbs. per acre are used, although this quantity must be increased in proportion to the magnitude of the danger from drought, weeds, or lifting of the seedlings by frost. Sowings are less frequently made broadcast than in rows, or strips, or on small patches, and clean seed is now alone used, a soil-covering not exceeding a quarter of an inch being provided by light raking. The operation is carried out towards the end of April or the beginning of May, as a rule, and only exceptionally in autumn. Except where rank growth of weeds demands broader strips the soil is generally prepared to a breadth of 1½ to 2 feet and in rows 3 to 4 or at most 5 feet apart; patches are usually 1½ to 2 feet square and about 4 feet apart. On hilly situations the rows should run horizontally, and not vertically, to prevent the seed being washed away.

Planting.—The best results are obtained with transplants from regular nurseries, although younger seedlings taken from seeds beds, or wisps (three to five) from rills in temporary nurseries, also at times find favour. Plants from two to five years are usually put out, in preference to yearling seedlings, as the planting of the latter often costs nearly as much as if two-year-old plants be used, whilst the results are generally not so good as with these.

Notching, and the use of naked seedling or wisps, are only suited for the more favourable soils of a light character; on tenacious soils, or where there is a strong tendency to growth of weeds, this otherwise cheap and good method is not advisable. In general, too, this method seems to affect the rootlets of the spruce to a greater extent than those of the pine, which latter do not so long retain the flat shape induced by the pressure employed at the time of planting.

The use of transplants with earth attached is on the whole far more advisable, and usually leads to better results, than the use of naked seedlings; and in localities where growth of weeds does not call for the use of older material, the operations of transport and planting can be carried out at a very reasonable rate if the preparation of the holes on the area to be planted, and the lifting of the material from the nurseries, be carried out with small cylindrical spades (Heyer's[1]), which besides have the additional advantage of rendering too deep planting impossible,—one of the worst, but most common mistakes made in regard to the spruce, particularly in tenacious soil.

Planting should take place in spring to as great an extent as is practicable; but at high latitudes or elevations, or where a moist soil has first to get rid of some of its superfluous moisture, autumn planting also yields good results. On windy situations, and on dry soil, the most favourable time for planting is is spring, just before the buds flush and form the new shoots. Plantations formed in autumn are less able to resist the action of frost during their first winter than those formed in spring, whilst the plants can more easily be pulled out of the ground by deer.

The best average distance between the plants has been

[1] These useful instruments were first described in a report "On the Corsican Fir," printed in the *Transactions of the Highland and Agricultural Society*, 1876.

found to be four feet; whether greater or less distances recommend themselves in any particular case depends upon local circumstances and on the funds available, the principal advantages of closer planting being in the speedier attainment of close canopy and protection of the soil, in greater freedom from branches, and in earlier returns from small material removed during the operations of thinning out. When requisite, it is better to give the individual poles more growing-space by means of the bill or the axe, than to endeavour to secure it from the very outset by means of planting at wide distances; but where there is a poor market for pea-sticks and the like, and where labour is neither plentiful nor cheap, a preference will often be justified in favour of somewhat wider planting. Where the soil is fresh and good, and only sound four to five-year-old transplants are set out, wide planting at 5 feet × 5 feet should be sufficient; but care must be taken to fill up any blanks promptly, as with only 1,742 plants per acre to start with one cannot afford to lose any prematurely (*vide* tables on pages 22 and 43). But where, on the other hand, the soil is dry, or where rank growth of whortleberry, heather, or other weeds has to be contended with, considerations as to the speedy formation of close canopy and suppression of weeds may determine in favour of closer planting, for 2,725 plants per acre at 4 feet × 4 feet effect the purpose much more quickly and effectually than 1,742 at 5 feet × 5 feet. On dry slopes, or deteriorated soil, even closer planting is advisable when funds are at disposal, although a judicious admixture of Scots pine along with the spruce often leads to the attainment of the object in view at less cost than close planting of spruce alone. When planted for shelter, as a protective mantle along the edge of pine or other forests, they should not be put out closer than five or six feet in order that the individual trees may develop fully in foliage and be able to maintain themselves against storm-winds by a free formation of their root-systems towards the windward side.

Whether the setting-out of the plants should take place in squares, or triangles, or rows, is of less importance than the actual number of plants per acre; practically, planting in squares is the usual method adopted, although in situations where plantations are liable to suffer from accumulations of snow or ice, planting in rows of 6 feet × 4 feet, or 6 feet × 3 feet are said to yield the most satisfactory results. Close planting increases the danger from snow, whilst ice causes most breakage when the individual plants have a fair amount of free growing-space.

As previously remarked, notching is not so well applicable to the spruce as to Scots pine, but recommends itseif on account of its cheapness wherever the nature of the soil is suitable. The usual methods adopted are planting by means of Heyer's cylindrical spade for one and two-year-old seedlings and three-year-old transplants, and pit-planting,—or on wet soil, tumping or planting on mounds —when older material is put out.

3. Silver Fir (*Pinus picea*, L. = *P. abies*, Du Roi = *Abies taxifolia*, Desf. = *A. excelsa*, Lk. = Abies Pectinata, D.C.).

Distribution.—The silver fir is a tree of the mountains of central and southern Europe, from the Pyrenees eastwards to the Caucasus, northwards to the Vosges, Luxemburg, the southern edge of the Harz, Silesia, and Galicia, and southwards to Navarre, Corsica, Sicily, Macedonia, and Bithynia. Its vertical distribution averages 5,000 feet in the Bavarian Alps, 4,000 feet on the Vosges, 3,250 in the Black Forest, and 2,700 feet in the Thüringer Wald.

It is not indigenous to north-eastern Europe above $51\frac{1}{2}°$ latitude, but finds its natural home in the mountains of eastern France, south-western Germany, Bohemia, Hungary, Tyrol, and Switzerland, where it is met with on the outlying and lower hills, generally forming mixed forests with spruce, beech, or larch, rather than pure forests. Where it occurs to the north of $51\frac{1}{2}°$ latitude its introduction has been due to artificial means. It was introduced into Britain early in the seventeenth century (1603).

Tree-form and Root-system.—The silver fir resembles the spruce in the formation of a straight long bole, which approaches the cylindrical shape, yielding a maximum of timber and good long squares. Its thickly-foliaged, though narrow, but deep-reaching crown is supported by a somewhat sparse branch development, subdivided, however, into a large number of twigs, on which the short needles are retained from six to nine years, thereby giving great density of leaf-canopy. The shape of the crown is less conical than that of the spruce ; in older trees it generally becomes somewhat bushy after the growth in height is practically completed, and makes the crowns look from a distance as if a large nest had been built near their tops. Its demands on growing-space are therefore on the whole of a very moderate character, although not quite so limited as in the case of spruce.

The silver fir is a deep-rooting tree. Its tap-root resolves itself at an early age into several main branches, which push their way deep into the soil and form a heart-shaped root-system ; side-roots developed near the surface also tend to penetrate into the lower layers so long as the soil is not wanting in depth.

Requirements as to Soil and Situation.—For normal development the silver fir requires[1] a mean annual tempera-

[1] Willkomm, *Die Forstliche Flora, &c.*, 1887, p. 103.

ture of at least $43\frac{1}{4}°$ Fahr., and a mean temperature of $63\frac{1}{4}°$ Fahr. during July and August, whilst it can bear without injury a mean temperature during January not lower than $20\frac{3}{4}°$ Fahr. Localities with great extremes of summer heat and winter cold are less suited for it than for the spruce, and also such as have great atmospheric humidity, although its growth is decidedly better in moderately damp air than in dry localities. Near its lower vertical limit it naturally seeks the cool, moist, gently sloping northern, north-eastern, and south-eastern aspects, whilst towards the upper limit considerations as to warmth necessitate its growth on the sunnier southern exposures.

In demands as to mineral strength of soil it occupies a position between the beech and the spruce. The richer soils of the older geological formations favour its development, but it is also found forming extensive forests, especially when grown along with spruce, on the better varieties of sand. Cool slopes with limy or clayey soil often show vigorous growth, but the timber is generally somewhat inferior in quality. The thriving of the silver fir is, in short, less dependent on any particular kinds of soil than on a fair amount of moisture permeating deep into the soil and subsoil, and on favourable situations, such as the coombs and hollows, the dingles and dells, and other protected localities in the sinuosities of mountainous tracts and hilly ranges. Whilst dry soil is unfavourable to it, on wet sour land it cannot thrive at all.

Requirements as to Light.—Among the forest trees silver fir ranks first in capacity for bearing shade, even excelling the spruce in this respect to a slight degree, as might be expected from the longer life of the old foliage. This high shade-bearing capacity enables its natural reproduction to be much more easily carried out than might otherwise be the case, as after standing for a long time, first under the necessary shelter, and then under the unnecessary shade of the parent trees, the seedlings retain for twenty to thirty years, and often more, the capacity of attaining a good normal development when the standards are finally removed in accordance with whatever conditions as to fall and clearance are laid down by the working-plan.

For the retention of soil-moisture, shade during the first few years is indispensable, and during the youthful period of growth a moderate amount of it is not injurious, although of course the extent to which it may be borne without injury depends in each case on the concrete factors of soil and situation.

Attainment of Maturity and Reproductive Capacity.—The silver fir attains in the Black Forest[1] an age of 300 to 400 years, and stems of 130 to 150 ft. in height, with a girth of 13 to 18 ft. at breast-height, are frequently to be met with in that district. The period of rotation is usually fixed at about 120 years, and natural reproduction by seed is spread over a term of twenty-five to thirty years, or even forty years, in order to allow the standards to thicken in girth and rapidly develop into valuable timber; on the lower hills, where the younger assortments of timber have a fairly good market, periods of rotation vary from 80 to 110 years, with reproduction extending over fifteen to twenty-five years. Seed-production on a scale sufficient to accomplish natural regeneration begins about the seventieth year, and whilst some seed is expected on an average once every two years, a good year may be looked for about every third year. Owing probably to the oil in the seed, essential in its character and therefore liable to be dissipated by evaporation, its reproductive power soon diminishes, and the quality is good when test experiments show a germinative capacity of 50 to 60 per cent. There are about 11,000 to 13,000 seeds in one pound, without

[1] Gerwig, *Die Weisstanne im Schwarzwald*, 1868, pp. 67 and 87.

wings. As with the spruce, a good seed-year can generally be foretold by the flowering shoots being bitten off and thrown down by squirrels. The cones ripen in the September or October after flowering, and the seed is shed at once in the autumn, so that arrangements for collection must be made early.

Liability to Suffer from External Dangers.—In comparison with spruce, the silver fir is less exposed to most kinds of danger. Deep-rooted, however, though it be, it is still liable to be thrown by the wind; but as each individual tree has its own well-developed root-system, storms are seldom able to make whole forests windfall, only the upper portions of the stems being usually broken off, which happens especially when the stems are attacked by cankerous fungous disease (*Æcidium elatinum*). Injuries caused by snow or ice are also, owing to the greater elasticity of the branches, less wide-spread or serious than in the case of the pine or the spruce, and the loss of a leading-shoot is soon replaced by one of the side-branches assuming that function.

As in the mountainous regions where the silver fir is indigenous there is little or no variable spring weather, but wintry conditions may be said to obtain till late in April or even May, and then a sudden change, extending often over only a few days, takes place to summer-like heat, the danger from late frosts in spring or early frosts in autumn is not great; and it is further lessened by the usual form of natural reproduction carried out under the shelter of the parent trees. It is greater in localities at lower elevations, or near its northern limit of indigenous growth, where the leading-shoot is apt to be killed by frost during the youthful period before it can raise its head out of the coldest, damp layers of air near the surface of the soil.

Insect enemies also attack the silver fir less than other conifers, and they do not in general commit the same ravages over extensive areas. *Gryllotalpa vulgaris*, both as grub and perfect insect, feeds on the roots of seedlings, and *Melolontha* species damage plants of two to three years old both in nurseries and in the open, whilst the weevil *Hylobius abietis* gnaws their bark ; the sap-wood of poles and trees is devoured by the larvæ and beetles of *Bostrychus curvidens* and *Hylastes palliatus*, and the timber of felled or fallen trees by those of *Xyloterus lineatus*, whilst the leaves of both young and old trees are occasionally almost decimated by the caterpillars of *Liparis monacha*, *Tortrix murinana*, and *Grapholitha rufimitrana*. But in comparison with the injuries inflicted on Scots pine or spruce by insect enemies, those to which the silver fir is subject are usually slight ; when, however, a periodical plague of *Liparis monacha* sweeps across the coniferous forest tracts, its foliage too is requisitioned by the devouring legions of voracious caterpillars.

Red-rot in the timber is occasionally caused by *Polyporus vaporarius*, and white-rot by *P. fulvus*. Like most conifers, it is liable to attacks from *Agaricus melleus* and *Trametes radiciperda* at the base of the stem and in the roots, whilst *Trametes pini* and *Æcidium elatinum* are often very injurious to the bark and the sap-wood of stems and branches (the mistletoe-like excrescences of twig-clusters—called *witch's brooms* in Germany—often seen at the tops of old trees, being due to the latter), and less frequently *Nectria cucurbitula* in the bark ; *Æcidium columnare*, *Hysterium nervisequium*, and *Trichosphæria parasitica* occasion leaf-diseases, but seldom of any very injurious nature. Along with the spruce, it is also subject to injury from *Pestalozzia Hartigii* in nurseries and young plantations, the bark assuming a diseased condition just above the soil. Roe and red-deer often seriously damage young plantations, especially beyond the natural limits of growth of the silver fir, when it is planted as a subordinate species along with other conifers; and during the pole-forest stage of growth deer sometimes peel the bark to a considerable extent, though in this respect it suffers less than spruce. In recuperative power, however, it far excels spruce, and has even some advantage over Scots pine.

Sylvicultural Treatment of Silver Fir.—Notwithstanding its large timber production per acre (*vide* page 44), its fine cylindrical growth, its high percentage of timber of the largest assortments, and its other good qualities from a sylvicultural point of view, opinions are divided in Germany about the advisability of extending its cultivation in pure forests on areas otherwise suitable for spruce. In the warmer districts of southern Germany, where, according to the custom of the trade, the prices of timber for export are fixed with reference to the upper-end girths, its more full-wooded stem gives it an advantage over the spruce; but in central Germany the area over which the silver fir forms pure forest is less now than formerly, and there seems no desire to diminish the area under spruce in its favour, as on the whole spruce yields better, stronger, and more durable timber, which also fetches better prices in the open markets within reach of export.

Thus whilst in Britain actuarial considerations will naturally point to the formation of pure forests of spruce rather than pure forests of silver fir, other prudential considerations will even more emphatically urge to the more frequent formation of mixed forests, which not only (as already mentioned at length in treating of the spruce) yield greater quantities of timber per acre than either variety of pure forest, but also ward off, or at any rate diminish as far as possible, calamities to which spruce forests are unfortunately liable, arising from snow and ice, violent storms, and the devastations of insects. So far, too, from its natural zone of distribution and its warmer southern home, pure forests of silver fir could scarcely be expected to yield in Britain, and especially in Scotland, such favourable outturn of large timber per acre as in southern Germany and France, so that it seems here principally suited for admixture along with some other ruling species. There are in particular three cases in which the sylvicultural importance of the silver fir can hardly be questioned, viz.—*firstly*, as its branches have a considerable degree of elasticity, it suffers less from breakage through snow or ice than either spruce or Scots pine, and consequently minimises damage arising therefrom in mixed forests, whilst being also less liable to infection from root-rot (*Trametes radiciperda*) than the spruce, it therefore in mixed forests hinders the disease from becoming wide-spread and serious, and thereby directly improves the ultimate outturn from the mature crop; *secondly*, in forests of broad-leaved, deciduous species, in which for obvious sylvicultural reasons beech ought usually to be the principal ruling species, the silver fir is on the whole better able to accommodate itself to the peculiarities of growth of broad-leaved trees, and in general yields better returns than other conifers; *thirdly*, as on suitable soil it bears more shade than any other conifer, not even excepting the spruce, it often yields excellent service when planted as underwood, especially under oak or under Scots pine on a somewhat binding soil, without losing the power of developing fairly into good, useful timber when the overwood or standards have been cleared for sale. In the filling up of blanks, where the shade may be somewhat too great for even the spruce, it is a welcome species except where frost is to be feared.

When grown in pure forests in southern Germany, it is usually worked with an average rotation of 100 to 120 years; even on soils of average medium quality the outturn per acre varies from 8,700 to 10,900 cubic feet per acre, as shown by the yield tables of the Baden forest department, although for the Black Forest Schuberg gives 11,600 to 14,500 cubic feet per acre for average soils and situations, and up to 16,820 cubic feet for the best localities.

With its strong recuperative power, silver fir suffers little when branches are removed, either for decreasing the shade cast, or for the production of large clean boles; this operation is best conducted from the middle of August till October, and by means of the saw. With its naturally dense habit, thinnings of this species should be on the whole light, until the tree-forest stage of growth has been reached, when they are made somewhat heavier in order to stimulate the trees to rapid growth in girth, except on exposures liable to heavy falls of snow.

Pure Forests of Silver Fir.—No other species of forest tree has so slow a development during the youthful period as the silver fir, for its growth is at first in breadth rather than in height, no matter whether naturally or artificially reproduced from seed or by means of planting; it is a peculiarity of its growth that there is generally one very long side-shoot, probably provided by nature for the purpose of protecting the soil-moisture. At ten years of age the silver fir is usually no larger than a four-year-old spruce, but from about ten years of age its growth in height in the open becomes vigorous. The growth of the leading-shoot is not energetic so long as the young crop stands under shade, which it often has to do for twenty to thirty years and even longer, often under dense shade from the parent standards. Its latent energy and recuperative power are, however, such that when the standards are removed, and a fuller measure of exposure to light and air is available, an energetic growth in height at once sets in on good soils, and is of long continuance. Seedlings grown under light shade from the side or from above, and plantations in the open, begin to develop leading-shoots normally from about ten years of age; they attain the maximum average annual growth in height on soils of the better class about the twenty-sixth to thirtieth year, on average soils about the thirtieth to fortieth year, and on the poorer classes of silver fir soil about the fortieth year (*vide* tables on pages 36 to 38).

Notwithstanding its latent energy in growth, seedlings of silver fir run considerable danger from rank grasses, frost, or drought, unless they are reared under the protective shade of standards, and during the first two or three years they are absolutely classifiable as *shade-demanding* like the beech. When once the young crop has outgrown these three dangers of the earliest period of growth, and has formed thicket, it quickly develops into the pole-forest stage, and continues to maintain a lively growth in height, although not in general quite so energetic as in the case of the spruce. It is only during the pole-forest stage of growth that silver fir is much exposed to breakage from snow.

The timber of silver fir trees grown in pure forests is not so good in quality as when it has been produced in mixed forests, a circumstance which offers an additional reason, if one were at all necessary, for preference being given to the formation of mixed rather than of pure forests. Where, however, pure forests are desired, silver fir can yield more satisfactory results when worked in numerous small patches than when operations are strictly confined uniformly to one large area during the period of reproduction and of utilisation of the mature crop. This method of treatment has reached its highest development in the state forests of Baden. The parent standards, showing wide differences in age, are scattered over the whole area in groups whose canopy is interrupted to a constantly varying degree, whilst the younger crop is similarly scattered about in groups or patches varying from ten to twenty up to fifty and sixty years of age. The increase in girth on the standards in full enjoyment of sunshine and air is very rapid, and far outweighs in technical and monetary value the loss of increment on the young crop, without prejudicing the future development of the latter in due time. Schuberg found a greater cubic quantity of timber per acre on forests treated thus than was to be found when the forests were reproduced more regularly in smaller blocks, where, with shorter periods of reproduction, the trees forming the mature crops were more nearly equal in age.

Though the average rotation of silver fir is about 100 to 120 years in pure high forest, yet by reason of the special treatment accorded to it for the production of boles girthing well at the upper end, to suit the requirements of the timber market, the actual fall is begun in the mature timber about the eightieth to ninetieth year, and continued till final clearance takes place often only as late as about the hundred and thirtieth to the hundred and fortieth year.

Mixed Forests with Silver Fir as the ruling Species.—Among conifers, spruce is of most importance as a subordinate species in forests where silver fir forms the matrix or major portion of the crop. Where it is intended that the spruce is to remain permanently subordinate till the crop reaches marketable maturity, care must be taken to protect the silver fir whenever the thinnings take place, otherwise the more rapidly growing spruce is apt to form canopy above the silver fir, which then never afterwards gets a chance of a fair share in the enjoyment of light and air. Where, however, the spruce has only been scattered individually throughout young crops of silver fir, it develops into fine stems, often of exceptionally good growth. For practical purposes in Britain, the mixture of spruce with silver fir is of less importance than that of silver fir with spruce (*vide* pages 99 to 101).

As forests of silver fir are usually to be found only on deeper and better soils than forests of spruce or of Scots pine, larch would naturally find a more suitable home along with the silver fir than with either of the other two conifers forming pure forests. And where such opportunity is available the admixture of larch with the silver fir, either singly or in patches or groups, is productive of excellent results, the larch developing rapidly and healthily into fine stems, whilst on good soil the silver fir maintains itself fairly well under the light shade of the larch.

Where forests of silver fir exist, Scots pine also thrives uncommonly well in admixture along with it, and, though still remaining a light-loving tree, is by no means so impatient of shade as on the poorer soils where alone it is usually to be found in pure forests. Stimulated by the deep moist soil and the beneficial protective shade cast thereon by the unbroken canopy of silver fir, it shoots up with a straight, full-wooded bole, and though ultimately caught up in growth in height by the latter, it can hold its place fairly well in the canopy till about the hundred and twentieth year, when it may be removed as a stem of fine dimensions and very good marketable value. Even when no advantage in age over the silver fir is given to it, its quicker development in early years secures to it a substantial benefit, and all that is requisite later on is some little attention when thinnings are being made during the period of largest annual increment in height of the silver fir, that is to say, during the pole-forest stage of growth of the latter; on good situations even this is unnecessary, as the pine generally maintains the advantage it has won. On deep fresh soils, where Scots pine has been planted pure on account of temporary deterioration of the soil, the underplanting of thirty to forty-year-old pole-forests of pine with silver fir often yields very excellent results, as the former gains immensely through the soil being kept cool and moist, and the latter can often thrive well under the light shade and grow up to form canopy along with the pine, so that the whole attains maturity as a mixed crop. In such cases indifferent stems of pine should of course be removed in favour of the younger silver fir.

Mixed forests of silver fir and beech are of considerable sylvicultural and economic value on suitable situations, but as the latter almost always forms the ruling species, the nearer consideration of such woods will be more convenient later on (*vide* pages 175, 176).

In demands as to soil and situation, the oak resembles the silver fir much more than it does the spruce, so that an admixture of oak, in forests where silver fir is the principa species, is by no means out of accordance with the teachings of nature, though such a mixture is more successful when the beech also finds a place in the woods. When oak and silver fir are to form a crop of nearly the same age, an advantage must be won for the oak by the use of good stout transplants, and by putting them out as early as possible. Even then, however, it is of little use to plant singly, or in rows, or small patches, as the oak is almost bound to be sooner or later overtaken and suppressed by the more rapidly growing silver fir. Experience has shown that it is best to introduce the oak in large groups, which are able to form canopy for themselves and to throw sufficient shade on the ground to hinder the silver fir somewhat in normal development; later on, when the oak begins to have an interrupted canopy, the weaker stems can be thinned out so as to permit of the silver fir enjoying a greater measure of light and air, and in the later stages of growth the oak will usually be found to require some protection against the ruling species. Long before reaching maturity, such groups are considerably reduced below their original area, for the silver firs growing round the edges usually succeed, despite ordinary operations of tending, in overtopping and suppressing the oaks along the fringe of the groups. As a matter of fact, such mixed forests are in reality very small oak woods prematurely underplanted with silver fir; an equally satisfactory and perhaps safer method would be to form pure clumps of oak, thin them out moderately in the pole-forest stage of growth, and then underplant with silver fir.

Silver fir forests with a fair percentage of oak and beech often yield on good soils most satisfactory returns, as a high percentage of the total outturn consists of timber of valuable dimensions both as regards length and girth.

Self-sown birches are often to be found in blanks in forests of silver fir, and are welcomed wherever there is a tendency to rank growth of weeds, by suppressing which better opportunity is given for natural reproduction of the silver fir. On average qualities of soil the fir is perfectly well able to maintain itself under the moderate shade of the birch, which, however, should be cut out at about thirty to forty years of age, otherwise it interferes with and damages the leading-shoots of the ruling species.

Formation and Reproduction of Silver Fir Forests.—Forests of silver fir are treated in many respects similarly to beech crops; in pure forests they are mostly reproduced naturally under the shade and shelter of parent standard trees. In mixed growth of silver fir and spruce a similar method is also adopted, but when light-loving species are underplanted, planting up with small seedlings or transplants is generally preferred to sowing.

Natural reproduction is seldom so complete as to be altogether independent of artificial assistance in the way of sowing or planting. For the formation of woods in the open, planting is adopted, as sowing leads to greater danger from rank growth of grass; in both cases, however, wherever the shelter of standards is wanting, some quick-growing temporary nurse is requisite in order to diminish the danger from frost. It is only during the first year or two that seedlings of silver fir absolutely require the shade and shelter of parent trees or protective standards, as, except at first, side-shade is on the whole more beneficial than direct over-shadowing. During natural reproduction, seedlings often spring up in blanks where parent standards are wanting, and do well in the shade cast laterally by neighbouring trees or woods, particularly where such protection is afforded to them against the hot midday and early afternoon sun; they thrive well, too, under shrubs and upright-growing weeds so long as there is no danger of their being choked beneath rank grasses, against which, as against late frosts, they require some protection. Protective reasons, therefore, combined with considerations relative to stimulation of the mature crop towards an accelerated increment in girth, have led to natural reproduction under parent standard trees being the usual method of regeneration adopted with the silver fir. Its fair germinative power, and the high capacity of the seedlings for bearing shade, adapt themselves well to this form of reproduction, for even in mixed forests a comparatively few seed-shedding trees yield a fair proportion of seedling growth capable of good development if favoured during the subsequent operations of tending.

Silver fir and beech correspond closely in regard to the various stages of natural reproduction; the extent to which the mature crop should be removed and the ground should remain overshadowed, before, during, and after the principal seed-year, is in general about the same, with perhaps a slight tendency to greater density of the silver fir standards, except where the soil is somewhat wanting in moisture, and the young crop consequently stands most in need of atmospheric precipitations. These two species correspond also in the length of time requisite for natural reproduction under the mature parent crop, and though reproduction is usually extended over a longer period in the case of the silver fir, this arises from actuarial motives rather than from sylvicultural requirements.

In extending the reproductive process often over thirty years and more, the gradual clearance of the parent stems takes place more slowly than is at all necessary or beneficial to the younger crop; but this delay in the removal of the standards has its substantial reason in the financial advantage to be gained by allowing the smaller classes of standards to thicken in girth near the top of the bole, and thus to attain more profitable dimensions. The solution of this problem is more easy in the case of the silver fir than of any other conifer, and the advantage to be gained much more than counterbalances the temporary poverty of annual increment in the young crop.

It is true that, under this method, the appearance of the young growth after the final clearance of the mature crop resembles a series of patches and groups of different ages and heights; but experience has shown that this is productive of less permanent harm in the case of silver fir than of any other tree, and in central and southern Germany the method continues to enjoy the favour of the most eminent sylviculturists.

Where, however, timber prices are good, and transport is easy and cheap, it by no means follows that the production of equal-aged crops, and their complete removal by total clearance annually, as in the case of Scots pine and spruce, followed by immediate planting up of the area cleared with good transplants, might not in Britain prove more remunerative than the above-sketched method of natural reproduction under parent standards, with only very gradual clearance of the latter.

The long retention of standard trees on areas under reproduction naturally leads to a desire for the removal of all branches not strictly requisite for increasing speedily the girth of the top end of the bole, and, thanks to the strong, quick, recuperative power of silver fir, this process can be carried out without much fear of the quality of the timber being prejudiced.

In the reproduction of mixed forests some attention must be given to the silver fir during the youthful period of growth, as otherwise species like beech and spruce, when they have once won a material advantage in growth in height, are apt to maintain it permanently afterwards, for the silver fir is not able to attain its normal energetic development under the strong and repressive side-shade cast upon it by these densely foliaged trees when predominant. Such mixed forests of beech and silver fir are best reproduced naturally, with the result that the young crop is scattered in mixed patches and groups over the area; when the mature crop consists principally of silver fir with spruce or Scots pine, natural reproduction of the silver fir is first carried out, and then an admixture of the subordinate species in groups of transplants takes place.

For the formation of new forests of silver fir, or its introduction as a subordinate in forests of other ruling species, sowing and planting are both applicable, although as a rule planting in general finds greater favour, and sowing is confined to places where there is some canopy overhead or other protection against rank grass, frost, cold winds, &c. A heavy fall of leaves is also apt to choke the young seedling growth, and even the heavy shade of beech standards is less beneficial than the lighter canopy of oak, pine, or larch.

Natural Reproduction.—Before the clearing for reproduction is made, in order to stimulate the parent trees to increased formation of flowering-buds (cones), preparatory fellings are usually carried out, which are in reality only an accentuated measure of thinning out, an operation otherwise lightly performed in crops of silver fir of advanced age. When the actual felling for reproduction takes place about ten years later, the extent to which the standards are removed is mainly dependent on the nature of the soil, the greatest number being retainable on the fresh or moist patches where the young crop is likely to suffer less from the overshadowing of the standards. On drier patches reproduction in groups is preferable, where the seedlings can have the full benefit of rainfall and dew whilst still obtaining the protection of side-shade; in hollows, and coombs, and all other places where frost is to be feared, the disposition of standards should be nearly equal over the area. This clearing for reproduction should be made when the number of cones shows a favourable year, as otherwise, should the seed-harvest fail, moist soil is apt to become overgrown with weeds, and dry soil to become somewhat deteriorated. Where self-sown growth has already taken possession of the soil in patches, it should be tended as far as possible by removal of standards above it, especially of those in the centre which are likely to do most damage by overshadowing. By this method of reproduction, however, considerations regarding the young crop are really subordinated to those relative to the greater remuneration expected in the harvesting of the mature crop, so that in general the canopy of the standards is interrupted only so far as to ensure the ultimate well-being of the younger growth, when it at length attains the enjoyment of a greater measure of light and air. The clearance in a seed-year is therefore, under normal conditions of soil, usually confined to such interruption of the canopy that the crowns of the standards cannot close up again for the next four or five years. Atmospheric precipitations can under these circum stances reach the soil in sufficient quantities to satisfy the young crop, whilst, should any accidents befal the seed or the young seedlings, the canopy above is sufficient to protect the soil against rank growth of weeds on moist soil, or deterioration on dry, until another good seed-year comes round. As a matter of course the first trees to be removed are those of subordinate species, and also such as are not likely to profit much from further retention.

Wherever the soil seems to have good receptive capacity for the seed, which is particularly the case when the soil-covering consists of a thin layer of *Hypnum* moss, an average interruption of the canopy may be made without any hesitation, and where such thin layer of moss, or a slight covering of dead leaves, or perhaps a very light growth of grass is found on the soil, no preparation is usually necessary to stimulate it for the reception of the seed. In places where there is tendency to a strong growth of grass on moist soil, it usually happens that the previous measure of light accorded has already, without any seed-felling, resulted in a self-sown growth of young silver fir, before the light became strong enough to favour the ranker development of the weeds. But, as might be expected, the more difficult problems of natural reproduction of this species have to be faced where the soil is deficient in moisture, or where there is a strong tendency towards rank growth of grass. Where the layer of moss is thick, or the covering of whortleberry or heather at all considerable, some measure of soil-preparation is seldom avoidable. In the former case the removal of the moss with wooden rakes in strips of twelve to sixteen inches will be sufficient, but in the latter some work with the hoe may be necessary, the strips being usually made about eighteen to twenty-four inches broad, and in either case of course prepared before the fall of the seed during autumn. Under ordinary circumstances the seed requires no artificial covering, but in localities where seed-production is somewhat deficient, and where there is probability of early germination and consequent danger from late frosts, it is advisable to go over the strips with iron rakes after the seed has fallen, unless the soil has been previously broken into clods with the hoe.

Where the wishes of the proprietor lead to the formation of forests in which the annual or periodic fall is to consist of timber of about equal age, there exists less necessity than in the case of the spruce for dividing the total area under silver fir into separate independent blocks, each having its self-contained growing-stock of all ages from one year, or the mean age of the first period, up to maturity, or the mean age of the last period. The rate at which the clearance of the standard trees takes place after natural reproduction has been satisfactorily carried out, depends to a great extent on local circumstances; in some places it is gradually performed by the annual removal of a portion, in other places a heavier fall takes place only every four or five years. Most anxiety is caused on moist soil where there is no proper covering of moss, but a strong growth of grass instead, or again on dry slopes with southern exposure. On good fresh soil the retention of the standards in greater numbers does not permanently injure the seedling crop, but on dry situations deficient in soil-moisture a speedier clearance must take place in order to let the young growth have the full benefit of dew-fall, without which any considerable degree of overshadowing might soon permanently damage the weakly crop, or materially prejudice its ultimate recuperative power after removal of the standards. On dry soils the total clearance can hardly be delayed more than eight to ten years after the seed-felling, and in some cases it is advisable to complete it as early as the fifth or sixth year.

In addition to considerations as to the direction of prevailing high winds, some heed must be taken in regard to the extraction of the mature timber from the regenerated areas in such a manner as to entail least injury to the young crop. This is effected most advantageously when the fellings for reproduction are conducted so that the commencement is made from above, instead of from below, as would be the case if only danger from storms required to be taken into account. In addition, the areas on hill-sides are not felled over in oblong but in rhomboidal form, and at as sharp an angle as convenient, in order that on the extraction of mature trees the timber may be dragged as speedily as possible into the tree-forests adjoining, and which will be the next to be operated upon. That of course such areas should be as long and narrow as possible hardly requires mention; but local circumstances of soil and situation assert themselves just as much in this as in most other matters. Greatest damage is done to the young growth when the felling and the extraction of the mature stems take place in winter during frost and without a heavy fall of snow on the ground; less damage is done when operations take place in summer, especially after the young shoots have hardened fairly, and when the stems have been barked to avoid attacks of weevils and bark-beetles, and to make it lighter for transport and whiter in appearance.

In the Black Forest, a method recommended by Gerwig[1] consists in reproducing in patches of about twenty-four to thirty feet diameter cleared here and there over the whole area, or of larger diameter where the soil is deficient in moisture. As a prudential measure, seed is sown broadcast over such patches without trusting to seed being shed by the surrounding trees, and the gradual clearance of the remaining standards takes place by widening the diameters of the patches till finally all the mature crop has been harvested.

[1] *Die Weisstanne im Schwarzwald*, 1868, p. 97.

Artificial Formation and Reproduction of Silver Fir Woods.—The results of natural reproduction are seldom so complete as to be entirely independent of artificial assistance in the way of filling up blanks. So long as standards admit of it, sowing often has the preference, but otherwise the use of seedling plants is usual, and wherever there seems little prospect of a natural crop of seedlings being generated by the parent trees, the artificial assistance is best given at once without waiting for seed-years which may again prove disappointing. Where sowing has been decided on, little soil-preparation is requisite beyond the removal of too thick a layer of moss in strips with a rake, or, at most, breaking up of the soil in narrow strips with the hoe, or on squares, or small oblong patches here and there, or horizontally on steep hill-sides. When the filling up of blanks takes place, all badly-grown young poles should be removed, and transplants of one, two, or three feet in height with large balls of earth around the roots can be utilised from the neighbouring patches of denser growth which have been freely exposed to light; they can be put out at three, five or even six feet apart, according to the size of the transplants. It is, however, not necessary or advisable always to plant up such blanks with silver fir, for it presents a very good opportunity for the introduction of spruce or pine as a subordinate species.

Although natural reproduction is the usual method of treatment of the silver fir, there are many cases in which a choice is given only between sowing and planting, as for example in introducing silver fir as a subordinate into mixed forests of other ruling species, or transforming woodlands of other species into coniferous forests, or in the formation of woods which have not recently been under any timber crop.

Sowing is usually adopted only where there is a sufficient canopy above to give the necessary amount of protection to the seedlings after germination, and the rapidity with which the removal of the protective standards is advisable depends on considerations affecting both the mature crop and the soil. With any species like spruce, danger from wind would point towards speedy clearance (total clearance of the spruce, and planting up at once would, however, be the usual method adopted), but under pine the soil would probably be drier and likewise demand the rapid removal of the standards.

Where the protective standards consist of conifers, seed-beds are prepared as for natural reproduction in strips or patches, upon which the seed is sown as soon as possible after the ripe cones are obtainable, since, owing probably to loss of the essential oil contained in it, the seed rapidly loses in germinative power; a sufficient covering is given if the strips or patches are gone over lightly with an iron rake. Under standards of deciduous species, where the seedlings are apt to be choked by the dead foliage, narrow bands of about one and a half feet broad are prepared with the hoe, the earth being heaped up in the middle so as, when pressed down, to form a ridge about four inches in height along which the seed is sown in a rill and then covered by gentle raking. The distance between these bands depends on the proportion in which the silver fir is intended to form part of the future crop; if it be intended to form the ruling species, the recurrence of these strips should take place six feet apart, which comes somewhat expensive, but if only $\frac{1}{4}$ to $\frac{1}{3}$ of the crop is to consist of silver fir, they need only occur every 18 to 24 feet apart. When sowings of silver fir have been made in places where the young plants are apt to get covered with dead foliage, they must be freed from this during the second and third years before they send out their young shoots; but from the economical as well as the sylvicultural point of view, the adoption of the method of planting in groups will usually be found a speedier and preferable way of attaining the object desired.

Planting of silver fir can take place with satisfactory results in the open, though when it is available some protection from light standards, or from side-shade, is at any rate desirable; but in localities subject to late and early frosts it becomes essential, and if not available, necessitates the planting of some quick-growing species like birch, pine, larch, willow, or alder, as a nurse.

The silver fir can be planted out with naked roots up till the sixth year, but after that successful results are only to be expected when the plants are put out with balls of earth attached. Its development at first is so slow, and at the same time its sensitiveness to drought or rank growth of grass so unmistakable, that it is never planted out as a one-year-old seedling, and even as two or three-year-old seedlings only under protective standards in localities tolerably free from a soil-covering of grass or fallen leaves.

The best material is doubtless four or five-year-old transplants that have been pricked out in the nursery as two-year-old seedlings. They develop so much more equally and quickly than unschooled plants, that the results are well worth the slight difference in the cost of the plants over those obtainable from patches of self-sown growth.

The methods of planting are essentially the same as with the spruce, but when naked seedlings are used, particular care must be taken to maintain the rootlets moist by dipping them from time to time in mud or loam; each planter should be supplied with a pot or basket, in which it is easier to keep the plants moist. Where the soil is not tenacious, notching is practicable, but better results will in general be achieved at very slightly greater costs by the use of Heyer's small cylindrical spade for preparing the holes on the area to be planted up, and for lifting the transplants out of the nursery, whereby the danger of the roots suffering from drying up is minimised. Otherwise planting in pits, and in moister localities tumping or planting on mounds, are the usual methods of planting employed. It frequently happens that in these young plants there is no decided leading-shoot, but rather a tendency to forked growth, which should be counteracted by clipping off the minor shoot.

The distances at which the plants are put out are in general the same as with the spruce, that is about 4 feet × 4 feet on the average for transplants; but where young seedlings are notched in, planting is often as close as 4 feet × 2 feet owing to the slower development of such plants, and the consequent delay in the formation of canopy. On the better classes of soil a wider distance, up to 6 feet × 6 feet, is occasionally in usage when older transplants are put out; but when high forests of oak are underplanted, or woods are fringed with silver fir, rows of 6 feet × 3 feet are usually found quite close enough.

The most suitable time for planting out silver fir is spring; planting in autumn should only be undertaken when special circumstances demand it. And as in regard to other species also, but especially in the case of silver fir, planting is least likely to be successful and satisfactory if carried out during dry east winds, which are prone to stimulate the plants to excessive transpiration through the foliage before the roots have established themselves so as to provide for the further due supply of moisture from the soil.

For the preparation of transplants, two or three-year-old plants, but mostly the former, and more seldom one-year-old, are taken from the seed-rills and pricked out in rows in the nursery, where they should stand for three years in order to attain the same development as spruce that has stood for two years, so that the age of the plants is more often five than four years when they are finally put out. When four-year-old transplants are to be used they should be schooled in rows of 5″ × 3″, or 6″ × 4″ if to be used at five years of age, and 7″ × 5″ if at six years of age, *i.e.* if they are to remain two, three, and four years respectively in the nursery beds. Where there are nurseries of oaks, the silver fir transplants can easily be pricked out between them with advantage to the former. Wherever any signs of fungoid disease (*Æcidium elatinum*) are visible on the young shoots, the plants should at once be removed and burned so as to prevent the infection of others. Nurseries should be located in protected spots, and, in particular, where danger from frost is not imminent; windy situations, coombs and valleys, or southern exposures should all be avoided, so long as level or gently-sloping sites with mild, fertile, fresh soil are available.

4. LARCH (*Pinus Larix*, L. = LARIX EUROPÆA, D.C.)

Distribution.—The larch is indigenous to the Alps and the Carpathians, the lower portion of the Silesian and Moravian mountain ranges, and the southern edge of the woodland area of Bohemia and Moravia; outside of these limits its growth is due to artificial measures. In the Bavarian Alps it occurs at elevations of 3,000 to 6,000 feet, and at 1,100 to 2,700 feet on the lower hills of Silesia and Moravia. It is essentially a tree of the mountains, and of the Alpine districts in particular, where it ascends the slopes even higher than the spruce. On the central ranges of the Alps, especially on the southern exposures, and on the eastern branch of the Bavarian Alps, it attains its best development, and often forms pure forests. In the other portions of the Alps it occurs in admixture, mostly in groups and clumps, with the beech, spruce, and Cembran pine, at the different elevations above sea-level corresponding to the habitat of these species. It was introduced into England early in the seventeenth century (1629), into the lowlands of Scotland in 1725 by Nasmyth of Posso, and into the highlands by the Duke of Athole in 1727. The larch has been extensively cultivated in Scotland (twenty-seven millions are said to have been planted out in the highlands between 1738 and 1820), and in northern Germany. Removed thus far away from its true home, and subjected to climatic conditions differing from those that obtain there, its development has often been unsatisfactory and disappointing; its growth is in many parts marked by a sabre-like, curved stem in place of a straight bole, and also too frequently by an unnatural robe of hanging mosses (varieties of *Usnea*), and by cankerous fungoid disease (*Peziza Willkommii*), whilst the foliage is liable to be attacked by the larch-moth (*Coleophora laricella*).

Tree-form and Root-system.—Like the spruce and the silver fir, the larch develops a long, straight stem whose growth in height is of long-continued duration, as in the former especially. Where indigenous, it is characterised by straightness of growth, and attains, in close canopy, a good bole approaching the cylindrical form, and yielding good, long squares and beams. At lower elevations, where its growth is stimulated to too quick a rate in youth, or on stony soil, the formation of the lower portion of the stem is apt to be curved like a sabre. The pointed conical crown of sparse deciduous foliage is borne by slight branches, which do not form whorls round the axis as in the case of the other coniferous species; it retains its conical shape instead of rounding off like the crowns of Scots pine and silver fir at advanced ages.

Its root-system resembles that of the Scots pine, but if difficulties confront the development of a strong tap-root, it possesses considerable accommodative power of throwing out stout side-roots so as to form a heart-shaped system like that of the silver fir. On shallow or rocky soil it develops many and far-reaching surface-roots like spruce, which utilise every opportunity afforded by cleavage and fissure to penetrate deeper down. Under these latter circumstances the larch makes greater demands on growing-space than when the soil is deep.

Requirements as to Soil and Situation.—Somewhat higher demands in regard to atmospheric warmth are made by the larch than by its companion in the same region, the spruce. The minimum of total annual warmth believed to be necessary for the attainment of its normal development is estimated[1] at about 3,010° Fahr., which corresponds with the isotherm indicating a mean annual temperature of 36·8° Fahr. as its northern limit of growth. Extremes of winter cold are borne by it better than intense heat in summer. The short spring, followed quickly by equable and moderate summer warmth, to which, after a short autumn, the long winter period of rest succeeds,—the characteristically Alpine climate,—is the natural one in which it thrives best. There it attains its most vigorous growth in the hollows and coombs along the mountain sides, where it has protection from the violence of the storms. The larch can thrive in dry cool mountain air, but its frequent association with the spruce in hill forests proves that a considerable degree of atmospheric humidity is, if not requisite, at any rate rather beneficial than detrimental to its growth and development. When grown in localities

[1] Willkomm, *Die forstliche Flora, &c.*, 1887, p. 121.

beyond its indigenous northern limit, it prefers a damp insular climate, as in Scotland, Denmark, and Norway, rather than a dry one like that of north-eastern Germany, and does best on warm exposures that are not apt to be dried up by sun or wind.

As might be expected from the formation of the root-system, depth is the first quality demanded by the larch from any soil. Light, stony, moderately fresh mountain-soil suits it best on the whole, but a slight degree of tenacity is more favourable than the tendency to the opposite extreme often exhibited by sandy soils. In its Alpine home it is frequently found in excellent growth where boulders and stones cover the ground, provided that there is between them a fairly good deposit of humose soil, and that the penetration of the roots into the sub-soil is not hindered. As in the case of the Scots pine, constant equable distribution of moisture throughout soil and subsoil is the condition most favourable for the growth of the larch ; but though making greater demands than the pine, its requirements in this respect are not so great as those of the spruce. Wet soils, more especially when tenacious, are not suited to it, but still less suitable are those of a dry description.

As to mineral strength, its demands are certainly somewhat greater than those made by the spruce, although soil-moisture and depth are of greater importance to it than richness in mineral constituents. Loamy limes are exceedingly favourable to its growth, also the loamy soils arising from the decomposition of granite, basalt, clay-slates, and dolomite, whilst loamy sands, apart from their greater freshness, seem also to suit it better than sandy or limy soils either in the valleys, or on the uplands. The greatest claims are made on mineral strength where the larch is grown away from its indigenous region, and transplanted to tracts where climatic conditions obtain differing greatly from those of its true home.

Requirements as to Light.—The larch is the most light-demanding of all conifers, and indeed of all our forest trees with perhaps the exception of the birch. Even in the Alps it is intolerant of shade falling from above, and can bear side-shade only on the better classes of soil. It is enabled to maintain the crown well in advance of other forest growth of equal age, owing to its very rapid growth in height, which is well maintained throughout its whole period of development. For the normal growth of larch, therefore, such provision must be made as will secure to each individual stem a due amount of enjoyment of light and air without danger being incurred of the summit of the crown being interfered with by pressure or shade of the crowns of neighbouring trees.

As larch is, even where indigenous, so essentially a light-loving tree, it is only what might be expected that, in our northern but by no means Alpine climate, its demand for light and freedom of crown should be accentuated so as to be absolutely the first condition for its satisfactory development, except on soils very much above the average in quality.

Attainment of Maturity and Reproductive Capacity.—The introduction of the larch on a large scale into Scotland was begun by the Duke of Athole in the second quarter of the eighteenth century, and most of the oldest original plantations in northern Germany were also formed between 1725—1756. The bad growth in some localities necessitated clearance at forty to fifty years; others gave good timber at sixty years, while on the better situations larger timber was kept over till about eighty years. Unless, however, planted up with underwood to protect the soil, a rotation so high as a hundred years is not advisable with the larch. Away from its Alpine home, where it attains an age of over two hundred to two hundred and fifty years, and forms dark red heartwood greatly prized on account of its extraordinary durability and high general excellence, its timber never attains the same quality, because the whole of the natural conditions of its growth are interfered with. When branches are removed, either intentionally or accidentally, close to the stem, larch possesses the power, rare among conifers, of being able to throw out shoots, but its reproductive power in this respect has no sylvicultural value whatever.

It bears seed early and often from about the twentieth to thirtieth year, and this retains its germinative power for three or four years, although fresh seed is always preferable when obtainable. The small cones ripen in October or November of the year of flowering, and the seed is scattered in the following spring; the old cones remain sessile, but the new are easily distinguishable by their light brown colour from the old weathered cones of any former year's production. A germinative power of 30 to 40 per cent. shown by experimental tests to determine the quality of the seed is considered satisfactory. The seeds are just about the size of those of the spruce, but not having the same rich brown colour are easily distinguishable from them, and they are considerably lighter as 72,000 to 77,000 go to a pound.

Liability to Suffer from External Dangers.—In the mountainous tracts in which it is indigenous, the larch suffers little from frost, or, being a deciduous tree, from accumulations of snow or ice, though in localities into which it has been introduced, the atmospheric changes affect it more; the damage done, however, is seldom serious. But under the latter circumstances, and in proportion as soil and situation are unsuitable to its growth, the larch has developed a tendency to suffer from the attacks of caterpillars of *Coleophora laricella* and *Grapholitha pinicolana* on the foliage, and from the much more serious fungoid disease occasioned by *Peziza Willkommii*, which breaks out most frequently in the pole-forest stage of growth (ten to twenty-five years), and more especially after bad attacks of the above-named insects. With these exceptions the larch does not suffer much either from fungoid diseases or insect enemies, although it shares the liability of other conifers as regards the rot caused at the base of trees by *Agaricus melleus*, and the canker in stem and branches due to *Trametes pini*; red-rot is occasionally generated by *Polyporus sulphureus*.

Similar remarks obtain with regard to its resistance to storms. In the Alps, its deep root-system, its leafless condition during half the year, and the elasticity of its branches and of the upper portion of the stem, secure it comparative immunity from the violence of heavy winds; but on the lower hills, uplands, and valleys, where it has often been somewhat indiscriminately planted, its power of resistance is weakened, although this is still not to be reckoned slight.

It is eagerly sought after by roe and red-deer, and notwithstanding great recuperative power, the damage done is often considerable, as affording a favourable germinating bed for the spores of *Peziza*.

Sylvicultural Treatment of Larch.—Even where indigenous, the larch is much less frequently to be found forming pure forests of large extent than in groups or clumps along with spruce, beech, and silver fir at lower elevations, or as the ruling species in mixed forests containing spruce and mountain pine towards the upper limit of vegetation. Thus the pure forests that have been so frequently formed in Scotland are at the very outset a departure from, and almost a contrast to, its natural habit of growth. Its cultivation in the mountainous tracts of central and northern Germany and eastern France has on the whole been as unsatisfactory as in the Scottish Highlands. Although at first more rapid in growth than the spruce, it did not long fulfil its early promise, but was often caught up in growth, if it had not already sickened and died off, and had finally to be cut out. Somewhat better results were in general obtained on the more level situations and uplands (in Scotland up to 1,500 feet) than at elevations corresponding more to an Alpine climate, and in Scotland, Denmark, and Norway plantations near the coast thrive well when not directly exposed to the sea-wind.

The cultivation of larch should not be attempted on the poorer classes of sandy soil, nor on tenacious land, nor on moist or wet soils of any description; it seems on the whole to prefer mild, stony, moderately fresh soil having sufficient depth to permit of the normal development of the root-system. The soil-improving qualities that were claimed for the larch in Scotland, when the Duke of Athole reckoned that an increase in grazing returns would render the planting of this species very remunerative, without even taking the return from timber into account, have not invariably made themselves apparent; for in some localities heather gains a foothold in the woods instead of grass, although it is only fair to say that in many places an original growth of heather often becomes transformed into grass. For grazing-ground in mountainous tracts the good service done by larch in improving the quality of the grasses is undeniable, but it should then only be planted in rows of 8 to 10 feet × 20 to 30 feet, and not with any sort of ultimate intention that they should form forest. Though the soft, easily decomposed foliage is well capable of improving the soil, the usually interrupted canopy of pure larch woods prevents a rich layer of humus being accumulated on the soil. Whilst of energetic growth, its soil-improving qualities are evident, but later on its inability to protect the soil is equally apparent, as at an advanced age its canopy is interrupted even more than in the case of Scots pine ; and where whortleberry and heather are in the neighbourhood they soon effect an entrance, unless the larch woods are underplanted, as they invariably should be if the stems are of good development, with some good shade-bearing and soil-improving species like spruce, Douglas fir, or silver fir.

Its demand for light is so great that it is on the whole less suited for the formation of pure forests (to be underplanted later on) than for admixture as a subordinate species along with other kinds of trees better able to protect the soil, and it also seems to thrive best when it grows well in advance of the ruling species. In its light foliage lies the explanation of the value of larch as nurses or protective standards, whilst to its rapid growth is due the good service it can yield in stimulating to a more energetic growth in height such clumps of young oak and beech poles as are somewhat backward in development.

The characteristic crooked growth of the larch, which often seriously affects the utilisation of the stems, has not yet been satisfactorily explained ; some assert that it is caused by the wind, others that it is due to unsuitable soil and situation, others again that it is the outcome of inferior seed. That soil and situation have influence in determining the shape of the bole is as indisputable as that constant winds can and do also affect its shape ; but sheltered localities often show the same sabre-like form of the lower end of the bole, whilst even in windy exposures straight growth can frequently be noted. Without doubt a better form of stem may in general be expected when, along with careful selection of seed from good parent trees, the larch is cultivated as a subordinate species in mixed forests, than when it is grown in pure woods, or as the ruling species.

Small scattered plots of ground in mild open situations are on the whole more suitable for plantations of this species than patches in the interior of dense forests.

For the small forest-proprietor the growth of larch has certain recommendations. It shoots up rapidly, and if underplanted at about its twenty to thirtieth years, and harvested about forty years of age, it yields good returns where the smaller assortments of timber find a fair market. Or if the rotation be extended to the fiftieth or sixtieth year, so as to permit of the thickening of the stems into remunerative classes of timber, spruce or silver fir can still easily maintain themselves under the shade and shelter of the lightly foliaged larch standards. It is well suited for retention as standards in copse after it has once been able to maintain itself well throughout the first period of rotation of the underwood, and can often remain as a standard in healthy good development till 120 years of age, although 80 to 100 years give large timber. The admixture of larch in woods of other species should take place in single individuals, or in small knots or patches, and not in larger groups, so that whenever its removal seems advisable the operation can be carried out without forming blanks or materially interrupting the canopy in an inconvenient manner. It increases the timber production in beech forests, and finds a very suitable home in woods of spruce and silver fir, but should not, except on very favourable soils, be largely interspersed in Scots pine forests, on account of the risk which the soil runs of becoming deteriorated.

The cultivation of the larch is generally effected artificially, the preference being in most localities given to planting. Without being intrusive like the birch, the light seed of the larch flies far into the forest, and natural reproduction not infrequently takes place to a slight extent in neighbouring areas where some soil preparation has been made for reception of the seed of the ruling species that is being regenerated; but unless specially tended, self-sown seedlings die off under the shade of the standards. And to specially tend or favour such self-sown growth would often be inadvisable as the introduction of larch can be much better arranged for later on by planting. As a subordinate species in forests of beech, spruce, or silver fir, the larch, to yield good results, must be planted with so much advantage in height, that not only the top but nearly the whole of the crown shall be in the undisturbed enjoyment of light. To introduce larch into forests where the ruling species consists of either spruce or silver fir, after these latter have begun to throw up leading shoots of fifteen to sixteen inches, is of very little use notwithstanding its rapid growth in youth. It is best introduced in blanks, either singly or in small patches, when seedling crops of beech or silver fir are having the parent standards cleared away, and good transplants of larch can assert themselves when the surrounding growth has the advantage over it of six to eight years in the case of silver fir, or three to five in the case of beech.

As nurses of oak plantations, larch is preferable to Scots pine for several reasons; it can be planted out in larger transplants, it has little tendency towards branching growth even when in full enjoyment of light, its foliage is lighter, and as its growth is also quicker, it can remain longer as nurse without injuring the oak, whilst on favourable situations it can even be retained up to the sixtieth or seventieth year to the extent of about twenty stems per acre.

Pure Forests of Larch are formed either by sowing or planting, although on the Alps such occasionally have their existence from seed being borne from adjoining woods to areas where clear fellings have been made. Rapidity of early growth, and imperfect retention of close canopy later on, are the most characteristic features of larch forests; in respect to the first, this is so energetic that rank growth of grasses or weeds is soon outgrown, and complete canopy is often formed in five or six years with close planting. Shortly after the formation of close canopy, the period of its liveliest growth in height is entered on, the maximum being attained on low-lying situations and uplands as early as between the tenth to twentieth year, although not till much later in its Alpine home. On favourable situations with fresh, deep soil the energy of growth in height is maintained till about the thirtieth to fortieth year of age, with shoots averaging two to three feet in length and sometimes more; but on less favourable soils and situations this has often sunk so far by the twentieth to thirtieth year of age that further growth in height is less than with most other conifers. In regard to no other species of forest tree do soil and situation make their combined influence more evidently felt than with respect to the cultivation of the larch in pure forest,—an influence likewise equally visible in the density of the crop, and in the degree to which close canopy is formed and maintained. Under no circumstances can these latter ever be so complete as in forests of shade-bearing conifers, or even of Scots pine. Early in the pole-forest stage of growth the total number of larch per acre becomes reduced by more than 50 per cent., and by the time the twenty-fifth to thirtieth year has been completed, the canopy is very much more broken than in forests of Scots pine, often to such an extent, indeed, that, except on soil of exceptional quality, its deterioration and a diminution of productive capacity must be feared. Henceforward, the appearance of the crop affords no pleasant sylvicultural picture. The canopy becomes more and more interrupted and broken by stems dying off when interfered with by more energetic neighbours, tufts of beard-mosses (*Usnea*) clothe the lower portion of the bole; the weakened energy of the individual trees also predisposes them to attacks from the larch moth (*Coleophora laricella*), and weakens their power of resistance to infection from the cankerous fungal disease (*Peziza Wilkommii*), which has followed the larch from its Alpine home, and finds in the milder climate of central and northern Germany, and throughout Britain, more favourable circumstances for its development than in the Alpine tracts where also it is indigenous but can less frequently develop its spores.

Such is the usual life-history of pure forests of larch formed on inferior or merely average soils and situations, and it is generally found advisable to utilise the crop about the fortieth to fiftieth year, if the attacks of these two above-named enemies have not necessitated clearance at little over half that age. Without underplanting at an early age, pure forests of larch can only be worked at any higher rotation when the soil is of such exceptional quality that defective protection does not lead to marked deterioration. The more the situation varies from the natural requirements of the larch, the less is its cultivation in pure forests recommendable for the production of good timber-stems; where, however, a preference has been given to rearing crops of larch in this manner rather than as a subordinate in mixed forests of other species, the formation of an undergrowth of some soil-protecting species should invariably be undertaken by sowing or planting at the time when the canopy begins to be much interrupted, if it seems desirable to retain the larch as standards for the production of large timber in place of gradually clearing off the crop, and utilising the land for some other kind of timber.

Mixed forests, in which the larch is the ruling species growing along with others of approximately similar age, should not be formed, as any attempt at their formation could only be based on a total misapprehension of the sylvicultural characteristics of this species. Except in its Alpine home, it occurs in mixed forests only as a subordinate species in admixture with beech, spruce, silver fir, and also to some extent in Scotland with Scots pine, and moreover is here advisedly introduced into such woods sparsely as individuals, or in wide rows, or small patches, in place of larger patches or groups, such as may often be noticed amid Alpine scenery. Its sylvicultural treatment in such mixed forests has been referred to when dealing with the ruling species concerned. It may merely be remarked here, that in equal-aged mixed crops on good average soils it maintains its crown free in beech forests till about the tenth year, and in silver fir till about the fiftieth; but in spruce usually only till the thirtieth. When it has thus been overtaken by the latter two species it should be removed and utilised, as for all sylvicultural purposes these are preferable woods after the larch has ceased to be predominating in height. In cases where larch, originally planted as a nurse for oak, has remained to form part of the existing crop at sixty to seventy years, this is due to its being retained only so long as it does not appreciably interfere with the development of the oak, and not to any deliberate intention to form such a mixture with a view to larch forming any part of the mature crop.

Artificial Formation and Reproduction of Larch Forests.—In the formation or reproduction of larch, whether in pure or in mixed forests, artificial regeneration is the rule, and a decided preference is given to planting, for, as in the case of the oak and the beech, transplants can be put out at almost any age.

Natural reproduction, where practised at all, can take place along small strips at the edge of mature woods whence the seed might be wafted. Many of the mixed forests in

Switzerland are thus formed, as the seed germinates easily wherever it falls on broken soil.

Sowing.—The main disadvantage of sowing larch is that one can never tell how the seed is likely to germinate in bulk, as it usually comes up either too thick or somewhat patchy. The poor quality of larch seed sold by dealers, who can get it at cheaper rates at lower elevations than they would have to pay for the best quality of seed collected from forests at higher altitudes, and the low germinative power of 30 to 40 per cent. only which is usually obtainable, necessitate somewhat thicker sowing than in the case of Scots pine, although when sowings come up too dense the drawback is even greater with the larch than with the latter. Sowing takes place either broadcast, or in strips or patches, according to the nature of the soil, but it should under ordinary circumstances not be preferred to planting, except where this is inconvenient, as on rocky or stony soil.

Larch seed should be sown early so as to have the benefit of the winter moisture ; it is even sometimes sown in autumn. The small seed requires little or no soil-covering, and shade either from the side or from above is in every way uncongenial to it. When the larch is to be mixed with the beech, and planting is not the method preferred—as would generally appear advisable,—the seed is sown on small patches here and there ; but when it is to be sown along with Scots pine so as to form about one-sixth of the crop, 1 lb. of larch seed is usually mixed with 2½ lbs. of pine seed.

Planting, however, deserves the preference in the generality of cases, whether for the formation of pure forests of larch, or for its introduction into mixed forest with other ruling species, as it establishes itself more readily than most other trees, especially when transplants are put out. It can be planted out as yearling seedlings, but is then apt to suffer from drought, so that material under two years is seldom used, a preference being given to transplants that have had one year's schooling in the nursery at about $6'' \times 4''$. Two-year-old seedlings can also establish themselves fairly well, but develop less quickly than transplants of the same age. The best results are obtained with plants from two to four feet in height; but for putting out in copse, on pasture-land, or along roads, larger transplants can quite well be used.

Spring is the best time for planting out the larch, but this must be seen to early, as it soon breaks into leaf; where early putting out cannot be conveniently arranged for, it is better to plant in autumn as soon as the little tufts of foliage are becoming yellow. Owing to the ease with which it establishes itself, planting with balls of earth attached to the roots is only necessary with the larger assortments of transplants, which also bear trimming, like oak and beech, into pyramidal form. Pit-planting is the rule, though on suitable soils one or two-year-old seedlings can easily and cheaply be notched with broad spades.

As might be expected from its demand for light, planting is not so close as with other species of forest trees. Transplants of three feet high are usually put out at distances of five and six feet apart, or in rows 8 feet × 4 feet, whilst larger classes of plants are given 9 feet × 9 feet and greater distances. When larch is scattered singly throughout mixed forests, only well-grown transplants should be used, and these should be put out not nearer than 24 feet × 24 feet.

The rearing of seedlings and transplants has no special difficulties to contend with. The nurseries should be selected, if possible, on mild, fresh loamy soils without tendency to be binding. The seed should be sown broadcast on the prepared beds, and not in rills as with other species; where the young plants come up too quickly, they can be thinned at each time of weeding. The pricking out of the yearling seedlings in the nurseries is done at 6″ × 4″ if the young transplants are wanted in the next year; one or two-year-old seedlings are pricked out at 12″ × 12″ or 15″ × 10″, if they are to stand two years and develop into plants about 4′ high, and no injury is done if the tap-root is slightly shortened. No attempt should be made to prick out any seedlings which appear bent or of indifferent growth. When transplants are wanted for planting out in copse, or on grazing-land, a larger growing-space is of course necessary.

Deciduous broad-leaved Trees.

A. *Hardwoods.* I. BEECH (FAGUS SYLVATICA, L.).

Writing in 1791, Gilpin [1] said of the beech :—

"The oak, the ash, and the elm, are commonly dignified in our English woods, as a distinct class, by the title of timber trees. . . . . After timber trees, the beech deserves our notice. Some indeed rank the beech among timber trees ; but, I believe, in general it does not find that respect, as its wood is of a soft spongy nature ; sappy and alluring to the worm."

Professor Gayer of Munich, the greatest living authority on Sylviculture, is of a different opinion. He says :—

"There are many localities in which beech will continue to be a valuable wood from a financial point of view" (*i.e.* for fuel in Germany), "but, where such may not be the case, it will still retain its insurpassable sylvicultural value, for without the beech there can no more be properly tended forests of broad-leaved species, as along with it would have to be given up a good many other valuable timber trees, whose production is only possible with the aid of beech."—*Waldbau*, 1889, p. 448.

Distribution.—The beech is found throughout the western, the central, and most of the southern portion of Europe, also in the Caucasus, and in northern Persia. Its north-

[1] *Forest Scenery*, Lauder's Edition, 1834, pp. 97, 98.

eastern limit is in Scotland latitude 56–57°, in Scandinavia 60½° on the western and 57° on the eastern side, 54½° on the east Prussian sea-coast, thence across eastern Poland, Bessarabia, and the Crimea, towards the Caucasus. It is essentially a tree belonging to the hilly and the lower mountainous tracts of central and south Germany, and north-western Austria, but it also forms pure forests on the plains within the Baltic region, in upper Silesia, and in that portion of Alsace drained by the Rhine. On the Harz mountains it ascends to 2,150 feet elevation, in the Thüringerwald and Black Forest to 2,600 feet, on the Erzegebirge to 2,700 feet, to nearly 5,000 feet on the Bavarian Alps, and to 5,125 feet in the Tyrol. Its chief sylvicultural characteristic is its capability of forming dense pure forests, like the spruce and in a less degree the silver fir, over extensive tracts of country.

In the earliest times it formed large pure forests on the calcareous and chalky soils throughout central and southern England, attaining its finest dimensions in Buckinghamshire and Hants, but was not indigenous to Ireland or to Scotland, where it was introduced largely early in the eighteenth century. It is grown on the Continent in pure forests over enormous areas on account of its fine quality as fuel. In Britain there exists no such reason for its cultivation on a scale relatively so extensive, and as its timber is less remunerative than that of other high forest growth, it must chiefly claim attention on account of its soil-protecting and soil-improving qualities, and as a ruling species in admixture with which large timber trees of the more profitable broad-leaved species can most remuneratively be grown without danger of the soil deteriorating through any interruption of the leaf-canopy, and the insolation consequent thereon.

Tree-form and Root-system.—When grown in pure forest, the beech develops a straight, long, nearly cylindrical bole, excelling in this respect nearly all the other broad-leaved trees, although not attaining such straightness or length of stem as the silver fir and spruce. In the pole-forest stage of growth its crown is spindle-shaped, but afterwards becomes first oval, and then obovate with advancing age. When grown in close canopy, its foliage reaches down to about $\frac{1}{3}$ of the height of the tree, but in isolated positions it droops down to the very ground. Its crown is formed of strong branches, which ramify freely, and bear a dense crop of large, broad leaves. On deep loamy soil the density of its foliage is greater, and indeed the whole development of the tree better, than on sandy soils, although on the latter, especially on the better class of soil in which good mould is plentiful, the greatest growth in length is often attained. Towards the northern limit of its distribution a tendency to develop branches at the cost of the bole becomes apparent.

The root-system developed by the beech is somewhat heart-shaped, like that of the silver fir, but is on the whole not so deep; it possesses a fair capacity for accommodating itself to the conditions of the soil and subsoil, though not to such an extent as, for example, the Scots pine. Its development depends greatly on the nature of the soil, and is in every way stronger on deep, rich limy or loamy soil than on somewhat inferior land of a more sandy description.

Requirements as to Soil and Situation.—Raw, cold exposures, where snow is often on the ground for months, and the forests are bathed in mist for weeks at a time, are more suitable for the spruce than the beech, which resembles the silver fir somewhat closely in its antipathy to long-continued, severe winter cold, and its inability to stand a lower average temperature in January than $20\frac{3}{4}°$ Fahr. On the other hand, without absolutely demanding it, the beech can bear a greater degree of mean summer warmth than the silver fir, and an equable warmth maintained throughout a long season of active vegetation is beneficial to its development. A moderate degree of atmospheric humidity is characteristic of all localities in which extensive pure forests of beech are to be found indigenously; the insular climate of Britain, especially of the southern portion of England, is therefore well suited to produce beech forests, in association with which the other more valuable deciduous species may be grown, according to the precepts and principles of sylviculture, to their better development and most remunerative production.

On the hills and lower mountain slopes of central and southern Germany, the beech prefers the eastern, north-eastern, and northern aspects, with their greater degree of moisture both in soil and atmosphere; but at higher elevations, considerations as to warmth dictate a preference for south-eastern and southern exposures.

It exhibits a decided preference for limy soils, and those of a clayey nature containing lime. Mild loams, clayey marls, and loamy limes, no matter of what geognostic origin, are therefore those which suit it best, although fresh sandy soils, especially with a loamy or marly subsoil, and the better varieties of loam often found on the uplands, also induce good growth and development, more particularly when the atmosphere is humid. Pure limy and sandy soils are alike unsuited for the beech.

It demands, more than many other species, depth of soil, uniformity of soil-texture, mineral strength, and a moderate amount of moisture both in soil and subsoil, whilst any tendency either to dryness or to excess of moisture is unfavourable to it.

By means of its thick fall of leaves, it makes a natural effort to provide the soil with a good non-conducting cover for the preservation of the soil-moisture during the heat of summer, and on decomposing this yields a rich variety of humus or mould, which modifies and improves all classes of soil with respect to their physical properties. Though it extracts a considerable amount of mineral nourishment from the soil, it replaces this again by the humus formed from the fallen leaves, for most of the mineral matter is left in the foliage during the natural process of assimilation. It is therefore by no means an exhausting forest crop; it is on the contrary, on good soils certainly an improving one.

Requirements as to Light.—Among the broad-leaved trees no species equals the beech in density of foliage, or in its capability of bearing shade; but the extent to which it is endowed with this capacity varies within considerable limits, being dependent both on the degree of shade to which it is subjected, and on how far soil and situation favour its growth in general. Under certain circumstances it thrives normally even after having been kept in shade for twenty to thirty years, whilst under other less favourable circumstances an insufficient supply of light for only a few years shows its evil effects throughout the whole remaining life-period of the crop.

[Under normal circumstances beech seedlings do well after remaining under the shade and shelter of their parent trees and protectors against frost for about ten to fifteen years, towards the end of which period a gradual clearance of the standards takes place. The shade of lightly foliaged trees, like the oak, ash, larch, or Scots pine, can be borne by it without injury for a longer time; localities on which such moderate shade seems injurious to the thicket of seedlings, can in reality form no suitable situation for the beech.]

Attainment of Maturity and Reproductive Capacity.—The beech begins to bear seed or mast, *beech-nuts*, in fair quantities sufficient for reproductive purposes, in forests of about sixty to seventy years of age, after the activity of growth in height has culminated, but it is generally worked with a rotation of about 90—120 years before being gradually reproduced by seed over a period of fifteen to twenty years. In Germany the great bulk of beech is used for fuel, it being the wood most prized for domestic heating purposes. But when there is a good demand and a fair market for large assortments of this timber, a forest is cleared at seventy to eighty years of age, and about eighteen or twenty-two of the best trees per acre are left as standards to widen rapidly in girth, and then be cleared off at the next fall along with the reproduced portion of the forest some seventy to eighty years later on.

Seed-years are foretold by the thickening of the flower-buds in the previous autumn; good ones do not occur more than once every three to five years, and really abundant mast-years are, like good vintages, unfortunately of somewhat infrequent occurrence. On favourable soils and situations there is seldom lack of seed for natural reproduction, though on poor soils, and in localities exposed to late frosts, the work of regeneration has often to be carried out with seed obtained elsewhere.

About 2,000 beech-nuts without husks are contained in one pound, and a germinative power of 50 per cent. is considered satisfactory in experiments for testing the quality. The seed ripens and falls in the autumn after flowering. Where it is necessary to harvest the mast till the following spring, it must be kept cool, airy, and well covered, and runs a danger of becoming heated on the one hand or dried up on the other. Seed kept longer than till the spring after its ripening, cannot be relied on to germinate at all satisfactorily.

Its capacity for reproduction by stool-shoots is on the whole not great; when once the bark has thickened and hardened, the dormant or adventitious buds become much less capable of being called forth into active life than on the younger portions ot the tree with their thinner and softer covering of bark, and a greater abundance of sap.

Liability to Suffer from External Dangers.—The dangers to which the beech, in common with the other deciduous broad-leaved trees, is exposed, are on the whole of far less magnitude than those by which the conifers are threatened. The beech-nuts are often eaten up by mice and voles. Late frosts in spring, and the scorching midday sun in summer, though both mitigated by shelter from the parent trees, are injurious to the seedlings, which break into leaf just when the greatest danger from frost may be apprehended. Late frosts are less to be feared on the higher-lying tracts and uplands, and on the cool northern and eastern exposures, where seed is later in germinating, and saplings do not break into foliage so early as on lower and warmer localities. Old forests, too, are often affected in growth when late frosts destroy their young and tender foliage in May.

As the worst storms generally occur when the trees are bare, the beech does not suffer greatly from the violence of winds, and the same may also be said with regard to accumulations of snow and ice on the branches.

From the attacks of insect enemies it is comparatively ree. Species of *Melolontha* in their grub state injure the roots of seedlings, and larvæ of *Agrilus viridis*, *Scolytus intricatus*, and species of *Dryocetes* damage the cambium and sap-wood of young growth, whilst the caterpillars of *Dasychira pudibunda* and *Liparis monacha* destroy the foliage and buds in the older stages of growth, as also in a less degree do beetles of the species *Orchestes*, *Phyllobius*, and *Rhynchites* ; the timber is liable to be bored by the larvæ of *Hylecœtus dermestoides* and *Ptilinus pectinicornis.*

A cankerous disease of the stem is caused either by *Nectria ditissima*, or by the beech-aphis *Chermes fagi*, or by frost,—or, according to Hess,[1] by the occasional combination of any two or more of these possible causes. The fungus found in the affected parts was called *Fusidium candidum* by Willkomm, but has been recognised by R. Hartig as merely the gonidial or intermediate form of *Nectria ditissima*. This disease of the bark and sap-wood is most frequently to be met with on the western or exposed sides of older trees suddenly cut free from side-shade. At the time of germination many seedlings fall victims to a disease induced in the cotyledons by *Phytophthora omnivora*.

All trees having smooth bark, like hornbeam, ash, sycamore, lime and chestnut, and among conifers spruce and Weymouth pine, but most particularly the beech, are liable to suffer from scorching or sunburn on the west and south-west, less frequently the south, side of the bole near its base, soon after the movement of the sap begins, and just where the heat reflected from the soil is greatest. The defect thus caused in the timber often diminishes its value considerably.

Though deer love to nibble, and cattle to browse on the tender, succulent leaves of young beech thickets, the damage they do is never very great, unless the grazing of cattle be habitual, when of course it interferes with the normal growth and development.

Sylvicultural Treatment of Beech.—Even in Germany, where immense pure forests of beech were formerly found clothing the lower hills and uplands, and also occurring extensively on the plains, the extent to which they are to be met with at the present day has been greatly diminished. Various causes have led to this result. Throughout most of Germany, the areas under forest were burdened with servitudes in all localities where the woods

[1] *Der Forstschutz*, vol. ii. 1890, p. 219.

themselves were not actually declared communal, village, or corporation forests, and rights of user of many kinds had to be satisfied, such as the delivery of timber for building and for fuel, right of driving in herds of swine for pannage and cattle for pasturage, right of extraction of dead leaves for manure for the fields, &c. With the increase of population, and the restriction of the areas under forest, the time arrived in many places where, notwithstanding the soil-improving qualities of the beech, it has not been able to maintain the productive capacity of the soil when the natural covering of dead foliage has been stripped and utilised as manure for neighbouring fields. Bereft of its leafy mantle, and incapable of otherwise producing the humus or mould necessary for the retention of soil-moisture, and both directly and indirectly active in the formation of soil and the preparation of nutrients for the benefit of the timber crop, the growth of the beech woods began ultimately to show signs that the soil was becoming exhausted ; natural reproduction became feebler and less satisfactory, and some less exacting crop, usually spruce, had to be formed in place of beech, in order to avoid further deterioration of the soil through inferior and patchy growth of beech alternating with patches of self-sown softwoods. In other places, in many of the state forests and in private woodlands, purely financial reasons have led to the transformation of beech woods into coniferous forests, as the long period of natural reproduction, the poor prices obtainable for the smaller assortments of timber forming a considerable portion of the crop harvested when reproduction is commenced, and the relatively less remunerative prices for the largest dimensions of beech as compared with spruce or Scots pine, were all naturally taken into account wherever existing forests could legally be transformed. In addition to that, with the improved methods of communication developed and perfected during the last half century, the use of beech as fuel has to a great extent been supplanted by the use of coal, coke, and peat, so that there is no longer the same necessity for the production of large pure forests of beech in the interest of the fuel-consuming population. The preparation of bricquets of coal-dust, and the compression of peat, have also thrown vast quantities of heat-producing material on the market, which had at most only a local consumption formerly.

Thus even in continental countries circumstances are gradually bringing the proprietors of forests to look at the matter—within certain limits only, in the case of state forests—from *the actuarial point of view, which must ever be the principal and only sound one in Britain.* With its shade-bearing and soil-protecting qualities, beech undoubtedly stands pre-eminent and unrivalled as the ruling species in subordinate admixture with which can best be grown the more light-loving species, such as oak, ash, elm, maple and sycamore, which are on average classes of soil unable to maintain undiminished in pure forest, or in mixed forests consisting of themselves only without a shade-bearing species, the reproductive capacity of the soil. In such mixed forests the subordinate species develop into larger, better grown, and more valuable boles than when reared in forests consisting entirely of light-loving species; in mild crops even the beech itself is benefited so much as in general to yield timber well capable of being utilised for technical purposes in place of merely becoming fuel.

Where pure forests of beech form the crop for the production of fuel only, the fall usually takes place during the eightieth to hundredth year, natural regeneration under parent standards being effected during that period; but where there is any fair market for beech as timber, reproduction is begun about the ninetieth year, and continued till about the hundred and twentieth, when the final clearance of the parent standards takes place.

The principal treatment accorded to the beech is growth in high-forest with natural reproduction, the total area under beech being divided into four blocks representing respectively the areas on which are to be found the portions of the growing stock 0–30 years, 30–60 years, 60–90 years, and 90–120 years,—or averaging 15, 45, 75, and 105 respectively, counting from the middle of the period of reproduction. Growing in closed canopy, the beech here develops a long, smooth stem well adapted for technical purposes.

As coppice, beech cannot be compared with the oak, either in regard to reproductive capacity, or as to energy of growth of the stool-shoots. In copse or stored coppice it is often to be found among the underwood, especially on limy soils which stimulate its development; but usually, owing to its comparative unremunerativeness, it is encouraged there mainly with a view to protect and improve the soil for the benefit of the standards of oak, ash, and the like. For standards in copse it is not at all naturally suited, on account of the dense shadow thrown around by its close, heavy foliage. This increases with advancing age when trees are grown in the full enjoyment of light and air, for as a standard it is prone to branch development; at the same time it does not bear well the removal of branches, whose loss might increase the already existing danger of scorching or sunburn and might directly affect the quality of the timber for all technical purposes. Where a good market for fuel exists, the most advantageous rotation for beech as coppice is twenty-five to thirty years; but coppice is only advisable where the soil is good, and, under the ruling principle that forestry in Britain must be guided by purely financial considerations and actuarial calculations, the preference would be almost sure to be given to some more remunerative crop.

Beech forests require a considerable amount of tending. All coppice-shoots of beech and hornbeam should be removed during the weedings and clearings of young seedling growth, and as a rule all softwoods also, whilst in thinnings the clearance of the latter along with all suppressed poles of the ruling species should certainly take place. On drier and poorer patches of soil, where light and air are most requisite, and the struggle for individual existence is most equally balanced, the axe has usually to give considerable assistance to nature in the work of hastening on the selection of the predominating and dominating poles. But on the whole the golden rule in the thinning out of this species is that it should be carried out *early, often, and moderately*, anticipating to a slight extent, in crops of advanced age, the results slowly being attained by nature.

In contradistinction to the treatment usually accorded to the oak, natural reproduction under parent standards finds by far the most favour in regard to beech, although (as with the silver fir, the only other forest tree with which a similar method is largely in vogue) artificial aid has generally to be invoked to a greater or less extent in filling up blanks where reproduction is unsatisfactory.

Where crops of beech are to be formed for the first time in the open, planting is the usual mode of formation, as seedling growth demands shade and shelter during the first two or three years of its existence. But where it is to be introduced into other forests either as underwood, or with a view to forming part of the future crop of high-forest, the choice still remains between sowing and planting, although in general preference is given to the latter method as attaining satisfactory results in the least time, and at a cost not necessarily greater than sowings often amount to before the operations can really be considered completed.

Pure Forests of Beech.—Although, to be consistent with the principle that actuarial considerations alone should form the basis of purely sylvicultural operations in Britain, any reference to the treatment of pure forests of beech is almost superfluous, yet they exhibit so many of the sylvicultural characteristics of the species that a knowledge of their treatment on the Continent must be of material benefit and assistance with regard to the utilisation of beech in the formation and tending of mixed forests, in which the first and principal object is the production of the most remunerative classes of timber of the nobler species of forest trees.

When, after natural reproduction, the young crop of beech finds itself freed from the shade of the parent standards, it is generally scattered in larger or smaller patches showing slight differences of age. As the results of the shelter afforded by the parent trees against frost, rank growth of grass and weeds, sunburn, &c., the energy in growth of the seedlings is so far prejudiced, that the young crop seldom forms canopy before the tenth year; but with the attainment of this, growth in height becomes energetic throughout the thicket stage of development, reaching an annual average of about 15″ on good soils and situations, and achieving its maximum annual increment with leading-shoots averaging 19″ in young poles of twenty to thirty years of age. This does not happen until ten to fifteen years later, and only with a lower average, on soils of less favourable quality (*vide* tables on page 36 to 38). During this period of growth the soil is covered with a thick fall of dead foliage, which, secured by the density of the young poles from being blown away by the wind, protects the soil-moisture, and under the influence of the three chief factors,—moisture, air, and moderate warmth (52° Fahr.),—slowly decomposes to form humus or mould of excellent quality, thereby enriching and improving the soil in a greater degree than any other forest crop is capable of. The stimulus thus given to the soil finds its immediate expression in the increased current annual increment in cubic contents, which attains its maximum between the fortieth and eightieth year, according to the quality of the soil, although the average annual increment does not culminate till between the eightieth to the hundred and twentieth year (*vide* table on page 45). Although pure beech forest on soils of average quality yields over 8,000 cubic feet per acre, only 10 to 20 per cent. of this is usually first-class timber for technical purposes, the rest being merely good fuel.

When once the seedlings have passed through the stage during which their cotyledons are apt to suffer from the fungoid disease caused by *Phytophthora omnivora*, the chief danger to which the young crop is exposed is frost, and in localities where late frosts in spring are frequent, the damage done is often very appreciable throughout the thicket stage and even later. So long as the natural soil-covering of dead foliage is preserved from being blown about by wind, or being removed for agricultural manure, pure forests of beech can easily on average classes of soil attain an age of a hundred and twenty years if desired in the interests of the proprietor. But if the retention of this fall of foliage be not achieved, the formation of good humus is out of the question, and the protecting and soil-improving qualities of the beech are squandered, as the crop, which makes higher demands on the soil than spruce [1] for example, or than most other trees, gradually exhausts the soil in place of enriching and improving it.

Pure forests of beech are reproduced naturally during periods of twenty or thirty years, according as the fall of the mature crop is desired between the eightieth to hundredth, or between the ninetieth to hundred and twentieth year. The process takes place by means of three fellings viz. :— preparatory, reproductive, and gradual final clearance, which will be referred to more particularly when treating of natural production.

[1] *Vide* page 30.

Mixed Forests with Beech as the ruling Species are undoubtedly the form in which beech is of most sylvicultural importance in Britain, and even then chiefly as far as the development of the subordinate species is concerned, the aim being to increase the production of timber, and to improve its quality, so as to obtain from any given area the most remunerative returns, whilst duly protecting the productive capacity of the soil. This object can be attained by a suitable admixture of oak, ash, maple, sycamore, elm and softwoods among deciduous broad-leaved species, and of silver and Douglas firs, spruce, larch, and pines among conifers. Soil and situation naturally determine generally in favour of one or other species, and regulate the proportion to which it should be introduced into the ruling species or matrix, as also whether it is advisable to give the admixture the form of groups, patches, rows or merely scattered individuals; local demands and the state of the local market, however, are also entitled to their full consideration in regard to the choice of species and of the treatment to be accorded to them. Where groups or patches are formed, they should usually be circular in shape, in order that the soil may derive full benefit from the ruling species. Oak can be introduced in all four ways, but admixture in groups, or in knots or patches, is preferable in order to facilitate tending; ash, elm, sycamore, maple, softwoods, larch, and pine, are best scattered among the beech in single individuals only, or merely in small knots or rows; silver fir is most easily tended in groups, although quite capable of developing well in the other forms of admixture; spruce should also be introduced in groups, or even in clumps of larger size, where poorer soil than the average makes this step advisable,—for when grown in small knots, rows, or scattered individuals it rapidly becomes predominant, breaks out into a larger crown of heavy-foliaged branches and sprays, and injures the beech through its dense shade, whilst at the same time it forms knotty timber of inferior quality to that produced by trees growing in close canopy.

Oak is the principal subordinate species to be considered in admixture with beech, for though it has lost that former importance in regard to shipbuilding, which led to large plantations being made in the state forests of southern England—the New Forest, the Forest of Dean, Alice Holt, Bere and Parkhurst,—for the future supply of timber for the Royal Navy, and though its use has been to a great extent superseded owing to the development of steam transport and the present usual construction of iron hulls, in which the use of teak timber (*Tectona grandis*) from Burma, an oily wood preservative of steel and iron bolts, &c., has undeniable advantages over oak, the tannic acid of which corrodes iron in place of preserving it like teak, yet oak still remains the most highly prized and best paid home-grown timber for many varieties of technical purposes, and is likely to remain so as long as costs of transport prohibit the many fine timbers of the tropical forests of our Indian Empire being laid down in the English market at remunerative rates. This wealth of timber obtainable from the Greater Britain beyond the seas is another argument,—if any such were required,—why forests in Britain should not be formed unless they can show sound financial prospects of moderate remunerativeness. Are not the streets of London being paved with timber from Australia? Is not almost the only timber used in building the "wooden walls" of England imported from India? Burma alone yields annually over 200,000 tons of teak timber in the log, and whenever necessary it might yield more than 4,000,000 tons annually of other kinds of timber, suitable for ordinary use in the climate of Britain, for which there is at present practically so little demand that its extraction is not remunerative. Until, however, costs of transport become much lighter than they are now, the future market for good classes and qualities of home-grown timber seems well assured, and every endeavour should be made sylviculturally towards producing them in the finest dimensions and of the highest technical quality. And the finest growth of the oak can undoubtedly be obtained where it receives the benefit of that soil-protection which can be so well prvoided by the beech.

Both species resemble each other to a considerable extent in regard to rate of growth, tree-form, and demands made as to soil and situation. But in admixture with the beech, the oak has all the advantages to be derived from close canopy, protection of the soil from insolation and from the drying effects of winds, rich fall of leaves to form humus, and has also an improved development of the bole, more especially to be noted in the case of the sessile oak. On good deep soils of the lower uplands and undulating plains of southern England (New Forest) this mixture is frequently to be found occurring naturally, although artificial assistance is usually necessary to protect the oak against the beech.

The most important point is, indeed, to maintain the oak in advance of the beech throughout the whole period of its existence, for as a light-loving species it can only attain its finest normal development so long as the upper portion of its crown is in the undisturbed enjoyment of light and air, and is secured against the dense, suppressive side-shade of the beech. On most classes of soil the oak is, from the very earliest period, of somewhat quicker growth in height than the beech, and in warm localities with long periods of vegetation and genial summer temperature, it as a rule maintains the advantage thus early won, except where the soil ultimately proves so deficient in depth or in soil-moisture, that the natural conditions requisite for the normal development of its root-system are wanting. But where these conditions are secured, the admixture of the oak may take place in single individuals scattered throughout the whole beech forest, so as to gain to the fullest extent the advantages derivable from the ruling species, though care must be taken not to introduce it in such numbers that it may form canopy for itself to the detriment or ultimate suppression of the beech. When the oak has been scattered too thickly along with the beech, all indifferently developed individuals should be cut out early, so that on the better classes of soil not more than thirty-five to forty per acre should attain the age of a hundred to a hundred and twenty years; but the better development of these should be carefully tended during all thinnings out. In many places strong transplants of 6 to $7\frac{1}{2}$ feet high, are put out every 16 feet in rows about 120 to 150 feet apart; in other localities a preference is given to one or two-year-old seedlings notched in at every 15 to 20 feet × 15 to 20 feet, whilst in other places again small groups and knots of transplants three to four feet high are scattered here and there in patches wherever there are blanks in the young beech seedling growth which show good soil. This latter method is generally preferred on cool northern slopes, or on somewhat limy soils, where the growth of oak is not only slower than on warmer exposures, or milder loamy or sandy soils, and where at the same time the growth of the beech is more luxuriant than on most other soils or situations.

In cases where the oak needs any protection against the beech, it is usually during the pole-forest stage of development that tending is most requisite, although where the soil is somewhat deficient in depth, or in mineral strength, the need of assistance is often noticeable even in the thicket stage of growth. Thus, while on the better classes of soil, oak remains predominant, on inferior localities the beech is naturally of quicker development, and unless the former is scattered here and there in circular groups of about twenty to twenty-four feet in diameter, it is difficult to protect the oak from being overtaken and suppressed by the ruling species; with groups of larger size the advantages of mixed growth become fainter and less substantial, in direct proportion to the increase of area.

As, for the production of large remunerative assortments of timber, it is advisable to give the oak a much longer period of rotation than would be advisable for the beech, the latter can be naturally reproduced between the eightieth to ninetieth year, or by means of sowing or planting should seed-production prove deficient, and the *rôle* of the latter is then confined to underwood until the standard oaks are harvested at any convenient time during their hundred and fiftieth to two-hundredth year, whenever the state of the timber-market renders their fall advisable. Under such circumstances this second generation of beech is not usually of the best normal development; but the loss of increment on it is replaced by the greater quantitative, qualitative, and financial increment of which the oak standards reap the advantage. On the better classes of soil, thirty to forty oak stems per acre overshadow the whole area lightly by the end of the second period of rotation of the beech; on poorer classes of soil, only such number of oaks should be retained as standards as will ultimately overshadow not more than $\frac{1}{4}$ or at most $\frac{1}{2}$ of the area, that is to say about ten to twenty per acre. Care should be taken to remove the beech gradually, as, when suddenly exposed to light and air, the boles of the oak are apt to become covered with a flush of shoots from dormant, adventitious buds, which utilise the sap during its upward flow, with the consequence that the trees become "*stag-headed*" and dead in the top part of the crown. For this method of treatment small clumps of good sound trees, in vigorous growth, with well-formed crowns, and not over a hundred years of age, should be selected, as otherwise experience has shown that the measure is apt to fail in effecting the object intended.

From what has been said above, it is evident that under most circumstances some growth in advance should be secured to the oak, and this is better obtainable by the use of strong transplants than in any other manner. The case in which oak forests are first of all formed nearly pure, and then underplanted, belongs properly to the later consideration of the oak (*vide* pages 190, 194, 200, and 202).

The regeneration of such mixed forests can take place naturally by reproducing the oak first, but it will usually be found most advantageous to adopt planting.

Ash, elm, maple, and sycamore are usually associated with the beech on uplands and hill-sides having fresh soils with a fair degree of mineral strength, and here these species are frequently to be met with self-sown on places most congenial to their natural habits of growth. This is more usually the case on all varieties of soil other than sand, where, however, oak finds for the most part the situations best suited to its growth. Where their presence along with the beech on strong mineral soil is wanting, owing to an absence of parent seed-trees, the mere strewing of seed is sufficient to effect a suitable degree of admixture, unless planting of individual stems here and there is preferred. The elm is less commonly to be found, which may be explained by its poor seed-production in Britain, though when once it has established itself it can generally effect reproduction by means of stoles or root-suckers; but the planting out of good transplants three to four feet high is perhaps the best method of introducing the elm into seedling growth of beech, as larger transplants often fail to establish themselves well, whilst seedlings and smaller transplants are apt to fall victims to rank growth of grass. The admixture of ash, maple and sycamore is best also provided for by planting in single individuals, in wide rows, or in small knotches or patches scattered here and there; the formation of patches or groups larger than twenty to twenty-five feet in diameter is inconsistent with their natural habit of growth and their general inability to protect the soil, whilst their tendency towards the formation of a somewhat widely-branching crown is apt to interfere with the normal development of the ruling species.

As these subordinate species are not intended to be removed early in thinnings out of the beech, but to remain for eighty or a hundred years so as to develop into good, valuable assortments of timber, they must be carefully tended throughout the whole period of their growth. Like the oak, they are all light-loving species, and in general of speedier growth than beech, although this advantage lies more with elm and ash than with maple, or in particular with sycamore, on situations that may be somewhat deficient in atmospheric warmth.

In general these forest trees, and particularly the maple, thrive best on a moister soil than is congenial to the beech, so that wherever patches of moist ground occur here and there, they can be suitably introduced in larger patches and to a greater extent generally than where the soil is merely fresh; for the protection of the soil, however, underplanting with beech, silver fir, or spruce, is then often necessary later on. A suitable admixture is seldom obtained by means of natural reproduction of such subordinate species; better results are obtainable by sowing on small patches after previous soil preparation. But perhaps on the whole the planting of strong transplants deserves the more general practical application in regard to all four species.

Among conifers, the principal subordinate species introduced into beech forests for the production of large assortments of timber are silver fir and spruce. The former is at first somewhat backward in growth, but, from the age of thicket onwards, corresponds fairly well with the development of the beech, maintaining itself till maturity; and if towards the end of the period of rotation it may on better or moister soils show growth in advance of the ruling species, this does not do so much harm as in the case of the spruce. Wherever, therefore, blanks show the better qualities of soil, a preference should be given to the admixture of the silver fir. With its slow initial development, some advantage has to be given it over the quicker growing beech, and this is perhaps best arranged for, by introducing it early into seedling growth of beech by means of planting, as the shade of standard beech trees is somewhat too dense for sowing; later on, however, the silver fir is of more rapid growth than the beech, which it is apt to suppress with its heavy shade. Where patches of self-sown birch have found their way into beech forests, they often prove very good nurses for the silver fir, protecting them against frost, though not overshadowing them to any injurious extent. Tending can best take place when the silver fir is introduced in small patches, or in rows, rather than as scattered individuals.

The association of spruce with the beech takes place usually only on soils that are not sufficiently good or deep or the profitable admixture of the nobler broad-leaved trees, or of silver fir. Under certain circumstances its introduction is more or less of a necessity, as for example on many localities where constant removal of the dead foliage, with consequent deficiency of needful humus, has been followed by deterioration of the soil; here the reproduction of broad-leaved forest cannot, for the meantime at least, be so remunerative as that of the more easily satisfied spruce with its good soil-improving qualities. Both species show wide variations in manner and rate of growth, and in regard to the formation of their root system, but they are frequently found in natural mixed forests showing good development; this is especially the case in forests varying in soil-quality, the shallower, moister, or poorer parts being often found covered with patches or groups of spruce, these being spots where the beech is less likely to thrive. Although at first beech is more rapid in growth, it is on moist soils usually about the tenth year overtaken by the spruce, which then generally remains predominating throughout the later stages of growth; on dry soils, however, it not infrequently happens that the shade cast by the young seedling-growth of beech interferes so much with the development of the spruce, that this is unable to develop its characteristically energetic growth in height, and is consequently suppressed. Where either species wins any decided advantage over the other, it uses it to suppress the latter as much as possible. To derive the maximum of advantage from the mixture, it is therefore best to admix the two species, to as great an extent as convenient, in circular groups of about a quarter to half an acre in area, so that no matter which gains the advantage in growth, the other is still protected sufficiently by its own species to maintain itself partially till maturity. When the spruce is scattered individually among the beech, its tendency to injure the latter can of course be diminished by the removal of the undermost branches with the saw,—a measure, however, that is difficult of application on any very extensive scale. The introduction of the spruce in rows has also practically the effect of suppressing the beech to a great extent unless the rows are planted out wide apart. In the formation of mixed forests of beech and spruce, it is well to assure to the former some growth in advance before the latter is introduced, and this is perhaps best attained by reproducing the beech naturally first, and then planting up all blanks with spruce when the beech seedling growth is about ten years old, or, in other words, when the parent standards are removed, which can take place somewhat earlier than if it were desired to have the whole area under a crop of beech. Even when the beech thus at first forms the crop over considerably more than half the area, it usually gets so much suppressed by the spruce, that towards maturity it rarely exceeds 20 per cent. of the crop. But although the admixture of spruce may not exceed 30 to 40 per cent. of the mature crop, it adds very considerably to its remunerativeness; for not only is the total production of timber per acre appreciably increased, but both beech and spruce also yield higher percentages of large-girthed and valuable assortments of timber. In Britain it will probably recommend itself to lay most weight on the growth of the spruce, and to have the beech as the subordinate species, in order to counteract the dangers to which the former is exposed from windfall, from snow and ice accumulations, and from insect enemies and fungoid disease.

As subordinate species Scots pine and larch have many advantages over spruce. Throughout the whole of their life-period they are of quicker growth than the beech, but with their lighter crowns of foliage are not liable to do so much damage by overshadowing, and under many circumstances often afford beneficial protection against frost and insolation. Grown along with the beech, they develop into boles of fine proportions, yielding first-class timber, and can be worked with higher periods of rotation than when in pure forests, because the soil is not so apt to deteriorate. It also not infrequently happens that the natural reproduction of the beech under the pine can be carried out even more satisfactorily than under the shade of parent standards alone.

Form their natural habits of growth, these two species are capable of being grown both in groups or patches, and in rows, or as single individuals, in which latter case they develop into fine stems. But where a preference is given to the former mode of admixture, it is necessary to underplant the pine between the thirtieth to fortieth year with beech, so that with a fall of a hundred to a hundred and twenty years the mature crop consists of large coniferous stems of that age with a reproductive beech underwood of seventy to eighty years old, and surpasses either class of pure forest in profitable outturn. Where the larch is admixed in groups or patches, these must be underplanted about ten years earlier; but, in general, planting singly or in wide rows is preferable in regard to this species, as it often attains its full normal development at a much earlier age than pine.

The introduction of both species is usually most conveniently carried out by means of sowing or planting during the final clearance of the parent standards of beech from areas that have been naturally reproduced. In general the end is best attained by planting with material not much higher than the surrounding matrix of young beech, as otherwise in the case of the pine the tendency to branch development becomes more prominent than is desirable for the formation of fine clean boles of high marketable value.

Both of these species do good service as nurses, on inferior soil, especially the pine, or where the young seedling crop of beech is thin and unable to form canopy readily, or apt to be sickly in growth; in such cases, however, the requirements of sylviculture are provided for by the introduction of the nurses individually here and there, and care must be taken not to plant out so many as may, by forming canopy later on, suppress the beech or interfere very materially with its development.

Particularly in eastern Germany, mixed forests of beech and hornbeam have an importance which they can never acquire in Britain, although as undergrowth in copse the latter is often welcome.

Wherever birch finds broken soil in young beech-woods, it is apt to assert a foothold, and to become more of a noxious weed than anything else, giving trouble, through its reproductive capacity, with regard to the introduction of more desirable species, and when springing up in any considerable numbers, despite its light foliage, often interfering greatly with the development of the beech. As groups of birch thin themselves out strongly between the twentieth to thirtieth year, this species should be grown only as single individuals, or in small knots on favourable situations, so as not to interrupt the canopy too much when they become mature at forty or at most fifty years of age. Its introduction takes place preferably by planting rather than by sowing, but under many circumstances the cutting out of all self-sown seedlings is alone requisite to have a sufficiency of birch.

The other softwoods, of which lime, aspen, and sallow are, next to birch, the chief species to be found in admixture with the beech, have much in common with the birch. They very usually find their way into beech forests during reproduction as self-sown growth, or as stoles from former trees; and where they do not occur in such numbers, or so disposed over the area in groups, as to damage the development of the ruling species, they perform good service as nurses, quickly form marketable timber, and yield at an early date fairly appreciable returns. But where allowed to form large patches, they tend like the birch and pine to branching growth, neither congenial to the ruling species nor profitable to the development of their own boles. Such groups have the further disadvantage of being difficult to fill up with any remunerative species when these quick-growing trees have to be removed, long before the ruling species has approached maturity. If the proper time for their removal has not been taken advantage of, the softwoods should only be eliminated very gradually where they predominate, in order that the beech poles, which will usually be found to have been drawn up too quickly, may have time to thicken so as to support their own weight, in place of being bent down. Where, therefore, they are to be found self-sown in moist patches, the best individuals should be selected here and there, and reserved for growth only to such an extent that their removal about the fortieth to fiftieth year will not cause any serious break in the leaf-canopy. Where no adventitious seedling growth or flush of root-suckers is available, planting will generally be preferred to sowing, as affording a much better means of obtaining what seems the most advantageous disposition of the softwoods throughout the ruling species.

Natural Reproduction of Beech Forests under parent standards forms the rule with this species, as the seedling growth demands, like the silver fir, protection against frost and insolation during the first two or three years of its existence. As already mentioned, three classes of fellings in the mature crop may be distinguished, viz., (1) the preparatory felling, (2) the reproductive or seed-felling, (3) fellings to strengthen the young growth, and to effect the final clearance of the parent standards. The first two fellings are made previous to regeneration, whilst the latter is best carried out as gradually as local circumstances and the provisions of the working-plan permit.

The preparatory felling is made in order to stimulate the parent standards, through greater enjoyment of light and air, to speedy and increased production of seed, and at the same time to accustom them gradually to the isolation they must ultimately have before the final clearance, as well as to harden them against wind and scorching from sun-burn. The best opportunity is also at this time given to remove all the other species growing in admixture with the beech, so as to confine the reproductive operations to the latter alone, subordinate species being best introduced later on. The soil-covering in mature forests in close canopy is seldom of such nature that it can at once offer a good germinating-bed for the seed ; hence a certain deliberate interruption of canopy is necessary in order to allow rain, light, and warmth to accomplish the decomposition of the dead foliage covering the ground, except on the fresher and more fertile soils where the greater moisture has all along been more favourable to the formation of humus. Under ordinary circumstances, with a moderate preparatory felling, the decomposition of the soil-covering of dead foliage is accomplished in about four to five years. This takes place quickest on limy soils, where felling is sometimes hardly necessary at all, owing to the danger of the soil becoming overrun with weeds, but proceeds more slowly on the sandy varieties of soil.

In addition to the subordinate species, only the smaller dominated stems are removed, so that about 12 per cent. of the cubic contents are harvested, which would include about every fifth to seventh tree of the smaller classes. The fall can always be greater on the cooler northern and eastern aspects, and in localities where the foliage lies thick ; where the soil already shows tendency towards growth of grass or weeds it is unnecessary, and would be out of place. Young self-sown growth should only be allowed to remain if of good development and not over six to eight years old, as beech differs greatly from silver fir in respect to the recuperative power of seedlings that have stood long under dense shade, and such badly grown patches only interfere with a free circulation of the air, thus increasing danger from frost. By driving in cattle for grazing, or swine for pannage, the work of breaking up the soil, and rendering it receptive for the seed, is greatly furthered.

The reproductive or seed-felling takes place when a good mast-year has come round, which can usually be foretold by the thicker, swollen appearance of the future flowering buds in autumn and winter, especially after a hot summer. About $\frac{1}{4}$ to $\frac{1}{3}$ of the crop then on the ground may be removed, those left as parent trees being preferably such as show a breast-height diameter of about twelve to sixteen inches, and have well-developed crowns which do not reach far down. The largest fall of timber is permissible on soils not having a strong tendency to the growth of weeds, and is demanded by dry soils below the average in mineral strength, as in these latter localities the young seedlings derive most of their supplies of moisture from the nightly precipitations of dew, and though temporary shade does them no harm, the constant overshadowing of numerous standards cuts off their requisite supply of moisture in the form of dew and gentle showers of rain. The work of reproduction is greatly aided by driving in cattle and swine, and by the use of the rake in order to provide the beech-nuts with a covering of soil.

The fellings for strengthening the young growth, and for effecting the total clearance of the mature crop should begin in the year following the fall of the seed on dry soil, or where considerations in regard to it have made a comparatively dense overshadowing of the parent standards desirable during the seed-year. But under ordinary circumstances they are not begun until the seedling-growth is two years old. The rate at which the gradual final clearance takes place depends to a great extent on the vigour of the seedling crop, for where this shows that fuller exposure to light, air, and atmospheric precipitations are required, the standards should be first removed. As it is during the final stages of the gradual clearance that the greatest increment in girth takes place on the standards, they are retained wherever, and so long as, they do not appreciably injure the young crop. The second fall usually takes place about two or three years after the first, and the others after similar periods, but these can be hastened where danger from frost or weeds is not to be apprehended, or where the soil is deficient in moisture. On the average, the final clearance is effected in about ten to twelve years from the mast-year. On warm dry exposures it has often to be carried out within six to eight years; whilst on cool aspects with moist soil it may be extended over fifteen to twenty years, during which period it should be conducted very gradually.

Artificial Formation and Reproduction of beech woods takes place, as a rule, only under the shade and shelter of standard trees, though not necessarily of its own species, for under the shelter of pine or larch the seedling growth thrives even better than under parent standards. Where such shelter is available the preference is given to sowing, but where young woods are to be laid out in the open, planting is almost universally adopted. In all cases in which light-loving species like oak, pine and larch, or patches of elm, ash, and maples, have to be provided with underwood, sowing generally yields better results than planting, and at a less cost.

Sowing is usually performed by dibbling in a few beech-nuts at distances of about twenty to twenty-four inches, or else sowing broad-cast or in rills either in rows or patches where some special preparation of the soil has taken place for the reception of the seed. Whether sowing should be carried out in autumn or in spring, depends for the most part on the danger to be apprehended locally from frost; this also determines the soil-covering that should be given to seed sown in autumn, for a covering of over one inch of earth retards the process of germination appreciably. As the result of experience, autumn sowing is preferred on the higher hilly land, and spring sowing on the lower tracts and uplands, and more particularly on warm southern and south-western exposures.

Planting with yearlings or two-year-old seedlings is only carried out under protective standard trees when the conditions of the soil are favourable but as a rule two to four-year-old seedlings taken from adjoining woods, or from temporary nurseries, with balls of earth attached to the roots, find most demand. On good and not too binding soil younger plants of six to twenty-four inches in height can be put out in wisps by means of notching; they are planted about 4 feet × 4 feet, whereas seedlings of 2 to 3 feet are usually only put out about 5 feet × 5 feet on account of the greater cost. Larger transplants of 3 to 5 feet are generally put out at 6 feet × 6 feet when required for the filling up of blanks.

Planting operations should be conducted early in spring before the buds begin to swell much. Where the use of large transplants is necessary in the open, the twigs on the lower portion of the stem should not be altogether removed, as otherwise the young plants are more liable to injury from sun-burn; trimming in a pyramidal form is therefore to be recommended.

2. OAK (*Quercus Robur*, L. = Q. PEDUNCULATA, Ehrh. and Q. SESSILIFLORA, Sm.)

Originally, both varieties of the oak were known under the general name *Quercus Robur*, L., but they are now recognised as having decided sylvicultural as well as botanical differences; they differ in bark, arrangement of branches, foliage, flowering, fruiting, and habitat. The leaves of the English, common or pedunculate oak (*Q. pedunculata*, Ehrh.) have a short petiole, or are nearly sessile; those of the sessile or durmast oak (*Q. sessiliflora*, Sm.) have mostly a petiole over half an inch long; except on one-year-old seedlings, the leaves of the English oak have a small lappet at the base, which is not generally found on the foliage of the sessile oak; young leaves of the latter have a downy covering of hair on the lower surface, and older leaves at least show traces of this in the angles of the veins, whilst leaves of the former are usually quite smooth. It is, however, from the differences between the flowers and fruits that the distinctive botanical names have been chosen; the female flowers and the acorn are sessile in the sessile oak, but are separated from each other on short stalks or peduncles in the pedunculate oak. Even during the leafless period in winter, the varieties are in general easily distinguishable, the latter having a more branching growth and a more rugged and deeply fissured bark than the former, whilst its leaf-buds are also shorter, thicker, and less pointed.

Quercus.	*Leaf stalk.*	*Base of leaf.*	*Acorns.*	*Buds in winter.*
Pedunculata	Short.	Broad, heart-shaped, with crinkled lappet on each side.	Laterally arranged along a stalk.	Paraboloidly conical.
Sessiliflora ..	$\frac{1}{2}-1''$ long.	Forming a wedge-shaped junction with the petiole.	Sessile, often racemose.	Pointedly conical.

Distribution.—The English oak is found over the greatest portion of Europe, Asia Minor, and the Caucasus, its northern limit being about 58° in Scotland, 60—63° in Scandinavia, $57\frac{1}{2}$° in Russia, thence eastwards to the Ural; its southern limit through Spain, Sicily, and Greece is not fixed. Its maximum development takes place in the southern portion of central Europe (in the area drained by the lower Danube it is the chief tree over extensive tracts of woodland), and everywhere it is indigenous rather on the plains and uplands than on the higher hills. In the Bavarian Alps it ascends to 2,500 feet eastwards of the river Inn, and to 3,050 feet to the west of it; in the central district of the Tyrolese Alps it attains an elevation of 3,300 feet.

The region in which the sessile oak is indigenous corresponds in general with the habitat of the English oak, but does not extend so far to the north or east, although the former is able to ascend hills and mountain slopes to a greater height than the latter, viz. 320 feet higher in the Harz, 1,080 feet higher in Baden, and 1,500 feet higher in the southern Alps.

In England the pedunclate oak is far more common than the sessile, but in Scotland the latter species increases in number.

Tree-form and Root-system.—No forest tree outrivals the oak, especially the English oak, in its tendency to branch formation when growing in isolated positions; but in close forest, its energy being concentrated on growth in height, it develops a good, fairly straight and cylindrical, clean bole. The weaker tendency to branch development in the sessile oak exhibits itself in the generally straighter growth of this tree in close canopy. Sufficient growing-space for the development of a moderately-sized healthy crown is essential for all oaks that are to be held over for the production of the larger-girthed and better paid assortments of timber. Otherwise, on trees being cut free from side competition for light and air in order to obtain large increase of growth in girth and cubic contents, the bole is apt to become covered with shoots (particularly in the case of the sessile oak), on the adventitious buds being called into activity by the increased supply of sunlight and warmth made available, whilst the upper part of the crown often dies off and the trees become '*stag-headed*' or dry there.

The oak is a deep-rooting species of tree—no growth of the forest is more so. It develops a large tap-root, and strong, heart-shaped side roots, which often force their way down to a great depth in deep, easily penetrable soil. With advancing age, after the main growth in height has been completed, the tap-root becomes more or less inactive, and the side-roots near the surface gradually assume a greater share in the task of nourishing and supporting the tree.

Requirements as to Soil and Situation.—Willkomm estimates that the oak can thrive wherever the mean temperature from May till October is not less than $54\frac{1}{2}°$ Fahr.; but in any case it, and especially the English oak, makes greater demands on warmth than the majority of other trees. The sessile oak is content with about the same degree of warmth as the beech.

The oak seems to tolerate both a humid atmosphere and a dry one, but this capacity is naturally regulated by the conditions of any particular situation as to soil-moisture and warmth; in general warm, sunny, southern exposures show the best growth when the soil is fresh and deep, conditions found more frequently on south-eastern than on south-western or western aspects. At the higher elevation even the sessile oak prefers the warmer southern exposures to the damp, cold, raw northern aspects.

The principal demands that are made on soil by the oak are depth, a low enough degree of tenacity to allow of the root-system ramifying easily, and a sufficiency of moisture permeating both soil and subsoil. The English oak can stand more moisture in the soil than the sessile oak, and can even thrive with an excess of it in warm localities, when its growing-space is ample, and its crown well developed, these being the circumstances favourable to rapid evaporation and transpiration through the foliage. In its demands with regard to mineral strength, the oak occupies a position very similar to the beech, with which it is most frequently associated in growth. The sessile oak is the variety chiefly found on the sands and poorer loams of the plains, on the sandy formations of the uplands and hills, and on the soils formed by the older stratified rocks (porphyries and granites), whereas the English oak is the predominating variety on limy soils, on clays and loams formed from basalt, on rich humose alluvial deposits of sandy loam and loamy sand, and on fertile marshy soil. The geognostic origin of the soil, however, is of far less moment than its general quality, especially with respect to freshness, although loamy soils generally produce better and more durable timber than sandy soils. The oak is said to take up more lime and phosphorus from the soil than any other species of forest tree.

When the oak is treated as coppice, its root-system is superficial, and its requirements in regard to depth and moisture are less than when timber production is the object in view; fresh loamy sands, and fresh sandy clays, with warm, sunny, southern exposure are therefore the most favourable soils and situations for the growth of oak coppice.

Requirements as to Light depend to a great extent on the general quality of the soil, especially on its freshness, but in any case the oak must be classed as requiring a large amount of light for its proper growth and development. Its demands are greatest on light sandy soil, least on deep, fresh, loamy soils in cool dingles, coombs and valleys. Throughout the pole-forest stage of growth, and even before entering that, it is, in not very favourable localities, impatient of shade from the side as well as from above; later on it cannot thrive in close canopy unless some such advantage be secured to it by tending, as may permit of the free lateral enjoyment of light by a moderately developed crown never apt to be very densely foliaged. In general the English oak appears to make somewhat greater demands with respect to light than the sessile oak.

In copse, or in coppice-woods, the oak is absolutely intolerant of any shade which interferes with the free and undisputed enjoyment of the light and warmth necessary to stimulate the growth of the stool-shoots.

Attainment of Maturity and Reproductive Capacity.—When once the oak has entered the seed-bearing stage, which in woodlands it attains about the sixtieth to seventieth year, a partial seeding takes place every two or three years; but really good seed-years occur only once every six to nine years. The probability of a seed-year can be foretold in the preceding autumn and winter by the thickening of the flower-buds, which are formed most plentifully after hot summers. About 150 acorns run to a pound, and good seed should during experimental tests show a germinative power of about 65 to 70 per cent.

No attempt to grow historical trees, or to rear giants for the æsthetic edification of future generations, would in general be rational in sylviculture, although at the same time it would be churlish to cut down for sale the large and very often over-mature trees growing here and there at the edge of forests, or near cross-roads, and perhaps known far and wide locally as old trees for the last two or three generations; but the oak can easily attain an age of over 200 years as a forest tree, before beginning to show signs of over-maturity or senile decay. When grown in pure forest, it is usually thinned out strongly about the seventieth to eightieth year, and then planted up with underwood of shade-bearing species (beech), the standards being left till removed along with the underwood seventy to eighty years later. Grown in beech woods having a rotation of ninety to a hundred and twenty years, good oaks are often left over till the second fall, when they are removed first to allow of the natural reproduction of the principal species; by these means the finest old oak timber of two hundred to two hundred and forty years of age can often be produced.

The reproductive capacity of the oak can be readily judged of by its ability to develop dormant buds along the stem on being suddenly isolated after growing long in close canopy, or on being coppiced, or pollarded. The power of shooting from the stool is greatest when the bank is thin and smooth; it diminishes sooner on sandy soils, or those liable to inundation, than on powerful soils, even when the latter may be somewhat wanting in depth. Recent experiments at Nancy have shown that the power of throwing out shoots from the stool is retained up till the sixtieth, and even till the eighty-fifth year of age.

Liability to Suffer from External Dangers.—Thanks to its strong root-system, the oak suffers little from the violence of storms. Of physical dangers that from frost is greatest, but the oak is less exposed in this respect than the beech, as it does not break into foliage until about a fortnight later, and has also a stronger recuperative power; situations known to be subject to frost are, however, hardly the most suitable localities for the growth of oak.

Selby, evidently borrowing from Loudon, mentions in regard to the oak:—

> "The extraordinary number of insects that are wholly or partially supported by it, amounting it is supposed, to nearly 2,000 species, 1,500 of which may be considered to be phytophagous, or actual feeders upon some portion of the tree, the remainder as parasites attached to these, and belonging to the ichneumonidæ, and other parasitic tribes."

Leunis,[1] with more circumstantial detail, gives the number of animals and plants living on the oak as "500 insects, 36 fungi, 16 hanging mosses, 7 leaf-mosses, and 3 liverworts

[1] Leunis, *Synopsis der Pflanzenkunde*, 1877, p. 1017.

—also by no means a small total. Whatever may be the accurate number of phytophagous insects, the vast majority of them are fortunately not noticeably injurious from a sylvicultural point of view, though at the same time the oak has a good many enemies in the insect world. Species of *Melolontha* damage the roots as grubs, and the buds and leaves as complete insects; trees are sometimes almost completely defoliated over considerable tracts by the caterpillars of *Cnethocampa processionea*, as also to a less extent by those of *Gastropacha neustria*, *Porthesia chrysorrhœa*, *Liparis dispar*, *Chematobia brumata*, and *Tortrix viridana;* young stems are attacked by larvæ of *Scolytus intricatus*, *Coraebus bifasciatus*, and species of *Agrilus*, and older stems by those of *Xyleborus monographus*, *dryographus*, and *dispar*. Flowers and buds are often destroyed to a very great extent by the caterpillars of *Chematobia brumata*, *Gastropacha neustria*, and *Tortrix viridana*. The timber is also liable to attacks from *Lymexylon navale*, the eggs being deposited on unsound boles or barked logs (never, according to Hess,[1] on sound growing stems), and the larvæ boring inwards thus and damaging the wood for technical purposes; this insect is the scourge of dock-yards. Galls on various parts are occasioned by the females of *Cynipidæ* depositing their eggs; the large galls, or *wood-apples*, often so prominent on the lower sides of leaves, being the nursery beds of the larvæ of *Cynips quercus folii*.

On cold situations with wet subsoil, the lower portion of the bole is often subject to a disease that renders it useless as timber; observation and examination have not yet quite determined whether this unhealthy condition is primarily due to the action of frost or of a fungus, but in any case the fungus found in the diseased wood is *Nectria ditissima*. The roots of one to three-year-old seedlings in nurseries are

[1] Hess, *Der Forstschutz*, vol. ii. 1890, p. 11.

killed by *Rosellinia quercina*. Red-rot in the timber is due to *Polyporus sulphureus*, *Thelephora perdix*, and *Stereum hirsutum*, white-rot to *Polyporus dryadeus* and *igniarius*, and *Hydnum diversidens*, the diseases often gaining foothold where branches have been broken off, or where trees have been trimmed with the saw without the sawn surfaces being tarred. A better-known parasite is the mistletoe (*Viscum album*), though it is of rather rare occurrence on the branches, and does not practically do any damage to the timber of the bole.

The oak suffers less than any other forest tree from the effects of accumulations of snow and ice on the branches, and, owing to its rugged bark, does not get scorched or sunburnt. Rank growth of grass on the soil is only prejudicial to its growth at the youngest stages in so far as it increases the danger from frost. Owing to the rapid development of a tap-root, long-sustained drought also occasions it little damage. The astringent properties of the young shoots and foliage protect them from being browsed on by cattle to any very great extent. Serious damage may, however, be done in plantations of fifteen to twenty years of age by deer stripping the bark in spring and summer where strong herds of red-deer are maintained.

Sylvicultural Treatment of Oak.—As a light-loving species soon becoming interrupted in canopy and having, moreover, foliage which does not yield good humus on decomposition, oak is not under ordinary average circumstances naturally suited for growth in pure high timber forest. It is not well endowed with a capacity for retaining and conserving the quality of the soil, which sometimes deteriorates so much with long periods of rotation that, unless improved by underplanting, it would hardly be possible to produce future crops of oak until after some soil-improving species had first been grown in order to recuperate the productive capacity of the exhausted soil. Even on the best classes of soil, therefore, when pure forests of oak have been formed, they are usually thinned out when the chief growth in length is completed, and after being underplanted with beech, hornbeam, silver fir, or spruce, are then allowed to develop till the latter grows up to maturity. Except on such exceptionally favourable soils, the oak is usually grown in high timber forests along with the beech, the relative proportion in the admixture of the species being mainly dependent on the quality of the soil. In moister, low-lying tracts it is also grown in admixture with the alder, and in localities subject to frost along with aspen and birch, which however require to be removed as soon as they have performed their duty as nurses, and before they begin to interfere with the normal development of the oak. No tree is so well adapted to assist the development and to supply the deficiencies of the oak as the beech, which can thrive fairly well under the light shade of the former; but at every stage of growth care must be taken to provide the oak with some advantage as regards growth in height, as it is otherwise apt to be weak in branch development, and consequently in growth in girth, when it is hemmed in by beech of equal, or nearly equal, height.

The oak, particularly the pedunculate oak, is eminently suited for standards in copse, *i.e.* over coppice, but care must be taken to train up the different classes of standards only from among seedling growth, and not from stool-shoots. As this method tends to induce excessive branch-development, and as the removal of branches on a large scale is costly, and also affects the quality of the timber for technical purposes, besides offering unnecessary opportunities for the entrance of fungus spores into the wounds, the same object can be better and more effectively attained by the formation of pure forests of oak, and then underplanting them after thinning out at about seventy years of age; longer straighter and more full-wooded boles are then produced, even although the girth is large in the lower half. Where there is a demand for crooks and strong knees of oak, such as were especially required in former days for shipbuilding, and are even now in good request for sailing craft, these assortments of timber are best producible by oak standards in copse.

Should there be a good market for tanning-bark, oak coppice may often give very excellent returns, especially on somewhat shallow, but otherwise fertile, soils with warm sunny, southern and south-western exposures; when treated in hags with a rotation of fourteen to sixteen years, it yields the smooth-barked variety of tanning material most prized for the preparation of leather for bootmakers. Coppice-woods for the production of tanning-bark should be formed pure on good soil, as the stool-shoots from the oak are vigorous, and amply suffice to protect the soil against insolation even when worked with a low rotation. Although the harvesting can only be begun whilst the sap is in flow, care must also be taken to complete it as soon as possible, in order that the shoots reproduced from the stools may be able to harden properly before the early frosts set in in autumn. The best time for cutting is in May, when the young flush of foliage is taking place. The comparatively very early returns, their high monetary value, the relatively small capital represented by the soils plus the growing-stock on the fourteenth to sixteenth annual falls, and the general security and simplicity of this form of treatment, all speak in favour of oak coppice on good upland soil, wherever the demand for the bark exists or can be created. There is not the slightest doubt that there are many thousands of acres of land now lying idle along railway cuttings and embankments, which are perfectly well adapted for oak coppice, and would yield highly remunerative returns under proper treatment.

The oak thus finds its place in all methods of sylvicultural treatment,—high forest, copse, and coppice. As the most valuable of our trees, it is favoured under the most varying circumstances, and forms, outside of the true woodlands, along with the elm the most characteristic feature in English and lowland Scottish landscape. As *High Forest* it is to be found forming pure or nearly pure forests on the deeper, richer soils still preserved under woodland, and also in mixed woods on undulating ground and upland and hilly tracts, sometimes forming the major species, at others scattered merely in groups, or patches, or only individually throughout other species; principally associated with the beech, it is also to be found along with alder and birch on the moister, low-lying tracts with good soil. In high forest of beech it is the principal standard retained to develop throughout another period of rotation into timber of large dimensions, and of highly remunerative quality. Throughout the earlier periods of forestry its pannage and acorn harvest had a value often far exceeding that of the timber produced. As *Standards in Copse* it yields good returns, whilst still permitting the growth of the underwood under its light foliage, and on upland grazing grounds it brings in a very good monetary return, besides often affording grateful shade and shelter to the cattle, without damaging the grass when planted far apart. Its reproductive power from the stool, and the superior properties of its bark for tanning purposes, make it in its proper place one of the most remunerative forms of sylvicultural crops when treated as *Coppice;* it is willingly seen, too, among the coppice under standards, but under the shade of the latter it seldom develops so satisfactorily as with a freer enjoyment of light and warmth, and is more apt to be outgrown and suppressed by shade-bearing species.

By no other species of tree does the fall vary so much as in the case of the oak; between the harvesting of coppice every fourteen to sixteen years for the sake of the smooth bark, and the clearance of two hundred to two hundred and forty-year-old trees, that have grown through two complete periods of rotation of mature beech, there lie wider differences than can be shown in the treatment of any other species of forest tree. Throughout all periods of existence it deserves and receives as much attention in the way of tending as can conveniently be bestowed upon it, although the retention of timber beyond the hundred to hundred and twentieth year should only be strictly confined to such trees as promise good future development. A little timely assistance is often all that is required to ensure normal development. As Evelyn noticed and pointed out more than two hundred years ago, wherever there were mixed woods of oak and beech the latter slowly but surely ousted the former from its foothold in the forest; wherever mixed forests are now to be found or formed it is the duty of the forester to see that such shall not be the case, and to arrange that at least the major part of the normally developed crown shall at all times be enabled to have a comparatively unrestricted enjoyment of light and air in order to provide for more plentiful and thorough assimilation, and a consequent richer production of timber.

The better classes of soil, where oak might be grown in pure forest to maturity, have for the most part long since been cleared for agriculture, and to attempt to grow oaks on merely average or inferior soils, without subsequent underplanting after they have entered the tree-forest stage of growth, leads too frequently to indifferent development, and partial deterioration in the quality of the soil, as evinced by growth of whortleberries and similar weeds; this leads later on to greater interruption of the canopy and increased liability to deterioration of the soil, when even the future production of forests of broad-leaved species may be at stake, and the formation of coniferous woods, for one rotation at least, may become a necessity.

In its requirements as to light, hints may be looked for with regard to the measures requisite for the tending of oak, either in pure or in mixed forests. Freedom from side-shade, and a fair amount of growing space, are necessary for its normal development, although, until after growth in height has culminated, these should never be permitted in such abundant measure as to allow of rapid expansion in girth at the expense of growth in height. It is particularly in the clearing out of softwoods and of other species interfering with its development, and in the weeding out of indifferent individuals of its own species where they stand too thick, that assistance needs to be given to oak during the thicket stage of growth. When beech is grown along with oak on soil favourable to the development of the former, it has sometimes to be topped in order to free the latter from the pressure of its immediate neighbours.

Throughout all the later stages of growth tending is mainly confined to thinning out, and there is no other species of forest tree, except perhaps the larch, in regard to which well-regulated thinnings are so necessary; when they are begun too late, or not continued regularly, or not carried out to a sufficient extent, the effects are almost immediately noticeable in more or less imperfect development, exhibited in poverty of crown, weakness of stem, and often in a flush of shoots from adventitious buds along the bole. Only such individuals are suited for retention to the full period of maturity as have normal development both of stem and crown. Without actually much interrupting the canopy, the thinning out of oak forests or groups should be begun early and repeated often, throughout the whole period of tree-forest, except when the necessity of further thinnings has been obviated by partial clearance and underplanting about the seventieth to eightieth year. Cramped or confined growing-space, uncertainty about the development of the predominating stems, and long-continued individual struggle for the supremacy, all militate so much against the ultimate returns derivable from the mature crop that, in the case of oak, thinnings must be carried further than with the beech, and should include all individuals that can be spared from the canopy, as, even where petty interruptions are thus made, the blanks soon close up again. *Thin early and often* is the golden rule in the tending of the oak, and in the frequent removal of indifferent individuals lies the best means of permanently retaining a good canopy; by this means the best mature crop is not alone assured, but also the advantages of early and sometimes good returns in the meantime.

Pure forests of oak are more usually the outcome of growing or planting than of natural reproduction, and they exhibit differences of growth, especially in the more advanced stages of development, varying with the qualities of soil over which they are found. Where not hindered by strong growth of grass, the young plants rapidly shoot ahead of the dangers most common to the youngest period of development, but from then till about the eighth to tenth year they tend more towards lateral than to upward growth. Shortly after forming close canopy, however, the young thicket begins to clear itself from branches, to confine the foliage to the upper portion, and to enter upon the struggle for individual existence shown in vigorous growth in height. On deep, fresh soil in mild localities this culminates about the thirtieth to fortieth year of age, but on less favourable soils and situations not till ten to fifteen years later if the density of canopy has been maintained, which is not always the case as, except on fresh fertile soils, there is often a tendency towards interruption of canopy throughout the earlier part of the pole-forest stage of growth, in consequence of insufficient light and growing-space. With the efforts of the survivors to extend their crowns, a considerable degree of sunlight is allowed to play over the soil, and the fall of leaves is both too light, and of too poor a humus-producing quality to conserve the productive capacity of the soil, which, losing both its moisture and its fertility, can no longer give generous supplies of nutriment to the timber crop. Under favourable circumstances a self-sown growth of hornbeam, hazel, and other minor trees and shrubs finds its way into the woods and forms undergrowth protecting the soil against insolation; but too often the oaks are apt to become stag-headed and sickly, and to show a growth of mosses or lichens on their boles, in place of exhibiting a clean healthy bark. On soils of merely average quality, therefore, experience has shown it to be advisable to make a partial clearance of the oak at about seventy to ninety years of age, by which all individuals not likely ultimately to yield really good timber are removed, and to underplant the remaining selected trees with some soil-improving species, generally the beech, but also hornbeam, silver fir, or spruce, according to the nature of the soil.

As all species of trees protect the soil during the early stages of growth, whilst they form close canopy, there is not as a rule any danger of deterioration when pure forests of oak coppice are formed on soils of average quality, and in many parts of Germany this form of sylvicultural treatment has taken place uninterruptedly for centuries on favourable situations. For oak coppice, the most favourable localities are those with long periods of annual active vegetation, with warm, sunny exposures, and moderately deep, loamy soils; even where a fertile soil seems shallow on the hill-sides, it is still sufficient if the subsoil is fissured so as to admit of the penetration of the root-strands in search of soil-moisture. Marshy situations, or sandy soils poor in loam and deficient in humus, are not localities suitable for this kind of sylvicultural crop. When the area is sufficiently stocked with stools, and the fall of the last crop has been made close to the ground, the growth of the shoots is usually so vigorous that close canopy is attained in three to four years, and growth in height is continued thereafter with energy, culminating in the tenth to twelfth year, when the shoots attain the size of small poles. At that age there has of course been a considerable diminution in the number of shoots originally sent out from the stools. The better the situation, the more rapid and the more vigorous is the development of the predominating class of shoots, producing not only a larger quantity of bark, but also bark that is thicker and finer in quality. Pure oak coppice on the more favourable sites yields about 35 cwt. of bark as well as about 850 to 900 cubic feet of wood per acre, when worked with a rotation of sixteen years.

Mixed Forests with Oak as the ruling Species are only to be found to a limited extent on deep fresh soils of the better class, as far as other light-loving species like elm, ash, maple, and sycamore are concerned. In low-lying tracts with deep moist soil, where insolation would not necessarily lead to excessive diminution of the soil-moisture, and where also all these light-loving species are more densely foliaged, and at the same time more capable of bearing shade from above or from the side, forests are often formed with oak as the matrix, and these other valuable woods of our forests as the subordinate species, introduced however as individuals only, and not in groups or patches. As the oak is the principal species to be favoured at all times, these subordinates are removed in the course of thinnings whenever, and wherever, they make themselves troublesome or self-assertive; but in any case they are cut out when about thirty to forty years of age, by which time they may have attained good marketable proportions, whilst the oak also needs somewhat enlarged growing-space for its further normal development; occasionally, however, good stems are retained longer for the production of finer assortments of timber for cabinetmaking. When felled, such subordinate species are often able to coppice and grow up into underwood under the shade of the standard oak trees.

On still moister classes of oak soil, alders, willows, and birch are often planted to stimulate the ruling species to rapid growth in height; but they have all to be cut out early, else they are apt to suppress the principal species, though the alder is able to reproduce itself as coppice twice, before it is finally suppressed, and often yields fair returns from its rapid growth.

The beech, however, is by far the most important subordinate species grown along with the oak on soils which are somewhat better than those on which the oak must be subordinated to beech as the ruling species, but which at the same time are not quite good enough to be planted up with pure oak at first, and then partially cleared after completion of their chief growth in height, and underplanted with beech. The admixture of the latter depends on the extent to which the soil requires its protection against loss of soil-moisture, involving subsequent deterioration. When sufficient advantage in growth has been secured to the oak over the beech, little tending is requisite beyond what may be ordinarily given in the way of thinning throughout the period during which the beech attains its maturity. About the eightieth to hundredth year, after the main growth in height has been attained, the beech is naturally reproduced under the oak standards, with more or less artificial assistance wherever necessary, and the whole grows up till the young crop of beech also attains maturity, when the oaks are 180 to 200-year-old stems, of fine dimensions and high technical and market value. The oak standards should, at the time of the clearance of the first crop of beech, be distributed as equally as possible over the area, so that each individual stem can have the fullest enjoyment of light and air ; thirty or forty standards per acre will again form almost close canopy by the time the second crop of beech attains maturity, so that a larger number of oaks per acre would bring no benefit so far as the oak crop is concerned, and would only militate against the development of the beech underwood.

The principal ruling species with which oak is usually associated as a subordinate, occurring either in groups, or patches, or rows, or merely as individuals scattered here and there, is undoubtedly the beech, which has most in common with its natural habit of growth. No other species of forest tree supplies so well as it the soil-protecting qualities in which the oak is deficient, and none is at the same time able to thrive so well under the side-shade thrown by the usually older and quicker-growing oaks. The less the proportion in which the latter is admixed, the greater must be the attention paid and the assistance given to it during all the operations of thinning out, for where it is scattered singly, it is not sufficient that it should be merely dominating along with the beech, it must be unquestionably predominant over its neighbours, otherwise it has a weakly expansion of crown not suitable for its retention to the full term of maturity; an insufficiency of coronal development is more likely to lead to stag-headedness than to expansion of the crown when such trees are freely and fully exposed to light, air, and sunshine on the beech being harvested. Its treatment as a subordinate of the beech has, however, already above been dealt with in detail (see pp. 170 to 174).

Oak is less frequently to be found growing along with spruce, except in places where the latter has had to be introduced to fill up blanks in the natural reproduction of beech forests, or where the soil has deteriorated so far that the cultivation of a crop of spruce instead of beech seems preferable under the shade of the standards that are retained to develop into full maturity. But, for the formation of mixed forests of about the same age, the oak is out of place along with the spruce, as the latter is, during the thicket and pole-forest stages of development, of so much more rapid growth in height that it shoots ahead of the oak, and is very apt to suppress it even when introduced in patches or small groups; where the groups are larger, the drawbacks of pure forest of oak are noticeable on a small scale. Where, however, it is desired to introduce the oak into woods of spruce, it is best to plant it in small groups surrounded with a girdle of beech, silver fir, or larch, to protect it to a greater or less extent against the more aggressive suppressing power of the ruling species. In spruce tracts generally, the cultivation of mixed forests of purely coniferous species will as a rule be found much more remunerative than any attempt to grow the oak as a subordinate tree.

In forests of Scots pine, the oak has also no right to expect a favourable welcome and a home, for on the poorer classes of soil it would not thrive, and on the better classes the principal species would be of so much quicker growth that the oak could not compete with it at all, besides which its admixture to any extent, under either of these circumstances, would only entail forfeiture of some portion of the full remunerative returns that might otherwise be fairly expected from the soil. Where old oaks are still at the present day to be found growing in admixture with Scots pine, they are in all probability only the last survivors of deciduous broad-leaved forests on areas where the present ruling species had to be resorted to in order to recuperate the exhausted vigour and productiveness of the deteriorated soil.

The Formation and Reproduction of Oak Forests are usually carried out artificially by sowing or planting in the open, although natural reproduction under parent standards is occasionally adopted where the danger from rank growth of grass is not to be feared. As the light-loving oak requires no early shade, and is not apt to suffer from frost and weeds, standards are by no means essential to its well being; but when parent trees of full maturity show a good acorn or mast year, natural reproduction is often most satisfactory, as well as being the cheapest method of regeneration.

The formation of oak coppices frequently takes place by planting three-year-old transplants, the leading-shoot being removed close to the ground as soon as ever the roots have established themselves. A preference is in many places, however, given to the use of four-year-old transplants, the leading shoots being removed close to the roots, and only these latter planted out. The reproduction of the coppice woods is accomplished naturally by the growth of stool shoots, which spring more plentifully, and form roots for themselves more easily, when the cut is made smooth and close to the ground, so that hardly even a short neck is visible; where stools die off here and there, fresh ones are planted in their stead.

For the production of standards in copse, and for the maintenance of a due supply of good stems of the various age-classes grown from seed, and therefore better likely to thrive to a ripe old age than stool-shoots, it is usual to plant up small groups here and there with large transplants, and to protect them as far as possible against being interfered with too much by the surrounding coppice-shoots and softwoods of quicker growth.

Artificial formation and reproduction of oak takes place both by sowing and planting, the preference being determined to a great extent by local circumstances; as a rule these more frequently demand the adoption of the latter method, sometimes, too, with strong transplants, and at considerable outlay. Where one has free choice in the matter, sowing generally comes cheaper than planting, even if small plants be used, so that in a good acorn year sowing is preferable on soil that does not require any extensive or costly preparation for the reception of the seed. Thickets of seedlings often have advantages over those formed by planting, as the development of the predominating classes takes place sooner, and makes the earlier clearings and thinnings easier to carry out, whilst the returns yielded in such cases are obtained earlier, are more remunerative, and recur more frequently. On the light or prepared soils where sowing is preferable, the fact of the tap-root not being interfered with in any way, enables the seedlings to develop more normally and regularly than when more or less injury is done to it in the operation of transplanting. Wherever acorns are not plentiful, or where it is advisable to give the oak some advantage in growth over its neighbours, planting deserves the preference, the choice of the size of the transplants varying greatly according to the circumstances of each case.

Natural Reproduction by Seed can be accomplished in mature pure forests of oak, or where it is the ruling species in mixed forests, as in many parts of northern Germany, France, and Austria, simply by the removal of the subordinate species, or by a seed-felling made during the mast-year and confined to the small-girthed oaks, so that on the average the number of trees will be about fifty to sixty per acre. But as old oak forests, and mixed forests with oak as principal species, have usually only a patchy growth of mature trees to show, the disposition of the parent standards over the area is seldom so regular as in the case of the beech. The probability of a seed-year can be foretold, although not so plainly as in the case of the beech, by the larger, swollen appearance of the future flowering buds during autumn and winter, signs chiefly to be met with after warm summers favouring the formation of starchy reserves.

Wherever the soil is suitable for the reception of the acorns, a good flush of seedling growth follows the mast-year, but, in order to take full advantage of it, herds of swine should, if convenient, be driven into the woods for pannage, as, though they feed on the acorns, they do much more good than harm by treading the seed into the ground, and by disturbing the soil-covering both with their feet and with their snouts. Where such simple means are not at hand, some artificial assistance must be given by dibbling or treading in the seed, or by hoeing the ground, as unless the acorns have a covering of earth about one to one and a half inches deep, they are apt to lose their germinative power through the frosts of the ensuing winter.

Even in mixed forests of beech and oak, a good acorn year is generally followed by a fair growth of seedlings of the latter species, which only require light and air, through clearance of the standard trees, to enable them to develop normally into groups of oak. But whenever, under the light shade of aged oak trees, the soil has any strong tendency to growth of grass, natural reproduction is less likely to yield satisfactory results than planting, and in general it may be said that regeneration under parent standards offers its best results on soils of only average or inferior quality; more or less of artificial aid is, however, usually requisite under nearly all ordinary circumstances.

In order to utilise a good seed-year to its fullest, the area, over which the seed-felling extends, should comprise the fall of several successive years; but care must be taken not to include more annual falls than can be totally cleared during the period of regeneration, as the seedling growth demands the speedy removal of the parent standards. It is better to await the advent of the next good seed-year for a portion of the area, than to comprise too many annual falls in any one seed-felling. Wherever convenient, the largest standards, whose felling and dressing would be most likely to do some injury to the seedling growth, should be removed at once after the fall of the mast, and during the subsequent clearances of the mature crop it is well to remove the largest stems first.

When oak forests are being reproduced naturally, the admixture of beech on drier situations, and of ash, elm, maple, sycamore, or, where advisable for soil-protection, hornbeam on those that are moister, can easily be accomplished by sowing seed. If these species are only introduced by means of planting when once the oak is in active growth, they run great risk of being suppressed.

Sowing.—Like the Scots pine, oak well repays any soil preparation which may permit of the easy development of its large tap-root; wherever, therefore, it can be carried out without too great outlay, this should take place by ploughing, or by trenching or bastard-trenching in strips or patches on the drier varieties of soil, and by the formation of ridges or of small mounds on those that are moister. An excess of moisture is not good for seedling growth of oak on any class of soil, but in carrying out drainage works in woodlands it is not easy to regulate the extent to which the process should be confined, and on deep, light sandy soils the thriving of oak or pine is intimately connected with the supply of moisture available for their deep root-systems.

The simplest method of sowing is broadcast over the whole area, but this requires large quantities of seed, sometimes as much as ten to twelve bushels or more per acre when no special preparation of the soil has taken place, so that it is only applicable in years when the acorns have been plentiful. Even for broadcast sowing on trenched strips or bands only, from five to eight bushels are found necessary, whilst for partial sowing in furrows made by the plough, or for dibbling-in in rows on the strips, about four to five bushels are needed, and for broadcast sowing on prepared patches, or for dibbling-in with ordinary or with two-pointed hoes, about three to four bushels are requisite; where dibbling-in is confined to prepared patches only, two to three bushels per acre may suffice.

In general, fresh acorns require a covering of earth about one to one and a half inches thick, the rapidity of germination being regulated by its thickness; when mixed thus with earth the seed is much less apt to lose its germinative power than if simply lying under the dead foliage, or incompletely incorporated with the soil by means of harrowing or raking. The lighter the soil, the thicker should be the covering of earth, but when the acorns are not sown till the spring following the mast, this should be thin in order to stimulate germination. Except where circumstances are unfavourable, autumn is the best time for sowing, as being most in accordance with the natural process, the simplest to carry out, and yielding on the whole the best results. On low-lying tracts and moist localities where late frosts are frequent, a preference is, however, often given to sowing in spring, as the seedlings run less danger owing to their later germination.

When coppice is formed by sowing, this is best carried out in lines four and a half to six feet apart, the soil being well trenched, and the acorns sown closely.

Planting of oak of all sizes up to seven or eight feet can quite well be carried out without balls of earth around the roots, but with the older plants some mutilation of the tap-root can hardly be avoided, which may later on lead to hollowness of the stem in the mature tree; at any rate there can be no doubt that, when the tap-root has been reduced to any considerable extent, the young plant does not regain a healthy appearance, until its underground nutritive organs have recovered from the injuries inflicted. On the other hand, planting with an undiminished tap-root is comparatively expensive, especially on hilly or stony soil, where the pricking out of the seedlings with iron pegs or notching tools is not as feasible as on deep low-lying soils.

One and two-year-old seedlings from self-sown woods or seed-beds are usually notched in thickly on the lighter varieties of soil, no shortening of the tap-root being then necessary; but for all seedlings and transplants beyond that age, some trimming of both the ascending and the descending axes is necessary. Very good results can frequently be obtained by the use of two to three-year-old transplants in rows of 4 to 5 feet × 3 feet. When older transplants are desirable the distances at which they are put out vary from about 4 feet × 4 feet to 10 feet × 10 feet, or the equivalent growing-spaces if in rows, as the initial costs rapidly increase with the size of the transplants. It is in fact this question of cost that at times determines in favour of sowing, for quicker, and on the whole more reliable, results are undoubtedly attained by planting than by sowing.

Planting is usually carried out in spring, but somewhat later than in the case of the beech, as the oak is about a fortnight later in breaking into leaf. As, owing to the tap-root, transplants are seldom put out with balls of earth attached, care must be taken to preserve the rootlets from becoming dried up. The transplants are put somewhat deeper in the soil than they have stood in the nursery, especially in loose porous soils, as experience has shown that the soil has generally a tendency to sink in setting. Where pits are prepared for single plants, or patches are trenched for groups or knots, the earth-work should be carried out in autumn, so as to give it full opportunity of setting on the surface before the transplants are put out in the following spring. The use of older transplants of four to six or eight feet in height is generally now confined to situations where it is necessary to give the oak a good advantage over the beech, and in localities where it is exposed to danger from cattle or deer.

Wherever coppice woods are to be formed in localities prone to rank growth of grass, planting has undoubted advantages over sowing, and in order to stimulate to quicker growth of shoots, the transplants used should be at least three years old. As soon as the roots seem to have established themselves the ascending axis may be removed close to the ground. A preference is, however, given to the use of four-year-old transplants whose leading shoots are removed close to the roots, which are then planted out rather deep in the soil. Transplants thus cut back yield a thicker growth of shoots.

B. Softwoods.

1. BIRCH (*Betula alba*, L. = B. VERRUCOSA and B. PUBESCENS, Ehrh.)

Distribution.—The original *Betula alba* of Linneus was found by Ehrhart to comprise two distinct varieties, *B. verrucosa* and *B. pubescens*, whose indigenous zones seem to overlap and merge into each other, so that hard and fast lines of identification and distribution can hardly be drawn. The southern limit of the birch, within which *B. verrucosa* is chiefly found, extends from north-west Spain, across the Pyrenees, and along the southern slopes of the Alps to Croatia, Servia, and Thrace ; this is the chief variety occurring on dry soils throughout northern Germany and Britain, but on moist and wet soils it often passes from the warty into the soft-haired form, *B. pubescens.* In the birch forests of the far north, which extend from Scandinavia across Russia to Siberia, Blasius found that *B. pubescens* was the variety of most frequent occurrence. Gayer again states that *B. verrucosa* goes much further to the north and east, whilst *B. pubescens* extends further towards south and west.

The macroscopic differences between these two varieties of *B. alba* are:—

verrucosa.—Leaves and young twigs warty; leaves without hairs; lower portion of bole with coarse, blackish, deeply fissured bark. This is the usual variety.

pubescens.—Leaves and twigs without warts; young leaves, petioles, and shoots covered with velvet-like hairs; bark remaining white and smooth at lower extremity of the stem.

On the mountains of southern Europe there is no zone of birch corresponding with its extension towards the colder, higher northern latitudes, but it remains rather a distinctive tree of the plains and uplands. In Scandinavia, though more particularly in northern Russia, it forms extensive forests, and attains a high degree of development. In northern Germany it often forms forests along with the aspen, the alder, and the Scots pine.

Tree-form and Root-system.—In its northern home the birch develops a tall, straight, fairly cylindrical stem, with a well-formed, but thinly-foliaged, oval crown borne by comparatively few branches, though in Scotland, and throughout central Europe, its growth is usually neither straight, nor approaching the cylindrical form of bole so prized in timber trees. On suitable soils it has a tendency to extend its crown laterally, and to assume a somewhat circular to obovate outline of canopy, whilst in isolated positions a lively and vigorous branch development often gives it the pendulous appearance known as a "hanging or drooping birch."

It has a weak root-system, weaker than that of any other species; the growing-space required by the roots is not extensive, although on loose soils they spread further than in tenacious or binding soils. In addition to the root-system being weak and inextensive, it is also shallow, though not quite so shallow perhaps as that of the spruce, for the horizontal development of the side-roots always takes place at some little depth below the surface of the soil.

Requirements as to Soil and Situation.—The birch is more a tree of the cold, raw north, with its prolonged winter, than of localities with a milder, southern climate; more an inhabitant of the lowlands and uplands, than of mountain districts; indigenous rather on sandy and loamy soils, than on varieties of any very strong nature; more frequently to be found self-sown on light soils, than on heavy tenacious clays or limes. Its best development is attained on loamy soils.

Both varieties can endure great cold throughout the winter, and a considerable degree of warmth in summer; they excel, indeed, all other species of forest trees in this power of accommodation to both extremes of climate. Both, however, make considerable demands on humidity of the atmosphere, those of *B. verrucosa* being somewhat the greater. A large supply of soil-moisture is essential for the proper development of *B. pubescens*, whilst *B. verrucosa* requires merely freshness of soil, and is often found in comparatively dry situations.

On the whole, birch is seldom found forming forests in Britain on the better soils and situations, and forest land on which it is plentiful can not in general be regarded as being utilised to the greatest possible advantage.

Requirements as to Light.—The birch stands on a level with the larch as the most light-loving of all the species of forest trees; it demands entire freedom of crown, even on the soils and situations which suit it best. It therefore shuns the coombs and dingles, and avoids the bends and hollows of hilly land, preferring the insolation of open plains or of warm southern and western exposures. In mixed forest it is to be found in companionship with other light-loving species, Scots pine, aspen, oak, alder, &c., rather than with the densely-foliaged beech, silver fir, or spruce, which evidently keep the soil too cool for its requirements. The growing-space required for the crown is considerable, as the birch brooks no interference or competition even from the lightly foliaged crowns of its own species.

Attainment of Maturity and Reproductive Capacity.—The birch begins to bear seed as early as the twenty-fifth to thirtieth year, though not infrequently even so soon as the fifteenth to twentieth where the crown has free development, and produces it nearly every year, ripening in September, or on sandy soils often in August. It has a very small germinative capacity, and 20 to 25 per cent. are reckoned a good result in experiments for testing the quality of the seed. There are about 800,000 to 900,000 seeds in one pound. As might almost be expected from its enormous seed-production, the power of regenerating itself from the stool is somewhat limited and capricious, though varying with the nature of the soil and situation.

Wherever it is desirable to restrict the number of self-sown seedlings at the time of natural reproduction of other species, the birch must be cut out early from mixed forests; but where there is little danger of the seedlings interfering with the regenerated growth, as for instance in copse or stored coppice, the birch is well adapted for being held over as a standard, and allowed to develop into a fair-sized stem. In general its sylvicultural maturity is reached between the fortieth and eightieth year, according to circumstances, and only exceptionally is it allowed to attain so long an existence as a hundred years.

Liability to Suffer from External Dangers cannot be ascribed to the birch. Against drought and frost it is equally insensitive ; winds, snow, and ice are alike incapable of doing it much damage ; from deer or cattle it has little to suffer, although rubbed stems have only a weak recuperative power ; in the insect world it has no enemies of real importance. Stems covered with the tree-louse, *Lachnus longirostris*, attract swarms of wood-ants, *Lasius fuliginosus*, which gnaw the cambium, and undermine the bark. Many larvæ and weevils feed on the foliage (*Anomala*, *Brachyderes*, *Cimbex*, *Nematus*, *Polydrosus*, *Phyllobius*, *Porthesia*, *Rhynchites*, &c.), without in general committing very much havoc or destruction. Somewhat more important, however, is the damage done to timber by the grubs of *Hylecætus dermestoides*, and the caterpillars of *Cossus ligniperda*, *Sesia culiciformis*, and *Zeuzera æsculi*.

From fungoid disease it is also comparatively exempt, although red-rot is occasionally caused in the wood by *Polyporus betulinus and sulphureus*, and white-rot by *P. lævigatus* at places where the stems have sustained injuries.

Sylvicultural Treatment of the Birch.—However valuable may be the services of the birch in forming forests in the far north and north-east of Europe, its sylvicultural importance is somewhat limited in Britain, particularly in the southern portion, and its chief value is rather as a nurse against frost, or for stimulating to growth in height, with subsequent retention here and there as a subordinate species, than in the formation of pure forests. For with its unequivocal demand for light, its branching growth, its early interruption of canopy, and its light foliage, it does not unite the qualities necessary to improve in the slightest degree, or even to conserve against deterioration, the productive capacity of the soil. Except during the earliest periods of growth, when all forest trees protect the soil, the ground is only too apt to become overgrown with grasses and rank growth of weeds on moister localities, or with whortleberry and heather on drier situations. Where the birch occurs more frequently than simply scattered here and there, it is not usually considered a very creditable sign of able sylvicultural treatment. With its light seed, it is apt to make its appearance in large numbers wherever clearances are made in the vicinity of seed-bearing trees, and often becomes a perfect weed, the eradication of which not infrequently causes great trouble. Wherever it has been retained as a ruling species under such circumstances, or wherever it has been deliberately sown with the intention of yielding early and good returns as a quick-growing species, deterioration of soil has in general been the result, for the insufficient overshadowing of the ground, and the light fall of foliage render it incapable of forming much mould. Even on soils by no means deficient in humus, the birch is of itself unable, when in large groups, to protect the soil from deterioration for any length of time. Where such experiments have been made, although the first crop of birch may have been satisfactory, later crops (especially when formed from stool-shoots) have only too often necessitated the planting up of areas with Scots pine or spruce, in order to revive the deteriorated productive capacity of the soil. To a certain extent this failure is due to relying too much on the natural capacity for reproduction through root-stools, in place of carefully selecting plants of seedling growth for the second and following generations, as though the development of the stool-shoots is lively and energetic at first, they do not remain faithful to this early promise, but soon fall off in their growth in height, and spread out their slender branches to form a comparatively wide-reaching crown. The best returns are obtained when each generation of the birch is formed by planting, or by thinning out judiciously wherever patches of self-sown seedlings stand, especially on fresh, but not too binding loamy soil, on loamy sand, or on moist, sandy, or gravelly soil, or in short on soils that have a greater tendency towards growth of grass than of heather,—soils, however, that are as a rule perfectly well adapted for more remunerative species of trees than birch. On heavy tenacious soils, or on their opposite extremes, poor, dry, sandy situations, its growth is neither vigorous nor remunerative; on moist, marshy soils it does fairly well, especially on the higher-lying localities, and is often gladly seen there, although it is not usually able to attain large dimensions. Its best development is attained on soils suitable also for the oak, where, scattered as single individuals here and there on moist patches, it soon develops into a large and profitable assortment of stem. On marshy soils that are becoming too dry for the alder, it often also yields very satisfactory results.

Although both as regards soil-protection and the yield of satisfactory financial returns, pure high forest of birch is not recommendable, it finds as standards in copse a *rôle* much more suited to its natural requirements. In the full enjoyment of sun-light and air, it rapidly thickens in girth; whilst, under its light shade, the hardwoods forming the coppice do not suffer much. For underwood it is totally unsuited. At each fall of the coppice, birch and other soft woods are apt to find their way in among the hardwoods, and often occasion much trouble owing to their rapid growth before they can be cut out, or at any rate reduced to the proper scanty proportion, during the weedings and clearings. According to the soil, birch varies greatly in respect to reproductive power from the stool, and it generally happens that on fairly good soils, where it is not wanted, it becomes a noxious weed, whilst it reproduces itself sparsely where one might be glad to have it. Deep felling, close to the ground, increases its power of reproduction, as also an early fall before the flush of leaves comes, for otherwise there is apt to be considerable *bleeding* and loss of sap, from the stool.

With a tree so easily satisfied as to soil, of such spontaneous growth, and so easily transplanted, there are many ways of utilizing the birch without encouraging its growth at the expense of nobler and more remunerative species. In high forests of beech, birch along with other softwoods often finds a suitable home till they are all removed earlier or later in the periodical thinnings. Sometimes it may have for sylvicultural reasons to be cut out about the thirtieth or fortieth year, if not earlier; but at others it can perfectly well remain till the seventieth or eightieth year, by which time it should yield a valuable assortment of timber for cabinet-making and similar technical purposes. As nurses to stimulate the growth in height of oak and pine, it has, however, usually to be cleared away as soon as its services are completed, particularly in the former instance. In pine woods it is the best tree for planting along roads, or along the fringe of the woods to mark the compartments; and several rows of birch, with the ground below them carefully cleared of inflammable material, are the most generally adopted, but unfortunately not always successful method of protection against fire in northern Germany, wherever a railway line runs through pine forests.

Birch as a Subordinate in Mixed Forests of other Species.—Of the species forming pure forests, and naturally capable of being the ruling species in mixed forests, Scots pine has certainly more in common with the birch than any other tree. They are both capable of accommodating themselves to soils of the most varied description, from dry sand to marshy moors, and it often happens that naturally mixed forests of these species are to be seen in fairly good growth wherever the soil-moisture is supplied in sufficient quantity; where this condition is wanting, however, interruption of the canopy and deterioration of the soil are too often the results. Even on poor classes of soil, birch is more rapid in development than pine until about the fifteenth to twentieth year, but the latter then generally overtakes it, and succeeds in suppressing it, unless it seems desirable to come to the assistance of the birch when the woods are being tended by thinning; yet even then it is as a rule necessary to utilise it about the thirtieth or fortieth year in order to avoid the bad effects of a considerably interrupted canopy. On good, moist soils birch can hold out a rotation of seventy or eighty years along with pine, but its cultivation under such circumstances would be somewhat inconsistent with the fundamental principle that in Britain sylvicultural operations must be mainly guided by actuarial and financial considerations, as the introduction of spruce, silver fir, or beech would yield much better ultimate results in favour of the main crop of pine. For fringing pine woods at every possible opportunity however, there is no better species than birch, and even this scant admixture can assert appreciable influence in diminishing the dangers from insects, snow accumulations, and fire.

On the poorer qualities of beech soils, and in localities where natural reproduction of the beech is a matter of difficulty, birch and other softwoods usually manage to effect an entrance and assert a foothold, often to the great detriment of the former. Unless prompt measures be taken to secure their removal, they maintain themselves so obstinately that seedling growth of beech is a matter of impossibility. They shoot up quickly in pure patches or even in groups, but soon thin themselves out, and by the twentieth or thirtieth year are so broken and incomplete in canopy, that the soil beneath them is bound to deteriorate. Whilst their retention in patches, or singly in too great numbers, would undeniably be a mistake, yet the selection of good, healthy, individuals of vigorous growth, scattered here and there wherever nature has shown the soil to be congenial to the birch, is in every way justifiable, and often yields very fair returns about the fortieth or fiftieth year, up to which time they can under such circumstances usually hold their own with the beech, and when they can be removed without interrupting the density of the canopy of the crop to any serious extent. This is perhaps still more the case where the silver fir is concerned, and then even the retention of the birch in small patches also often yields satisfactory results, for the former can thrive fairly well on good soils under the light shade of the latter until its removal, which, however, is often necessitated when the silver fir begins to catch up the birch in growth, as otherwise the whip-like twigs and sprays injure the leading-shoots of the fir. The injury thus caused is still more marked in the case of the spruce, into young growth of which the birch very frequently pushes its way; but until the spruce begins to equal it in height, which happens sooner than in the case of the beech or silver fir, it is generally advisable to allow it to continue forming a portion of the crop, provided always that it occurs merely as scattered individuals, or in lines or rows, and not in patches or groups ultimately unable to protect the soil, and then finally only forming unprofitable blanks. Older patches of birch often give good returns if underplanted with spruce and removed later on when they begin to interfere with the further development of the latter by rubbing off the foliage of the leading-shoots. Along with aspen, ash, and alder, it often forms mixed forests on soils of a more swampy character, which will be referred to in treating of the alder (*vide* page 230).

Formation and Reproduction of Birchwoods can be easily accomplished naturally wherever broken soil is in the vicinity of trees over twenty-five to thirty years of age, for this species usually produces a large quantity of seed annually, which, being very light, is carried far and wide by the wind. Wherever it seems desirable to form forests of birch for the first time, sowing is usually adopted except on dry soils; but for the artificial introduction of birch as a subordinate into mixed forests of other species, the preference is given to planting as better enabling the number and position of the plants to be fixed.

Sowing.—Fresh birch seed easily becomes heated, and soon loses its germinative capacity, so that sowing should be carried out early in autumn, especially on situations with sandy soils, where the seed often ripens in August; seed that has been dried, often lies for eighteen months in the seed-bed before germinating. Some little preparation of the soil is necessary, but this need only be confined to passing over the soil with a coarse harrow, or bestowing on it any similar treatment, to break up the surface of the ground and expose the naked soil; where any strong growth of weeds makes this necessary by manual labour, the breaking up of the ground is confined to bands or strips, and, after sowing, the covering of the seed is amply provided for by passing along the strips with light rakes or even with simple foot-pressure. If sowing has been carried out soon after rain, the seed adheres to the ground, and requires no further attention. From 35 to 50 lbs. of seed per acre are required, according as broadcast sowing is confined to strips or carried out over the whole area.

Planting is generally carried out with seedlings of two to five years, a preference being given in the older plants to such as still have brownish bark ; older plants already having a grey or white rind are reckoned somewhat inferior in quality, although under certain circumstances their use can hardly be avoided. Except on sandy or marshy soil, where notching can be practised with success, the seedlings are usually put out with balls of earth attached to the roots, and under any circumstances, mutilation of either the ascending or the descending axis should be avoided as much as possible, for which reason the use of two to three-year-old seedlings with earth attached is advantageous wherever practicable. On moist soils tumping on mounds is the usual method of planting out older seedlings or transplants of three to five feet in height, and in general, care should be taken not to plant too deep. Where birch is to be introduced as a subordinate species in mixed forests, transplants should be reared in nurseries, as the use of the very best class of material is advisable. The most favourable time for planting birch is early in spring, before the buds have swollen much ; but, on account of the early flush of leaves, one is often forced to plant in autumn on marshy soils. Close planting yields the best returns in the thinnings ; seedlings of $1\frac{1}{2}$ to 3 feet high should be put out at about 4 feet × 4 feet, and transplants of 3 to 5 feet high about 6 feet × 6 feet. On dry sandy soils planting deep is recommendable as long as small pits are left open above for the catchment of rainfall, so that the root-system is not actually deep or much below the surface of the soil.

2. ALDER, COMMON OR BLACK ALDER (*Betula alnus*, L. = ALNUS GLUTINOSA, Gaert.).

Distribution.—The alder is found in moist situations throughout nearly the whole of Europe from Asia Minor and the Caucasus up to the 62° of latitude on the average ; it is also indigenous to Siberia, to Japan, and to Algiers. In Norway it ascends to 1,080 feet above the sea-level, in the Harz mountains to 2,170 feet, in the Bavarian Alps to 2,800, and in the Tyrolese Alps to 4,100 feet.[1] At anything approaching to these limits, however, its development is not normal, it being essentially a tree of the low-lying lands, marshes, and riverine stretches, and of the tracts adjacent to the sea-coast, especially when they are subject to freshwater inundations rich in silt. On fen soil in the Baltic provinces of northern Germany it is often found in pure forests of scores of square miles in extent, and at other times in extensive mixed forests along with birch, aspen, ash, &c.

When met with on the uplands and hilly tracts, it is nearly always in low-lying wet localities, in the valleys, coombs, and dingles formed by the undulations of the hill-sides, and kept wet and marshy by springs, or owing to an undrained, impermeable or impervious subsoil.

Tree-form and Root-system.—When grown in close canopy, and to a considerable extent even when grown in an isolated position, the alder develops a straight bole, with an easily traceable ascending axis. In this respect it somewhat resembles the conifers, more so indeed than any other broad-leaved species, but in their approach to a cylindrical form of

[1] Burckhardt, *Säen und Pflanzen*, 1880, p. 209, states, however, that this alder is not indigenous to the Alps, "One sees here, especially in the valleys, only the white alder (*A. incana*, D C.), and higher up the bushy mountain alder" (*A. viridis*, D C.).

the stem it falls far behind. Its branch development is slight, whilst the foliage forms a somewhat light crown confined to the uppermost portion of the stem, and bluntly conical in general outline. On the cessation of activity of growth in height, the upper portion of the stem tends more towards branch formation and ramification, whilst the crown in extending assumes a somewhat blunted and flatter form.

In root-system it differs from other trees by having no proper tap-root, but in sending out instead a number of comparatively weak strands from the short main root : these work their way down to the subsoil, and there ramify into long stringy rootlets, which determine its claim to rank as an essentially deep-rooting species.

Requirements as to Soil and Situation.—The demands made by the alder as to atmospheric warmth are by no means so great as those made in regard to atmospheric moisture. It attains normal development both in warm and in cold climates, but it cannot thrive in dry localities, and attains its best growth in a damp insular climate, and in situations which, from local causes, have great relative humidity. For the proper normal and unhindered development of its peculiar root-system, depth of soil is essentially necessary ; swampy tracts with shallow soil and impermeable subsoil of moorpan, tenacious clay, or undecomposed, unfissured rocks, are not the situations suitable to it. At the same time it demands a greater degree of soil moisture than can be borne by the majority of other timber trees, and thrives best when both soil and subsoil are moist. When the amount of moisture is so great as to render the soil wet during the dry period of the year, it can no longer be expected that the alder will attain its normal development. This is more especially the case if the water be stagnant, for when the soil-moisture is in motion, the chances of aeration are considerably better ; thus at the edges of streams and rivulets its growth is better than in fens, marshes, bogs, and swamps. It can, however, stand an approach to wetness of soil better than any tendency towards mere freshness in the ground. A slight alteration in the amount of soil-moisture, such as might be occasioned by the reduction of the water-level owing to neighbouring drainage-works for example, at once affects its development, and speedily leads to the crowns becoming dry and dying off.

With regard to the mineral constituency of the soil, the alder is, taken all in all, by no means indifferent, or even easily satisfied. Its best development is attained on humose loam, or loamy sand, with an admixture of lime, or on humose sand with loamy or marly subsoil. The less the percentage of loam the poorer the subsoil, and the more the tendency towards stagnation of soil-moisture with consequent formation of humic and other similar acids owing to the imperfect decomposition of dead vegetable matter, the less suitable are marshy soils for the alder. Pure limes, and pure sandy soils, are alike unfavourable to its growth. And not every moist soil produces its fair growth of alder woods; cold clays, poor loam, peat-bogs, and salt alluvial deposits along the coast with brackish soil-moisture, yield alike unsatisfactory results.

The alder is not particular as to aspect; its preference for northern and eastern exposures is to be attributed rather to their greater relative humidity of atmosphere and generally moister soil than to any conditions dependent on their low degree of warmth.

The yield of timber varies greatly according to the soil and subsoil, the average annual increment ranging from 15 to 150 cubic feet per acre. The better classes of alder soils are, however, as a rule such that they can easily be drained to serve a higher economic purpose as grazing lands and meadows.

Requirements as to Light.—The density of its foliage, and consequently its capacity for bearing shade, are determined to a very great extent by the general qualities of soil and situation. On sandy soils and rubble deficient in subsoil-moisture, or with such excess of it as to cause an approach to stagnating swamps, the alder must be ranked as requiring a large amount of light; but on good, moist, loamy soils it can bear a considerable degree of shade, and makes lower demands on individual growing-space. In the warm climate of southern Germany its capacity for enduring shade seems considerably greater than in central and northern Germany, where it ranks next after birch and aspen as a light-demanding species.

Attainment of Maturity and Reproductive Capacity.—The alder begins to produce seed freely, and almost annually, from its twentieth to thirtieth year. From 280,000 to 300,000 seeds are contained in one pound, which, when fresh, should exhibit a germinative power of about 35 to 40 per cent. in experimental tests; it loses its germinative power after it is a year old. It ripens in September, and falls in November.

It possesses a strong reproductive capacity for shooting from the stool, which it retains up to beyond the fortieth year; but it does not, like the white alder, reproduce itself by means of stoles or suckers thrown out from the roots. When the soil is suitable, and the amount of soil-moisture not excessive, the power of shooting from the stool is long maintained in such vigour that the shoots can develop into as good stems as are formed by seedlings. Where, however, conditions of soil and moisture are unsuitable, the effects of frost are greater, and the reproductive power is so weakened as to cease after the first or second coppicing. Its sylvicultural maturity varies according to the treatment to which it is subjected; coppices are cut over at periods varying from twenty to forty years, whilst in the less frequent clumps worked as high forest the fall is usually fixed between sixty to eighty years; reproduction as coppice is, however, the rule.

Liability to Suffer from External Dangers is on the whole not a plea that can be urged against a more extended cultivation of the common alder. From the brittle nature of its wood it is apt to have its branches snapped off by heavy winds, but with its deep root-system it is little apt to be thrown as windfall. Late frosts often damage the young foliage, especially of coppice-shoots, but the recuperative power is so great that, as a rule, the damage done is not very considerable. Inundations occurring in spring to such an extent as to submerge the stools, act injuriously on the coppice-shoots, and also on the foliage of older alders if taking place at the time of the flushing of new leaves; otherwise a temporary excess of moisture is not in general followed by injurious results. On the other hand, it can maintain no successful struggle against drought, and is injuriously affected by loss of subsoil-moisture.

From insects it suffers little damage on the whole, its chief enemy being the larva of *Cryptorhynchus lapathi*, which attacks the wood of young shoots and stems, whilst older trees suffer from the larvae of *Anobium tesselatum* and *Ptilinus pectinicornis*, and the caterpillars of *Cossus ligniperda* and *Zeuzera aesculi; Apoderus coryli*, *Rhyncites betulae*, and *R. betuleti*, both as larvæ and beetles, do noticeable damage to the foliage. *Nectria ditissima* originates cankerous fungoid growth in the stem, whilst species of *Polyporus* cause red and white rot in the timber.

Sylvicultural Treatment of the Alder.—The common alder is capable of forming pure forests, or the ruling species in mixed forests on low-lying marshy soil where it often covers extensive areas, but on the lower hills and uplands, and in moist valleys and patches, or along the banks of streams, it is usually limited to large groups or clumps differing essentially in treatment from the surrounding woods, and practically forming pure forests on a small scale.

Its treatment in pure forest is as a rule rather as coppice than as high timber forest, after its growth has once been begun ; the original formation of crops usually takes place by means of planting rather than by either natural or artificial sowing. When the stools are young, and the area is not subject to inundation in spring, the fall takes place close to the ground, but when, on the contrary, the stools are old, and the soil inundated, larger stumps are left standing. The growth of the stool-shoots, which are usually numerous and not spreading, is very vigorous on the more favourable classes of soil ; but the rate and continuance of their growth in height, the total production of timber, and the reproductive capacity of the stools, depend to a very great extent on the general quality of soil. The best marshy soils are those having good loamy, limy, or marshy subsoil, but most extensive marshes have only a sandy, stony, or clayey substratum, or consist of deposits of peat with humose surface-soil. Stagnating, sour water, or a large percentage of iron held in solution, spoils the quality of marshy soil ; whilst from the low levels they sometimes occupy they may at all times of the year be too wet for sylvicultural operations to be properly conducted. Whilst willows and aspen are the first trees with which cultural operations can be begun so long as the soil is still too wet for the alder, any spontaneous growth of birch, pine, and spruce, indicates that the requisite quantity of soil-moisture is no longer available, and that a change in the crop would seem advisable.

On the better classes of soil suitable for the alder, such as moist loamy deposits with excess of moisture throughout the summer months, the growth in height and in average annual increment does not culminate until the twentieth or twenty-fifth year, and continues without marked decrease till about the thirtieth to fortieth year, yielding crops far in excess of any other species of coppice, and especially prized for the manufacture of cigar-boxes.

Grebe[1] gives the following as the average out-turn from alder coppice :—

Age of crop in years.	Cubic feet per acre. Quality of soil.				
	I.	II.	III.	IV.	V.
15	1,580	1,197	899	546	261
20	2,102	1,624	1,189	739	333
25	2,624	2,015	1,479	913	377
30	3,117	2,363	1,740	1,058	420

On good soil each stool bears two to three dominating shoots that ultimately form part of the mature crop; with their smooth straight stems these have far more the appearance of young high forest than of mere coppice. Where the demand for wood simply extends to the smaller assortments for cigar-boxes, a rotation of twenty-five to thirty years is ample, but where good soil and a fair market for larger dimensions of timber exist, the fall may be extended to forty to fifty years without jeopardizing the reproductive capacity of the stools. On sandy soils with only a poor admixture of loam, the period of rotation should not in general exceed twenty years; for although the growth of the shoots is rapid at first, yet it soon falls off, and the regenerative power of the root-system and the stool at the same time diminishes, as may be noted in localities subject to inundation during winter and spring, but liable to dry up in

[1] *Die Betriebs- und Etragsregelung der Forste*, 2nd edition, 1879, p. 103.

the warmest season of the year. Even on the better classes of alder soils there often comes a time when one cannot fail to note that the soil seems somewhat lacking in moisture for the normal and remunerative growth of the alder, though it may be still rather too moist for the normal requirements of other species of forest trees. In many cases the way can certainly be at once prepared for these others by drainage, and often easily and cheaply; but care must be taken not to go too far in this direction, as a dried-out marshy soil does not by any means promise good results sylviculturally. When diminution of the returns from alder coppices is properly ascribable to decrease of soil-moisture, the question naturally presents itself, whether the area in question should be retained under sylviculture and transformed into woodlands of other species, or should be utilised agriculturally and transformed into grazing-grounds and pasture-land, a certain amount of drainage being necessary in both cases. When still retained under wood, the transformation may take place into willow coppice, or into mixed forests in which ash, birch, pine, spruce, and oak are the chief species—the oak and the ash on the better patches of soil, the Scots pine on the higher-lying, drier parts. Local configuration of soil is an important factor in such cases, and it often happens that the whole woodland is made up of small groups of alders and birches on the moister parts, oaks, ashes and elms on the merely damp portions, and pine and spruce, both pure and mixed, on the drier patches; but it must be borne in mind that on such localities the spruce is apt to suffer from late frosts, unless it has the shelter of some good nurse like birch.

In mixed forests the alder is often found associated along with the birch and the aspen in marshy hollows in upland and hilly districts, unless the soil has become soured by long-continued growth of heather, or from other causes. Such woods, composed for by far the most part of light-loving species, and growing on soils not particularly well suited to their normal requirements, seldom show anything like close canopy, but consist of sparse patches often of indifferent development; where, however, the soil is good, and the moisture not excessive, they occasionally show very fair development, and include also good specimens of the ash. In other localities, whenever the water-level has slowly sunk from one reason or another, the spruce often also finds its way into the alder groves spontaneously, and shows a development more or less generally proportional to the degree of moisture contained in the soil. The alder is usually the more forward in growth, and stimulates the spruce to rapid development in height, and where the latter occurs in scattered individuals only, this is sufficient to improve the shape of the bole of the former. Where the spruce is not self-sown, but is introduced artificially, the admixture takes place most advantageously after the alder poles have thinned themselves freely.

The fall of timber in alder coppices is usually accomplished during hard frost, as the harvesting of the crop is much easier then than at other times; but felling and extraction must then take place almost simultaneously. Where such difficulties do not exist as to extraction, the fellings can preferably be made either in late autumn or in spring, as, there being then less danger of the stools chipping, the fall can be made low down close above the ground; where inundations are to be feared in spring, higher stools must be left, otherwise the shoots run the risk of being suppressed by rank grass and weeds. In many alder woods raised mounds are necessary as paths here and there; without these, sylvicultural operations could sometimes hardly be carried out or superintended properly.

The Formation of Alder Woods by sowing is occasionally accompanied with greater difficulties than are usual with other species of forest trees, the principal reasons being excess of water in spring and insufficiency in summer, combined with danger from rank growth of grass, and from frost as well as from cattle. Planting is, on the contrary, much easier and more satisfactory, although special arrangements are often necessary on account of the soft spongy nature of the moist ground, and the danger of the soil lifting through frost.

Sowing is usually confined to the production of seedlings for planting out, as the ordinary circumstances of forest nurseries are not adapted for the special requirements of this species, the first condition being the equable distribution of a considerable degree of moisture throughout a good soil. This is best arranged for by forming beds often ten to fifteen feet broad between ditches connected with some drainage scheme; the earth taken from the ditches is spread equally over the beds, and sand is scattered over this to keep down the growth of grass and form a better seed bed, on the top of which the seed is sown. A simpler method, often employed with good results, consists in merely digging trenches about $1\frac{1}{2}$ feet broad and deep and 6 feet apart, levelling the output as beds between the ditches, and sowing somewhat thickly on these beds. The seed is obtainable almost every year, and should, wherever possible, be collected locally, as it only retains its germinative power for one year, and it is impossible to tell how much old seed may be admixed if it has been bought elsewhere. The little "cones" ripen in October and November, and should be plucked soon after that; when brought into warm rooms, the seed soon falls out. Where the collection of the cones is inconvenient, and only small quantities of seed are requisite, a sufficient supply may be obtained on sunny December days by holding large sheets under the seeding trees, and shaking the stems so that the seed may fall out. Where neither of these methods is adopted, the seed can be easily collected by being skimmed off the surface of the water of ponds, or of pools on the ground; but such seed is always deficient in germinative capacity as compared with that collected by either of the other methods, and should always be utilised at once.

When the plants are to remain and be put out as seedlings, the beds must be carefully weeded, and at the same time all weaklings should be plucked out. But better results are ultimately obtainable with transplants pricked out in lines of twelve to fourteen inches by six to eight inches when one year old, or twelve inches by twelve inches when they are two years old, before being brought into the nursery.

Planting with one-year-old seedlings is usually out of the question, on account of the strong growth of grass on alder soils, and on the whole the use of two to four years old transplants is most general after they have stood a couple of years in the nursery-beds.

As a rule, the transplants are put in without earth attached to the roots, except on wet soil, where the balls of earth enable them to establish themselves sooner, and where also the larger assortments of the four to five-year-old transplants are generally used. The operation of planting is simple, notching being frequently adopted on moist soils, but tumping or planting on mounds has often to be resorted to on wet situations. Close planting of the quick-growing alder is out of place, and the plants should not be put out nearer than four and a half or six feet apart, or in rows of five feet by seven feet. The time of planting depends very much on the soil. Where mounds or beds have been previously prepared, the putting out of the plants may take place in the spring, though as a rule this operation is performed in autumn, when there is less moisture in the soil; but when this is even then too soft, the advent of the first frosts has to be awaited. Plantations can also be made in the latter part of summer, when least moisture is present in the ground, but the transplants must then have balls of earth attached to the roots, and this heightens the cost considerably.

The Reproduction of Alder Coppices takes place in the usual manner from the stool, but the height of the latter is dependent on the height to which the soil is apt to be inundated in spring. Should high water not be probable, felling close to the ground is advisable ; but if there is likely to be water above the ground at the time when the shoots spring from the stool, the latter must be left standing at such a height, varying from one and a half to four and a half feet, as will ensure that the shoots are not submerged, for experience has shown that even a few days' submersion of the stools at the time of flushing is apt to kill off the shoots. Where blanks in coppice are filled up with transplants that have not been cut over above the roots before being planted out, they are often allowed to grow up during the first period of rotation without being cut back to the stool.

MINOR SPECIES *either not capable of forming, or at any rate not usually forming pure forests in northern Europe, but generally associated in mixed forests along with one or more of the chief species above described.*

Concerning a good many of these it will only be necessary to give a very brief description, as they are included in this work more for the sake of completeness than on account of their present sylvicultural importance in Britain. A fuller description of the more important broad-leaved subordinate species will, however, be given, following the lines above adopted in treating of the chief species.

CONIFERS. A. *Indigenous to Europe.*

1. THE BLACK, AUSTRIAN, OR CORSICAN PINE [1] (*Pinus Nigricans*, Host. = *P. Austriaca*, Höss. = P. LARICIO, Poir., Var. AUSTRIACA, Endl.). This pine, two-leafed like the Scots pine, extends from Spain across southern Europe to Asia Minor, and in the specially recognised former variety forms extensive pure forests in lower Austria, and south-east towards Bosnia and Herzegovina. In the first-named localities it ascends the mountains to 3,000 feet, but is in general indigenous to the outlying hills and the gently undulating plateaux rather than on the steep mountain slopes in the inner ranges. In its true home it attains, with good straight growth, a height of a hundred feet and a girth of over ten feet at breast-height, with dark, blackish-grey, deep-fissured bark. Its crown is conical, and densely foliaged during the youthful period of growth, the leaves being retained for three to four years; but with advancing years it becomes rounded off to a semicircular or ovoid contour, with the thick foliage confined to the younger twigs. The further northwards it is removed from the region to which it is indigenous, the weaker becomes its development of bole, and the stronger its tendency to crown-formation and ramification generally. In southern Germany its growth in height is by no means equal to that of the Scots pine.

Its root-development is energetic and extensive, being similar to that of the Scots pine, but with greater power of accommodating itself to the nature of the soil and sub-soil, of throwing out strong horizontal roots, and of sending ramifications from these deep down into the soil and sub-soil.

[1] For fuller details of this species see the author's "Report on the Corsican Pine" in the *Transactions* of the Highland and Agricultural Society for 1876. (Fourth Series, Vol. VIII., pp. 220–238.)

Being an inhabitant of a southern clime, the black or Austrian pine naturally demands a high degree of atmospheric warmth, but combined with this it shows a considerable capacity for sustaining the severe cold of the hard Continental winter, and it has equal claims with the Scots pine to be classed among the hardy species of forest trees. As regards soil-moisture, it seems to prefer dry situations so long as they are not shallow, and at the same time not superposed on impermeable subsoils hindering the development of the root-system; otherwise it will thrive on dry soils where even the Scots pine finds difficulty in maintaining itself. Wherever it grows indigenously, the black pine shows a preference for limy soils, and for dolomitic lime in particular, although its demands in this respect do not prevent its growth being satisfactory on soils of other geognostic origin. Both with reference to mineral strength and to soil-moisture, its demands are even somewhat less than those of the Scots pine, and it must therefore be reckoned as the most easily satisfied species of forest tree growing—although not of course luxuriantly,—on poor soils, where even the former finds the situation too hot and dry. For the planting up of poor lands, especially those with warm, southern exposures, and of a limy nature, the black or Austrian pine is a most useful tree.

On soils of fair quality it is better able to stand shade than the Scots pine, and its position as regards demands on light may be assessed at about midway between the light-loving and the shade-bearing species; on favourable soils and situations it becomes the latter, on unfavourable the former.

Like the Scots pine, it enters its reproductive age at about thirty years; its cones ripen in the second autumn, eighteen months after flowering, and the seed is scattered during the following spring. Its germinative power is considerable, good seed showing 75 to 80 per cent. in successful experiments for testing; about 25,000 to 27,000 seeds without wings are contained in one pound, the seeds being much larger than those of the common pine.

External dangers threaten it less than the Scots pine. It is not liable to be damaged by frost, or to be thrown by violent winds; accumulations of snow and ice on its branches do little harm on account of their great elasticity; though subject to attacks from the same insect enemies as the Scots pine (*vide* page 61), it is generally less liable to them, and much less seriously injured when befallen; mice often kill it by gnawing, and roe-deer are fond of the succulent leading-shoots, but, protected by its branches and coarse needles, roe and red-deer leave it comparatively unmolested when rubbing the velvet from their antlers.

It is richer than any other conifer in the production of resin, and is worked chiefly for this—from which the *Venice turpentine* of commerce is made—in many localities whence timber transport to the nearest markets would be too costly to be profitable, and where labour is scarce and insufficient.

Its total energy in production of timber may be put at about 20 per cent. lower than Scots pine; according to Feistmantel, its average yield under average circumstances as to soil and situation, is 3,335 cubic feet per acre at sixty years of age, 4,495 cubic feet at eighty years, and 5,220 cubic feet at a hundred years; it culminates in average annual growth in height between the fortieth and sixtieth years, and in average annual increment of timber between the sixtieth and eightieth years.[1]

2. MARITIME PINE (PINUS MARITIMA, Lam.), including also the *Pinaster* or *Cluster Pine* (*Pinus Pinaster*, Ait.). This species has attained celebrity owing to the success with which its cultivation has been attended on the barren "Landes" of

[1] Hempel and Wilhelm, *Die Bäume und Sträucher des Waldes*, seventh number for July, 1892, p. 153.

Bordeaux, and throughout the enormous sand-dunes stretching along the shores of the Bay of Biscay. Favoured by the warm southern climate, its production of resin is very considerable, yielding the ***French turpentine*** of commerce. It is on the whole little suited for growth in the colder climate of Britain, except perhaps in the south of England. Early frosts in autumn often find its shoots with the wood not properly formed and ripened into hard wood, but in our insular climate its growth in height is vigorous and satisfactory wherever it is protected from frost.

Its root system resembles that of the Scots pine, and its demands on soil are not great. It shows a preference for light and dry sandy soils, where the tap-root can be developed without hindrance, and where, the annual period of vegetation being somewhat shorter than on those of a more loamy or clayey description, it has a better chance of hardening the wood in the young shoots and branches. It enters the reproductive period about the twentieth year; its seed is somewhat larger than that of the black pine. It improves the soil considerably, having a somewhat dense foliage, retained for three or four years.

3. CEMBRAN PINE (PINUS CEMBRA, L.) is found in the Alps and Carpathians at elevations above those of spruce and larch, ranging from about 2,300 feet to 7,500 feet, and also both on the plains and mountains of Russia and Siberia. It attains in Alpine districts a height of sixty to seventy feet, and a girth up to fifteen feet at breast-height. Its crown is conical in youth, then somewhat cylindrical in middle-age, and finally irregularly ovate in form throughout the more advanced periods of growth; its foliage is dense rather than sparse, the leaves being persistent for four or five years. Its root-system is extensive and deep-reaching, a necessity of the exposed localities to which it is indigenous. Although its timber is of good quality, and often beautiful in colour

and texture, its growth is so slow that it could never be grown in Britain with a view to profitable money returns; for æsthetic reasons, however, it deserves a place in plantations, more especially on moist clayey or loamy patches on high hill-sides.

4. THE MOUNTAIN PINE (PINUS MONTANA, Mill) is also a native of the mountains of central and southern Europe, often attaining a height of seventy-five feet, but at high elevations gradually dwindling down to an almost creeping shrub before yielding place to the rhododendrons or Alpine roses. It is found at elevations varying from 550 feet in Silesia to nearly 9,000 feet in northern Italy. Its principal use is as protective forest, binding the soil by means of its extensive root-system, and thereby hindering land-slips and offering mechanical opposition to avalanches starting on their destructive course. For Britain its production in forests is fortunately not necessary, and, like the Cembran pine, its cultivation is a matter for the favourable consideration of the arboriculturist rather than of the forester. Its foliage is somewhat dense, the leaves being retained for four or five years.

5. NORDMANN'S FIR (ABIES NORDMANNIANA, Link.), introduced from the Caucasus in 1845, is a tree of frequent occurrence in the Crimea and the mountainous tracts to the east of that. It makes less demand on the quality of the soil than silver fir, but more than the Scots pine; it thrives both on light and on binding soil, on fresh or on moist, but evidences a stronger objection to a wet than a dry soil. In its general growth and sylvicultural qualities it resembles the silver fir, but is hardier in respect to frost, as its buds are later in opening; it suffers badly from deer, however. Owing to its excellent shade-bearing capacity it is very well adapted for the underplanting of pine standards on soils of the better quality.

B. *Introduced from North America.*

1. WEYMOUTH PINE (PINUS STROBUS, L.). This species was introduced by Lord Weymouth about 1705 on his estate in Wiltshire, and has since then become thoroughly acclimatised in northern and central Europe. It is indigenous to the eastern part of North America, from Canada southwards to Virginia, forming forests on the uplands and hills, and reaches its finest development from 43° to 47° north latitude, attaining a height of 200 feet and a girth at breast-height up to twenty feet. In Europe it is occasionally to be found in pure forests, but more generally forming clumps, groups, and patches in mixed forests of other conifers. In production of timber it is second in rate of growth only to the poplar, but its timber, known as American *white pine*, is neither so durable nor so remunerative that its production is likely to become as inviting as would undoubtedly be the case if it could command an easy and good market. As, according to Gayer,[1] it is the lightest of all our acclimatised exotics, its cultivation may be recommendable wherever there is any fair demand for timber for packing-cases or similar requirements.

In general growth the Weymouth pine resembles the spruce and the silver fir rather than the Scots pine, being straight, sending out branches in regular whorls almost horizontally from the stem, and forming a crown of conical shape. Grown in close canopy, the crown is confined to the upper portion of the stem in a pointed spindle-shape; but it is thicker and denser than on the Scots pine, whilst the needles are longer and finer, and also remain persistent for two to three years. It develops a root-system similar

[1] *Die Forstbenutzung*, 7th edition, 1888, p. 28.

to that of the latter, but even stronger and sinking deeper into the soil and subsoil.

The Weymouth pine possesses a considerable power of accommodation in respect to climate; it is found on the Swiss Alps at 4,000 feet elevation, as well as on loamy soils in northern Germany not much above sea-level. It can thrive on soils too poor for the spruce, or too binding for the Scots pine, but prefers a light soil not wanting in moisture; it can even stand a moist soil better than the larch. In contradistinction to the black or Austrian pine, limy soils seem unsuited to this variety of pine. Situations exposed to violent winds are not adapted for it; broken tops, diminished growth in height, and bent crowns are too frequently the poor results, although, owing to its forming dense, close-canopied forests, it suffers less in this respect than the Scots pine.

The Weymouth pine occupies an intermediate position in regard to demand for light, but it is only on soil unsuited to it that it must be classed as light-loving. In general it can bear a considerable amount of shade without losing the power of developing normally when cut clear and free, and excels the other species of pine in this respect; side-shade, and a confined growing-space in youth, are even to a certain degree necessary in order to repress the natural tendency to branch-development and ramification.

It enters the seed-bearing stage about the thirtieth year. The seed, which is produced freely almost every alternate year, ripens early in the second autumn after flowering, and has a germinative capacity of about 65 per cent. in experiments; about 30,000 to 35,000 seeds are contained in one pound. Germination takes place somewhat late in spring, and often not until July, with some of the seed.

From late frosts little danger need be apprehended to it, and accumulations of snow and ice do less injury to it than to the less elastic Scots pine. Its insect enemies, in general those of the Scots pine (*Hylesinus piniperda*, *Pissodes notatus*, &c.), do on the whole little damage, and altogether it is classifiable as rather a hardy forest tree. Roe and red-deer select it eagerly for rubbing off their velvet, but it possesses a strong recuperative power in respect to such wounds.

2. PITCH PINE (PINUS RIGIDA, Mill), was introduced from North America about 1759. It attains a height of eighty feet on sandy soils of good quality, but also thrives, and yields good timber on those of inferior quality; in general its development is not so straight as might be wished. It prefers a deep sandy or somewhat loamy soil, and an amount of moisture varying from fresh to moist, although it can still thrive either on a dry or on a wet soil. In tree-form and root-development it generally resembles the Scots pine, and like it is classifiable as light-loving, though not to the same degree. It is strongly reproductive, beginning to bear seed about the tenth year, and has the power of throwing out shoots from the adventitious or dormant buds. It is not liable to be damaged much by external influences either of an organic or an inorganic nature. *Pinus australis* (Mich.) is also known as pitch pine.

3. YELLOW PINE (PINUS PONDEROSA,) introduced from North America in 1826, and

4. JEFFREY'S PINE (PINUS JEFFREYI, Murr.) introduced from Oregon and California in 1852, are very similar in their normal requirements, and in their general qualities, to the preceding species; they yield good timber, and suffer less from insect enemies than our indigenous Scots pine. The former is, however, little able to withstand danger from frost.

5. DOUGLAS FIR (PSEUDOTSUGA DOUGLASII, Carr) introduced from Canada and the north-eastern States about 1826,

and recently receiving almost more attention than any other exotic in northern Europe, reaches a height of 300 feet and a girth of 27 feet in its own home, and yields timber of excellent quality. It thrives on sandy downs, but attains its best development on loose, mild, permeable, fresh soil, whilst on a dry soil it does better than on a damp or wet one. In Germany it is said—although this seems to be contrary to experience in Scotland—to make a good stand against the violence of winds, and also bears a considerable degree of shade. In rapidity of growth in height it far excels the spruce, the Scots pine, and even the larch or the Weymouth pine. Being tardy in sending out its shoots, it is little apt to suffer from late frosts. In a great many respects it resembles rather the spruce than its closer relative the silver fir. It begins to bear seed about the twenty-fifth year. It does not suffer so much from insect enemies as our indigenous conifers, and is not particularly sought after by roe or red-deer. Up till the present, experience and experiments throughout Germany have tended to show that it bids fair to prove the most remunerative of all the exotic conifers (with the exception perhaps of spruce so far as Britain is concerned). It certainly deserves very special attention in the formation of fresh woodlands, and during the reproduction of existing coniferous forests. Seedlings put out in nursery beds at 8 inches × 4 inches can be transplanted in the following year if necessary, as they develop rapidly.

BROAD-LEAVED, DECIDUOUS TREES. A. HARDWOODS.

1. ASH (FRAXINUS EXCELSIOR, L.)

Distribution.—The ash is to be found over nearly the whole of Europe and the Caucasus, southwards from 63°40′ in Norway, 61° in Sweden, and 62° in Finland, and forms one of the comparatively few species indigenous to Britain in the earliest historic times. It is mainly an inhabitant of the valleys and the uplands, but seldom of the mountain chains of middle Germany extending above 3,500 feet, although reaching up to and over 4,000 feet in the Alpine districts. It extends further northwards than the beech, but does not attain an equal elevation above sea-level. It is seldom found forming pure forests, and its *rôle* seems to be emphatically that of a subordinate species in mixed woods, occurring scattered as single trees rather than in large groups or clumps.

Tree-form and Root system.—If comparatively undisturbed in the enjoyment of light and air, the ash at an early stage exhibits a decided tendency to forked and branching growth; but when its growing-space is limited, it can on favourable situations develop a straight, full-wooded stem of eighty to ninety feet high, surmounted by a lightly-foliaged crown. In the later stages of growth its natural tendency to ramification and branch-development is irrepressible, the crown increasing laterally to a considerable extent.

Its root-system is deep. Numerous and strong branches extend laterally from the tap-root, but soon exhibit likewise a tendency to work their way down deep into the soil; whilst as the tree advances in age, the development of superficial roots beomes marked, more particularly on the poorer classes of soil, and on such as are somewhat deficient in moisture.

Requirements as to Soil and Situation.—In the whole character of its growth the ash plainly shows its preference for localities which are rather moist both as regards soil and atmosphere. Low-lying tracts of country, or the cool, damp, northern and eastern exposures on hill-sides, are therefore more congenial to it than well-drained plains or warmer, sunnier aspects. Not every soil, however, and not even every moist soil, is suited for its growth, as the ash is, so to speak, discriminating and particular in its choice; where other species fail to find a sufficiency of nutriment to stimulate them to good growth, attempts with the ash may at once be given up, and needless time and trouble spared.

Its root-system requires depth and a fair degree of porosity of soil for its proper development, whilst a due supply of moisture is necessary both in the soil and the subsoil; but stagnating subsoil moisture is unsuited and detrimental to it, unless combined with a full enjoyment of genial summer warmth stimulating the foliage to increased evaporation and transpiration from the leaves. Sandy soils, unless moist, are in general unfavourable to it; it thrives best on strong, rich, loose, mineral soil, and is altogether in this respect one of the most exacting species of our forest trees.

Requirements as to Light.—On the whole the ash must at least be classed along with the oak with regard to its demands for light, although its foliage is sparser and lighter. Growing generally only on the best classes of sylvicultural soils, it often appears to be more capable of bearing shade than is actually the case under ordinary average circumstances. As it approaches maturity, its requirements in this respect increase, although throughout the earlier stages of growth it can often thrive under standards with a light canopy, when such is necessary to protect it against frost.

Attainment of Maturity and Reproductive Capacity.—Occurring usually as scattered individuals in forests of shade-bearing species, and of beech in particular, the ash must be privileged at every time of thinning, and of course rapidly increases in girth and in cubic contents. Sylvicultural considerations, however, demand its removal before reproductive measures are to be carried out for the whole forest, so that it is seldom allowed to attain an age beyond eighty to a hundred years, by which time it has already assumed good proportions for the technical purposes to which its timber is suited.

From the fortieth to the fiftieth year onwards, the ash yields, almost annually, large quantities of fruit or '*keys*'; about 7,000 of the seeds are contained in one pound. They possess a germinative capacity of about 65 to 70 per cent., which they retain for one to three years. Seed sown at any time does not usually come up till the second spring after the time of sowing.

The ash possesses strong reproductive power, coppices freely, and under favourable circumstances sends out suckers from the roots as well as vigorous shoots from the stool; easy replacement of injured shoots renders it suitable for pollarding.

Liability to Suffer from External Dangers.—In respect to frost, the ash stands on about the same level as the beech, but as it prefers the moister, low-lying localities it is exposed to greater dangers during the youthful period of growth; nurses are therefore desirable. On loftier situations the ash is backward in breaking into leaf, hence many of the dangers of late frosts are obviated. Red-deer, roe, and cattle are all inimical when the ash is young; but, on the other hand, it soon outstrips weeds in growth, and easily gets beyond reach of cattle, whilst later on it has little to fear from winds and storms. With its deep root-system, light foliage, and tough, elastic wood, it stands in little danger of being either thrown or broken by the wind.

The ash is comparatively exempt from attacks of insects, although *Lytta vesicatoria* and *Pachytylus migratorius* destroy the foliage, whilst species of *Hylesinus* (especially *H. fraxini*) and *Scolytus* in their larval stage injure the cambium and sap-wood, and wood-lice, *Chermes fraxini* and *Aphis fraxini*, destroy the bark. The omnivorous *Melolontha* also spares the roots or young seedlings of ash as little as it does those of other species of trees.

It is free from fungoid diseases except those, common to most forest trees, originated by *Phytophthora omnivora* on cotyledons and leaves, and by *Nectria ditissima* in the branches and near the base of the stem. Like the beech, hornbeam, sycamore, lime, and chestnut, it is somewhat subject to a diseased condition of the smooth-barked bole on the west and south-west sides owing to the scorching and drying-up power of strong sunshine, in consequence of which the technical value of the stem is often greatly lessened. From this '*sun-burn*' the rougher barked trees are happily exempt.

Sylvicultural Treatment of the Ash.—Pure forests, or even large clumps of ash that have been produced either artificially, or by the retention of too many self-sown seedlings, seldom yield satisfactory results, even on the better classes of soil, as their light foliage, broken canopy, and early attainment of maturity, render them somewhat unsuited for treatment as pure high forest. Spontaneous growth of self-sown seedlings is seldom wanting on the moister patches during regenerative fellings in beech woods; and when once the young crop of the latter species is in vigorous growth, a struggle begins which sometimes reduces the number of the former to a desirable proportion, but at other times ends in favour of the ash, and with bad ultimate sylvicultural results, unless the aid of the axe is freely given in favour of the beech. Even on moist, low-lying situations, which in general are such as show the best development of ash, its growth as scattered individuals, or in small knots or patches only, is decidedly better than in groups or larger patches. For large groups or clumps of pure ash there can be no better treatment than early under-planting with beech, spruce, silver fir, or hornbeam according to the nature of the soil, as has already been described with reference to the oak (*vide* pages 194 and 199), for the chief sylvicultural importance of ash lies in the production of the larger assortments of timber for cabinetmaking and the like, and this can only be well arranged for by insuring the protection of the soil. Wherever this is moist and fertile, the ash deserves to be associated with the oak and the beech; even though it can never hold out the full period of rotation of the former, and only under favourable circumstances the shorter one (100 to 120 years) of the latter, it yields good, remunerative returns, without leaving serious blanks in the canopy when its admixture has been confined to single scattered stems only. On the better classes of marshy soil where the oak is grown, a sprinkling of ash seldom fails to improve the growth of the former, and among alders it is often characterised by excellent development in patches and rows. Where it occurs in groups along with alder, the treatment accorded has practically much resemblance to under-planting after the average growth in height has culminated. When suddenly exposed to light and air during the later stages of growth, it is apt like the elm, and to a less extent the oak, to show sickly growth, and often eventually becomes "stag-headed" and dry.

During its younger stages of growth, ash has a much more rapid development than beech, and on suitable soils maintains the advantage thus won; but later on, when its growth in height has culminated, and it is gradually caught up by the beech, the development of its crown begins to be interfered with, and it then becomes advisable either to harvest it at this juncture, or to assist it materially in the struggle.

An admixture of ash with silver fir, spruce, or pine does not in general yield good results, as it is too easily caught up and over-topped in growth; and besides this, spruce or pine soils are seldom good enough for the ash.

As a standard in copse, the ash finds conditions very well adapted to its requirements, for with a comparatively undisturbed enjoyment of light, air, and sunshine, it soon thickens in girth, without throwing too great a shadow over the surrounding coppice-growth. Among the coppice, and even under a considerable degree of shade, it can throw out vigorous shoots, which rapidly develop into good-sized poles; but the stools are apt to get exhausted soon. Where any considerable demand exists for hammer-shafts, carriage-poles, felloes or spokes, oars, and similar small material, coppice-shoots often give very good and remunerative returns.

Agriculturally the ash is also a very useful tree, besides adding beauty to the landscape. On low-lying pasture lands it affords a grateful shade to the cattle, without diminishing the growth of grass; and when pollarded, the foliage and young shoots yield healthy fodder readily eaten by sheep, and also by red-deer. Along with elm, maple, and sycamore, ash is deservedly prized for the formation of avenues.

As already mentioned, self-sown seedlings are frequently to be found on moist suitable localities in beech forests undergoing regeneration, where the shade of the beech after the seed-felling does them little harm—less at any rate than would be done by rank growth of grass on lighter situations. But where natural reproduction is not likely to effect itself spontaneously, and where no parent standard trees exist, the mere sprinkling of seed on prepared patches here and there during the seed-felling of the beech is generally all that is required in order to produce a sufficient admixture of ash; and even then a weeding out of all the weakly seedlings is usually necessary, so as to retain only the better developed plants. No particular attention or after-tending is requisite, as, although unequivocally a light-loving species during the later stages of growth, it can during the earlier periods of development sustain a very fair amount of shade. But in many localities the preference is given to planting, as giving a better and much more effective control over the disposition and interspersion of this subordinate among the ruling species. In copse and coppice, and on all varieties of marshy soils, rank growth of grass threatens it with greater danger than may be apprehended from frost; for although late frosts often damage the seedlings and the young shoots, its recuperative and reproductive power is good. Where grass and frost are feared, planting is usual, transplants of all sizes being easily put out so as to establish themselves readily. Where a strong head of game is maintained, ash, like maple and sycamore, is apt to suffer considerably, for deer love to strip the comparatively smooth bark from trees, as well as from young poles.

As nearly every October brings a good supply of ash '*keys*,' which mostly remain hanging on the twigs throughout the winter, there is seldom any lack of seed which may easily be plucked by hand. And as the bulk of the seed only germinates in the second spring after its ripening, it is preferable to bring it under cover until it can be sown during the second autumn or spring after its production, otherwise voles and field-mice are apt to devour it. The preservation of the seed can be effected simply by mixing it with sand, and putting it away in boxes in a damp place; when wanted, it can be sown out just as it is, or the seeds can be collected by running the sandy soil through a sieve. For seed-beds, preserved seed is preferred; but for sowing in beech or other mixed forests, the fresh seed is merely strewn on the prepared patches. Except for the production of seedlings and transplants, sowing of ash seed on any extensive scale is not adopted; even if pure forests, or mixed woods with ash as the chief species, were considered desirable, the danger from rank growth of grass would usually determine in favour of planting. Where, however, *Sowing* is carried out under the shade of standards of oak, alder, willows, or aspen, or on moist places in beech seed-fellings, the soil is prepared either in strips, or, especially in the latter case, in small patches by means of the rake; the surface-growth is removed and the upper soil lightly mixed, then the seed is sown in the proportion of about thirty pounds per acre actually operated on. Passing over the strips or patches lightly with the rake gives the seeds the thin covering of soil, which is most favourable to their germination.

Planting of the ash, either as naked seedlings or transplants of almost any size, is easy, as the plants establish themselves readily when put out. In moist frosty localities it succeeds best when carried out under shelter, as for example under alder poles a few years before their clearance, so that the young ash may have a few years' growth in advance of the future flush of quick-growing coppice-shoots; the assortments then used are either healthy seedlings, or transplants from the nursery. Although the ash can stand trimming of the rootlets and sprays better than most other species, this operation is seldom necessary, owing to the simplicity of planting in the loose, soft soil; the methods adopted are much the same as with the elm, and the maple, that is to say, generally notching and pit-planting with the hand. The production of seedlings in nurseries takes place on beds having a fair supply of soil-moisture, transplants being pricked out as one or two-year-olds at distances varying from 9″ × 9″ up to 12″ × 12″, and care being taken to supply more growing space for the older and larger classes of transplants by the preliminary removal of every alternate plant.

2. Maple or Norway Maple (Acer platanoides, L.), and Sycamore or Great Maple (Acer pseudoplatanus, L.).

Distribution.—The maple extends from 61—62° in Scandinavia throughout central Europe eastwards to the Caucasus, Armenia, and northern Persia, and southwards to the Balkan Peninsula, Dalmatia, central Italy, the Cevennes, and the central Pyrenees, whilst it is not indigenous to western Europe, including Great Britain. It does not ascend so high above the sea-level as the sycamore, scarcely attaining an elevation of 1,650 feet in central Germany, 2,350 feet in the Vosges, and not over 4,000 feet in the Bavarian Alps.

The sycamore extends across central and southern Europe to the Caucasus with a northern limit from the upper Carpathians through Silesia and Saxony, skirting the Harz mountains, and crossing the hilly tracts of western Germany; owing, however, to extensive artificial introduction and distribution, its natural limit is hard to define exactly. In the Harz it ascends to nearly 2,000 feet, in central Germany to 2,700 feet, and in the Bavarian Alps to a little over 5,000 feet on the average. Whilst, therefore, the maple extends further northwards, the sycamore is capable of ascending the hill-sides and thriving at higher elevations.

Neither maple nor sycamore occur forming pure forests over large areas; both are naturally better adapted for forming groups, or for scattering as patches or individuals throughout high forests of other species of trees. Neither of them is indigenous to Britain, but the sycamore was introduced at least two centuries earlier than the maple, which was brought across during the seventeenth century.

Tree-form and Root-system.—The sycamore attains a height of over ninety feet, and a girth of about twenty five feet, and in respect to both height and girth somewhat surpasses the maple, although both take rank along with the oak and the beech as regards dimensions generally attainable. In early youth their development is straight and regular, and grown in unbroken canopy there is little tendency to ramification and branch-development; but at later periods of growth they throw out branches at a low angle, and make considerable demands for growing-space. In form of stem the maple approaches nearer to the beech than does the sycamore, which is apt to deviate very much from the cylindrical, full-wooded form of bole, and to develop an elliptical, or often fluted or flanged stem, and a buttressed trunk, especially on binding and stony soil. In fact, though the growth in general is straight, the boles of both species are rather apt to taper. Their crowns are moderately foliaged and of moderate expansion, but when grown in the open they extend far outwards, and are formed by a comparatively few, strong, irregularly developed branches with somewhat scanty foliage.

The root-system is heart-shaped, consisting of several strong branches from the tap-root, which penetrate deep into the soil, but do not usually ramify much or extend far horizontally. Strongly-developed surface-roots, like those of the oak and beech, are seldom to be found either in the case of the maple or the sycamore, both of whose roots are distinctly classifiable as deep-reaching, and indeed eminently so as regards the latter.

Requirements as to Soil and Situation.—Like the beech, maple and sycamore in general make only moderate demands regarding climate; but the sycamore requires more warmth, and particularly more summer heat than the maple, which is thus able to extend further northwards than the otherwise hardier sycamore. Both, however, can bear a considerable degree of winter cold. The moist air of mountain forests, of damp valleys, and of the sea-coast, is beneficial to the growth of both species, and is in fact almost a necessity for the maple. The sycamore is more the tree of the hills and uplands, where it prefers the cool, moist, northern and eastern exposures, whilst the maple thrives best on the plains or gentler slopes.

For the production of good boles, a considerable measure of mineral strength in the soil is necessary, and where this fails, their growth is not satisfactory. Depth and penetrability of soil are important factors demanded for the normal development of their root-systems. A shallow soil, more especially with stiff or rocky subsoil, is no suitable situation for either maple or sycamore, although, of the two, the latter can the more readily accommodate itself to a rocky soil sufficiently fissured and broken to admit of the strong side-roots penetrating deeply. Like the ash, both species make higher demands as to mineral composition of the soil than the beech, and differ also from the latter in not accepting a due admixture of vegetable mould as an equivalent for actual want of mineral strength. Sandy soils, pure limes, and heavy clays are alike congenial to neither species; their best growth is attained on light loams, and somewhat clayey limes not liable to be dried up. On the whole, the maple is less exacting than the sycamore, and, except in hilly tracts, deserves more attention than the latter for cultivation on fresh loams, and moist sandy soils with a fair amount of humus; sour marshy soils are suited to neither species.

In respect to soil-moisture, too, the maple is less exacting than the sycamore, being able to accommodate itself more readily to any excess of moisture on loamy flats, or to a merely fresh soil on the uplands. Soil-moisture is, however, as requisite as in the case of the beech, and the best growth is obtainable where subsoil, as well as surface-soil, has an abundant supply. Dry exposed situations, and such as suffer from frost, are not the localities for which either maple or sycamore are in any way really adapted by nature.

Requirements as to Light.—Although not, perhaps, to be reckoned among the absolutely light-demanding species of trees, maple and sycamore require a free growing-space for the expansion of their crowns, in order to attain their full development. At early stages of growth they can bear without permanent injury the shade of lofty standards, provided the soil is strong and moist, but on soils deficient in either of these respects intolerance of shade soon exhibits itself; in this respect again the maple shows itself more tolerant and accommodating than the sycamore. Pure plantations of maple or sycamore maintain themselves longer in moderate canopy than the majority of other light-loving trees, especially on strong fresh soils; but they can never be ranked as shade-bearing, or as naturally and sylviculturally suitable for planting as underwood, even under light-demanding standards. In the damp climate of Holland, however, oaks may sometimes be seen under-planted with maple on fertile soil.

Attainment of Maturity and Reproductive Capacity.—From about the fortieth to the fiftieth year onwards, maple and sycamore bear seed annually, in September and October, fairly freely every second year, though only sparsely in the alternate years. The seed retains its vitality till the second spring, but is then apt to be a year late in germinating after being sown, if it has been kept too dry during the winter. Its germinative capacity is about 50 to 60 per cent., whilst from 5,000 to 6,000 seeds are contained in one pound.

Their reproductive power is only moderate. On good soil they throw out numerous stool-shoots of rapid growth, but these do not maintain their power of development long, whilst the quickly-decaying stools soon diminish in power of reproduction. By felling the stems almost flush with the ground, the stool-shoots can, however, be forced to throw out roots for themselves, and thus become independent of the parent stool. True stoles or suckers from roots are of comparatively infrequent occurrence, as these species have not usually a system of surface-roots. On the whole, maple and sycamore are not well adapted for coppicing. They have weaker recuperative power, and are much less able to heal wounds than the ash, and consequently require more careful treatment at the time of transplanting or of pruning.

Like the ash, maple and sycamore are well placed in copse as standards over the coppice, or in mixed forests where fair enjoyment of light and air can be secured to them. When cleared then at an age of 100 to 120 years, their boles usually bring very fairly remunerative prices.

Liability to Suffer from External Dangers.—When special measures are not taken to obviate danger from frost, both species are apt to suffer severely, but especially the sycamore; late frosts in May are particularly dangerous to young plants till they are over three feet in height. Endowed with a good root-system, and on the whole bearing but a moderate foliage, little danger is in general to be apprehended from storms. When fully exposed to the direct or the refracted rays of the sun, a diseased condition of the bole on the west or south-west side is often occasioned in the sycamore, but is much less frequent on the thicker and rougher-barked maple. Inundation is more fatal to them than to any other species of forest tree, whilst roe, red-deer, cattle, and hares all inflict wounds that are only healed with difficulty; but to counterbalance these weaknesses and defects, maple and sycamore suffer less from injuries inflicted by insect enemies than any other trees of the forest.

They are not, however, altogether exempt from attacks by insects. *Lytta vesicatoria* and species of *Melolontha* destroy the foliage; caterpillars of *Zeuzera æsculi* and *Cossus ligniperda,* and to a slighter extent larvæ of *Anobium tesselatum* and *Hylecoetus dermestoides*, injure the quality of the timber.

Fungoid diseases of the stem are originated by *Nectria ditissima* and *N. cinnabarina*, the latter with characteristic bright vermilion gonidia, which subsequently turn darker. As with other trees, *Phytophthora omnivora* infects the seed-lobes and leaves in nurseries. The curious black spots so frequently seen on leaves is a disease caused by *Rhytisma acerinum*; it is much more common in parks and ornamental woods than in true forests, but should be treated as a disfigurement of the foliage, and encountered by collecting and burning the leaves in autumn and winter in order to prevent the scattering of the spores and the spread of the disease during the following spring.

The Sylvicultural Treatment of Maple and Sycamore resembles in most points that accorded to the ash and the elm. They are not naturally intended to be grown in pure forests, or even to be allowed to grow up in clumps or groups, as they are distinctly light-loving after they have passed through the pole-forest stage of growth; hence they soon exhibit a tendency towards branching and sparse crown, and with their scanty broken canopy, and light annual fall of foliage, prove unable to protect the soil against ultimate deterioration. Scattered here and there, however, and interspersed as single stems, or in occasional small knots or patches throughout woods of other species, that are more efficiently endowed by nature with soil-protecting qualities, they develop into valuable timber trees, and often yield very handsome returns where there is a good market for furniture woods.

Like other species of trees that are beyond all doubt light-loving, maple and sycamore can stand a considerably greater degree of shade on rich, fresh soils, than on situations deficient either in moisture or in fertility; but to underplant oak with maples, as is done in Holland, is, despite the greater relative humidity of the air, in accordance neither with the true natural requirements of these species, nor with the fundamental principles of sylviculture. Better results, both for the soil and the increment on the standard trees, might undoubtedly and confidently be expected if the underwood were made to consist of the soil-improving species, beech or hornbeam.

It is especially in high forests of beech that maple and sycamore reach their finest development when scattered as single individuals, or in knots of a few trees, which can receive any requisite attention that may be thought necessary during the ordinary operations of thinning out. When in good growth, they hold out the full period of rotation (100 to 120 years), and are harvested as large-girthed valuable assortments of timber whilst the beech is being reproduced; but except on the better soils, and the more favourable situations, they have usually to be removed at an earlier age. During the regeneration of the beech, self-sown seedlings of these species frequently make their appearance to a greater or less extent, and very often the mistake has been made of allowing them to remain in too great number as individuals, or in patches almost large enough to be called groups; in such cases, where the superfluous individuals have not been removed in favour of the young crop of beech during the earliest clearings and weedings, the development of the ruling species is greatly interfered with by the more rapidly developing maples, as soon as these have outgrown the danger of suppression by rank grass and weeds, and not infrequently the beech entirely disappears when they form canopy in the thicket stage of development. As in the case of the ash, which is very commonly found associated with them, perhaps the best that can be done after that is to await the time when they begin to get somewhat broken in canopy after culmination of the average annual growth in height at about thirty to fifty years of age (according to the quality of the soil), and then to thin them out, and underplant with beech. Wherever any intentional formation of pure clumps or holts of maples has taken place, the best treatment that can be accorded is practically the same,—aiding Nature when it is evident that she is making efforts to attain freer individual enjoyment of light and air after the greatest activity of growth in height has been accomplished, and providing, by underplanting with some shade-bearing species, not only for the protection of the soil, but also for the better growth of the standard trees. Whether the choice should be given to beech, hornbeam, spruce, or silver fir, is a matter that depends in each case on the local peculiarities of the soil and situation; but in general no mistake will be made by giving the preference to beech, unless a special market for bean-sticks and poles points to conifers as likely to be more remunerative. But it may be remarked that the areas having the necessary qualities of the soil to make them suitable for pure forests of maple are somewhat limited in our woodlands.

Where an admixture of maples has to be artificially produced, beech offers advantages beyond other shade-bearing trees as the ruling species, for in respect to requirements regarding soil and situation, and in development, there is a considerable degree of similarity between them, whilst the former still have the great advantage of being somewhat forward in growth during all the earlier stages of development, when tending would otherwise be most difficult. During the first years the maples are also more rapid in growth than the spruce, and considerably more so than the silver fir, but these both catch them up sooner than the beech,—

the spruce often during the fifteenth to the twentieth year, —and soon succeed in overtopping and suppressing them, without assistance being possible in the way of thinning out except at the cost of ultimate loss, or of deviation from the principle that the treatment of the woodlands shall be such as to yield the most remunerative returns.

As standards in copse, maple and sycamore find, like the ash, circumstances admirably suited to their development; and among the coppice they are to be found wherever the shade of the standards does not weaken them in the struggle with their neighbours for existence.

In very many respects alike, so far as sylvicultural characteristics and treatment are concerned, there is, however, this marked difference between maple and sycamore, that the former is more the tree of the low-lying tracts and the gentle uplands, whilst the latter is distinctly a denizen of the hilly tracts, and is in general more exacting as regards the mineral strength of the soil. On sandy soils, only selected patches of good quality are suitable for either species, but the best development is usual on fresh, humose soil, especially when containing some admixture of lime; dry, exposed situations, sour soils, or those exposed to frost or inundation, and unprotected tracts along the sea-coast, are not localities likely to show good, healthy, and remunerative growth.

Seed is produced almost annually, and is sown with the wings attached; the seed of the maple should be gathered in September, but that of the sycamore does not ripen until October, and then remains some time hanging before it falls. The seed can be gathered either by shaking down on sheets, or by collecting the fallen fruits from off the ground. Its germinative power is but of short duration, so that it should usually be sown in autumn, when it comes up early in the following spring; though where the danger from late frosts is great, it can easily be mixed with sand, and kept over the winter in sacks hung up in damp places, out of the reach of mice and voles. Seed that has become too dry during the winter often does not germinate until the second spring.

Sowing is confined, as in the case of the ash, to sprinkling the seed on prepared patches wherever the introduction of these species is desired in forests where no self-sown growth has made its appearance; a sufficient soil-covering is given by raking superficially. Where the use of seedlings or transplants seems preferable in order to gain some advantage in growth, to avoid danger from rank weeds and grass, or to secure a better disposition of the subordinate species, the choice ranges from two-year-old seedlings up to strong transplants of nine or ten feet in height; but in general a preference is given to transplants four to six feet high, especially for putting out singly. On mild soils notching can be performed with younger material, though in general pit-planting is better, the plants being set deep in the ground, with a cup-shaped hollow left above for the collection of rain-water. For the production of seedlings, beds of good moist soil are best, the seed being sown in rills, or else broadcast, and then raked in and pressed down with a roller; transplants are put out in the nurseries in similar manner as in the case of the ash. *Planting* should be carried out in spring, and somewhat late when frosts are to be feared, even although the buds may be beginning to break into leaf. Trimming of the seedlings or transplants should usually be unnecessary, and ought not to be done if avoidable, as both species are somewhat deficient in recuperative power, and rather susceptible to damage, especially of the rootlets.

3. Red or Hardwooded Elms, including the Common English or Small-leaved Elm (Ulmus campestris, Sm.),

the MOUNTAIN, SCOTS, OR WYCH ELM (ULMUS MONTANA, Sm.), and the CORK ELM (ULMUS SUBEROSA, Ehrh.), which were all comprised (as also the soft-wooded WHITE ELM, *U. effusa*, Willd.), by Linneus under the comprehensive name *Ulmus campestris*. These species show so many mutual interchanges, that they are often exceedingly hard to distinguish; they seem to be varieties rather than distinct species.

Distribution.—The red or hard-wooded elms are distributed throughout the greater part of Europe, Algiers, Asia Minor, and Siberia as far as the drainage of the Amur, but are characteristic rather of southern than of northern Europe, where they are never found forming pure forests, and not generally even in large clumps. They are to be found more frequently in France, Spain, and Italy than in Germany and Switzerland, more frequently in the south of England (where, indeed, throughout many counties, as in Suffolk, Essex, and Dorsetshire, they form quite characteristic features of the rural scenery) than in Scotland or in Norway. The wych elm, more abundant in Scotland than in England, is indigenous to Britain and Ireland, but it seems probable that the English or small-leaved species was originally introduced by the Romans,—a conjecture strongly supported by its poor-seeding capacity in this country, as well as by historical data.

The mountain elm ascends the Alps to over 3,300 feet, but in general the elms prefer the lower-lying localities, such as dingles, coombs, and sheltered valleys, or level stretches even when subject to inundation, where they thrive equally well as coppice, pollards, or high timber trees. In many respects useful and valuable trees, it is to be regretted that more is not done for their cultivation on a large scale in compact forests, although no doubt large quantities of fine timber are produced at present along roads and in the hedgerows dividing fields. They thrive well in the neighbourhood of the sea-coast.

Tree-form and Root-system.—Although under favourable circumstances the elms can assume first-class proportions equalling those of the oak, ash, maple, and sycamore, yet when grown in forest canopy such good dimensions are not generally attained. Isolated stems in hedge-rows often attain a height of 130 feet, whilst a girth of over twenty feet is at the same time not uncommon. But the development of the bole is also often unsatisfactory, bent and crooked, with an irregular, wavy-lined, elliptical section, and frequently deformed by gnarled and knotty excrescences. When growing in the full enjoyment of light and air, they have rather a strong tendency to forked growth, and freedom from branches can only be obtained by confining their growing-space to the narrowest limits. The branches are long, and only moderately thick; they do not ramify much, but towards their ends divide into broom-like wisps or clusters of twigs bearing a somewhat thick and dense foliage. Seen in their bare winter condition, the elms are readily distinguishable from oaks by the greater regularity of the twigs, and the smaller angle formed by these with the branches. The Cork elm has a narrower crown than either of the other two varieties or species.

The root-system is heart-shaped, and consists of several strongly developed, branching side-roots, with strong determination downwards; these do not expand much horizontally, unless the soil is wanting in depth or penetrability. At the later periods of growth, and particularly on shallow soils, their expansion laterally becomes considerable, superficial roots being thrown out in all directions.

Requirements as to Soil and Situation.—All varieties of elm demand a somewhat mild climate, and thrive best in warm localities, more especially where the atmosphere is humid. Severe winters not only retard the growth of young plants, but often do considerable damage to mature trees, although the common and mountain elms seem hardier in this respect than the Cork elm.

A good fertile soil is necessary for all three varieties, none of which attain satisfactory dimensions except on the deep, light or mild accumulations in coombs and valleys, or at the base of hill-sides. Alluvial deposits, strong, friable mineral soil on hill-sides, good loam, and moist humose sand are, however, their favourite soils. Shallow limes and dry loams are no situations on which to experiment with elms as high-forest, although for coppicing these soils yield fairly good results. Like the ash, the elms can endure a considerable degree of soil-moisture; but in general they may be ranked mid-way between the beech and the ash as regards the amount of it requisite for their proper development, although the mountain elm is more moderate in its requirements than the other two varieties. Temporary inundations do not injure their development, and in general a superfluity of soil-moisture, or even an actual excess (within moderate limits), is preferable to any deficiency. Their development is conspicuously improved by a rich admixture of humus in the surface-soil; in forests from which the dead foliage is regularly removed as manure for any adjacent fields, *stag-headedness* and decay of the crown soon make their appearance.

Atmospheric humidity is congenial to their growth though not a necessity for it, and in regard to aspect they exhibit no distinct or decided preference. On the uplands, and along the lower ranges of hills, they do well with north-eastern exposures when protected, but shun the situations unprotected from the cold, dry, north-east winds. They break early into leaf, but are not on that account liable to suffer much from late frosts in April and May.

Requirements as to Light.—The elms occupy, in regard to their demands for light, a place between the oak and the ash, on the one hand, and the maple and sycamore on the other; they are certainly classifiable as light-loving, if not exactly light-demanding species. In their earlier stages of growth they can bear, on sufficiently moist soil, the shade of lofty standards for several years without suffering loss of recuperative power when allowed to have a freer enjoyment of sunshine and warmth. Their love of light is, however, unmistakable; groups of pure elms do not maintain themselves long in full canopy, and, in coppices especially, the necessity for a fuller measure of light and air is soon noticeable. The crown of foliage is distinctly dense in the English and Scots elms, but the shade cast by the Cork elm is somewhat lighter. According to Ney, they bear less shade than the beech and hornbeam, but more than ash, maple, and sycamore; they are certainly endowed with a denser foliage than these latter species.

Attainment of Maturity and Reproductive Capacity.—From about their thirtieth year onwards, elms produce seed almost annually; they flower in April, and the fruits ripen and fall about the end of May or the beginning of June. Good seed-years occur every two or three years; but unless utilised at once, the seed is apt to become easily heated and to lose its germinative capacity rapidly, which even in fresh, good seed averages only about forty to forty-five per cent. Owing to the loss of germinable capacity, the seed cannot be kept over winter till the following spring, though, as a sufficiency of seed seldom fails in any year, this is of little importance. The English elm, which makes greatest demands on warmth of climate, does not bear seed in Scotland, and even in England, is a very poor seed-producer; but it compensates for this by its capacity for throwing out stoles or root suckers, which establish themselves, and are removable as single individuals. The Scots elm throws out very few, if indeed any, suckers, but produces good seed abundantly. The seed of these two varieties is very much alike; in the English elm, however, the seed is above the middle of the obovate fruit, and the notch between the wings reaches down to near the top of the seed, whilst in the Scots elm the seed is nearer the centre of the almost oval fruit, and the notch in the wings does not reach down to it.

The reproductive power of elms is considerable, exhibiting itself not only in shoots from the stool and along the whole stem, especially from the cicatrices or *callus* growth of former wounds, but also in suckers from shallow superficial roots,—although in this respect aspen shows still more energy. In isolated trees and in avenues this capacity is also exhibited by the tendency of adventitious buds to develop into shoots along the bole. On good fresh soil their reproductive power is especially good. They stand pollarding well, and both as pollard and coppice yield good fodder for cattle, as well as fair returns in timber, whilst they long retain their power of shooting from the stool.

Liability to Suffer from External Dangers.—As regards frost, elms belong to the hardier species of deciduous trees. Late frosts do them little damage, in which respect they follow closely on the hornbeam, but on the other hand drought, or strong growth of rank grass, is very prejudicial to their development. During severe winters, however, superficial roots, both of young and of old trees, suffer when the soil has no proper covering to protect it. When in healthy growth, they are neither apt to be thrown nor broken by the wind ; but as they continue to flourish outwardly long after they are over-mature and rotten in the heart of the stem, their power of resisting storms may sometimes appear less than it really is. Deer and cattle both love to browse on elm foliage, but with its strong recuperative power the damage done is not of much consequence. Rubbing by stags and roe-buck often occasions severe wounds on young stems, and red-deer are apt to strip the bark of poles before it becomes thick and hard; but in the power of healing such wounds the elm surpasses even the ash. As a tree of the forest, growing in admixture with other species, it stands next to maple and sycamore in immunity from the ravages of injurious insects. It is practically almost exempt from danger on a large scale, although both active forms of *Hylesinus vittatus* and *Scolytus destructor* often do considerable damage to the bark and sapwood of trees growing in the open, more especially in and around large, smoky towns. Among caterpillars, those of *Vanessa polychloros* and *Porthesia auriflua* do most injury to the foliage, whilst the greatest damage inflicted on the mature wood is caused by the larvæ of *Ptilinus pectinicornis* and the caterpillars of *Zeuzera æsculi.*

Elms are exposed to the same fungoid diseases as maple and sycamore, arising principally from *Nectria ditissima, N. cinnabarina*, and *Phytophthora omnivora.*

Sylvicultural Treatment of Elms.—Nowhere in northern Europe do elms occur forming pure forests, or as the principal species in mixed woods, and there are very many localities, well suited to its growth, where it is not even to be found among the subordinate species, despite its vigorous growth, the fine dimensions attainable on good soil, and the beauty of its wood for cabinetmaking and furniture. Its neglect sylviculturally—and there is every reason to believe that it was formerly to be found in our woodlands to a greater extent than is now the case,—is doubtless entirely due to the large extent to which it is to be found throughout the greater part of Britain along roads, as standards in hedgerows, in avenues, parks, &c., whence the supply of timber is enough to cover the present demand for this particular kind of wood. Throughout Holland, Belgium, and northern France, it is to be seen adorning the towns and villages, as well as along the main highways, to a much greater extent than in Britain. In England it is a favourite tree for avenues, one of the best known being that on the Wimpole Estate, in Hertfordshire, consisting of a double row nearly three miles in length.

Where grown in woods, the culture of the elm should be confined to warm, sunny exposures, and to soils undoubtedly congenial to it, such as the moist patches suited to the ash, the better qualities of binding soils that are just a little too tenacious for the oak, fertile marshy land, good loamy or moist, humose, sandy soil, and the fresh, better classes of beech soils; for, on the whole, elms undoubtedly belong to the species that make considerable demands in regard to the quality of the soil.

Elms are as little qualified by nature as ash and maples to form pure forests, or even clumps or groups, and in general their sylvicultural characteristics and treatment exhibit very close resemblances to these species; their proper position is as single stems in mixed crops. But where, either intentionally or through force of circumstances, they have grown up in large patches or groups, they should be thinned out when their chief growth in height has been completed, and when the natural desire for lateral development begins to make itself distinctly apparent; after that they should be underplanted with beech or hornbeam, silver fir or spruce, according as the nature of the soil, and the wishes and interests of the proprietor, indicate one or other of these species as preferable. When grown among oaks and beeches, elm has sometimes, if lagging behind in growth in height, to be cut out about fifty to sixty years of age; but, in the majority of cases, on suitable soils it can maintain its crown dominant among the neighbouring trees, and can well hold out the full rotation of the latter, being then removed during the first or second reproductive fellings at ninety to a hundred years of age, as a large-girthed stem of considerable technical value.

The most natural treatment that can be accorded to elm is its growth in admixture with beech or hornbeam on moist patches with a warm aspect; for without a considerable degree of warmth its development is not energetic. Under such circumstances it often attains a more rapid growth in height than these species, but when intermixed with the spruce or silver fir it is more easily overtaken in growth, and soon outgrown and suppressed by them. Rank growth of grass or weeds is very inimical to elm at the earliest stage of growth; yet when once it has passed through the bushy period and commenced its upward growth, it shoots up rapidly ahead of the beech, and maintains a vigorous growth in height into the pole-forest stage of development, towards the end of which, however, it is apt to be caught up by the latter. After that, except on good soils, even assistance given at the time of thinning out fails to prevent its being suppressed, unless it has been grown in small knots or patches, the centre of which cannot be reached by the ruling species; but on soils and situations more favourable to its development, it either remains dominant, or can be aided during the operations of thinning. On the better classes of low-lying, and deep, moist, humose soil, to be still found here and there under forest, mixed woods of oak, ash, elm, &c., with the two first-named as ruling species, are often formed, care being taken either to avoid close planting, or better still to arrange the different species in groups on the various patches of ground best suited to their individual requirements, so that each species may at any particular time receive the special treatment, as regards thinning, underplanting, &c., best adapted to its cultivation, and to the production of the most remunerative assortments of that kind of timber. This latter method is in many respects the better, as, even with the use of strong and large transplants of oak, the ash and elms are of speedier growth, and succeed in shooting ahead of it, often very much to the detriment of the oak, although on such soils it can bear more side-shade than elsewhere, and has less distinctly the character of a light-demanding species. On these fertile soils—which, however, are far more usually under agricultural than under sylvicultural treatment,—it is possible to reproduce the ash, elm, and maple naturally under the light shade of the standard oaks, and to allow all these species to grow up till the latter reach their full period of marketable maturity. Natural regeneration of the minor species has generally little then to fear from its chief enemies, rank grass and frost,—although in any case the elm does not suffer much from the latter,—and can be easily accomplished, with a little outlay for soil-preparation in strips or patches, whilst the seedling growth—especially that of the ash—can develop fairly well under the chequered, broken, and mobile shade of the high forest of oak. Where this is not the case, utilisation of the existing undercrop, and timely formation of underwood of the shade-bearing and soil-improving species best adapted to the particular circumstances of the patches in question, can always be taken in hand. Well-managed mixed forests of the above description form the most valuable crops of timber, and every individual group deserves the careful attention of the forester.

The reproductive power of elms, especially of the English elm, is relatively greater from the root and stool than by seed-production, which is on the whole poor except after exceptionally warm summers that have favoured the secretion of reserve supplies of starch &c., for the formation of flowering buds. It is therefore well adapted for pollarding, or as coppice under standards; but in the latter position the root-stools are apt to grow rapidly, and to spread out widely to the detriment of the other hardwoods, whilst the number of shoots per stool ultimately diminishes so much, that, as coppice, it is less remunerative than many other species. As standards in copse, however, it finds its normal requirements, and rapidly develops a large-girthed bole.

Sowing of elm is usually confined to the production of seedlings and transplants in nursery-beds, and requires some care as the young seedlings are sensitive to drought. The seed, which should be sown on loose, fertile, fresh soil immediately after it ripens about the end of May or the beginning of June—for it has no period of rest before germination, and loses its germinative capacity before the following spring—is scattered broadcast over the beds, and receives a very slight covering of earth passed through a sieve. What falls first is only imperfectly formed fruit; but the matured seed, even if only collected in heaps or sacks for a few hours, gets heated very easily and then its germinative power becomes materially diminished. In dry weather, watering daily for seven to ten days is necessary till germination takes place, and after the seedlings have appeared, they should have some protection from the strong summer sun, whilst care must be taken to weed out all grass that makes its appearance. Before autumn the plants develop quickly, harden so as to be able to resist the cold of winter, and can even be put out in the forest if desired; but it is better to prick them out in the nursery at distances varying from 8″ × 8″ to 12″ × 12″. At the latter distance the seedlings develop into plants of one and a half to three feet in one to two years, and, by the removal of each alternate transplant, into strong transplants of five to seven feet high in four to five years. Forked growth is somewhat common in the nursery, but the elm stands trimming well.

Planting has no difficulties to contend with, and the choice of material extends from yearlings to four or five-year-old transplants, a preference being generally given to two to three-year-old transplants, in order to obviate danger from rank growth of grass. Reproduction of elms can also take place by layering, as is extensively practised in Holland ; but this is rather a matter for the arboriculturist than the sylviculturist. Layering and planting take place most advantageously in autumn, from the middle of October till the middle of November, as the movement of the sap begins early in spring. As in the case of the maples, planting may be either performed by notching and replacement of the sod, or by pit-planting with the hand, either operation being easy and without any special peculiarities.

4. Hornbeam (Carpinus betulus, L.)

Distribution.—The hornbeam is described as being indigenous from the south-west of France eastwards across central and eastern Europe to Persia, northwards to England and Ireland (but not Scotland) and the southern portion of Sweden, and southwards to lower Italy and Greece. The evidence of historical records goes, however, to prove that it was not originally among the forest trees of England, but was introduced from the Continent before the close of the fifteenth century. Its vertical distribution is limited to about 3,300 feet in the Swiss Alps, 2,900 feet in the Bavarian Alps, 2,600 feet in the Vosges and the Black Forest, and 1,200 feet on the Harz mountains. Although not liable to suffer from cold, it does not stretch far northwards, its growth being practically limited as a forest tree by the German Ocean and the Baltic. It hardly belongs to the ruling species of forest trees, although in eastern Russia, and beyond the Weichsel and the Oder, where the beech ceases to form forests its place is taken to a great extent by the hornbeam, which there attains excellent growth, and covers an area of immense extent. It is prized rather for its toughness and its adaptability to machinery requirements and cogs of wheels, and for its great heating power as fuel, than for any of its other qualities as timber. It is more the denizen of the valleys and the lower uplands than of the higher hill-ranges, which it cannot ascend so far as the beech. It is principally found in groups or patches, or as individual trees interspersed among beech along with oak, lime, ash, and Scots pine on moist patches of soil.

Tree-form and Root-system.—On thoroughly congenial soil and situation, the growth of the hornbeam closely resembles that of the beech in regard to tree-form and development of the stem, and when there grown in close canopy, it attains to equal height and symmetry of bole, the ramification of the branches beginning also at about the same height as in the case of the beech. Single stems grown in the open on strong, fresh soil attain a height and girth in no way inferior to the beech.

The hornbeam is, however, as a rule relegated to soils of only inferior, or at least average, quality, and there its development sinks rapidly to very indifferent proportions, the bole becoming short and tapering, with a very irregular, fluted and flanged section, and soon dividing into branches that ramify into numerous clusters of broom-like twigs with somewhat dense foliage forming an extensive crown. Under such circumstances the hornbeam hardly approaches the majority of our forest trees in regard to attainable proportions, seldom exceeding sixty to seventy feet in height and about three feet in girth, whilst on the poorer qualities of soil it assumes rather the form of shrub or bush than of a normally developed tree. Growth in close canopy is necessary to secure a straight bole; with enlargement of growing-space the tendency to ramification soon manifests itself.

Its root-system is endowed with a considerable power of accommodating itself to the circumstances of the soil, and although on the whole heart-shaped in form, it exhibits a tendency rather towards lateral development than to deep growth; on deep soil, however, the ramification commences lower down, and the numerous side-roots spread through the soil at a moderate depth below the surface. On shallow soil, more especially when subject to drought, the root-system resembles that of the spruce, long superficial roots being thrown out close to the surface for the purpose of utilising to the full the moisture supplied by the atmospheric precipitations. It is therefore not reckoned among the deep-rooting species of forest trees.

Requirements as to Soil and Situation.—The hornbeam cannot be classed as at all exacting with regard to soil, in which respect it differs considerably from the beech, and on the whole its demands may certainly be called moderate. It is to be found alike on fresh sandy and loamy, as well as on clayey, limy, marly and other strong soils; but for the attainment of its best development either a fresh and humose, or at least a strong, mineral soil is desirable. It shows, however, an undeniable and distinct preference for the fresh or even moist soil to be found in dingles and dells, and skirting the base of hill-sides; a sour soil is unfavourable to it, although it manages to maintain itself on the edge of marshy land, and can withstand the effects of temporary inundation. Porosity and penetrability seem of greater moment than depth of soil, although of course, other things being equal, the best growth is to be obtained when depth is also available; hard, tenacious soil is totally unsuited to it.

In regard to demands on soil-moisture it occupies a position between the beech and the ash. Grown along with the beech, it asserts itself on the moister patches; and where the soil is somewhat too moist and shallow for the former, the hornbeam can still often yield satisfactory results. Altogether, it is less exacting than the beech, both as regards soil and soil-moisture. When grown as coppice, a good layer of humus or mould is desirable, and at times indispensable, particularly on soils that are inclined to be stiff and dry. When, however, soil-moisture and a good layer of humus fail, the want of these must be counterbalanced by a good strong mineral composition of the soil in order to achieve anything like good development and vigorous growth.

Although a hardy wood not suffering much from frost, and content often with but a meagre degree of warmth, yet the best results of its cultivation are obtained in localities favoured with genial atmospheric temperature. Low-lying, sheltered tracts, where during the heat of summer the air is always damp and heavy with aqueous vapour, answer better for the hornbeam than open, upland situations where the comparatively free play of winds and breezes tends to stimulate transpiration from the foliage, and to carry off by evaporation any surplus moisture from atmosphere and soil. As underwood, grown in coppice under standards, on hilly land, it is often worked with short rotation, one of the most advantageous crops. Its moderate demands on temperature, combined with its preference for atmospheric humidity, of themselves indicate that in hilly tracts the damper eastern and northern exposures are best suited for its growth and normal development.

Requirements as to Light.—At no period of its growth does the hornbeam take rank among the light-demanding, or even among the light-loving trees, but it is rather to be ranged somewhere near beech and spruce as a shade-bearing species. Not only during the earlier years of growth, but later on in the more advanced stages of development, it can bear, without marked diminution of vital energy, a considerable degree of shade, more particularly on a good, fresh soil. On shallower ground, however, and on poorer localities mainly dependent on rainfall for their supply of moisture, the want of free enjoyment of light and air is more rapidly felt; its development under such circumstances suffers considerably, and its yield in cubic contents is of course much diminished. Under the more favourable circumstances it can yield good returns when grown as coppice, with or without standards, and as such is often allied with the beech, which, however, on the whole ranks higher as a shade-bearer than the hornbeam.

Attainment of Maturity and Reproductive Capacity.—From about its thirtieth year the hornbeam bears seed almost annually, even when nearly suppressed in growth by standards. The seed, which ripens in October, and of which about 14,000 to 16,000 go to a pound, has a germinative capacity of about 70 per cent. (according to Gayer; Ney gives 50 per cent as satisfactory), lies over one year, and only germinates during the second spring, but retains its germinative power for from two to three years. In the reproduction of stems and of branches it likewise possesses a recuperative faculty of the highest power. It coppices freely, and maintains[1] its reproductive power for sixty or even eighty-five years like the oak, whilst on soils of the best classes it also sends out root-suckers when the stem is felled close to the ground. It is well adapted for pollarding, and for the formation of live hedges. Pollarded hornbeams may attain the age of a hundred and fifty to two hundred years.

Liability to Suffer from External Dangers.—Thanks to its strong recuperative power, the hornbeam suffers little from external dangers. When once it has taken good root, it can bid defiance to attacks of all sorts; as coppice it maintains

[1] According to recent experiments conducted by M. Bartet at Nancy.

itself, and the shade overhead must be heavy indeed before it succumbs. The bite of cattle, and the nibbling of sheep, do less permanent damage to it than to other species of trees, for its recuperative power is such, that, whenever badly bitten, or even regularly grazed over, a short period of protection suffices to repair the damage done. In damp localities exposed to frost it is one of our hardiest trees, thriving where even the beech is unable to. It is equally exempt from serious damage through snow and hanging ice, and, having a well-shaped root-system, it is little apt to be thrown by wind ; but on the other hand it often suffers during periods of drought, and like the beech and other smooth-barked trees, is apt to be damaged or "sunburnt" on the west and south-west side of the stem, if exposed to the scorching heat of the sun.

Among its enemies are to be numbered chiefly mice and squirrels. In the wood-mouse (*Mus sylvaticus*), indeed, it has a bitter enemy which kills many young seedlings; the damage, however, is not so great as would be the case with other species less endowed with recuperative faculty, for the stems are easily replaced by stool-shoots, without necessitating either coppicing or the removal of the damaged portions. Injuries from insects are comparatively unimportant, although species of *Melolontha* often do considerable damage to the roots, the caterpillars of *Cheimatobia brumata* to the buds and leaves, and those of *Gastropacha neustria* and *Porthesia chrysorrhœa* to the foliage. Like all the broad-leaved deciduous species, except perhaps the birch, infection with *Nectria ditissima* leads to a cankerous fungoid disease of the stem and branches.

Sylvicultural Treatment of Hornbeam must in Britain be mainly confined to its use as underwood for protecting the soil, and stimulating the standard trees to increased annual production, in situations that are somewhat too fresh or moist for the beech. It is less capable than most forest trees of attaining large proportions in our climate, and though its tough wood is excellently adapted to various small timber requirements, the market for such minor assortments is easily satisfied without the cultivation of hornbeam on any extensive scale beyond its natural position in coppice. There owing to its strong, long-sustained power of shooting from the stool, and of throwing out stoles also with deep felling, and its capacity for enduring shade, in which it approaches but does not quite equal the beech, it often forms a very considerable portion of the crop.

Wherever it is desired to grow the hornbeam in high forest, this can only be successful either on fresh and humose or strong mineral soils ; it is best attained by admixing the hornbeam with the beech, as except in close canopy it fails to develop a long, straight, round stem. Grown along with oak, ash, maples, and elms on damp or moist patches with good strong soil, where there is always a certain amount of danger from early and late frosts, it is often in some respects a better ruling species throughout such groups than the beech ; it is not so energetic in growth, and is therefore less likely to overtake and suppress, or at any rate inconvenience in growth, these nobler and more valuable species. As a subordinate scattered singly or in small knots throughout beech woods, even with some advantage in growth it is apt to be caught up about the twentieth to the twenty-fifth year, and in any case has to be removed—usually about the sixtieth to seventieth year—during the periodical thinnings, long before the ruling species has arrived at maturity. But near the edges of the forest, and wherever the shade overhead is not too dense, it generally endeavours to assert itself again as coppice ; as already remarked, the overshadowing must be strong indeed to suppress it altogether.

Where soil and situation are favourable to the hornbeam,—

on the better, fresh or moist deposits in low-lying tracts, or on the lower uplands and undulating localities, in contra-distinction to the distinctly hilly ground on which the beech asserts itself most readily,—it is perhaps deserving of more attention than any other forest tree as a protecting and soil-improving species distinctly conducive to the finer development of the more valuable varieties of forest produce. In many instances these localities, if still under forest crops, are somewhat too damp, moist, and frosty for the beech, or its growth is so energetic as in some cases to interfere with the further development and expansion of the light-loving species forming by far the most remunerative portion of the crop, and in many respects the hornbeam accommodates itself, better than any other shade-bearing species, in general growth and as regards special characteristics, to the sylvicultural treatment carried out in favour of the dominant mixed crop. Being slower in growth than the beech, hornbeam even on the richer classes of soil never interferes with the more rapidly developing oak, ash, maples or elm; and as it attains its economic maturity between sixty and eighty years of age, or just at the time when the oak requires a larger measure of growing-space, and a freer enjoyment of light, air, and sunshine, it can then be utilised and reproduced as underwood, regenerating itself naturally by seed as well as by stoles or shoots from the stool. At that age, too, its timber is more remunerative than that of beech, or even than oak of the same age. Where oak forests are being reproduced, a self-sown growth of hornbeam is welcomed, as, if cut back during the weedings and clearings, it still asserts itself as protective underwood to the advantage both of the soil and of the principal crop, although its fall of leaves is neither so great, nor productive of such rich humus as in the case of the beech.

On damp exposures subject to frost, hornbeam in admixture with Scots pine also in general gives better results than can be shown by beech, despite the lighter fall of foliage. Grown in equal-aged crops raised either from sowing or planting in the open, it leads to the early formation of closed canopy, and to vigorous growth in height of the pine; this soon outgrows the hornbeam, and the latter gradually disappears unless it is considered advisable to favour its retention by the formation of patches or groups at the time of sowing or planting. For the underplanting of pine or larch woods on fresh soils not quite moist enough for silver fir or spruce, hornbeam will usually be found the broad-leaved species most likely to yield fairly satisfactory results; the operation should be undertaken about the thirtieth to fortieth year,—or earlier in the case of the larch,—at the time the natural tendency towards lateral expansion manifests itself plainly by the self-thinning of the pole-forest.

For a standard in copse, hornbeam is not naturally so well suited as for coppice, as it casts too dense a shade over the surrounding underwood. But where the standards consist of oak, ash, and the like it does best service as coppice, and although not so soil-improving as the beech, it has a decided advantage over the latter in longer-sustained power of reproduction from the stool; it thus permits of a greater choice in the matter of fixing the periodic fall and the number of annual hags, the rotation varying from twenty to forty years according to the local demand for the material harvested from the coppice on the clearance of each hag.

Self-sown growth of seedlings is at times capricious, and even troublesome in reproductive fellings in beech woods on fresh soil; but in copse, free shedding of seed often remains practically abortive, as the young seedlings are easily suppressed by grass on the moister localities, whilst the seed either gets eaten by voles and mice or fails to germinate on the drier soils. Artificial production and reproduction are usually accomplished by planting,—which is essentially safe in its results, although the plants remain sickly for some time,—rather than by sowing,—which is exposed to great danger from grass on moist soil, from drought on dry soil, and from being lifted out of the ground by successive frosts on loose soil.

Hornbeam is a troublesome species to deal with in so far as it very often shows good spontaneous growth where not at all wanted, and is extremely difficult of cultivation where its appearance is especially desired. On the better classes of soil hornbeam seeds almost annually, with a really good seed-year about once in three years. Like that of the ash, the bulk of the seed germinates only in the second spring after ripening, so that it is usually only sown then, after having been collected in sheets by shaking the boughs and branches about the end of October, or early in November, when it is beginning to assume a brownish appearance; it falls best on days that have been ushered in by hoar-frost in the early morning. The keeping of the seed is exposed to no special dangers except from mice and drought; where large quantities are to be kept over, this can easily be managed by burying it in trenches about one foot deep.

Sowing is most successful where the soil is only slightly prepared with rake or harrow, and the clean unwinged seed simply raked in, as it should not have a greater covering than $\frac{1}{3}$ to $\frac{1}{2}$ inch, the quantity of seed sown being in the proportion of 25–40–50 to 60 lbs. per acre according as it is confined to patches, or strips, or sown broadcast over the whole. Unless measures are taken to protect the seedlings against rank growth of grass, the results of sowing are seldom satisfactory. *Planting* is in general preferable, but, except on fresh or moist soil, it also may prove somewhat disappointing unless a good stout assortment of transplant be used. Where seedlings of three to four years old are available from the woods, they should at once be put out in the nursery-beds about two feet apart, so as to develop into large transplants without loss of time, and with diminished danger of being gnawed by mice. Otherwise its treatment in the nursery consists of sowing in shallow rills, and pricking out in nursery beds as in the case of the beech. The planting of hornbeam offers no special difficulties to overcome; for underplanting groves of light-loving species with two-year-old seedlings, notching with broad spades, or in the usual manner, is easily applicable on all except very binding soils. But for all other cases in which seedlings or transplants from two to seven feet high are put out,—and even larger material is used for grazing grounds and the like,—they can easily be transplanted in ordinary pits without earth attached to the roots; the use of naked transplants, however, is not advisable on dry soils or for exposed positions, where the difficulty the plants find in establishing themselves is greater than on more favourable situations. For the formation of coppice, or the filling up of blanks there, good large transplants are preferable; they should be put out about $4\frac{1}{2}$ feet apart after having their tops lopped, and then cut back to the ground after a year or so, when they have thoroughly established themselves. The planting operations can equally well be carried out either in spring or autumn, as may be most convenient.

As pollards, the hornbeam yields a good flush of shoots, especially when one of the branches is left for a year "to draw the sap" each time that the crop is harvested, that is, every six to ten years; one of the lower shoots should be selected for this purpose as being easier of removal than if one near the middle of the poll were chosen. For shade and shelter to the cattle, it also finds a suitable abode on grazing-grounds at wide intervals, being pollarded at about eight feet above the ground; but where it may be intended to improve the grazing at the same time, better results are in general attained by wide planting of the larch.

With its strong recuperative power, young transplants of hornbeam stand trimming of the roots or branches well, but the latter should be sparingly done wherever there is danger from scorching or sunburn. This quality of the species finds its use in the formation of thick live hedges, which sometimes form quite a characteristic feature in old-fashioned gardens, especially in northern France. As underwood it forms an excellent cover for game during winter, thereby enhancing its other desirable qualities as underwood in mixed forests on good, fresh soil.

5. Sweet or Spanish Chestnut (*Fagus castanea*, L. = *Castanea vesca*, Gaert. = C. vulgaris, Lam.).

Distribution.—The edible chestnut occurs throughout the whole of southern Europe, and is also indigenous to the warmer, extra-tropical localities of Asia and North America. It is found as a forest tree in the outlying ranges of southern Switzerland and France, and forms forests of considerable extent and importance throughout Spain, Austria, Italy, and Greece. Wherever it may be met with north of the Alpine range its presence has originally been due to artificial production. It ascends to 2,900 feet in the Alps, 2,200 in Spessart and the Odenwald, 2,000 feet in the Vosges, and 1,700 to 1,800 feet in the Bavarian uplands. Even in Germany it is of importance from a sylvicultural point of view only in the warmer districts of the Rhine or Bavaria, where it is grown in coppice for vine-props, and in high forest for wine-casks and for general timber requirements. In Britain, where it was introduced by the Romans, its profitable growth as a forest tree must be confined strictly to the warmest localities.

Tree-form and Root-system.—In suitable locality and on good soil, the chestnut resembles the oak in the dimensions attainable, although in general it is neither so lofty nor so regularly developed. During the pole-stage of growth its stem is straight and normal, but it soon ramifies and breaks into branches, and forms on the whole only a short bole. With advancing years the crown broadens and spreads considerably; the strong branches become gnarled and twisted, reaching far and wide in circumference, and bearing a wide-spreading, closely-foliaged canopy.

In the development of the root-system it still more closely resembles the oak. It has a deep-seated, strong tap-root, the ramifications of which, as well as the ordinary side-roots of the stem, tend frequently towards an almost perpendicular growth into the soil; with the spread of the crown, a development of superficial side-roots also takes place.

During the early period of its development it has a somewhat more rapid growth than the oak, which, however, it equals in length of life, and often surpasses in attainment of girth, thus compensating for its subsequent feebler energy of growth in height. In the south of England it attains sixty to eighty feet in height in fifty to sixty years; in Scotland it is less rapid in growth, but still retains its advantage over the oak during the pole-forest stage of development.

Requirements as to Soil and Situation.—The demands made by the chestnut as regards soil are by no means slight. Depth and penetrability are factors more necessary for its satisfactory development than actual mineral strength. Stiff, binding, shallow soils are totally unsuited to it, even as coppice-wood; somewhat less unsuited are the much-fissured or broken, stony soils through which the root-system can, in ramifying, penetrate to a better subsoil. Though fond of moisture, a wet soil, or even temporary excess of moisture, is unfavourable to its proper development. Given, however, sufficient depth and porosity of soil, it can easily content itself with less than the favourable quantity of soil-moisture. Loamy soils are in general best suited to the chestnut, as they most frequently yield the conditions favourable for the development of its normal root-system, whilst limes, for exactly the opposite reason, seem in general unsuited to its growth. On the whole, however, it is not exacting with respect to the mineral composition of the soil; granites, basalts, clay slates, and sandstones, can each of them yield soils capable of affording it all the essentials for successful growth and normal development.

A mild, genial climate is necessary for the chestnut, and even a somewhat high mean annual temperature if maturity of the edible fruit is to be reckoned on; the extreme of summer heat is at the same time prejudicial to it, as may be deduced from its preference for eastern rather than southern exposures on hill-sides. It is a tree rather of the uplands than of the valleys, more suitable for sheltered localities than for situations exposed either to heavy winds or to frosts; mildness of climate exhibits its favourable influence on the general energy of growth more in regard to this than to any other species of our forest trees, particularly in the matter of coppicing. Sheltered localities on low hill-ranges and uplands, but avoiding the coombs and dells where frost is first to come and last to leave, woodlands bordering on the sea-coast, or within its equalising influence, and unexposed situations in parks and ornamental clumps, are the places where its cultivation is most to be recommended. Grown as coppice, it often yields good results and proves itself well adapted for forming an underwood under standards of Scots pine, larch or oak. In general, however, its success as a forest tree in Britain is somewhat uncertain; despite its many indisputably good qualities, it must continue to receive more attention from an arboricultural than from a sylvicultural point of view. It prefers the eastern aspects on hill-sides, and yields only poor timber on the colder northern exposures.

Requirements as to Light.—The chestnut is classifiable as a light-demanding tree, in which respect it takes rank along with the oak and the ash. In its true southern home, however, it can bear a greater amount of shade than in this colder climate, and even demands there a certain degree of light shade for the proper development of its fruit. Between the vineyards on the Rhine and in the vine-growing tracts of southern Germany, it is somewhat less intolerant of shade than the oak, along with which it is chiefly associated in growth, both in coppice, in high forest, and also as coppice under standards, in order to supply the various demands of the wine-growing and coopering trades. In these localities, however, the summer heat is great, and the climate in many respects more resembles that of its true home. Even further north, where the summer heat is less, it often surpasses the oak and the ash in shade-bearing capacity, as is proved not only by its often very fair returns as underwood below the light canopy of old Scots pine woods, but also by the less pronounced necessity for thinning-out during the pole-forest stage of growth. Grown as coppice for minor timber requirements, such as hop-poles, bean-sticks, cask-hoops, withes, &c., it should have the fullest possible measure of light and air, so as to stimulate speedy growth and at the same time attain the maximum of density and durability in the woody fibres. Grown in the free enjoyment of light, its crown has a thick foliage, and throws a somewhat dense shadow, unfitting it for the *rôle* of standards over coppice, save on exceptionally good soil where the underwood can bear a slight excess of shade; stems, however, that have been drawn up in close canopy bear only a moderate crown with comparatively light foliage.

Attainment of Maturity and Reproductive Capacity.—In the wine-producing districts of Germany this stranger from lands further south bears germinative and edible seed from about its twenty-fifth year, and even somewhat earlier in coppice-woods. The fruit ripens and falls in October, and has a germinative capacity of about 60 per cent. On the more favourable localities seed or mast is produced almost annually, but good seed-years occur only every three or four years, like good mast-years with the beech, or good vintage-years with the vine. The seed germinates in the following spring, the cotyledons, as in the case of the oak, being left in the ground whilst a strong tap-root makes its way down into the soil. Unless collected, the seed loses its germinative capacity from the effects of the winter frost. It does not generally attain full edible maturity in Britain, where, too, the seed developed is small in size in comparison with that ripened on the Continent. About 150 seeds are contained in one pound.

Although capable of attaining large girth and a great age, its maturity as a timber tree in our somewhat cold northern climate should not exceed sixty to seventy years, as it is then apt to develop "*ring-shakes*," which destroy to a considerable extent the value of the timber, although in no way interfering with the outward appearance and æsthetic value of the tree for ornamental purposes. In the open it can attain an age of over 500 years, and in point of longevity is only rivalled by the oak and the lime.

From a sylvicultural stand-point, chestnut is chiefly valuable as coppice-wood, not only for its yield in material, and its fairly moderate demands on mineral strength of soil, but also on account of the superior humus-producing quality of its fallen leaves, and their power of recruiting and improving poor or exhausted soils Its reproductive power is very great and long-sustained, but its capacity for forming new roots is not equal to its energy in developing stool-shoots. As coppice it reproduces itself vigorously from the stool, and occasionally, according to Burckhardt, develops root-suckers in addition, although Gayer and Ney expressly state the contrary.[1] Felling close to the ground and the heaping up of earth on the stumps stimulate its naturally strong reproductive capacity, which on suitable soils and situations is more vigorous and enduring than in almost any other species of timber tree. Even stools of a hundred years in age retain sufficient energy to throw out a good crop of shoots.

Liability to Suffer from External Dangers.—Notwithstanding its many good qualities, the cultivation of this southern exotic must always in Britain be a matter of uncertainty, as it is so liable to suffer from frost. The ordinary winter of our climate it is able to withstand, but in hard winters young plants and poles get frozen to death, the frost working down even to the roots. Hence sowings and plantings are only advisable in sheltered localities where some protection is afforded by lightly-foliaged standard trees. It is apt to suffer badly from late frosts in May, in consequence of which it is little adapted for woodlands on the plain, although this danger is to a great extent counterbalanced by the extraordinary reproductive power of the chestnut from the stool. Where exposed to a hot sun, it is also apt to develop the stem-disease caused by scorching or sun-burn, and is therefore unsuited for the warmer south-western aspects exposed to insolation and refraction. Windfall is of infrequent occurrence, as might be expected from the strongly ramified and deep root-system. Young growth suffers at times from the grazing of cattle and the browsing of deer; but, gifted with strong recuperative power, it soon rehabilitates itself. From injuries arising from fungi and insects it has comparative immunity.

[1] Gayer, *Der Waldbau*, 1889, p. 110; Ney, *Lehre vom Waldbau*, 1885, p. 410.

Sylvicultural Treatment of Sweet Chestnut can never be a matter of first importance in Britain. The climate is not sufficiently warm to yield such good results as are attained with the cultivation of this tree on the Continent, on the warmer parts of which, as for example in the Rhine valley, it has great resemblance to the oak, but is more rapid of development in crown, stem, and root-system, and even retains its power of coppicing freely up to a hundred years of age. In Britain, on the contrary, the cultivation of this species can only take place in sunny, sheltered localities, in woodlands skirting the sea-coast, in parks, &c. But in general it is too liable to danger from frost to hold its own with the other hardier denizens almost naturalised within our forests. The wine-districts of central Europe are the chief localities where the sweet chestnut is cultivated along with the oak as high forest or as standards in copse for the supply of staves for casks, whilst as underwood and coppice it yields excellent withes and hoops, as well as material for vine-poles in the vineyards, its reproductive power being stimulated and increased by cutting the stems flush with the ground and covering the stools with earth.

In the warmer tracts of southern England, wherever there is any good local demand for sticks for hop or bean cultivation or similar petty requirements, coppice of chestnut may yield very favourable returns on the sunnier exposures on uplands where little danger need be apprehended from frost; as the out-turn of small material is very large, a rotation of sixteen to eighteen yearly hags generally yields poles varying from twenty to thirty-five feet in height, according to the nature of the soil and the degree of warmth enjoyed. Well-stocked pure chestnut coppice in Germany, worked with a rotation of fifteen years, can yield [1] about 2,800 poles per acre averaging thirty feet in height and 3·2

[1] Gayer, *Der Waldbau*, 3rd edition, 1889, p. 210.

inches in diameter ; but a mild warm climate is a condition of greater importance than depth or fertility of soil. Newly-formed coppices should be cut over for the first time at ten years of age, in order to strengthen the stools. Owing to the expense of obtaining chestnut seed from the warmer parts of the Continent in order to be sure of its quality, and owing to the dangers to which it is exposed from mice, game, and frost, planting is usually adopted in the production of crops of this species, or for its introduction as a subordinate among other forest crops. The fruit, after being collected in autumn, should be preserved in the cupules till the following spring, and then sown out point downwards, in order to obviate malformation, at distances of three to four inches in rills eight inches apart ; about one to one and a half inches of soil-covering should be given to the seed. Transplanting is not as a rule necessary, as, after standing two years in the beds, the seedlings are sufficiently developed for ordinary requirements ; where, however, a larger assortment is desirable, they may be put out, either as one or two-year-olds, at one foot by one foot in nursery beds before being transplanted, every alternate one being allowed to remain if very large transplants are specially requisite for any particular purpose. As a rule one or two-year-old seedlings are put out at distances of four to six feet, whilst blanks are filled up with four to five-year-old transplants. The method of planting is practically the same as with the oak, pit-planting with the hand being perhaps most preferable, and on the whole yielding the best results. Planting operations can be carried out either in spring or autumn ; but, in general, experience tends to show that the latter is preferable, as enabling the plants to establish themselves more easily, and as causing less derangement in regard to the comparatively early flow of the sap in spring.

Chestnut stands thinning out well, whether as regards the roots or shoots. In the neighbourhood of Heidelberg the seedlings are cut back close to the ground at the time of pricking out in the nursery-bed, in order to strengthen the root-system, and to attain a more vigorous growth by means of a stool-shoot.

6. MOUNTAIN ASH, FOWLER'S SERVICE, OR ROWAN TREE (SORBUS AUCUPARIA, L.), is a species of minor importance, which, however, occurs so frequently over the whole of the mountainous tracts of Scotland and England that it certainly must not be omitted in the enumeration of the forest trees of Britain, more especially as it is undoubtedly one of our comparatively few indigenous species. It is found throughout nearly the whole of Europe and of northern Asia, but seldom attains over fifty to fifty-five feet in height. No kind of soil comes amiss to it, although it exhibits, like the beech, a preference for such as contains some admixture of lime. It thrives on soils of the most varied character, and under conditions of the most varying description, whilst at the same time it exhibits a similar disregard with respect to aspect and elevation. Alike as regards soil and situation, it is undoubtedly the hardiest and least exacting of all our forest trees.

Thanks to its extreme adaptability, it readily asserts itself wherever it can gain a foothold, the seed being widely disseminated in the excreta of birds, to which the berries afford grateful nourishment during winter. Pleasing alike in foliage, flower, and fruit, it is a welcome casual guest in woods formed of other species; but it must not be allowed to outstay the welcome extended to a temporary guest, by becoming a permanent resident. Its timber is highly prized on account of its superior toughness and elasticity, but as a tree it unfortunately only attains small dimensions in girth, and when these have been reached it should be cut out at once, for after that it can no longer keep pace with the further development of most other species of forest trees. On exposed hill-sides it often, along with the birch, does good service as a nurse, but it is then sometimes just as difficult to be got rid of when no longer required, since it is also gifted with strong reproductive power, particularly in respect to the production of stoles or root-suckers.

One can hardly speak of any particular sylvicultural treatment as being accorded to the rowan tree. It is the Israelite among our forest trees, thriving on soils of all descriptions—good, bad, and indifferent,—from the sea-level upwards to the limits of sylvan vegetation along with the mountain pine and the mountain alder (*Alnus viridis*), asserting itself wherever there is the slightest foothold on crags, rocks, ruins, or even where moss and fallen leaves have collected in the forks of trees, never receiving any material encouragement, but merely allowed occasionally to associate with other species for a certain time, then to be invariably removed during the operations of weeding and clearing, or later on of thinning out,—always being cut down and operated against, but always making its re-appearance wherever it has a chance of maintaining itself.

Even on raw exposed situations its cultivation in forests is not likely to be remunerative; but for the adornment of mountain roads, and for many similar æsthetic purposes, it possesses qualities unsurpassed by any other tree, and the ease with which it can be transplanted, either as seedling or stole, pleads for a little more being done for its distribution.

Closely allied to the mountain ash is the true *Service Tree* (*Pyrus torminalis*, Ehrh. = *Sorbus torminalis*, L.) with its fine-grained wood, which is occasionally to be found in dry situations along with the beech on limy soils, but is nowhere of anything like frequent occurrence. It also is characterised by beauty of foliage, especially during autumn, when its bright yellow, golden leaves contrast well with the darker russet hues of the oak and beech.

Growth in high forest is suited for neither species, whilst they are not remunerative enough, and do not attain sufficiently good proportions, to make it worth while to train them as standards in copse to take the place of trees yielding better monetary returns. For arboreta, parks and the residential portions of large estates, however, their cultivation deserves a fair amount of attention.

B. *Softwoods.*

1. The White Alder (*Betula alnus*, L. = Alnus incana, D.C.).

Distribution.—The white alder is distributed throughout central and northern Europe, and the greater portion of western and northern Asia and North America. It is found at elevations up to 5,100 feet in the Tyrolese Alps, 4,500 feet in the Bavarian Alps, 2,300 feet in the Baierwald, and 2,100 feet in the Erzgebirge. Its development, however, is incomplete at lofty elevations, and it is in reality more a tree of the plains, and the lower hills and uplands, than of the mountains. It nowhere forms extensive forests, but occurs mostly in small pure clumps and patches, or, when artificially formed, in combination with willows, hornbeam, and other moisture-loving trees.

Tree form and Root-system.—It develops a straight smooth stem with a moderately foliaged crown, which rounds off and broadens as early as the fifteenth to twentieth year, demanding thereafter increased growing-space. Its growth in height therefore is not great. The crown, borne by long, straight, elastic branches set at a small angle with the stem, is moderately dense, more so on favourable situations than that of the common alder; but like the latter the white alder may be classed as holding an intermediate position between the light-demanding and the shade-bearing species of forest trees. Its root-system is superficial and far-reaching; the side-roots are studded with small clusters of rootlets, sometimes of considerable length. In rate of growth, and as regards its attainable dimensions, it much resembles the common alder.

Requirements as to Soil and Situation.—The white alder is not a denizen of the fens and the marshy tracts like the common alder; nor does it, like the latter, form pure forests over areas of any considerable extent. For moist, porous soil, such as is so often to be found along the banks of streams and at the foot of hill-sides, it has a decided preference, but the soil-moisture must be water in slow motion, and not altogether of a stagnant nature. On sour marshes, or water-logged bogs, its growth is backward and unsatisfactory in comparison with the common alder. It thrives best on a rather fresh or even moist soil, not too stiff or binding, moderately deep, and not wanting in loamy constituents. Although on the whole a moisture-loving tree, it is content with a much smaller amount of soil-moisture than the common alder, without, however, being capable of showing vigorous and energetic growth on dry soil of any description. It also differs from the other species in making somewhat stronger demands on the mineral strength of the soil, and especially shows a certain degree of preference for soils with limy admixture. Cool localities with heavy humid atmosphere, such as coombs and hollows at the base of hills, are better suited for its growth than more open and exposed situations.

In Switzerland the white alder does yeoman service in bringing under cultivation the stony channels of disused water-courses. When once it has established itself, a good growth of grass soon follows on stretches where only bare stones were formerly to be seen; and frequent coppicing in such localities only strengthens its power of improving the soil. On the Rhine, too, it and willows are generally the first trees to assert themselves on fresh, stony soil, thus gradually paving the way for soil-formation and subsequent growth of grasses.

Requirements as to Light.—Both alders occupy an intermediate position between the light-demanding and the shade-bearing species of forest trees. But the white alder on the whole makes a lower demand for light and air than the other, as is shown by its somewhat denser foliage, its better growth in secluded dells lying at the base of hills and favoured perhaps with but scant sunshine, or as underwood below standards of birch, Scots pine, common alder, or even occasionally the oak. On suitable soil it can thrive fairly as coppice under standards casting only a moderate amount of shade, though under such circumstances its reproductive energy from the stool is apt to be prematurely weakened.

Attainment of Maturity and Reproductive Capacity.—The white alder is seldom allowed to attain its normal maturity as high timber forest, but under any circumstances its timber is not so good as that of the common alder. Its chief use is for filling blanks in plantations, and thus forcing young oak, ash, maple, &c., to a more energetic growth in height; it can be coppiced twice or thrice under such circumstances before the stools and roots lose their reproductive power. In cool situations, where soil and atmosphere are both humid, it can attain an age of forty to fifty years without exhibiting signs of senile decay and over-maturity; but in drier or warmer localities it reaches its full maturity in little over half that time, whilst not only its energy in growth, and its timber production in cubic contents, but also its reproductive power, become reduced in proportion. Under normal circumstances, however, it has a considerable power both of shooting from the stool and of sending out root-suckers, in which latter respect it has some advantage over the common alder. The shoots are of rapid growth for about the first ten to fifteen years, but then decrease considerably in their rate of annual increment.

The capacity for reproduction from the stool also diminishes much more rapidly than in the case of the common alder, but, with failing power in this respect, the tendency towards increased development of root-suckers becomes distinctly apparent. Deep felling of the timber and coppicing close down to the ground also stimulate the formation of suckers. As regards the production of seed, it closely resembles the common alder; the seed, however, is lighter in colour, and has not the same tendency to scatter quickly before it can be conveniently harvested. The seed is somewhat smaller than that of the common alder.

Liability to Suffer from External Dangers.—Grown usually in sheltered localities, the white alder is little exposed to danger from heavy storms, against which its root-system is little fitted to offer strong or effective resistance. Against hard frosts in winter it is somewhat hardier than the common alder, the reproductive power of the stools being less liable to be damaged by ice. Like the other species, however, it is not exempt from being killed outright, or being interfered with in growth, by having its roots exposed when a rapid thaw suddenly succeeds a sudden frost,—a danger that increases in proportion to the amount of soil-moisture. Inundation of the stools after felling is on the other hand more injurious to the white than to the common alder.

Like nearly all deciduous broad-leaved trees, it is liable to the cankerous fungoid attacks of *Nectria ditissima* on the stem. From insects it suffers comparatively little, although, like the common alder, its roots are exposed to damage from the larvæ of species of *Melolontha*, and its wood in the thicket and pole stages of growth to injury by the larva of *Cryptorhynchus lapathi*; this latter also feeds on the foliage as a perfect insect.

Sylvicultural Treatment of White Alder.—Although closely resembling the common alder in many respects, this species shows marked differences in others; it is no denizen of the marshy soils, and does not naturally form pure forest, but prefers rather the fresh, mellow soil to be found in the vicinity of brooks and streams, and in narrow valleys, where it usually occurs in patches or small groups that have arisen from stoles flushed by the roots of a parent tree. This capacity of throwing up a wealth of rapidly developing root-suckers is a marked characteristic in which it differs essentially from the common alder, whilst, as regards power of bearing shade, it also has some little advantage over this species. They are nearly alike as regards rapidity in growth and development, and in general reproductive capacity, but on the less moist soils preferred by the white alder this power is not so long retained. Like the common species it is only treated as coppice, and worked with a rotation varying generally from ten to thirty, but not exceeding thirty to forty years. Where there is any demand for its soft timber, it is well adapted for the underplanting of standards of oak, ash, maple, &c., in order to protect and improve the soil when these have completed their growth in height and have become interrupted in canopy; it can there be harvested several times before being so weakened in reproductive power by the shade of the standards as to be suppressed. For the planting up of stony soil through which a supply of water trickles slowly, this species is of great value as paving the way for a growth of grass, to better accumulation of soil, and towards subsequent utilisation either as pasturage or for sylvicultural purposes.

Production and reproduction of white alder are practically the same as with the common alder, except that deep cutting, close to the soil, stimulates the formation of stoles and obviates the necessity of filling up blanks after inundations of the stools, against which this species is more susceptible than its relative. Where it is necessary to provide seedlings and transplants for the purpose of planting, the procedure adopted in the nursery is the same as in the case of the common alder, except that the seed-beds should not be quite so moist. In planting out, somewhat wider distances are given to the white alder, as greater density is generally attained by the after-growth of suckers ; where grass is intended to be utilised for some time, it is best to plant out in rows of about eight to nine feet to allow for the swing of the scythe, the plants being then put out from four to six feet apart in the lines. The plants are generally put out as two to four-year-old naked seedlings or transplants, and the methods employed are either notching and packing below the turf, or else pit-planting with the hand. On the somewhat drier situations affected by the white alder, the operations may either be carried out in spring or in autumn, but the preference is generally deservedly given to the latter. Some measure of trimming, both of the roots and the upper portion of the plants, is often necessary. This is borne even better by the white than by the common alder, so that even when the whole of the upper part is lopped off, and the root alone is planted, as is sometimes advisable with weakly, drooping seedlings, and in windy localities, it soon establishes itself and commences to grow vigorously.

2. The Lime or Linden (*Tilia europæa*, L. = T. Parvifolia and T. Grandifolia, Ehrh.).

Linneus' original nomenclature has been altered by later authorities owing to certain botanical differences noted, and as these are accompanied by very apparent changes in the form and size of the leaves, the two species of linden are now known as the *small-leaved*, or *winter lime* (*T. parvifolia*, Ehrh. = *T. ulmifolia*, Scop.), and the *large-leaved* or *summer lime* (*T. grandifolia*, Ehrh. = *T. platyphylla*, Scop.).

Distribution.—The small-leaved lime extends from central and northern Russia, where it forms forests and attains its highest development, westwards towards the north of Spain, northwards to Finland and Scandinavia, southwards to southern Italy, and eastwards to western Siberia. In the Tyrol it ascends to nearly 3,900 feet above sea-level, and 2,000 feet in the Baierwald. The larger-leaved species is indigenous throughout southern Europe up to central Germany, and eastwards to the Caucasus, attaining its best development in southern Russia; it ascends to a greater elevation than the other lime, reaching 3,000 feet in the Baierwald. In Britain the limes are slow to break into leaf in May, and are usually among the first to defoliate in early autumn; they are only in activity during the warmest time of the year, and it is evident that they require in general a very considerable degree of warmth. It seems beyond question that neither species is indigenous to Britain, for the ripening of their seed cannot be depended on; but in any case it is known that the larger-leaved lime was introduced from the Continent during the eighteenth century, and it is supposed that both species had previously been brought across by the Romans. Along with the aspen, the small-leaved lime forms good forests in the plains skirting the southern coast of the Baltic. The large-leaved species, on the other hand, is more a tree of the uplands and the hills than of the plains and the valleys, and belongs rather to central and southern than to northern Germany. In Germany the limes were formerly much more frequently grown in clumps and patches among beech forests than is now the case, but its poor quality as fuel, and the want of any great demand for its timber for technical purposes, led to it being cut out as much as possible when it interfered with the development of the better fuel-producing beech, or of other more remunerative species of forest trees. The limes are in reality of far greater importance from an arboricultural than a sylvicultural point of view in Britain, and nowhere find a more suitable situation than in the formation of avenues, of which there are many noble specimens throughout the country.

Tree-form and Root-system.—Both limes have a considerable power of adapting themselves to circumstances in regard to growth of stem and formation of crown. When limited in growing space, they develop a long, straight, cylindrical and full-wooded, clean bole surmounted by sturdy branches bearing a semi-circular and moderate crown of foliage; with freer space for development their bole is short, and soon ramifies into numerous strong branches forming a broad and thickly-foliaged crown. Their growth in height is energetic, but when entering the tree-forest stage after completing their growth as poles, they make considerable demands on growing-space, and rapidly broaden in crown.

The large-leaved lime is quicker in growth, and more beautiful in foliage, than the small-leaved species, hence more favoured for arboricultural purposes in parks, avenues, &c.

In general form and development the lime resembles the beech and the chestnut more than other forest trees.

With quicker rate of growth, it has about the same attainable height as the former, but like the latter surpasses it in girth. In root-system it also resembles the chestnut, rather than the beech, in having a tap-root as well as strong side-roots which penetrate deep down into the soil. The side-roots are more prominently developed, however, than the tap-root, and spread wide apart in their individual efforts to circumvent obstacles opposing their downward progress in quest of subsoil moisture ; the roots ramify greatly, and easily adapt themselves to the nature of the soil. With advancing age a considerable number of more superficial roots is developed, and the base of the stem becomes somewhat buttressed and considerably enlarged.

Requirements as to Soil and Situation.—The lime grows on soils of the most varying nature, but deep, fresh, light loam suits it best. Rich soil on hill-sides or in coombs produces good timber-growth, but in rocky soil it often retains its power of coppicing for a long time. Low-lying tracts with fresh soil have also good growth to show ; in east Prussia it springs up like a weed over large areas, and in Russia it is extensively worked as coppice for the production of bast or *bass*, for ropes, mats, and the like. Its demands on soil are generally about the same as the beech ; but, with its somewhat deeper root-system, greater depth of soil is requisite for the lime. The small-leaved species can thrive better than the other with either a slight excess or deficiency of soil-moisture, and makes also the smaller demand on atmospheric warmth. For growth as timber trees, however, dry soil is suitable to neither species. Warm localities are in general better suited for the large-leaved species. Altogether, the lime is not one of the most remunerative of forest trees, and its cultivation in Britain must continue to take place rather for æsthetic reasons than in consequence of calculations from a monetary point of view. For ornamental purposes in parks, arboreta, at the fringe of forests, or in the neighbourhood of towns, they are especially adapted; they afford, too, an excellent feeding ground for honey-bees whilst in flower in June and July.

Requirements as to Light.—The lime is neither strictly classifiable among the light-loving nor yet among the shade-bearing trees; it stands along with the elms, alders, and maples on the debatable ground between the two main sections, to one or other of which it may be assigned according to the nature of the soil on which it grows,—depth and moisture being the factors principally determining the issue. From the character of its foliage and the considerable amount of shadow cast by the crown, which renders it somewhat unsuitable for standards over coppice—it should *primâ facie* belong to the shade-bearing trees; but the other features of its development—its clear and rapid bole-formation when grown in close canopy, and its increased demand for growing-space when it passes from the pole-forest to the tree-forest stage of growth—characterise it rather as naturally belonging to the light-loving class. This is certainly the case when it is grown as coppice, for the shade of standards at once interferes with the reproductive power of the stools except where the climate is genial and warm, and the sunshine bright and constant. No practical difference is observable between the two species in regard to the amount of shade they can bear. The large-leaved species comes first into leaf in May, though both are distinctly backward in this respect; but it also loses its foliage much earlier than the small-leaved lime, which is on the whole the better deserving of cultivation in Britain.

Attainment of Maturity and Reproductive Capacity.—Owing to the summer here being less warm than on the Continent, the lime only seeds occasionally. On the Continent it bears seed almost annually from about its thirtieth to thirty-fifth year; this ripens about the end of October, remains hanging till well into winter, and has a germinative capacity of about 60 per cent. The seed of the large-leaved species is plainly five-ribbed, and about the size of a pea, whilst that of the other is only two-thirds as large, one pound containing respectively about 8,000 to 10,000 and 15,000 to 16,000 seeds (according to Ney). It germinates sometimes in the following spring, sometimes not till the second spring, especially if kept too dry during winter.

The lime surpasses all other softwoods in attainable age,[1] and can well maintain the same periods of rotation as hardwoods. It is endowed with considerable and long-maintained recuperative and reproductive power, which displays itself not only in the healing of wounds in the bark, but also in the throwing out of shoots from the stool, stem, and branches; hence it is well adapted both for coppicing and pollarding. It does not, as a rule, throw out root-suckers, although deep-seated stool-shoots often have the appearance of true stoles, and it is easily reproduced by layering, a method extensively adopted in Holland and Belgium.

Liability to Suffer from External Dangers.—The strongly-developed root-system of the lime protects it against windfall, the danger of which is also decreased by the late breaking into leaf in spring and the early defoliation in autumn. Against late frosts, that nip the tender young leaves in May, its strong reproductive power is an adequate protection, so that it may be regarded as on the whole hardy; this is especially true of the small-leaved species. Where strong scorching action of the hot afternoon sun can take effect on

[1] Burckhardt (*Säen und Pflanzen*, 1871, p. 477), states that at Harste, near Göttingen, there is a large-leaved lime measuring 27½ feet circumference at breast-height (in 1871), under which the old open air courts used to be held, and which even in 1425 was referred to in the records of such proceedings as *the old Lime.*

the smooth-barked bole, *sunburn* not infrequently leads to a diseased condition of the timber. Other diseases of the stem are due to the fungi *Nectria ditissima* and *N. cinnabarina*. From insect pests it has not much to bear. *Gastropacha lanestris* and *Porthesia auriflua*, as caterpillars, damage the foliage and buds, along with those of six or seven less important moths, and the soft timber is at times badly bored by the caterpillars of *Cossus ligniperda* and *Zeuzera aesculi*, and the larvæ of *Xyloterus domesticus*. Deer and cattle love to browse on the young shoots and foliage, which are rich in mucilaginous albuminoid substance, and red-deer are apt to strip the bark both in winter and summer. Yet, on the whole, the limes suffer but little from external dangers, and are, as previously remarked, well endowed with recuperative power.

Any *Sylvicultural Treatment of the Lime* can hardly be spoken of in Britain, or indeed throughout any part of north-western Europe. Its proper place is rather in parks and gardens, and for ornamental purposes generally, than in woods along with other species whose timber is prized and paid more highly. For avenues it is one of the favourite and most beautiful trees, and is not liable to die off and leave gaps here and there. Perhaps the most celebrated linden avenue is that at Herrenhausen, near Hanover, formed during the reign of George I. in 1726; it is 2,200 yards long, and consists of four rows of large-leaved limes with sixty feet between the central lines, and twenty feet between the two outer rows, the trees being ranged alternately in the lines at twenty feet apart. With its strong reproductive power, it adapts itself well for pollarding and trimming into fantastic shapes, and its peculiarities in this respect were formerly much more utilised in quaint gardening than at the present day, except in Holland and Belgium where the old fashion still prevails.

As fuel, its soft wood is of little value, but wherever there is likely to be any market for bast for rope, cordage, or mats, it certainly deserves some little attention as coppice on railway cuttings, and embankments, and similar unutilised ground, along with oak coppice and osier-beds, on places where the soil is not quite good enough for these more remunerative species to be grown pure.

As might be expected from its strong recuperative and reproductive power, lime can easily be transplanted at almost any age from seedlings up to poles of thirty to forty years of age, whilst it also stands trimming or lopping better than any other species of forest tree. Sowing of the lime is much less frequent than planting, not only on account of the poor seeding qualities of both species, especially of the large-leaved one, in Britain, but also of the slow development of the seedlings at first, so that even for nursery-beds slips, layers, or rooted stool-shoots are often pricked out in preference to seedlings. Where seed is obtainable, it can be preserved over winter in the same way as ash-seed; but it is better to collect it from the ground in spring just before the time of sowing, as then it is less likely to lie over till the following spring before germinating. The seed is sown thickly in rills with a light covering of soil of about $\frac{1}{4}$ to $\frac{1}{3}$ of an inch, as the percentage of non-germinative seed is high; this is more particularly the case with the large-leaved species, which, on account of its greater beauty of form and foliage, and its more rapid growth and development, in general deserves the preference. When the seedlings appear in spring, they are somewhat sensitive to late frosts, and require some little protection until the most dangerous period, the middle of May, has passed by.

When the seedlings or layers are pricked out in the nursery beds at one, or more frequently at two years of age, they are usually put from sixteen to twenty-four inches apart, and as limes require a good deal of trimming and attention, they are generally trimmed and transplanted again in the fourth to fifth year, and finally planted out in the seventh to ninth year in the case of the large-leaved species, and tenth to twelfth year for the smaller-leaved. In the production of good two-inch transplants for avenue and ornamental purposes, ten to fifteen years are necessary, according to the species chosen and the preference accorded to layering or growth from seed.

3. THE HORSE CHESTNUT (ÆSCULUS HIPPOCASTANUM, L.).

Distribution.—The horse chestnut is indigenous to the mountains of northern Greece, Thessaly, and Epirus, where it ascends to 3,300 feet, and eastwards to Persia, Afghanistan, and Upper India. It was introduced into Italy (1569) and Austria (1576) in the sixteenth century, and into France (1615) and England (1629) in the seventeenth century according to Hess,[1] although Loudon states that it was introduced only in the eighteenth century into Britain.

Tree-form and Root-system.—Its growth is quick, but the bole remains short though cylindrical, and soon begins to ramify and break into branches supporting an expansive, somewhat rounded, oval crown bearing heavy dense foliage. The stems are almost always tortuous in growth, the tortuosity having invariably a plus motion. In the open the trees are, during their bare winter condition, easily recognisable from the ends of the branches being curved upwards like the arms of a candelabra. The root-system is well developed, moderately deep, on the whole heart-shaped, and sufficiently strong to offer very considerable resistance to

[1] Hess, *Die Eigenschaften und das forstliche Verhalten der wichtigern in Deutschland vorkommenden Holzarten*, 1883, p. 108.

storms; at first it develops a strong tap-root, but later on ramifies for the most part laterally.

In *Requirements as to Soil and Situation* it is somewhat exacting, as the soil must be good, and the situation level and sheltered, before it can attain the full beauty of its development. It prefers a fairly deep, light, moist soil, and a north-western aspect, when not growing on level ground; where late frosts are frequent, it seldom sets seed, although otherwise not sensitive to cold. As the rich fall of foliage yields good humus, the horse chestnut possesses in a very fair degree the quality of conserving and improving the productive capacity of the soil.

Its *Requirements as to Light* are on the whole moderate, as might be expected from the density of its foliage; in this respect it may well be graded between the sweet chestnut and the lime, and classed as a shade-bearing species, though not so in any pronounced degree, like the hornbeam or beech.

Attainment of Maturity and Reproductive Capacity.—As the horse chestnut is chiefly cultivated for ornament and in the full enjoyment of light, air, and warmth, it attains early the power of forming seed, and from about the twentieth year it bears almost regularly every year. It possesses a fair, but not strong power of coppicing, which is confined to the production of shoots from the stool, and does not extend to the formation of stoles or suckers.

Liability to Suffer from External Dangers.—From the isolated position in which the horse chestnut is usually grown, it is somewhat liable to sunburn and frost-cracks in the bole, but is otherwise comparatively insensitive to drought in summer, or to frosts and cold at the other periods of the year. Though here and there thrown by wind during violent storms, it is on the whole able to offer a very considerable resistance, and is by no means apt to become windfall, whilst snow and ice-accumulations on the branches in winter cause little damage by breakage.

It suffers comparatively little from the attacks of insect enemies. *Melolontha vulgaris* and *M. hippocastani* gnaw the rootlets as grubs, and feed on the leaves as beetles; the larvæ of *Xyleborus dispar* bore into young shoots and transplants, causing sickly growth and often death; species of *Anobium*, both as larvæ and beetles, work their way into the mature wood; the caterpillars of *Acronycta aceris* feed on the foliage, and those of *Zeuzera aesculi*, after feeding during the late summer and the early autumn of their first year in the cambium, winter in the wood, and feed in it during the second summer.

The chief fungoid disease to which the horse chestnut is liable is *Nectria cinnabarina*, the bright red pustules of which break through the buds and the bark of young shoots; by interfering with the ascent of the sap, in place of allowing it to be employed in the normal development of the buds, it kills young plants outright, and also twigs throughout the crown of the tree. The heart of old trees is somewhat apt to suffer from red-rot, which may be, but is not necessarily, occasioned by species of *Polyporus*, whilst stag-headedness often occurs as the preliminary to senile atrophy.

Sylvicultural Treatment of Horse Chestnut.—For the formation of woodlands this species is seldom of any importance, although its cultivation is easy; it is, however, one of the chief kinds used in the formation of avenues in towns, besides being extensively employed in the laying out of parks and ornamental woods. Its soft, even-grained timber is not apt to swell or shrink; but as durability is not one of its strong points, it is not much in demand, although it takes a good polish, and is otherwise in many ways suitable for the requirements of cabinet-makers and similar trades. Like alder and beech, its wood is used to a considerable extent in the manufacture of gunpowder. The bark contains a large supply of tannic acid, which might have some importance if its powers of coppicing were only greater. The fruit is eagerly eaten both by cattle and deer, so that where a strong head of game is maintained, the introduction of the horse chestnut along the skirts of the forest, or wherever an abundant supply of light, air, and warmth would stimulate to the production of large and regular supplies of seed, might prove of advantage; when macerated, the fruit is also a good form of nourishment for fish, being readily eaten by carp in particular.

The rearing of seedlings and transplants offers no special difficulties to contend with. The seed is usually put into the prepared seed-beds in autumn, being sown in rills with about four inches between every two seeds. Care must be taken to have the smooth side upwards and the grey scar undermost, otherwise malformation of the root-system and weakly seedlings are the results, as was proved by experiments in the forest-nursery at Carlsruhe.[1] When it is preferred to preserve the seeds through winter, and to sow in spring, this can easily be done by mixing them with fresh, sandy soil. The seedlings can do fairly well in the open, but should at first receive some slight shade and protection to assist in their better development. As they soon throw out a strong tap-root, they should usually be planted out as one or two year-old seedlings, the tap-root being trimmed at the same time; when older seedlings are put out, the amputation of the tap-root affects the growth of the plant considerably.

When transplants are wanted for the formation of avenues or for the adornment of streets in towns and cities, the one or two-year-old seedlings are set out close together in nursery beds, so as to stimulate growth in height and draw them up without many side-shoots; but the same end can perhaps be

[1] Weise, *Leitfaden für den Waldbau*, 1888, p. 172.

better and more easily attained by breaking out the side buds, and thus interfering with the development of lateral twigs, in consequence of which the growth in height is naturally greater.

4. Aspen (Populus tremula, L.) and Poplars (Populus).

Of the genus *Populus*, of which eighteen distinct species in Europe now occur, including the *Aspen* or *trembling Poplar* (*P. tremula*, L.), the *Black Poplar* (*P. nigra*, L.), the *Silver, white* or *Abele Poplar* (*P. alba*, L.), the *Grey* or *common White Poplar* (*P. canescens*, Sm.), and the *Lombardy* or *Pyramidal Poplar* (*P. pyramidalis*, Roz.), the aspen is the only species which can properly be regarded as of sylvicultural value; and even it was long considered rather in the light of a weed than an object worthy of sylviculture. More recently, however, their beauty as ornamental trees, the useful qualities of their bark for tanning, and of their timber for the manufacture of packing-cases, matches, cellulose for paper-pulp, &c., where the use of a soft, light wood is desirable, their ready growth along the banks of streams, canals, ponds, and similar localities, which they are called on to share only with their near relatives the willows, or sometimes the elm, and their extreme productiveness, all speak for their cultivation where feasible. According to Burckhardt,[1]

> "In rapidity of growth the poplars, especially the class of black poplars, outrival all other species of trees, and it often happens that the aged landowner reaps as large-girthed, valuable timber, what he planted out as a young man."

Their easy and cheap propagation by slips has considerably helped on the distribution of the species introduced into

[1] *Säen und Pflanzen*, 1871, p. 450.

Britain from the Continent and from North America. Some doubt exists as to the grey or common white poplar being a native of Britain; the only species which is undoubtedly indigenous is the aspen, and with reference to it principally the following details apply.

Distribution.—The aspen is found over the greater part of Europe, and is a characteristic tree of the plains, becoming more frequent, and attaining its best development, towards the north, north-east, and east; it ascends, however, the mountains of central Germany to about 3,150 feet, the Riesengebirge and Baierwald to over 4,000 feet, and the Bavarian Alps to 4,400 ft. It is likewise indigenous throughout Asia Minor and the Caucasus, the whole of northern Asia, and also in North America. On the low tracts south of the Baltic it covers large forest areas with the lime as its chief associate, and there often attains a height of 100 to 110 feet, with a girth of over six feet. Much loftier growth and larger dimensions are, however, attainable in England by the black and grey poplars. In Scotland the aspen extends northwards to the borders of Sutherlandshire, and has been found by Selby at an elevation of 1,600 feet, on Braemar and in Argyllshire. It occurs extensively in the Norwegian and Swedish forests, and is principally used there in the manufacture of the celebrated safety matches (*Taendstickor*).

Tree-form and Root-system.—It develops a tall, straight, full-wooded stem carrying a low-pitched, lightly-foliaged crown of moderate dimensions,—except when forced by stony soil to spread in breadth at the expense of height,—borne by comparatively few branches, which, however, are strong, and subdivide with considerable regularity. When grown from shoots or suckers, it seldom attains the same lofty development as when grown from seed, but, even in the pole-stage of growth, shows signs of decreased vitality and makes somewhat unreasonable and unremunerative demands on growing-space for a larger measure of light and air. It cannot therefore as a rule maintain the same periods of rotation as hardwoods, and is generally cut out of forests when the clearings and early thinnings take place.

Its root-system is not in general deep-seated, but tends more to horizontal than to vertical development, though endowed with great capacity of accommodating itself to the conditions of the soil. On shallow, stony soil the roots are mainly superficial, but, where free play is afforded, strong side roots are formed, which soon ramify at a very moderate depth, and disperse themselves horizontally, ending in many branching rootlets; the growing-space occupied by the roots is therefore not inconsiderable. On the whole it may be classed along with the birch and the mountain ash as a shallow-rooting species.

Requirements as to Soil and Situation.—In general the poplars need mild situations with a free exposure to light and air. Light, friable, fresh or moist, sand or loamy soil is better suited to them than a wet or tenacious soil, although the black poplar is fond of a limy admixture. Marshy tracts are frequently too wet for them, whilst a stony subsoil is also detrimental to their development. The aspen is the least exacting of them in respect to soil; it grows in most places, although it can hardly be said to thrive on dry sandy or sour marshy land. It asserts itself on soils of all sorts, and often of very shallow nature, but only attains good dimensions and strong reproductive power on such as are not wanting in depth. The moist soils favourable to the growth of the hornbeam, the lime and the white alder are best suited to it; but it is also found associating itself with the common alder on the moister patches, and with the birch and mountain ash on the drier. Moist, sandy loams and loamy sands, especially if rich in humus or mould, in general show the best growth and development, no great demands being made on mineral strength. Along with a sufficiency of soil-moisture, the aspen also requires a considerable degree of relative humidity or atmospheric moisture to enable it to develop into a good timber-producing tree, so that in hilly tracts it is generally to be found near streams and on wet patches in forests of beech, spruce, or pine, and oftener in sheltered dingles or coombs, and along the base of hills, than on exposed and windy situations. For these reasons the cooler and damper northern and eastern aspects are on the whole better suited for it than the drier southern and south-western exposures, although a high degree of atmospheric warmth is in no wise antipathetic to it, as is attested by its sporadic growth on the hotter situations.

Requirements as to Light.—Shade-bearing capacity is not a quality at all attributable to the poplars. That the aspen, with its lofty, open, sparse and lightly-foliaged crown, should be exacting in regard to the enjoyment of light is natural and self-evident. Among broad-leaved trees it is second only to the birch as a light-demanding species, and even in comparison with conifers is only outrivalled in this respect by the larch ; in demand for light and air it must be ranged alongside of the Scots pine, and of its own close relatives the willows. All poplars are light-loving trees, which can bear no measure of shade or overshadowing, and in their turn cast only a light shade over their undergrowth. When once caught up in growth by trees which it has outstripped in the first stages of youthful development, the aspen soon sickens and dies. Even the central individuals in groups or patches only display an energetic growth whilst the crowns obtain the full enjoyment of light and air, and at once become affected by such moderate side-shade as is cast by ash, oak, or Scots pine. When once the beech approaches it in height, the aspen had best be cut away at once in the next thinning. During the later stages of growth it is equally light-demanding with the birch and larch, and but for its small value as timber, it would be well suited to be grown as standards over coppice.

Attainment of Maturity and Reproductive Capacity.—The aspen soon gets unsound in the bole, which perhaps arises from the fact that most of those to be found in the forests are probably survivals of stoles or root-suckers that have shot up with greater rapidity than the seedlings which they have suppressed. In consequence of this, it cannot sustain the usual rotation of hardwoods, and has to be cut out early, before it can possibly yield much outturn in timber for technical purposes. Such sucker-grown stems are usually thinned out before they attain an age of forty years. Some of the poplars reach their physical maturity at about sixty to eighty years, but can under favourable circumstances maintain themselves up to a hundred years, before exhibiting the usual signs of over-maturity and senile decay.

The *Salicaceæ* are diœcious, and the male individuals vastly outnumber those that are of the female gender; the Italian or pyramidal poplar produces only male flowers in Europe (it is indigenous to Taurus and the Himalayas, where Royle found both the male and the female trees), and must therefore be propagated by slips or suckers. But when male and female-flowering individuals find themselves in close proximity, the formation of seed begins early and continues freely, almost annually. It ripens and scatters early in June, and though unwinged, can be wafted long distances owing to the downy filaments around it. It is exceedingly small and light, germinates within a week after falling, and loses a good deal of its germinative power if gathered and kept even for a day or two, so that artificial reproduction of poplars usually takes place, by means of slips or rooted stoles.

Poplars are gifted with very considerable reproductive power. Those of them which, like the aspen, do not throw out many shoots from the stool, send out all the more stoles or suckers from the roots. Wounds on the bark, or where branches have been broken off, heal quickly and completely, without leaving callus marks or diseased spots in the wood. Shallow, loose soil stimulates to rich production of root-suckers on the parent stem being felled, as is most notably the case with the aspen, and the reproductive power of the root-system can remain quiescent for many years till circumstances afford the sunshine and warmth necessary to call the dormant energy into activity. Areas over which clear fellings of other forest trees have been made, thus suddenly become covered with large-leaved aspen brood, though no trees of that species were among the mature crop just removed from the soil. There hardly ever exists any necessity for artificial reproduction of the aspen, for it only too often occurs in much greater quantity than is at all desirable ; on the contrary, as in the case of birch, measures have often to be taken against it as a weed interfering with the development of young growth of other more remunerative species.

Liability to Suffer from External Dangers.—With regard to late and early frosts, the aspen is hardy, and therefore often asserts itself in damp hollows liable to frost, where better species get killed off. Light-foliaged, and generally growing in sheltered localities, it is not much exposed to danger from windfall, although its shallow root-system is but little calculated to offer much resistance to violent storms ; where it shoots up quickly as a stole from half-rotten roots, it can also have little hold on the soil. When grown in the open, however, the poplars develop a good root-system, amply sufficient to protect them from being easily thrown.

Cattle and deer browse on the succulent and nutritious shoots, without doing much practical injury. With the exception of red-rot in the stem, due to *Polyporus sulphureus*, it is almost free from fungoid diseases, although the leaves of young shoots suffer from the willow-rust caused by *Melampsora* (which has a change of generation with *Caeoma* on Scots Pine). Many insects feed on its foliage, but no great amount of damage is thereby occasioned, the principal species being grubs of *Lina populi* and *L. tremulæ*, the caterpillars of *Gastropacha neustria*, *Porthesia chrysorrhœa*, and *Vanessa polychloros*, the larvae of two species of *Rhynchites*, and the full-grown insects, *Lytta vesicatoria*, *Polyphylla fullo*, and *Rhynchites; Agrilus viridis* as larva destroys the cambium and sap-wood; the larval forms of *Cossus ligniperda*, species of *Saperda* (*S. carcharias* especially), and *Zeuzera aesculi* are apt to attack the mature wood of the stems growing on unsuitable soil and situation, and, in its pursuit of these, woodpeckers often increase the damage done.

Sylvicultural Treatment of Poplars.—Aspen is naturally even less qualified than birch to form pure forests or groups of large size, and a preference is given to the latter wherever there is a conflict between the two species, as the timber of the former is poorer in quality and less marketable, the trees complete their normal development at an earlier date, and are even less able than birch to do anything for the protection of the soil. Wherever it occurs, therefore, it is usually only as an adventitious subordinate species, almost certain to be removed in the course of thinnings, long before the ruling species has attained its maturity. Though neither partial to dry sandy soil nor to marshy ground, it has a distinct preference for situations with moist atmosphere; and as it is comparatively insensitive to frost, it is apt to assert itself spontaneously in damp, frosty localities in beech and similar forests, usually in association with birch and sallow. But although its demand for light is at first not so great as that of the birch, it soon falls back in growth, unless its crown is dominant above those of its neighbours. The treatment accorded to the aspen in mixed woods is on the whole similar to that already described in regard to the birch, with this difference, that, in clearings or thinnings, wherever either a birch or an aspen must be removed for the tending of the other more valuable species, it is better to cut out the aspen and to let the birch remain, as the more remunerative individual. In timber crops of forty years of age aspens are hardly ever to be seen, having already been removed during the thinnings; but where left to that age, the stems are seldom sound. There is usually no necessity for the sowing or the planting of aspen, as it generally appears spontaneously, and often in quantities that make it a perfect weed interfering with the growth and development of the crop being reared on the ground. Where its artificial production is desired, this can easily and best be attained by the transplanting of self-sown seedlings or of rooted stoles, but not by slips like the other poplars;[1] the use of seedlings has, however, decided advantages over that of stoles, as being less liable to red-rot at an early period.

The other poplars are as little suited as the aspen for sylvicultural production on a large scale. But along streams and brooks, or for the adornment of roads and pathways, and wherever they can be grown on open places with light, fresh soil, their rapid growth and large returns of useful timber for minor purposes where it is not exposed to damp, plead strongly for their cultivation. In the manufacture of cellulose for the paper industry all the softwoods are more highly valued than spruce or silver fir, but none more so

[1] Ney, *Der Waldbau*, 1885, p. 426.

than poplars and aspen. For pure forests they are far too light-loving and broken in canopy, whilst, as subordinates in mixed woods, they are of too rapid growth, and too apt to interfere seriously with the ultimate development of the ruling species. As standards in copse they find the conditions naturally suited to their normal requirements, and can yield in comparatively short periods of rotation (usually thirty to forty but not exceeding sixty to eighty years) good monetary returns where the market for the soft timber is assured, though in general the nobler light-loving species in most common demand are more likely to meet the average requirements of the timber trade. As coppice they also do well in small woods on old water-channels, drained hollows, or the like, where the soil is not quite suited for willow-cultivation; but on the whole they are less suited to this method of treatment than for the production of large timber trees. The silver and grey poplars are best transplanted as seedlings, but black and Lombardy poplars are generally put into nursery-beds as eighteen to twenty-four inch slips of two to four-year-old growth without lopping off the top, for otherwise the growth in height is affected later on; poles of fourteen to fifteen feet and two and a half to three inches in diameter do well when put in deeply. Spring is the best time for putting out poplars, and, until required, slips or cuttings can be kept fresh by being placed with the lower end in water or in any trench covered with earth. When nursery transplants are desired, the slips or cuttings are put out in beds about two feet apart, so that in three to four years they attain a height of six to seven feet. When planting out such material, it is well to cut back the youngest leading-shoot so that only three to six buds remain, and to avoid trimming the side branches until later on. When the fungal disease *Caeoma pinitorquum* is rife in woods of Scots Pine, aspen should be cut out to prevent change of generation with *Melampsora*.

5. Willows (Salix).

The genus *Salix*, which together with *Populus* makes up the order *Salicaceae*, contains, according to Andersson, about 160 species in addition to a host of hybrid varieties or cross-breeds ever increasing in number. Of these about fifty to sixty occur in central Europe, but the number is already reduced to about thirty in Britain, although on this point opinion is far from being unanimous. When leafless in winter, it is often difficult to decide to which genus a tree belongs, until twigs have been obtained and examined, when the following general macroscopic distinctions will be noticeable :—

Salix—Terminal bud usually wanting ; buds enclosed in one large scale compressed at both sides, and situated immediately over the three punctured leaf-scar ; floral bracts entire.

Populus—Develops true terminal buds ; buds enclosed in several spirally arranged scales or bracts, often gummy or resinous ; flowers in the axils of divided bracts.

The willows that are of greatest sylvicultural value may be arranged as follows :—

Tree Willows :—

1. *S. caprea*, L., *saugh, sallow, goat willow, or great round-leaved willow.*
2. *S. fragilis*, L., *crack or red wood willows.*
3. *S. alba*, L., *white or Huntingdon willow.*

S. Russelliana, the *Russell* or *Bedford willow*, is said to be a cross between these two species.

Osiers, twig, shrub, or basket willows, or withies :—

1. *S. viminalis*, L., *the osier.*
2. *S. triandra*, L. (including *S. amygdalina*, L.), *the laurel osier.*
3. *S. purpurea*, L., *the purple osier.*

S. rubra Huds. (= *S. helix*, L.), *the red osier*, is said to be a cross between *S. viminalis and purpurea.*

Distribution.—The tree-willows enumerated appear to be all indigenous to Britain, and have a wide distribution throughout Europe and Asia. It seems, however, most probable that the osiers have all been introduced into this country from the eastern side of Europe for their special utility in basket-making, &c., due to the straight, unbranching growth of their stool-shoots, which materially increases their flexibility and toughness, and enhances their value to such an extent that osier-beds on good soil often prove one of the most remunerative forms of cultivation. Much land, now unproductive, is available in England for willow-coppice cultivation in the unutilised soil forming the bermes on both sides of the permanent way on railways. How well willow-coppice will grow on such land may, for example, be seen at different points on the Great Eastern Railway, a few miles to the west of Colchester or to the east of Brentwood. The objections to grazing or timber production on such land are of course at once apparent, but not the reasons for continuing this waste of fairly good coppice-producing areas.

In comparison with their wide horizontal distribution, the vertical range of willows is limited. The osier tribe is confined to the valleys and lower uplands, and of the tree willows it is only the saugh that can accompany the beech to higher elevations and occupy, if allowed to, sunny spots that are too damp for the latter. In the formation or reproduction of forests the tree-willows may often become a perfect nuisance. When their growth is stimulated by sunshine and warmth, their roots penetrate the soil in all directions, the cost of sowing or planting is heightened in getting rid of them, and finally the young crop is injured by the shade of the quicker-growing willow shoots and suckers, which do a good deal of damage by overshadowing, without bringing in much by way of return or compensation.

Tree-form and Root-system.—The tree-willows are not characterised by such lofty growth as the poplars, for they seldom attain a height beyond eighty to a hundred feet, the white willow indeed not often so much, as it has a greater tendency to dissipate its energy in branch development and forked growth than the crack willow and the saugh, which make the most successful efforts towards the formation of a clean, straight bole. They are therefore classifiable only as trees of the second magnitude. Taken as a class, the tree-willows have a strong tendency to branch development and ramification into twigs, although it is precisely the opposite quality in the coppice-shoots which determines their value. The branches are wide-spreading though not strong, and bear an expansive but lightly-foliaged crown.

In root-system they closely resemble the poplars, being naturally somewhat shallow-rooted ; but in exposed situations they establish a sufficiently strong hold on the soil to run little risk of being thrown by the wind.

Requirements as to Soil and Situation.—The favourite localities for the willow tribe are low shelving banks of streams and rivers, riverine tracts subject to occasional inundation with water holding rich mud and silt in solution, sandy and loamy deposits left after floods have subsided, and fresh or damp meadow land whose soil-moisture is not stagnant. For the osiers, low-lying tracts and marshy land, and sandy stretches with good subsoil, such as occur so frequently in Belgium and Holland, are the natural situations ; but in Bavaria their artificial cultivation has proved eminently successful on undulating land at considerable elevation, and with no wealth of subsoil-moisture. In Mecklenburg-Schwerin, too, osier-holts and withy-beds have long been formed successfully and remuneratively on bermes formed by the slopes and flat stretches of railway land unoccupied by the actual permanent way,—a hitherto undeveloped source of income that might surely be tapped in Britain also, in place of having thousands of acres of good soil absolutely unproductive and idle as at present. The tree-willows are also to a very considerable degree the denizens of the lower-lying and moister lands.

Although naturally classifiable as belonging to the less exacting species of forest growth in regard to fertility of soil, a due measure of mineral strength and a rich admixture of humus are requisite before highly remunerative returns can be expected from withy-beds and osier cultivation. This may be seen in the beneficial effect of silt-deposits during inundations, and of manuring, ploughing, or trenching, as on agricultural tracts, in upland plantations, where a good quality of soil and subsoil appears to satisfy the general requirements for a greater amount of moisture, bringing nutriment in solution, at lower elevations.

It has always been the custom to regard the willow-tribe as naturally and principally confined to the moister, lower lands; but the financial success of the osier-farm on a well-drained upland site at Freising near Munich proves that on good soil less moisture is requisite, as of course is quite in accordance with the laws of nature regulating tree-growth.

Although not developing a deep root system, depth of soil is one of the requisites for successful willow cultivation, whilst porosity and penetrability,—affording easy passage to the atmosphere as well as to the rootlets,—are factors that also make their influence beneficially felt in increased production. Where the soil-moisture is brackish or salt, willow cultivation is less satisfactory. Willow-culture is also often of great benefit in reclaiming land; the stools and shoots collect the silt brought down during inundations, and assist greatly in gradually raising the soil above the flood-level (see page 228).

Requirements as to Light.—Capacity for thriving under side shade or overhead shadow is perhaps even less attributable to the willows than the poplars. Both tree-willows and osiers make strong demands on light, although on the better classes of soil the number of shoots per acre in coppices is often very large during the first year or two, even when the stools are closely planted. The amount of shade cast by the tree-willows is comparatively slight, so that, where the timber finds any good market, they are well suited for retention as standards over coppice until they reach the most advantageous girth for felling.

Attainment of Maturity and Reproductive Capacity.—Natural reproduction of willows takes place partly by spontaneous layering, partly by seed-shedding. True root-suckers, like those thrown up by the aspen, are not developed to any great extent, though shoots made by the roots, wherever exposed, and specially where they may have received any injury, may often at first sight be mistaken for true stoles. This spontaneous layering is particularly useful in the binding of dunes and sand-drifts when once the creeping willow (*S. repens*) has obtained a foothold. For natural reproduction by the seed, which ripens in the end of May, a combination of favourable circumstances is necessary,—low elevation, wind-still situation, and freedom from growth of grass or weeds; after the spring floods have drained off, the seedlings appear early in June. Even where ebb and flood meet, the crop of seedlings can less safely be reckoned on, whilst the danger of their being choked by rank growth is much increased. The seed loses its germinative power very quickly. Reproduction by seed is the exception, not the rule, and is chiefly resorted to only when pollarding is kept in view, as seedlings yield the most durable stems; of all the genus, the white willow pollards best. All willows are diœcious,—the weeping willow (*S. babylonica*), however, only produces female flowers,—and exhibit a great tendency to the production of cross-breeds. They are endowed with great recuperative power of reproducing lost portions, and shoot freely from the stool when the stem is cut away. On favourable situations this power is often long maintained, although year after year the whole crop of shoots be harvested. Most of them can also develop suckers, but to a much less extent than poplars, and easily catch root as slips or layers, although the saugh, and the purple and red osiers are often somewhat backward in this latter respect. Withy-beds are generally formed by planting out the osiers as slips or cuttings.

Liability to Suffer from External Dangers.—Rank growth of grass and weeds, and inundations and late frosts at the time when the young shoots begin to develop in spring, are the chief dangers to which willow-culture is exposed. The parasitic dodder (*Cuscuta*) and various creepers are also inimical to the well-being of the shoots. Otherwise willows are hardy against frost and ice, and suffer little from the accumulation of snow or ice on the branches, with the exception of the crack willow, which derives the name from its tendency to break off at the joints of the twigs and branches, especially in the spring. Cattle and sheep find in the young leaves and shoots a succulent fodder, and often do considerable damage in young coppice and osier-beds, which require the protection of hurdles or fencing in the vicinity of pasture-land from which beasts are likely to stray. The water-rat (*Arvicola amphibius*) often occasions considerable damage by gnawing. Hail is detrimental to the thriving of all the osier species, owing to its tearing the foliage and bruising the cambium of the shoots.

Many insects find their favourite feeding ground on the willow, but, with few exceptions, the damage they do is not very serious. *Phratora vitellinae*, and species of *Lina* and *Rhynchites*, both as larvæ and fully developed insects, can commit great havoc on the foliage, whilst the caterpillars of *Gastropacha neustria*, *G. lanestris*, *Orgyia antiqua* and *Vanessa polychloros*, and *Melolontha* beetles are also far from innocuous. Two species of *Rhynchites* likewise gnaw the young shoots, and buds are destroyed by the caterpillars of species of *Porthesia*. The omnivorous *Melolontha* grubs often commit great damage among the tender roots, following along the lines in which the osiers are planted. In the tree-willows the caterpillars of *Cossus ligniperda* and the larvæ of *Ptilinus pectinicornis* are the worst for boring the holes into the soft mature wood, although species of *Cecidomyia*, *Cryptorhynchus*, *Sesia*, and *Saperda* all do more or less damage. Certain species of *Adimonia*, *Cecidomyia*, *Leucoma* and *Nematus* have received their specific names from the fact of being principally found on willows. Of the osiers, *S. viminalis* is on the whole the species most liable to injury from insect enemies.

If allowed to stand too long, tree-willows are attacked by *Polyporus sulphureus*, the fungus causing a species of red-rot. Rust on osier-leaves, most frequent on those of one-year-old shoots, is a disease due to species of *Melampsora ;* in the case of *M. Hartigii* the intermediate form (*Uredo salicis*, D.C.) is developed on the leaves of the previous year, and fructifies in spring after lying on moist soil through the winter, whilst in the case of *M. salicis* the intermediate form, *Caeoma*, finds a host on, and is nourished by, the foliage of other genera, such as cornel, raspberry, bramble, &c.

Sylvicultural Treatment of Willows.—Of the tree-willows, the saugh or sallow occasionally finds its way in among mixed woods along with birch and aspen on the moister parts, but the great sylvicultural importance of the whole species rests mainly on the returns they yield as coppice, or from pollarding. Where the saugh occurs spontaneously in mixed forests, it is seldom allowed to remain long, as it is apt to spread and to extend its branches so as to take up more room than, with the monetary returns it has to offer, it is justified in claiming ; it is therefore usually one of the first nurses or softwoods to be removed along with the aspen during the processes of weeding and clearing, or at latest during the early thinnings. The saugh is content with a much drier soil than any of the other kinds, and is even to be found on all classes of soil suitable for the beech. But, like the aspen, it can hardly be retained, even if desirable from a sylvicultural point of view, for longer than thirty to forty years in mixed forests, owing to its liability to suffer from red-rot.

The other tree species, the crack, white and Bedford willows, are not generally cultivated in osier-beds, owing to the lesser flexibility and toughness of the withes they yield; but they find their chief uses as ornamental trees for parks and damp spots on the fringe of forests, or as pollards on meadows and by the edge of streams. Pollarding is adopted wherever the sylvicultural utilisation of the soil is secondary to its use as pasture-land, or where inundations are frequent, or the land is usually under water for some time during the period of active vegetation. The lopping usually takes place at from six to ten feet above the ground, being regulated by the extent to which the ground may be overshadowed, which also of course determines the distances at which the trees shall be originally planted. Where pasturage is desired, they should not stand closer than sixteen to twenty feet, but where pollarding takes place mainly on account of the liability of the situation to be inundated in late spring and summer, the distances chosen are generally from ten to thirteen feet apart. For the first few years after the plants have been put out, the stems get covered with twigs from the adventitious buds, but these shoots must be regularly removed, so as to stimulate and strengthen the reproductive power of the poll. The harvesting of the poll-shoots takes place during the third or fourth year, and after that the finer withes may be removed annually, whilst the total clearance is carried out every three to six years. For a rotation of four years the pollards should stand about seven and a-half feet apart, as experience has shown that such distance yields the greatest outturn of shoots per acre. Harvesting of poll-shoots should be undertaken during the latter part of winter or very early in spring, the cut being made as smooth and close to the poll as possible.

Of the smaller varieties cultivated in osier-beds, the true osier (*S. viminalis*) is the most important, being characterized by the toughness and flexibility of its thin withes, which grow in thick clusters; the laurel osier (*S. triandra*) yields a plentiful crop of long, flexible twigs; the purple osier (*S. purpurea*), so called from the colour of its anthers during the time of flowering, produces very thin but exceedingly tough withes, principally used for basket-making. So far as the various species can be determined by their leaves alone, the following short descriptions may be of use:—

S. viminalis—Leaves very long, with white, close-lying hairs having a silky gloss. Stipules small, temporary or fugacious, shorter than the petiole, or altogether wanting.

S. triandra—Leaves quite smooth, finely serrate.

S. purpurea—Leaves often opposite, smooth, bluish-green, lanceolate, finely serrate towards the apex and becoming somewhat broader; without stipules.

Periodical inundations stimulate the growth of osiers; floods in winter do no harm even if lasting for weeks, but any lengthened submersion during summer is injurious to the crop. Mounds must be thrown up on soils that are too low-lying and wet, whilst stagnant water must be brought into circulation by digging trenches or ditches. Most osier-beds show a mixture of species, the ruling kind depending to a great extent on the nature of the soil and situation, and, as the willows have a very great tendency to cross, the number of species is constantly on the increase; thus *pentandra* and *fragilis* yield *S. cuspidata*, *purpurea* and *viminalis* yield *S. rubra*, &c. In the formation of new willow plantations the species should be segregated as much as possible in the various beds, according as the concrete factors of soil and situation promise the best returns, for the different osiers have distinct preferences in this matter, as well as in other sylvicultural respects. From this point of view Esslinger[1] has classified them into the following main groups:—

1. *Laurel-osier group* (*S. triandra, amygdalina, hippophaefolia*, &c.), demanding a light, fresh or moist soil, and yielding withes of first-rate quality for technical purposes. These species suffer comparatively little from insect enemies.
2. *Osier group* (*S. viminalis*, &c.), demanding a light, moist soil, and best capable of standing wetness of soil; yield a very good outturn of useful material for basket-making and wicker-work, but much liable to attacks from insects. These are the principal species for cultivation on sandy soils.
3. *Purple osiers* (*S. purpurea, rubra*, &c.), content with a dry soil, and yielding numerous, but thin, withes, suited for all technical purposes; not much attacked by insects or rats.
4. *Caspic or prunose osiers* (*S. acutifolia = prunosa = caspica, daphnoides*, &c.), whose young shoots are covered with a bluish soft bloom, thriving on dry soil, and yielding clean but not numerous shoots of ten feet in length, only suitable for coarser technical purposes. These species probably deserve most attention for railway cuttings and similar localities.

Osier-beds are usually formed either naturally or artificially in the low-lying localities adjacent to lakes, rivers, and large streams, as the first condition for the success of most of the species is either a plentiful supply of soil-moisture in motion, or else considerable fertility of soil. The holts of spontaneous formation are as a rule just above the level of the water, so that, whenever floods take place, the silt is

[1] *Transactions* of the Palatine *Forstverein in Kandel*, 1882, p. 54.

likely to be deposited on them for the improvement of the soil. In the artificial formation of osier-beds the forester is less dependent on the greater moisture of the soil than on its general fertility; and many localities, in which osier cultivation is at the present time profitably carried out, are far removed from the possibility of inundation and of natural enrichment through silt and humose deposit.

Osier-beds may be worked with different periods of rotation, some being cut over annually for the production of fine withes, or every two or three years for coarser material for wicker-work, or with a fall varying from three to six years if required for hedging, fascine-work, and the like. Where the market demands render such treatment advisable, a mixture of two rotations can be introduced, the majority of the shoots being removed annually, and the clear coppicing in hags taking place only once every three to six years. Pure coppicing can be carried on wherever inundations are not liable to occur at the time of the flush of young shoots in spring, and a somewhat close stand of the stools decidedly favours the production of long, straight shoots, which sometimes reach a length of six to nine feet during the year, and are characterised by greater flexibility, and more equal thickness throughout, than the more branching, thickly-foliaged and tapering shoots of less dense plantations. Soil, period of rotation, and age of the willow-stools of course all exert their influence in regard to the best normal density, but in general it may be reckoned at 1,800 to 2,000 per acre whilst in full working order, although in the formation of new osier-beds the number should be considerably greater, as many stools die off, and in any case the production of shoots is not so great from young as from seasoned stools. Where stronger assortments of withes are desired, it is best to thin out all but the best six to twelve shoots, and leave only these to develop, the fresh annual shoots being removed as thinnings each year.

The returns from willow-culture are often high, but vary of course considerably with soil, situation, species, and period of rotation. According to Danckelmann,[1] the annual out-turn in one-year-old withes from a fully stocked area is 188 cb.ft. (solid wood), or, on the average, 38·4 cwt. of peeled and dried withes, mostly however of coarse texture, in the case of *S. viminalis ;* 145 cb.ft., or, on the average, 28·8 cwt. of peeled and dried withes of the best, toughest, and finest material in the case of *S. purpurea ;* between these both in quantity and quality in the case of *S. helix ;* 90 to 100 cb.ft., or about 28 cwt., of peeled and dried withes in the case of *S. acutifolia*, but somewhat discoloured, and therefore only used for the coarser descriptions of wicker-work. In regard to monetary returns there are great variations, though with a good market near at hand the cultivation of osier-beds is one of the most remunerative forms of sylviculture. According to Burckhardt,[2] an annual average return of £3 12*s.* to £5 per acre, after deduction of the costs of harvesting, is nothing unusual either with a one or a four years' rotation, wherever there is normal density of crop and a favourable market near at hand. Newly-formed osier-beds cannot, of course, be expected to achieve such results all at once.

Formation of Osier-beds.—For the formation of new osier-beds a thorough preparation of the soil is the first requisite. This can best be accomplished either by the use of the plough, or by trenching to a depth of sixteen to twenty inches, with simultaneous manuring if the soil is not naturally fertile ; for the experience of the best willow cultivators shows the importance of this latter measure. Where feasible, the

[1] Gayer, *Der Waldbau*, 1889, p. 213.

[2] *Säen und Pflanzen*, 1880, p. 463.

soil-preparation can be well managed by previous agricultural utilisation of the land for a year. The planting-up of the prepared soil takes place preferably at once in April with slips or cuttings; but it can also be undertaken in June or July where the shoots are likely to mature and form hard wood before the period of vegetation closes. Where local circumstances in regard to labour make it more convenient, the putting out of slips of matured growth can also take place in late autumn, or in winter whenever the ground is soft enough. For slips the strongest yearling shoots should be selected from round stools, cut off close to the stool, divided into slips of about one foot long by a clean, straight, and not a slanting cut, and put almost entirely into the ground with the least possible delay. In many parts of northern Germany, however, a preference is given to eighteen-inch slips cut from good two to four-year-old shoots, which are put so far into the soil that only two-and-a-half to three inches of the upper end remain above the ground. The most favourable time for the operation of making the slips is the latter half of February and the first half of March; but if the setting out cannot take place till April, the shoots should be kept whole in bundles under cover in cool airy places, and only cut into slips of the required length immediately before being required for putting out. Where slips have to be got from a distance, they should be at hand in good time, as they can easily be preserved in trenches or other fresh soil until required. Planting usually takes place in rows, and at distances which depend mainly upon the period of rotation. For the finer species of willows, with annual rotation, the slips should be put out in rows about twenty inches apart, and at a distance of six to eight inches in the lines (about 40,000 to 45,000 per acre); but for the coarser species, to be worked with a rotation of two years, rows thirty inches apart, with the slips at twelve to fifteen inches apart in the lines, give ample density, (about 14,500 to 17,500 per acre). Where several species are to be cultivated, they should be kept apart in different beds, as the less vigorous are otherwise interfered with in development by the species of more energetic growth.

The planting out consists in shoving in the slips, thick end first, in a slanting direction into the soft soil, so that, if yearling slips be used, the tops are hardly visible, but, if stouter slips have been employed, only two-and-a-half to three inches remain above ground, slight pressure being applied with the hand above to bring the earth in close contact with the slip. Where the use of a pricking-iron or any similar instrument is advisable in order to prepare a hole for the reception of the slip, the soil is either somewhat too binding to be really suitable for willow-culture, or else the slip must be very large in size.

After the putting out of the slips has been completed, the chief effort in the way of tending should, especially during the first year, be to keep the beds clear of grass and weeds, which must be removed with the hoe as often as necessary. The filling up of blanks also requires attention, and it is well if a reserve of slips has been put out in some nursery-beds at the time of the formation of the osier-bed, in order that, if necessary, they can be transplanted so as to be of the same age exactly as the rest of the crop ; such transplants should invariably be put out with earth around the roots, and not naked. Blanks can also be filled by layering of shoots from the surrounding plants, but in general the transplanting of struck cuttings of the same age as the bulk of the crop is most to be recommended. On sandy soil where no special preparation has been made, the slips are often stuck into the ground in wisps or nests, a pyramidally-shaped clod being raised by means of four insertions of the spade, and pressed home again after the insertion of slips at the corners and round the edges. This method is also frequently used in the filling up of blanks; it yields good results with slips about two feet long, which are easily protected against rank growth of grass. According to Burckhardt the cost of the formation and tending of osier-beds, up to the end of the first year, is in Northern Germany £4 to £5 per acre, when slips are put out on light sandy soil requiring no costly preparation, and £6 16*s.* to £9 4*s.*, when beds have been raised between ditches, and slips are put out in the ordinary manner in rows.

Reproduction of Osier-beds.—Natural regeneration of willows takes place partly by means of spontaneous layering, partly through seed; true stoles like those of the aspen are not formed, although shoots spring from dormant buds on roots exposed to the air. For spontaneous growth from seed, favourable circumstances are necessary, as, after the seed is shed in early June, it has a comparatively small chance of germinating and asserting itself owing to the growth of grass. And in general but little use is made of willow seedlings, except when they are handy and easily obtainable for the filling up of blanks, for which purpose their bushy growth and straight twigs make them very well adapted. The artificial production of seedlings on osier-beds is generally unremunerative and unadvisable, for the same object can be satisfactorily and much more speedily attained by the use of slips. In nurseries, therefore, seedlings are only reared when wished for ornamental purposes or for pollards, as then they yield the more durable stems.

The usual method of reproduction of the osier-beds is by the natural growth of stool-shoots after the existing crop of withes has been removed by coppicing. The harvesting should take place by means of a sharp, clean, almost horizontal cut as close as possible to the stool, and although it may be arranged for at any time during the non-active period of vegetation, and should, according to Burckhardt, take place in late autumn, it is most frequently carried out in early spring before the flow of sap commences, the softening of the bark for easier peeling being afterwards accomplished by soaking in water. If the coppicing takes place whilst the sap is in flow, however, the stools are apt to suffer, and soon become weakened in productive capacity, more especially when cut over regularly every year. Old willow-stools, that have been properly treated, have somewhat the bristly appearance of a hedgehog.

In place of disposing of the finer varieties of basket-withes with the bark attached, it is usually advisable to peel them before offering them for sale, as the stripping of the bark can take place with the lightest descriptions of labour, and is otherwise remunerative; it also frees one from the necessity of forcing a sale at what may be considered an insufficient price. Withes cut in late autumn can be packed in bundles, brought under roof, and covered with straw, &c. in order to keep off currents of air likely to dry them. When the active period of vegetation comes round in spring, the bundles are placed with the cut ends in water, which ascends in the shoots like sap, and enables all the bark to be peeled off quite easily with the hand, after the withes have been pulled twice or thrice through a clip shaped like an old-fashioned wooden clothes-pin. When sorted, they are put out in the sunshine to dry, care being taken to prevent them getting wet with rain, as this discolours them, and decreases their market value. For shoots cut in late winter, it is sufficient to place the bundles, thick end down, in a cool shady place free from draughts, and throw up a slight mound of earth round them.

In most districts the harvesting extends to the whole of the shoots, as experience has shown that the quality of the withes is then better than when some are taken, and others left to develop into stronger material. Thus even in newly formed osier-beds all the shoots are harvested at the end of the first year, although of course the out-turn is much less than later on, when the stools have thoroughly established themselves, and are in full vigorous production ; *S. acutifolia*, however, is utilised for the first time at the end of the second year. In other localities, no great weight is laid on the first year's growth, but the three or four yearling shoots are cut back during winter to about eight to twelve inches, the first crop being harvested at the end of the second year.

On somewhat marshy soils which, after having been ploughed and planted up with slips at about sixteen inches apart, are annually coppiced for basket-withes, the stools are apt to become weak and unproductive as early as the twelfth to sixteenth year ; they may then be grubbed up, and the land used agriculturally for several years without manuring being requisite. Land that has been exhausted by continuous crops of cereals can be essentially recruited by one such rotation of willow-culture, and pasture-land similarly treated is said to be characterised by exceptionally nutritive crops of grass.

On other varieties of soil, the annual utilisation of the crop of shoots affects the qualities of the stools so much, that a re-formation of the osier-beds is generally necessary after twenty years' coppicing.

C. *Smaller Trees, Shrubs, and Brushwood in Coppice.*

Along with the shoots and suckers of the forest trees a great many minor trees (with the exception of the yew) and shrubs find a suitable home in coppice grown under standards, and often give fair remuneration in return, partly in the wood and withes they yield, partly in protecting and improving the soil, and in affording cover and food for game. Where, however, they are apt to interfere with the thriving or normal development of the more important species of forest growth, they should invariably be removed. They are not of sufficient sylvicultural importance to be treated of *in extenso*, but the principal among them may be fitly enumerated, the botanical equivalents being the names given by Linneus.

Field maple (*Acer campestre*).
Barberry (*Berberis vulgaris*).
Boxwood (*Buxus sempervirens*).
Nettle tree (*Celtis australis*).
Dogwood or cornel (*Cornus sanguinea* and *C. mascula*).
Hazel (*Corylus avellana*).
Hawthorn, whitethorn, or hawtree (*Crataegus oxyacantha*).
Laburnum (*Cytisus Laburnum*).
Spindle-tree (*Euonymus europaeus*).
Sea buckthorn (*Hippophae rhamnoides*).
Holly (*Ilex aquifolium*).
Juniper (*Juniperus communis*).
Wild cherry or gean (*Prunus avium*).
Blackthorn or sloe (*Prunus spinosa*).
Crab apple (*Pyrus malus*).
Buckthorn (*Rhamnus cathartica*).
Black alder or alder buckthorn (*Rhamnus frangula*).
Elder or Buntry-bush (*Sambucus nigra* and *S. racemosa*).
Bladder-nut (*Staphylea pinnata*).
Yew (*Taxus baccata*).
Snowball-tree or mealy Viburnum (*Viburnum Lantana*).
Gelder-rose (*Viburnum opulus*).

The majority of these are recognised as hardwoods, but hazel, juniper, black alder and elder are softwoods. In point of interest or of technical value, yew, juniper, hazel, alder, buckthorn, and hawthorn rank highest.

Yew is the only one of the above which occurs in high forest. A deep-rooted evergreen conifer, indigenous throughout the whole of central and northern Europe and Asia, but occurring most frequently in southern France, Italy, and Algiers, it has long ceased to have any great technical value; but where it occurs spontaneously in woodlands, it is tended carefully as a tree of interest. In general it is to be found on the uplands and the lower hills, and has an unmistakable preference for soils rich in lime. On whatever kind of soil it may be found, it is characterised by slow growth, and by a length of life exceeding that of any other forest tree. There are several yews throughout central Europe that are 2,000 to 3,000 years old, though not over thirty to fifty feet in height; and Burckhardt mentions[1] one growing on diluvial sand at Wiethmarschen in Bentheim, Prussia, which as early as 1152 was already celebrated on account of its great age, although even now (1893) it is no more than three feet in diameter at breast-height. In Britain, the cultivation of the yew is confined chiefly to cemeteries, for which its dark foliage and altogether somewhat sombre and impressive appearance eminently qualify it. Even among the Greeks and the Romans it was known as the *arbor mortis* bringing death to those who slept under its shade; and as a matter of fact, though goats and cattle can eat the foliage without any great apparent inconvenience, the after effects in the case of horses are usually quickly fatal. The beautiful red berries are generally considered poisonous, but this is denied by Rossmässler. From insect enemies it has little to suffer, although the grub of a *Cecidomyia* is found in the bud, and *Anobium tesselatum* bores into the dry wood, both as grub and beetle. It is endowed with extraordinary reproductive power, which is retained far beyond the limits of similar capacity in other trees—a capacity which was formerly taken advantage of in old-fashioned gardening, in the formation of hedges and quaintly-trimmed bushes. Since the days of bows and arrows, the yew has lost its footing in the woodlands, and is now solely a tree for ornamental purposes in parks and arboreta, though still deserving of its place here and there at any interesting point on the fringe of the forest, or where any knoll offers a wide look over the surrounding country. It can be propagated by slips and layers, but production from seed is on the whole more satisfactory, although by no means always easy. The seed usually lies over for two, and sometimes for four years

[1] *Säen und Pflanzen*, 1893, p. 470.

before germinating, and if it has been gathered in places where male-flowering trees are wanting, it does not come up at all. It is best to pack the seed at once in earth and sow it in rills with about a one inch covering of good mould in the second autumn or spring, and then prick out the seedlings in the first or second year into the nursery-bed, both operations taking place under shade and shelter. Transplants from nursery-beds can be easily put out up to three feet in height, planting taking place with balls of earth on account of the tap-root.

Juniper is a shrub also indigenous throughout Europe and northern Asia, which attains a height of twenty feet, is diœcious like the yew, and has false berries ripening only in the autumn of the second year after flowering, when they are round, blackish, and with a prunose bloom on them. It naturally, like the yew, belongs to the species capable of bearing a considerable degree of shade ; but it is sensitive to changes in respect to the enjoyment of light, and when once accustomed to light and air, grows well without shade or shelter. Its natural home is on plains with sandy soil, having a tendency to growth of heather, where it often grows spontaneously as underwood below pine ; but its appearance is an ominous sign of deterioration of soil having already begun. Where, however, a self-sown crop of juniper is to be met with, it indicates the better classes of soil, and generally points to depth, freshness, and a certain amount of loam either in the soil or the subsoil. It belongs to the deep-rooting species of shrubs. In Britain its cultivation can never be so remunerative as in Holland, where the berries are required in large quantities for the hundreds of gin-distilleries around Schiedam, and in general its appearance with us is interesting chiefly as indicating soils that are naturally suited for yielding good returns under forest. In parks and gardens it can, like the yew, be trimmed to form hedges or quaint bushes; but for growth in its natural condition, the male-flowering individuals are characterised by more rapid and graceful development than the female. The seed germinates in the second or third spring after ripening, and is sown, either broadcast or in rills, on nursery-beds under light shelter. Nursery-gardeners frequently reproduce it by means of slips and layers, which are generally put out as two-year-old transplants, as the roots are usually largely developed by the third year.

In parks and gardens the Virginian juniper or red cedar (*Juniperus virginiana*, L.) is a plant of common occurrence. The wood of this tree is largely imported from America for the manufacture of leadpencils. It grows on fresh, humose sand, or on good limy soils, but is hardly of sylvicultural importance, as it seldom attains more than forty feet in height. Though on the whole a shade-bearing species, it is not sufficiently so to be utilised as underwood under our light loving indigenous forest trees.

Hazel is a large shrub possessed of excellent reproductive capacity in throwing out long, straight shoots from the stool, and therefore often finding a home in coppice woods and under standards in copse, where it sometimes yields a very welcome and profitable addition to the outturn. It is to be found on soils of all classes, but has a distinct preference for those of a limy, loamy, marshy, or moist, humose, sandy character. Whilst yielding a good return from nuts and shoots in its proper place, it can often become a noxious weed, interfering greatly with the development and vigorous growth of more desirable species of coppice-crops on land under sylvicultural treatment. There are, however, in Britain thousands of acres of vacant ground along the lines of railway where, on soils less suitable for oak or osiers, the cultivation of hazel-coppice with a rotation of twelve to six teen years would yield good remunerative returns in small material useful for many technical purposes, not to mention the annual crop of nuts; a rotation of three to four years yields excellent withes for barrels, and good monetary returns. Its coppice-stools maintain their reproductive power for a long time, as the shoots take root for themselves, whilst blanks can be filled, or greater density of the crop attained, by the layering of living shoots, or the transplanting of rooted shoots; both of these methods effect the desired object more speedily and satisfactorily than by rearing seedlings from the nuts. The best time for harvesting the latter is in October, when they have acquired their full flavour, and have been mellowed by a touch of frost.

Hazel possesses very fair soil-improving qualities, and often does good service in this respect as a subordinate in oak coppices, where, however, care must be taken to prevent it from interrupting the growth of the principal species. On stony upland soils where there is a deposit of good mould between the rocks and stones, hazel-coppice often yields the best returns that can be reasonably expected from the ground.

Alder Buckthorn is also a shrub indicating, like juniper, the commencement of the deterioration of the soil, but it is generally to be found only in woods formed of the broad-leaved species of trees. It was formerly rather prized for the preparation of charcoal for gunpowder, but of recent years alder and beechwood have been more generally used for this purpose, the former being solely used for the manufacture of smokeless powder. Where it occurs in any quantity it yields bean and pea-sticks where spruce and silver fir poles are not available, also good sticks for umbrellas, walking-sticks, and similar petty technical purposes. Like many other shrubs, it is suffered to remain as underwood below standards of light-loving species, in order to afford some slight protection to the soil against insolation in places where it is not convenient to underplant with shade-bearing forest trees. When it is coppiced with a rotation of three to six years, it shoots freely from the stool.

Hawthorn, which furnishes the commonest, best, and most beautiful of hedges, thrives on all classes of soil, but attains its best growth on such as are of limy or marly composition. Hedges can be formed by planting out self sown seedlings, though in general much better results are obtained by the use of transplants. The *haws* are sown in rills eight inches apart, and with half to three-quarters of an inch of soil covering, on limy soil in autumn; the seeds germinate sometimes in the following spring, sometimes not until the second spring after they ripen. Where the soil is deficient in lime, marl should be added if it can conveniently be got in the neighbourhood, as it materially improves the seedlings in their development. The seed-beds should be covered with dry pine needles or broad-leaved foliage, over which straw and a few poles should be laid to prevent this being blown away during the winter; in spring this covering should be removed almost entirely if germination appears to be taking place, but if not it should be replaced till the following spring. Another method is to mix the seed with earth in boxes buried in ditches, &c., and to sow it out in rills, with a soil-covering of half an inch, during the second autumn or spring following the ripening. When the seedlings are two-year-old, the tap-root is trimmed and the plants pricked out in rows of eight inches by four inches on the nursery-beds, where they are allowed to stand for two years before being transplanted for the formation of hedgerows.

Sea-buckthorn is of interest as being one of the first species of shrubs of woodland growth to occur spontaneously on sand-banks thrown up by rivers.

Holly is often a troublesome weed on good soils when reproduction of other species is taking place, but it disappears from copse and coppice whenever the period of rotation exceeds ten years. In general terms, the same applies to the majority of the hardwood shrubs, such as *Barberry*, *Boxwood*, *Cornel*, *Dogwood*, *Laburnum*, *Spindle-tree*, *Bladdernut*, *Buckthorn*, *Snowball-tree*, and *Gueldres Rose*, which are all welcome as a soil-covering under lofty standards unable to protect the soil for themselves by close canopy, but can under certain circumstances become very troublesome during the period of reproduction of high-timber forests.

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THE END.

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