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POPLARS

LONDON: HER MAJESTY'S STATIONERY OFFICE

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By

T. R. PEACE, M.A.

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While some of the information given in this Bulletin is culled from papers and books, to which, of course, reference is made, many of the facts and opinions put forward were given verbally to the author during his travels to see poplars both in Great Britain and abroad. To list all who have willingly contributed of their knowledge in this manner would be an impossible task. It is refreshing to be able to record that so much information has been so gladly given. Three persons, however, must be specifically named ; Mr. P. G. Beak, who has steered the author through innumerable difficulties of systematy and nomenclature ; Professor G. Houtzagers of Wageningen in Holland, who has assisted the author on many occasions to get the maximum of information from his tours abroad ; and Lieutenant-Colonel E. R. Pratt of Ryston Hall, Downham, Norfolk, whose estate is a shining example of what can be done with poplars in Great Britain, and who has never stinted either his time or his knowledge in order to assist the author.

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NOTE

This Bulletin supersedes Forestry Commission Bulletin No. 5, also entitled " Poplars ", published in 1923. The text has been completely rewritten.

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INTRODUCTION

The chief attraction of poplar as a tree crop lies in its rapid growth, indeed on a good site it grows much faster than any other tree hardy in the British Isles. In addition there is a good market for the timber, both for special purposes such as matches and veneer, and also for more general uses. Propagation, which for most varieties is done by cuttings, is easy, and planting and subsequent treatment are not normally very difficult. Nevertheless, the whole subject of poplar cultivation is far from being as simple as it appears on the surface. The choice of varieties is bewildering, and is becoming rapidly more so as new hybrids are produced, the selection of site requires considerable care, and a large number of variations on the basically simple methods of propagation and tending are practised in various countries. It is in an endeavour to clarify these matters that the present Bulletin has been written. It may be regarded as filling in the gaps and elaborating the basic information given in Forestry Commission Leaflet No. 27, *Poplar Planting** (Forestry Commission 1948). It may also be said to replace the previous edition of Forestry Commission Bulletin No. 5 entitled *Poplars*,† but that, published in 1923, has long been out of date. Since 1923 enormous strides have been made in almost every branch of poplar cultivation, and although full use has been made of foreign experience in writing the present Bulletin, we know more now of the behaviour of poplars in Great Britain, and are no longer so dependent on Continental experience as we were in 1923.

It must, however, be realised that our knowledge of poplar cultivation and in particular of the growing of poplar on woodland or heavily grassed sites is still very far from complete. The traditional practices that have long been followed on the Continent are not necessarily the best, and in any case may not always be practicable under the conditions met with in Great Britain. As poplar cultivation extends, our knowledge will increase. In the meantime cultivation, except on obviously suitable sites, is in some measure experimental, and enthusiasm for poplar should be tempered by a modicum of caution.

The cradle of commercial poplar growing lies in Western Europe, and particularly in France, Belgium and the Netherlands. But interest has now spread to the majority of the temperate regions, though countries with large stands of natural poplar such as Sweden and Finland, or the United States and Canada, are naturally less interested in planting poplar than countries such as France, Italy or the Argentine, where the amount of natural poplar is insignificant or non-existent.

The published literature on poplar is enormous, but is mostly strictly specialised, and only in Holland and Germany are there text books covering all aspects of poplar cultivation. These (Houtzagers 1941, Hesmer 1951) are, unfortunately for growers in Great Britain, entirely in Dutch or German. Apart from these, there are a number of publications which cover certain aspects of the subject very thoroughly. Outstanding among these is an earlier publication by Houtzagers (Houtzagers 1937) which has done much to bring order into the dreadful confusion which existed in the botanical classification of poplars. No other work can be said to deal with nomenclature really thoroughly, though a recent French publication (Meunier, Guinier and Regnier 1947) does much to elucidate the confusion of local names existing in France, and gives a very good description of the status of poplar cultivation in that country. The same service has been rendered for Belgium (Herbignat 1949 A) in a paper, which also contains some useful information on current cultural practices. Interest in the subject is such that two research stations have been started, which are solely concerned with poplar, its breeding, cultivation and uses. The scope of research at the older of these, the Istituto di Sperimentazione per la Pioppicultura at Casale Monferrato, in Italy, which started work before 1939, is fully described in a recent paper (Piccarolo 1948). The younger institution, the Institut de Populiculture at Grammont in Belgium, was only recently opened. Work on the hybridisation of poplars has been proceeding actively in a number of countries for the last twenty years, hybrids older than this being nearly all chance crossings. A very good review of this work has recently been published (Pauley 1949). Some of the newer hybrids will be considered briefly later in this Bulletin, though it is beyond our scope to give details of the numerous crosses that have been made, most of which are still comparatively untried.

Evidence of the increasing interest taken in poplar cultivation is given by the number of countries which have formed National Poplar Commissions to promote the study of, and to encourage the cultivation of, poplar; these include France, Belgium, Holland, Italy and Germany. On the initiative of

* H.M.S.O. 4*d*. † H.M.S.O. Out of print.

the French, an International Poplar Commission was set up in 1946, holding its first meeting in Paris. This body has already done useful work on the naming and description of poplars, and by promoting international co-operation in the exchange of information on culture practices, poplar diseases etc. Great Britain, acting through the Forestry Commission, is represented on this body, which is under the auspices of the Food and Agriculture Organisation of the United Nations.

Chapter 1

BOTANICAL DESCRIPTION AND CHOICE OF VARIETY

The two genera *Populus*, the poplars, and *Salix*, the willows together form the family Salicaceae. Members of this family are dioecious, i.e. the male and female flowers are borne on separate trees. The flowers are characterized by their extreme simplicity, and by the complete absence of petals. They are borne in catkins, which appear early in the year, before the leaves. The distinction between *Salix* and *Populus* is not very marked ; *Salix* has usually upright catkins, nectaries but no floral disc, and buds with a single scale, whereas *Populus* has pendulous catkins, no nectaries, stamens and pistil borne on a cup-shaped disc, and buds with several scales. In practice, although the commoner poplars are very easily distinguished from the commoner willows by leaf shape and habit alone, there are poplars that to the non-botanical eye look like willows.

The flowers of poplar are wind-pollinated ; the male ones are usually closely packed in the catkin and have bright red anthers, which at close range make them quite decorative. The female catkins, which are green in colour, have the flowers more loosely arranged. Fertilized female catkins elongate as they ripen, which they do quite rapidly, the seed in some cases being ripe before the leaves are fully developed. The minute seeds are surmounted by tufts of long white silky hairs. Where a number of female poplar trees are planted together, the amount of seed shed may simulate a fall of snow, and for this reason female poplars are particularly undesirable in gardens or as street trees. It has been suggested that female trees are normally of poorer form than males (Pauley 1948) ; though real proof of this is lacking for the poplar *species*, where both sexes are available, there is no doubt that the majority of the male *hybrids* are superior to the female ones. It is necessary here to note that most of the hybrids have arisen as single individuals, subsequently propagated by cuttings, so that they still retain the sex and other characters of the original hybrid seedling, indeed strictly they are still only detached parts of that plant. Botanically they can be described as single clones. However, some of the older hybrids, such as × *P. serotina*, × *P. robusta*, and × *P. regenerata* now show considerable variation, which would appear to indicate either that more than one seedling of the particular hybrid exists, or else that variation has occurred within the original clone.

The genus *Populus* includes six sections, the geographical range of which is set out in Table 1. This table does not purport to give a complete list of species, and some of those included (those in brackets) are not further discussed in the text.

The section *Leucoides* includes a few species of poplar with very large decorative foliage, several of which, including *P. lasiocarpa*, can be grown in this country, but none of which appears to be of any importance for timber production. The section *Turanga* is confined to Central Asia, the southern Mediterranean region, and northern Africa, and is therefore of no interest to us. This means that for practical purposes we are concerned only with the poplars of the first four sections and of the hybrids between them. Full botanical characters for separating the sections will not be given, nor are they stated in the Key. A few simple characters for separating the sections are given below

In practice there is usually little difficulty in referring a poplar to the correct section after a cursory examination, but there are marginal species, and of course the divisions between the sections are rapidly becoming blurred by the production of hybrids between them.

Inevitably in such a complex genus, difficulties of nomenclature are bound to arise. Where these refer to individual poplars they are discussed later, when the species and hybrids are dealt with separately, but one general point requires mention here. Nearly all the older hybrid poplars originated from crosses between the American and European Black poplars. The only existing name which may possibly cover these is *P. canadensis* Moench. At the moment of writing, the name *P. euramericana* is under considera-

Geographical Distribution of Native Poplars

TABLE 1

Section	*Europe and North Africa to Western Asia*	*North America*	*Eastern Asia*
LEUCE White poplars	alba canescens	—	alba (tomentosa)
TREMULAE Aspens	tremula	tremuloides grandidentata	tremula (sieboldii) (adenopoda)
TACAMAHACA Balsam poplars	—	tacamahaca trichocarpa candicans (angustifolia)	laurifolia yunnanensis maximowiczii simonii, etc.
AIGEIROS Black poplars	nigra and vars.	deltoides and vars. (fremontii, etc.)	—
LEUCOIDES	—	(heterophylla)	lasiocarpa (wilsonii, etc.)
TURANGA	(denhardtiorum, euphratica, etc.)	—	—

Characters of the main Sections of the Genus Populus

TABLE 2

Section	*Leaves*	*Leaf Stalks*	*Buds*
WHITE POPLARS	Dense white hairs on under-side of leaves on rapidly growing shoots	Roundish	Dense white hairs on buds
ASPENS	Roundish without translucent margins	Strongly flattened	Dryish
BALSAM POPLARS	Without translucent margins	Roundish	Sticky with strong balsamic odour
BLACK POPLARS	With translucent margins	Flattened	Less sticky, and with less odour

tion to replace *P. canadensis*, which in any case has never been used for the full range of Black hybrids. This would mean that the so-called Black Italian poplar, usually known merely as *P. serotina*, but often referred to in the past as × *P. canadensis* Moench var. *serotina*, would become × *P. euramericana* (Dode), Guinier var. *serotina*. Such nomenclature, while necessary in strictly botanical publications, is probably out of place in this Bulletin, and it has been decided to use the prefix " × " before all hybrids, without giving any further indication of the group to which they belong, for example × *P. serotina*. Only in the preliminary consideration of each species and hybrid will the authority for the name be given.

SPECIES, VARIETIES AND HYBRIDS

It is not possible to discuss the cultivation, diseases and utilization of poplar without first giving some information on the different varieties that can be planted, since they vary in their nursery and silvicultural requirements, their resistance to disease, and, to some extent, in the properties of their timber. On the other hand it is hardly possible to refer to certain poplars without mentioning matters, particularly disease resistance, that will be dealt with more

fully later. It must be realized that the list given below is only a selection from the material available, a considerable number of less important species and varieties and a few of the older hybrids having been omitted, either because they are known to be of little value in this country, or because little is known of them at all. Hybrids produced within the last twenty years are dealt with separately on more general lines. If no sex is given, both sexes are known to occur.

White Poplars

Poplars in this section are harder to root from cuttings than are Black or Balsam poplars, though, given good cutting material, takes up to 50% are attainable. On the other hand they sucker freely and a limited number of plants can be produced from each parent tree by lifting these suckers.

P. alba L., the White Poplar, seldom makes a large tree in this country. Its silvery foliage is, however, very attractive, and it is a good tree for seaside planting, being resistant to salt winds. Its habit of suckering detracts somewhat from its value as an ornamental tree. It is of little value for timber production. It has a fastigiate variety, var. *pyramidalis* Bunge, which is a good street tree when it grows well. Often, however, it is subject to a dieback, the cause of which has not been ascertained.

P. canescens Sm., the Grey Poplar, is a faster growing tree than *P. alba*, and often reaches a very large size. It has been suggested that it is a hybrid between *P. alba* and *P. tremula*, but there is no proof of this. It is probably less demanding as regards soil than the Black poplars and less impatient of competition with other vegetation. It is able to grow well in the cooler parts of the British Isles ; there is a tree at Garve in Wester Ross of 45½ inches quarter girth at breast height. On the other hand it does not grow as straight as the Black Hybrids. It appears to be a rather variable tree, and selection of propagating material from trees of particularly good form is probably desirable.

Aspens

Poplars of this group are difficult to strike from cuttings, though young shoots can be rooted under glass in the early summer, and the usual method of propagation is from seed ; other methods are discussed later. *P. tremula* L. is the sole representative of this section in Europe. The American aspens *P. tremuloides* Michx. and *P. grandidentata* Michx. are essentially similar trees. In Great Britain, aspen seldom reaches any large size, although it is widespread, usually as one constituent of mixed woodland. In Scandinavia, Poland and Russia it forms a valuable timber tree, though its size is still small compared with the better varieties of Black and Balsam poplars. It is an extremely variable tree, and selected good forms would certainly be vastly superior to the average. Such forms have been well illustrated in two recent publications (Barth 1942, Johnsson 1949). Its timber is of particularly good quality, and is generally preferred by the match trade to that of other poplars. Attempts have been made to plant it in Great Britain, generally with almost complete lack of success, though one case is known where it has reached an average height of 29 feet ten years after planting, and is out on top of Sitka spruce planted at the same time. The possibilities of using hybrid aspens are discussed later.

P. tremula and the hybrid aspen *P. tremula* × *tremuloides* are both susceptible to bacterial canker, though it does not very often occur on them naturally. Since the trees of both the species and the hybrid are of mixed populations, the possibility of variations in susceptibility certainly exists.

Balsam Poplars

These poplars are generally easily propagated from cuttings. Unfortunately, most of them sucker with great freedom, which detracts from their value as ornamentals. The majority are susceptible to bacterial canker, and any Balsam poplar should be regarded as suspect in this connection, until it has been tested. Most of the species of interest to us are natives of America.

P. trichocarpa Torr. and Gray, is the finest timber-producing poplar in America ; though the timber is inferior in quality to that of the Black poplars. It has quite a wide distribution in the western United States and in British Columbia. As long as it remains free from bacterial canker, it grows well in all parts of the British Isles, and with particular freedom in the areas of higher rainfall. It does particularly well in parts of Scotland, in situations where the Black hybrids would hardly be expected to thrive (Balfour 1943). Existing plantations suggest that it may be more tolerant of acid soils than the Black poplars. It would, on present evidence, be the best commercial poplar for our mountain regions, were it not for its extreme susceptibility to bacterial canker, which can quickly ruin even quite large trees. There is the possibility that canker-resistant strains exist, and a large number of clones of the species, and hybrids with this species as one parent, are being tested for canker resistance. At present it is only advisable to plant it on a very small scale. Most people consider that the balsam odour, which is particularly strong when the tree is flushing in the spring, justifies its use as an ornamental tree, apart from its beauty of form.

P. tacamahaca Mill., which is normally a small tree, occurs naturally in Alaska, over much of

Canada and in some of the northern United States, though scarcely at all in British Columbia. It is possible that it should be called *P. balsamifera* L., but this depends on more critical examination of the type material. There are quite a number of trees in Great Britain which appear to be of this species, but their identity is still not quite certain. They occur mostly as roadside trees in Scotland. They are rather small bushy trees, and in the winter, because of their thick twigs, are curiously reminiscent of wild pears. They are of no value as timber trees, and are greatly inferior to *P. trichocarpa* in growth, appearance and odour ; but so far they have escaped attack by bacterial canker. This suggests that some *P. tacamahaca* × *trichocarpa* hybrids might be canker-resistant, and some of them are already known to be vigorous in growth.

P. candicans Ait., which has recently been renamed × *P. gileadensis* Roul. (Rouleau 1948), the Balm of Gilead poplar, is a tree of obscure origin, possibly a hybrid, which now has quite a wide distribution in America. In Great Britain it has been planted occasionally in plantations, but more frequently as an ornamental tree on account of its balsamic odour, rapid early growth, shining brown twigs and handsome foliage. However, it suckers very freely, and is so susceptible to bacterial canker that few large trees can be found except in the Highlands of Scotland. It is often sold under the name Ontario Poplar. On no account should it be planted.

Asiatic Balsam Poplars. The Asiatic Balsam poplars include a number of attractive trees, though most of them are untried as regards canker resistance. *P. maximowiczii* Henry is a handsome tree, but only grows well in the warmest parts of the country. *P. yunnanensis* Dode has very attractive red veins and petioles on coppice shoots, but is rather less handsome as a mature tree ; it is particularly susceptible to frost, a fault which it shares with many of the other Asiatic Balsams. *P. simonii* Carr. (sometimes sold as *P. obtusata*) has remarkably small leaves, somewhat reminiscent of a blackthorn or wild plum ; the fastigiate form is particularly attractive, but neither form makes a large tree. *P. laurifolia* Ledeb. and *P. koreana* Rehd. are known to be very susceptible to bacterial canker.

Black poplars

From the point of view of timber production the Black poplars are outstanding. Nearly all of them and their hybrids are very easily rooted from cuttings, though a few are, for unexplained reasons, harder to deal with. They do not sucker nearly as freely as the poplars of the three sections already dealt with, though suckers will arise from the roots of felled trees. This group has already been well reviewed (Cansdale 1938), but some further notes are needed to bring this work up to date, and the key given in this Bulletin is intended to replace that in Cansdale's paper.

P. nigra L. is the European Black poplar. It is usual to distinguish a number of varieties, of which only the most important are dealt with here. *P. nigra* var. *betulifolia* Torr. is a native of the British Isles and western Europe ; it has hairy branchlets, which distinguish it from the glabrous *P. nigra* var. *typica* Schn., which ranges from southern Europe to western Asia. Both forms have wide spreading crowns, comparatively short trunks, usually with large burrs ; the last mentioned character alone serves to distinguish them from other poplars, except when they are very young. They often reach a very large size, a tree of 58¼ inches quarter girth at 5 feet is standing at Brecon, and a log 34 feet long and 56 inches mid quarter girth (under bark but over burrs) and containing between 600 and 700 cubic feet (quarter-girth measure) allowing for the burrs, lay till recently in Weeting Park, Norfolk. They are not particularly rapid in growth and this, together with the short trunk and heavy crown, renders them of little value for timber production.

The fastigiate form, *P. nigra* var. *italica* Du Roi, the Lombardy poplar, is much better known than the ordinary forms. In fact to many people the word "poplar" suggests the Lombardy poplar only. Lombardy poplars appear to have originated as sports from both the normal varieties of *P. nigra*, and they vary slightly in habit, hairiness, and date of leafing. The common truly fastigiate form is always male, but so-called female Lombardy poplars do exist, which have a much looser, more broadly fastigiate habit. They may well be the result of a cross between the true Lombardy and female *P. nigra* var. *typica*. They are occasionally found mixed with male trees, having apparently been regarded as identical when planted.

P. deltoides Marshall, the American Black poplar, covers an enormous range in the United States and southern Canada. A large number of species of Black poplar have been distinguished in the United States, and *P. deltoides*, the main species in the east and central States, has itself been divided into the two varieties, *monilifera* (in general the northern form) and *missouriensis* (in general the southern form). Actually it is doubtful whether these species and varieties can really be separated, since so many intermediate forms and hybrids occur. It is probably better that all the Black poplars from the eastern and central United States should be grouped under the one species *P. deltoides*. Native American Black poplars have been introduced into Europe, particularly into France, where they have not only served as parents to some of the most

valuable older hybrids, but have also been widely planted for timber production. In France a confusion of names has been used for these American Black poplars, as indeed has been the case for the Black hybrids as well. These names have now been considerably clarified (Meunier, Guinier and Regnier, 1947) and no attempt will be made to deal with them here.

The poplar generally sold in Holland under the name *P. deltoides missouriensis* is almost certainly not in fact a true *P. deltoides*, but a hybrid between *P. deltoides* and *P. nigra*, which probably arose in the United States and was imported under an incorrect name. It is a rapid growing tree which might well be tried in this country. If further importations of *P. deltoides* are made into Europe, they should certainly be from carefully selected elite trees, such as are illustrated in a recent paper (Johnsson 1949). In Britain no form of *P. deltoides* has been at all widely planted, and the tree is seldom met with outside arboreta. *P. deltoides* var. *angulata* (Ait.), which would appear on botanical evidence to be a variety or form of *P. deltoides*, has not so far been found to occur wild in the United States, so that its origin remains obscure. It is a very characteristic tree, with vigorous shoots, large foliage and a rather sparse and very drooping habit. It does not seem to be particularly suited to our climate though large trees do occur. Its chief importance lies in its having been a parent of the two important hybrids × *P. generosa* and × *P. robusta*.

Black Poplar Hybrids

The older hybrids having Black poplars for both parents are discussed below. The evidence for the parentage of these hybrids is mostly circumstantial.

× *P. serotina* Hartig. (Figs. 2, 4 and 6), the tree usually planted in Great Britain under the name Black Italian poplar, is almost certainly a hybrid between some form of *P. nigra* and some form of *P. deltoides*, but it existed before 1755, and its origin is completely conjectural. As a mature tree it has a characteristic habit with a long bole and heavy, slightly upcurved, branches, which have a tendency to bend away from the prevailing wind ; it is a male tree. It is probably the only hybrid poplar which has been long enough planted to have reached its full size ; several trees have been recorded in which the combined volume of trunk and major limbs exceeded 1,000 cubic feet (quarter-girth measure). Older trees are rather liable to wind damage to the branches. While in rate of growth and straightness of stem some of the newer hybrids surpass × *P. serotina*, it is still a tree worth planting ; its late flushing and consequent hardiness, and its resistance to bacterial canker, are also in its favour.

Two quite definite varieties have arisen from × *P. serotina*. The better known in this country is the golden-leaved variety × *P. serotina* var. *aurea* Henry (sometimes known under the name " *Van Geertii* "), which has no particular value other than the unusual colour of its foliage, and which is slower-growing than the type. More striking is the fastigiate variety × *P. serotina* var. *erecta* (Selys Longchamps) Henry, which arose over 100 years ago on an estate in Belgium. This can easily be distinguished from the Lombardy poplar by its more regularly and more deeply furrowed bark, *serotina*-like leaves, and late leafing. In fact in all characters, other than its fastigiate form, it exactly resembles the tree from which it arose.

Apart from these two definite varieties there is no doubt that × *P. serotina* has a considerable number of forms differing in angle of branching and in vigour. Whether these have arisen since the hybrid first occurred, or whether we are dealing with a group of hybrids rather than a single clone, is a matter for conjecture. This tendency to variation makes it desirable that stocks of this hybrid should be started from trees known to be of good type. Types with distinctly narrow crowns are often regarded as a separate variety, and unfortunately were grouped by Houtzagers (Houtzagers 1937) under the name × *P. serotina* var. *erecta*. He suggested that they may be hybrids between *P. serotina* and *P. regenerata*. Since this name definitely belongs to the fastigiate variety, it is probably better to refer to them merely as × *P. serotina* narrow-crowned var. (Fig. 4). Their only advantage over × *P. serotina* is that their crowns take up less room in a plantation and that therefore they can be grown at slightly closer spacing.

There are a number of trade names that are best considered here. Nurseries often offer *P. serotina wilsonii*, *P. wilsonii*, Manchester poplar or Manchester poplar Wilson's variety. There is no consistency in the use of these names, though they usually apply to varieties of × *P. serotina* or *P. nigra*. Care should be taken if true *P. wilsonii* (of the section *Leucoides*) is required, lest one of the varieties mentioned above should be supplied.

× *P. regenerata* Henry is a female tree, which closely resembles × *P. serotina* in its foliage, but has a more steeply angled branching than the typical form of that hybrid. In habit it is far the best of the older female hybrids. It shows very considerable variation, although it is supposed to have arisen in 1814 as a single cross between *P. nigra* and × *P. serotina*. Some of the variation may have been accentuated by deliberate selection of good types, and it is possible that there may have been more than one original cross, or that there has since been backcrossing with × *P. serotina*. As in the case of × *P. serotina*, Houtzagers (Houtzagers 1937)

has separated these supposedly hybrid forms under the name × *P. regenerata* var. *erecta*, a name to which in this case there is no objection. Some varieties of × *P. regenerata* are very susceptible to bacterial canker, which has caused a great deal of damage to plantings of this hybrid in Northern France. There are certainly some varieties that are not so susceptible, but until these have been properly tested it is better to regard all × *P. regenerata* as suspect and to avoid planting them. Poplars going under the names "*P. carrieri*" and "*P. carriereana*" appear to belong to this group.

× *P. eugenei* Simon Louis is probably the progeny of × *P. regenerata* and *P. nigra* var. *italica*. It arose in the nursery of Simon Louis near Metz in France in 1832. It is a male tree with a narrower crown than × *P. serotina*, and grows rapidly. It has done surprisingly well on sites which are really too dry for poplar, such as Kew Gardens. Recently it has been found that there are apparently two distinct poplars in Great Britain under this name, both of which on botanical characters would be referred to this hybrid, but which differ in date of foliation and, in particular, in canker resistance. Separation is made more difficult by the fact that the canker-susceptible strain is invariably and so heavily cankered that it is very difficult to get typical foliage, all the shoots being abnormally vigorous ones produced as a result of natural "pruning" by the disease. At Ryston Hall, Downham, Norfolk, the apparently resistant strain is slightly superior to × *P. robusta* under comparable conditions, and it is growing quite well on a very dry site over chalk near Brandon in Suffolk. Once it is possible to be quite certain of the resistance of the better strain, and to separate it definitely from the other, it should form a valuable addition to the fast growing hybrids suitable for planting in Great Britain.

× *P. marilandica* Bosc is a female tree, with a crown even more spreading than × *P. serotina*, to which it is inferior in height and vigour. Nothing is known of its origin, though Houtzagers (Houtzagers 1937) regards it as a hybrid between × *P. serotina* and *P. nigra*. Generally it is resistant to bacterial canker, but one case is known where it has been quite badly attacked. It is not recommended for planting in Great Britain.

The four hybrids so far discussed, × *P. serotina*, × *P. regenerata*, × *P. eugenei* and × *P. marilandica*, have all, on occasion, been supplied under the name "Black Italian poplar," and mixed rows are known, where it seems that several of these hybrids were supplied under the one general name. This is not improbable, as poplars are very easily confused in the nursery stages.

× *P. lloydii* Henry is a female tree, with stout, irregularly spaced branches that give the crown a rather ragged outline, and rough irregular bark, so that the trunk has a greater resemblance to the burred *P. nigra* than any other hybrid. It appears likely that *P. nigra* var. *betulifolia* was one parent, and × *P. serotina* may well have been the other. Large trees are known to exist at Leaton Knolls near Shrewsbury, and in the neighbourhood of Woodbridge in Suffolk. Apart from these it occurs, as far as is known, only in arboreta. Nothing is known of its canker resistance. It is not recommended for planting, but may have value as a female parent in breeding work.

× *P. robusta* Schn. (Figs. 1, 5 and 9), a male tree, arose in Simon Louis's nursery in France in 1895. It is now considered that the parents were *P. deltoides* var. *angulata* and *P. nigra* var. *plantierensis*. Two seedlings were known to have been raised, and it is possible that two or more really separate clones may still be in existence. It is known to be variable in the amount of hairiness on the twigs. In 1914 Henry raised hybrid seedlings having *P. deltoides* var. *angulata* as their female parent, but of unknown male parentage, to which he gave the name × *P. vernirubens*. This has since been found to be identical botanically with × *P. robusta*, and now goes under that name. In Great Britain × *P. robusta* has been traced under the names "*P. angulata cordata robusta*" and "*P. angulata erecta*". On the Continent, and particularly in Germany, selection has been practised intensively on this tree, and numerous clones have been separated, for which superiority in growth is claimed. The best known of these is called × *P. bachelierii*. Further investigation is needed before the superiority of these selections can be admitted.

× *P. robusta* is a very rapid growing tree of extreme straightness, with moderate-sized, fairly steeply-angled branches. It is not outstanding in the nursery, but after planting it is superior to most other poplars, up to the age of 20 to 25 years. It has been suggested in France that its rate of growth falls off after this age, but this is of little consequence unless large sizes are being grown. It has been used on a large scale for match manufacture in Belgium, and has been successfully used on a smaller scale for this purpose in Sweden (Wijkstrom 1947). Its susceptibility to bacterial canker is slightly in doubt. It is certainly not as resistant as for instance × *P. serotina* or × *P. gelrica*; on the other hand it has been grown without serious injury in areas where bacterial canker is rife. One case is known, however, where what is apparently bacterial canker is doing considerable damage to this hybrid, and while it is not suggested that × *P. robusta* should be avoided, it is obvious that it would be unwise to put all one's faith in this one hybrid.

× *P. gelrica* Houtz. (Fig. 7) arose in Holland,

probably as a natural hybrid between × *P. serotina* and × *P. marilandica*. It is a fast growing tree with very white bark, which at a casual glance suggests *P. alba* or *P. canescens* rather than a Black hybrid. While it is in no way superior to × *P. robusta* in height growth, it tends to develop a greater girth, so that the actual volume of timber produced in a given time should be greater. It is not so straight as × *P. robusta*, indeed it joins × *P. serotina* in being one of the poorest of the Black hybrids from this point of view. In the nursery it is particularly liable to make curved shoots. Nevertheless its volume production and resistance to bacterial canker make it a tree well worth planting. Although it has not been fully tested in Great Britain, its behaviour in Holland makes it reasonably certain that it will prove suitable for the southern half of England at any rate.

× *P. brabantica* Houtz., which also arose in Holland and is said to have the same parentage as × *P. gelrica*, is only mentioned here because, while practically identical with × *P. gelrica* botanically, it is extremely susceptible to bacterial canker. These two hybrids illustrate clearly the need for extreme care in identification and separation of poplar plants, and form a strong argument for the supply of certified stocks, a system now in practice in Holland (Houtzagers 1941), which is being introduced in other countries (Herbignat 1949 A), and which is operating in a modified form in Great Britain.

× *P.* " *laevigiata* " was originally imported from France, and is now growing in the collection at Ryston Hall, Downham, Norfolk. It is obviously a Black hybrid, and is considerably nearer to × *P. robusta* than to any of the others. It is a male tree of considerable vigour, and with a good habit. The tree described by Dode in France under the name *P. laevigata* was a female tree, and so cannot be the same. It has done well in the trial at Yardley Forest on heavy clay, and is very vigorous in the nursery.

Black × Balsam Hybrids

Two hybrids, which have been long enough in existence to be considered here, have a Black poplar as one parent and a Balsam poplar as the other.

× *P. generosa* Henry is the best known of these. It was the first deliberate poplar hybrid, and was made by Henry at Kew by crossing male *P. trichocarpa* with female *P. deltoides* var. *angulata*. A number of seedlings of both sexes were produced, but all were distributed under the name *P. generosa*. As far as is known, all have the same characteristics, extremely vigorous growth when young, very large foliage on fast growing shoots, extreme susceptibility to rust fungi on the foliage and considerable susceptibility to bacterial canker. In addition the heavy crowns are particularly liable to wind breakage. In fact, despite its promising initial appearance, it is not a tree which can be safely planted. The rate of growth appears to fall off in later years, and twenty-year-old trees may be outdistanced by *P. trichocarpa*.

× *P. berolinensis* Dippel is said to have originated in the Botanic Gardens at Berlin, through the pollination of *P. laurifolia* either by *P. nigra* var. *italica* or one of the Black hybrids. Both male and female trees occur. Two other hybrids, × *P. rasumowskyana* Schr. (Fig. 8) and × *P. petrowskyana* Schr. appear to be closely related to it. Until the group has been further studied it is best to class poplars of this type as belonging merely to the × *P. berolinensis* group. Typical × *P. berolinensis* is a compact tree with dense foliage of an attractive deep green. It appears to be canker-resistant, and should be valuable for street planting. As a timber tree it is slower in growth than most of the Black hybrids, and cannot be recommended for general use ; but on heavy clay at Yardley Forest in Northamptonshire, it is almost holding its own with Black hybrids which would certainly surpass it on better sites. Another name, × *P. octorabdos*, is in use ; Dode described this tree as a native of central Asia, but it seems almost certain that the trees now grown in Great Britain under this name are not Dode's species but merely some hybrid very close to × *P. berolinensis*.

CHOICE OF VARIETY

For practical purposes at present, it is necessary to confine choice to the species and older hybrids considered at the beginning of this chapter. Even with these no comparable data on rates of growth, which can be regarded as generally applicable, are available. The remarks already made on comparative rates of growth are based on a large number of random observations on mixed plantations, and on individual trees growing side by side under similar conditions, and not on measurements of comparative experimental plots. Limited use on a trial basis may well be made of some of the recent hybrids which appear promising in the early stages ; but it would be folly to use them on a large scale, until more is known of their behaviour after planting and of their disease resistance. The Forestry Commission is at present limiting its distribution of cuttings to four varieties ;

× *P. serotina*
× *P. serotina* narrow-crowned variety (so far supplied under the name × *P. serotina erecta*)
× *P. robusta*
× *P. gelrica*

and it is considered that these are a safe choice for

the southern half of England. In time other varieties will be added to these. × *P. eugenei* (canker-resistant strain), × *P. laevigiata*, the hybrid poplar supplied in Holland under the incorrect name *P. deltoides missouriensis*, and some of the Italian selections (see below) are under consideration.

Much less is known about the behaviour of poplars in Wales, the north of England and Scotland. × *P. serotina* is known to do quite well in lowland regions as far north as Inverness, and is probably the safest choice. There seems every reason to believe that its narrow-crowned variety will behave similarly. × *P. gelrica* is quite untried in these regions and though it appears a hardy and accommodating tree, it should be used with caution. × *P. robusta* is of rare occurrence in these regions, and since the only known outbreak of canker on this hybrid is in Dumfriesshire, it should obviously be used with caution. A group of Black hybrids growing very satisfactorily north of Inverness at Brahan Castle appear to be a form of × *P. regenerata*, a hybrid which unfortunately is suspect on the grounds of canker susceptibility. It has already been said that *P. trichocarpa* would probably be the proper choice for the hilly regions with higher rainfall. But although parts of the Highlands of Scotland are apparently still free of bacterial canker, and may remain so, it is considered that even there its use is fraught with considerable risk. Further possibilities for these regions would appear to lie in finding a clone or hybrid with similar climatic preferences, but different canker susceptibility to *P. trichocarpa*.

The only other possibility among the older hybrids as a timber tree would appear to be the apparently canker-resistant strain of × *P. eugenei*. It might well be tried on a wider scale, though some caution is advisable till the confusion between the two strains is completely clarified. It is vital in this case to make sure that the stock is raised from definitely canker-resistant trees.

In view of the confusion that exists in the naming of poplars, and the risk of importing undesirable varieties, it was decided to include the genus *Populus* in the *Importation of Forest Trees (Prohibition) Order* of 1949. But it is there treated on a different basis from the other trees included, the import of which is prohibited, except under special licence for instructional or scientific purposes. It is still possible to import poplars, provided a licence is first obtained through the Board of Trade. Licences for very small quantities are normally granted for any variety from any source, unless the variety is known to be very susceptible to disease, or unless the source is known to be subject to a disease or pest not yet in Great Britain, but licences for large imports are restricted to varieties known to be disease-resistant, and to countries where stocks certified true to name by a recognized government agency are available. As has already been pointed out, poplars are difficult to identify, particularly in the nursery, and, in the absence of certification, an undesirable variety may easily be imported under a wrong name.

KEY TO THE CHIEF POPLARS GROWN IN GREAT BRITAIN

Difficult botanical terms have been avoided in this key; it is impossible, however, to describe leaf-shapes or leaf-bases without the use of terms which can only be clearly understood with the aid of drawings. It is hoped that the deliberately diagrammatic shapes given in Fig. 10 will prove of assistance to those using the key.

The leaf characters given are intended to apply to mature foliage on the lower third of long shoots of medium vigour. The leaves produced on rapidly growing terminal shoots, on epicormic shoots arising from the stem, on coppice shoots and on young nursery stock are often quite abnormal, and this key cannot be used for such material. For the correct identification of a poplar it is usually necessary to know the sex; this can of course be discovered by a visit at the appropriate time of early spring, i.e. in March or early April, but during the winter the catkin buds are far enough advanced for the sex to be determined by dissecting them under a hand lens. Another character of great assistance in differentiating some varieties, in particular the Black hybrids, is the relative date of coming into leaf in the spring. A table (No. 3) showing the usual order in which foliation occurs is given after the key.

KEY

1. **Leaves** near the apex of long shoots, together with the shoots themselves and the buds, clothed beneath when young with white or greyish-white *felted* hairs; **leaf-stalks** not conspicuously flattened; **buds** ovoid; **bark** white or yellowish, ringed with dark lozenge-shaped scars, furrowed only at the base of adult stems; **catkin-scales** persistent, fringed with long hairs; **seed-capsules** long and slender, narrowly conical ... ... 2 (White Poplars)

● Some or all characters differing from the above 4

2. **Long-shoot leaves** more or less persistently white-felted beneath, palmately 3- to 5-lobed like those of a maple (though often less deeply so) ; **short-shoot leaves** not lobed but very coarsely toothed, with little or no felt 3

   Leaves not lobed but coarsely toothed only, their felt often greyer and disappearing gradually with age ; **crown** spreading and very leafy, the finer **branches** more or less drooping ... ... *P. canescens*

3. **Crown** spreading ... ... *P. alba*

   Crown fastigiate, resembling that of the Lombardy poplar ... ... *P. alba* var. *pyramidalis*

4. **Leaves** all roundish (except on suckers or coppice), coarsely toothed, usually rounded or bluntish at their apex, sometimes clothed with *silky* hairs when young but quickly shedding them ; **leaf-stalks** conspicuously flattened ; **buds** ovoid, not hairy, dry or only a little viscid ; **bark, catkin-scales** and **seed-capsules** resembling those of the preceding species ... ... *P. tremula* (Aspen)

   Leaves usually without hairs on the undersurface, not conspicuously hairy, with numerous finer (sometimes obscure) and more or less regular teeth; **leaf-stalks** flattened or round; **buds** elongated, narrowly conical, viscid, usually not hairy and never conspicuously so ; **bark** usually furrowed for some distance up the stem in adult trees ; **catkin-scales** quickly shed, not fringed with long hairs, though usually lacerated ; **seed-capsules** more or less ovoid 5

5. **Leaves** green on both sides, though paler beneath, with a clearly defined translucent cartilaginous margin and often obvious toothing ; **leaf-stalks** conspicuously flattened towards their apex ; **buds** viscid but not very odorous ... ... 6 (Black Poplars)

   Undersurface of leaves with a whitish, greyish, or greyish-green metallic appearance, sometimes flushed with a rusty coloration, without an obvious translucent margin, often quite obscurely toothed ; **leaf-stalks** roundish in cross-section, not conspicuously flattened ; **buds** viscid and usually strongly odorous ... ... 17 (Balsam Poplars)

6. **Junction of stalk and blade** of all leaves without glands ; **leaf-margin** not ciliate* ; base of leaf-blade usually wedge-shaped in outline ; **branchlets** round in section, not angular or ribbed 7

   Junction of stalk and blade, at least on some leaves, with one or more glands (Fig. 11); **leaf-margin** ciliate* ; **branchlets** often angular or ribbed, especially when vigorously grown ... 10

7. **Crown** spreading ; **stem** usually with burrs 8

   Crown fastigiate ; **stem** usually fluted ... 9

8. **Branchlets** and **leaves** without hairs ... *P. nigra* var. *typica*

   Young branchlets, and often **leaves,** hairy ... ... *P. nigra* var. *betulifolia*

9. **Trees** male only ; **leaves** usually small and strongly rhombic, often broader than long ; **crown** strictly fastigiate ... ... *P. nigra* var. *italica*

   Trees female ; **leaves** larger, usually more triangular and longer-pointed ; **crown** looser ... ... *P. nigra* × *P. nigra* var. *italica?* (" Female Lombardy Poplar ")

10. **Glands** (Fig. 11) at junction of leaf-stalk and blade always present, two or more in number : **leaves** usually longer than broad, often " shouldered " near their apex, often well over 4 inches long, truncate to shallowly heart-shaped at their base ; **branchlets** strongly angled ; **catkin-scales** only irregularly notched, not lacerated. (A rare tree)... ... *P. deltoides* var. *angulata*

    Glands, when present, one or two in number but absent on many of the leaves ; **leaves** mostly about as long as broad, not " shouldered " near the apex, smaller ; **catkin-scales** deeply, irregularly, palmately lacerated 11

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* The ciliation (Fig. 11), when present, consists of short incurved hairs situated actually on the margin and properly visible only under a lens. Care must be taken not to mistake for ciliation the longer hairs which may exist on the leaf surface and project beyond the margin (e.g. in *P. nigra* var. *betulifolia*).

11. **Young branchlets** with minute erect hairs (visible only under a good lens) ; **leaves** appearing very early (see Table 3) and of a strong bronze-red when unfolding, rather large (about 4 inches long and broad on strong shoots), their base rounded, truncate or shallowly heart-shaped ; **crown** narrow and regular, densely leafy ; trees *male* only ... ... × *P. robusta*

Young branchlets with somewhat longer hairs ; **leaves** smaller ; **crown** (of old trees) rather ragged in outline, with stout, irregularly spaced branches ; trees *female* only ... ... × *P. lloydii*

Young branchlets quite hairless; **leaves** mostly smaller than in × *P. robusta* ; trees male or female 12

12. **Base of leaf-blade** mostly truncate to notched or shallowly heart-shaped ... 13

Base of leaf-blade mostly broadly wedge-shaped 16

13. **Trees** male only 14

Trees female only ; **leaves** appearing earlier and of a lighter green than in × *P. serotina* (see 15 below), and **crown** less spreading, with **branches** at a more acute angle to the stem, than in × *P. serotina* ... ... × *P. regenerata*

14. **Crown** narrow, with **branches** at an acute angle ; **leaves** appearing rather earlier than in × *P. serotina* (see 15 below), to which this form is otherwise very similar × *P. serotina* narrow-crowned var.

Crown spreading 15

15. **Leaves** appearing earlier than in the following, bronze when unfolding, lighter green when mature ; the one-year-old **twigs** grey ; **bark** of trunk white* ... ... × *P. gelrica*

Leaves appearing very late, bronze when unfolding, dark green when mature ; one-year-old **twigs** brown to greyish brown ; **bark** of stem not whitish ... ... × *P. serotina*

●Similar to the preceding hybrid, but mature **leaves** yellowish green to yellow ... × *P. serotina* var. *aurea*

16. **Trees** female only ; **leaves** rather large, longer (3 to 4 in.) than broad, with a pronounced wedge-shaped base and tapered at the apex into a rather long, fine point, light to yellowish green, appearing fairly early, with very little bronze coloration ; **crown** the most spreading of the Black hybrids, with **branches** at a wide angle to the stem and the top of the crown rounded even in youngish trees ; **twigs** slender, more or less drooping and up-curved at their extremities ... ... × *P. marilandica*

Trees male only ; **leaves** of uncankered trees smaller, 2½ to 3 in. long and broad (though often large on epicormic growth of cankered trees), less acutely wedge-shaped at base and rather abruptly short-pointed at apex, darker green, and flushing with a bronze coloration, the uncankered strain a little earlier than or at about the same time as, and the cankered strain about a week later, than the preceding hybrid ; **crown** (when uncankered) narrow, with acute branching ; **twigs** not drooping ... ... × *P. eugenei*

17. **Young branchlets** normally round ... 18

Young branchlets normally ribbed or angled 20

18. **Young branchlets** and **leaf-stalks** not obviously hairy; **leaves** rather leathery in texture, rounded to wedge-shaped at base, elliptic, ovate or ovate-lanceolate ... ... *P. tacamahaca*

Young branchlets and **leaf-stalks** obviously hairy 19

19. **Leaves** wrinkled, rather leathery in texture, elliptic-oblong or roundish, with an abrupt twisted point ; **leaf-stalks** less than one inch long ... ... *P. maximowiczii*

Leaves smooth, rather leathery in texture, broadly ovate and rounded to markedly heart-shaped at the base, less abruptly narrowed to a straightish, flat point at the apex ; **leaf-stalks** longer ; trees *female* only, bearing long catkins with conspicuous yellowish-green stigmas ... ... × *P. candicans*

20. **Leaves** dark green above, very white beneath, rather thick and leathery, ovate to narrowly ovate, with a rounded to slightly wedge-shaped base, their margin not translucent, with teeth often obscure ; **buds** very sweet-scented ; **catkin-scales** minutely hairy but not fringed with long hairs ... ... *P. trichocarpa*

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* This hybrid is keyed out on the characters of adult trees in Holland. Stocks in Britain are not yet old enough to show the distinguishing characters clearly.

Leaves not very white beneath, lighter green above and thinner than in *P. trichocarpa*, more ovate-rhombic to rounded-triangular in outline, with a very narrow translucent margin and more evident teeth ; **buds** less odorous ; **catkin-scales** without hairs 21

21. **Leaf-base** often heart-shaped to truncate ; **leaves** large (3 to 4½ in., often larger on young trees), pale green to greyish beneath, ovate to triangular-ovate, with teeth often well marked ; **leaf-stalk** and midrib often flushed with red ; **branchlets** hairless or with sparse minute hairs ... ... × *P. generosa*

Leaf-base rounded to broadly wedge-shaped ; **leaves** mostly smaller, rather pale greyish-green beneath, ovate to ovate-rhombic ; **branchlets** often rather hairy to obviously so ... × *P. berolinensis* (group)

The order in which the poplars come into leaf is a useful aid in their identification. Of course the actual dates vary quite widely from year to year, and in different parts of the country, but where a number of poplars are growing together under comparable conditions their order of foliation is usually approximately the same. In the table below, which is based partly on observations made over a number of years in Great Britain and partly on Dutch data (Houtzagers 1937), those poplars on which sufficient information is available are given in five groups in order of leafing ; within each group the varieties are given in their most likely order of leafing, but this cannot be regarded as constant, and in some years a variety may leaf so early or so late as to fall in the group above or below the one it occupies in the table. It is certainly not possible to identify poplars by date of foliation alone, but given a knowledge of the sex of the tree, its habit, and its summer foliage and twigs, date of leafing may be the deciding factor.

Date of Leafing of Poplar Varieties

TABLE 3

Comparative period	*Varieties*
Very early ...	*P. candicans* *P. trichocarpa* × *P. berolinensis* group × *P. generosa* *P. laurifolia* *P. maximowiczii* *P. tacamahaca*
Early	× *P.* " *laevigiata* " × *P. robusta* *P. nigra* var. *italica*
Mid-season ...	× *P. marilandica* × *P. eugenei* (canker-resistant strain)
Late	× *P. regenerata* × *P. eugenei* (canker-susceptible strain) × *P. gelrica*
Very late ...	× *P. serotina* and its varieties

P. alba, *P. canescens*, *P. tremula*, and *P. nigra* with its varieties other than *P. nigra italica*, show such a wide range of variation that it is not possible to include them in the table.

It will be noted that the Balsam poplars in general are very early ; some less well-known Balsam poplars such as *P. koreana* have been known to come into leaf as early as March, obviously an undesirable trait having regard to the vagaries of the English climate. Most varieties come into leaf during April in the southern half of England, though in an average season × *P. serotina*, for instance, may be only just coming into leaf at the beginning of May. When this character is to be used as an aid in identification, the last week in April or the first in May is probably the best period. The earliest varieties are by then fully in leaf, and can be distinguished by their complete covering of foliage ; slightly later varieties will have the blades of the earlier leaves full expanded, but will still look sparsely clothed ; the mid-season and late varieties will still be in different stages from leaves unrolling to buds swelling.

Since many of the American hybrids mentioned below have Balsam poplars as one or both parents, they have a tendency to fall in the very early group as regards date of leafing. The Italian selections, on the other hand, tend to come into leaf in the middle of the season, at about the same time as × *P. marilandica* or × *P. eugenei*.

NEW HYBRIDS

The whole field of work on poplar hybridization and selection has been reviewed by Scott Pauley (Pauley 1949), and the notes below are intended only to indicate the general lines on which work of this nature has proceeded in different countries, and to give what little knowledge is as yet available on the behaviour of the new hybrids in Great Britain.

A considerable period elapsed after the pioneer work of Henry, who produced × *P. generosa*, before any other work on the hybridization of poplars was attempted. However, in 1934 the preliminary results of work done for the Oxford Paper Company in Maine in the United States were published

(Schreiner and Stout 1934), and from then on work has proceeded with increasing activity in a number of countries. Stout and Schreiner produced a very large number of hybrids, most, but not all, with a Balsam poplar as one parent. A number of these, as well as the original ten described in 1934, are on trial in Great Britain. Some of them have proved extremely susceptible to rust fungi on the leaves, and Dutch work suggests that several are susceptible to bacterial canker (Ter Pelkwijk and Brink 1946, Koning 1941). Many of these hybrids have a strong tendency to crooked and branchy growth, and while the best of them, in particular × P. Androscoggin (*P. maximowiczii* × *P. trichocarpa*), are very vigorous indeed in the nursery, it is not considered that they have any great possibilities for Great Britain. Recent reports on their behaviour in America are not encouraging (Rudolph 1948). No particular care was taken to select elite trees as parents, which may in part account for the generally rather disappointing results from these hybrids.

More recently work has been proceeding in Canada, where one aim is the production of types suitable for a wider range of sites than the Black hybrids. Particularly promising in this connection are hybrids between *P. alba* and the American aspen *P. grandidentata*. Some of these crosses have shown exceptional vigour under nursery conditions in Great Britain.

Some of the hybrids between *P. trichocarpa* on the one hand, and *P. tacamahaca*, *P. koreana* and *P. nigra* on the other, produced in Canada, are showing extreme vigour in the nursery in Great Britain. One-year shoots from cuttings have reached heights up to ten feet. Nothing is yet known of their canker susceptibility, but in view of the possibility of resistance in *P. tacamahaca*, there is hope that some of them may prove to be resistant.

In Europe intensive work has not been under way for quite so long as in America, but already very useful progress has been made. The Scandinavian countries have concentrated on work with aspen and white poplars, and the hybrids *P. tremula* × *P. tremuloides* and *P. tremula* × *P. alba* are both available commercially. They appear to be rather more vigorous than *P. tremula*, and will be tried under a variety of conditions in various parts of the British Isles. Unfortunately it would appear that some clones of *P. tremula* × *P. tremuloides* are susceptible to bacterial canker. First-generation seedlings from crosses made in this way are naturally variable, in contrast to the uniform product resulting from a vegetatively propagated cross of the Balsam or Black groups. Selection in the nursery is probably desirable when dealing with a hybrid produced in this way.

Apart from the hybrids, experiments are also in progress with polyploid aspens. These are trees in which the normal number of chromosomes (which carry the genes controlling the nature of the tree) are increased in number, a character often associated with greater vigour.

A considerable amount of hybridization work has been done in Russia and Germany, often using white or aspen poplars for one parent in the hope of producing types suitable for more exacting sites than are suitable for Black hybrids, but with rapid growth and straight stems. But Russian results have not been published in detail, and many of the German hybrids were lost during the war years. Work on poplars in Germany is again very active ; efforts are being made to rediscover and re-identify the hybrids made before the war, and elite trees of the older hybrids are being selected and reserved for propagation. A considerable number of selections, purporting to be superior to type, are already widely distributed in Germany, many of these being of × *P. robusta*.

Similar selection of elite trees for propagation is in progress in Switzerland. Such activity is of course excellent, but inevitably limits improvement to the best available in the country where the work is in progress. It should always be combined with the trial of similar selections from other countries, and trials of newer hybrids.

The best development of such selection work has taken place in Italy, where there is a rich population of naturally produced hybrids between *P. nigra* and the imported *P. deltoides*, and later between the hybrids themselves and their parents. The wide alluvial areas in the Po valley have presumably provided conditions where poplar seed can germinate, and this, combined with the favourable climate, has led to the production of so many natural hybrids. Under the normal conditions of poplar-growing in other countries, damp bare soil, such as is required for the germination of poplar seed, seldom occurs, and no seedlings arise. Workers at the Poplar Research Station at Casale Monferrato (Piccarolo 1948) have selected a large number of promising individuals from the welter of hybrids (Fig. 3) ; many of these have been abandoned after further trials, on account of inferior growth, or lack of resistance to disease. Since bacterial canker does not occur in Italy, the behaviour of these selections as regards that disease is unknown. Preliminary trials in Holland of two of these selections (Ter Pelkwijk and Brink 1946) indicate that they are resistant to canker, but of course other selections may behave quite differently. One of the clones tested in Holland was × *P.* "A. M." which has been widely planted in the Argentine, where poplars are being used on a large scale on river-delta and alluvial soils. A number of the best

Italian selections are under trial in Great Britain. Here growth in the nursery is generally very promising, being vigorous and exceptionally straight, but in the only trial plantation which is properly established, two Italian clones are not holding their own with × *P. robusta* and × *P. gelrica*.

Work on poplar breeding and selection is now being carried on actively in Belgium and Holland. In France work is directed particularly to locating and extending the best of the many local varieties. In Great Britain a large collection is being formed of hybrids and selections which are considered of possible value for our conditions. Trials of their growth, under various conditions, and in various parts of the country, and of their resistance to bacterial canker and rust, are in progress. Most of these trials have only been in progress for a few years, so that no reliable results are yet available.

Chapter 2

SILVICULTURE OF POPLARS

CHOICE OF SITE

Climate

Most poplars are extremely responsive to climate, particularly to the summer temperatures. Within reasonable limits, provided soil moisture is available, the hotter the summer the faster will poplars grow. In addition they have a fairly long growing season, though many varieties are rather late into leaf in the spring, and though for some time after flushing growth is rather slow ; but from mid-June on the shoots elongate with increasing rapidity, reaching a peak growth rate in August or early September, and usually they do not form resting buds till towards the end of October. The dates given here apply to Great Britain ; in Italy for instance (Peace 1948) the season is longer and, while part of the extremely rapid growth of poplars there is due to the high summer temperatures, part is certainly due to the fact that they come into leaf earlier, and cease growth later in Italy than in Great Britain. On an optimum site, where the water table is maintained irrespective of rainfall, the growth of poplars will bear a direct relation to the summer temperatures, but on drier sites, where hot summers are likely to be associated with drought, the effect of higher temperature will be partially or even wholly off-set by lack of water.

From the point of view of poplar cultivation Great Britain should be divided into three regions. They are :

(*a*) That part of England lying south of a line from Chester to York, but omitting the southern Pennines.

(*b*) The lowland areas of north England, and of Scotland,

(*c*) Wales, the Lake District, the Pennines, the Border hills and the Highlands of Scotland.

Naturally within each of these regions there are hilly areas, flat areas or areas with locally favourable climate, which belong, from the point of view of poplar cultivation, to a region in which they are not situated geographically. In general (*a*) is the hottest and driest of the three regions, while (*c*) is definitely the wettest. Only the southern half of England (*a*) can really be regarded as part of the major region in northern Europe where Black Poplar hybrids are cultivated, and which stretches from south Sweden to northern France. On the basis of summer temperatures England is probably rather below the average for this region ; on the basis of rainfall, and length of season it is probably average or slightly above. When we consider the lowland regions of the north (*b*), summer temperature and length of season are both below the desirable figure for Black poplar hybrids, and this applies with even greater force to the mountainous regions (*c*), where the higher rainfall tends to be reflected in an even greater depression of the summer temperatures.

The southern area can be regarded as perfectly suitable climatically for the growth of the Black hybrids, though rates of growth are likely to be lower than in hotter climates abroad. The northern lowlands will support these poplars, but growth is slower, and there is a tendency for the crown to be rather sparse, and for a certain amount of dieback to occur, both of which are probably climatic reactions. Nevertheless, fine healthy Black hybrids occur as far north as Inverness. In the mountainous regions × *P. serotina* and occasionally other Black hybrids are found growing quite well, but in places they have failed altogether, or have grown very slowly and unhealthily. Until the reasons for these failures are known, and they may be due to soil or to climate or to both, planting of Black hybrids in these regions should be confined to

places where there are already examples of good growth.

Aspen, *P. tremula*, occurs in all three regions, but for unexplained reasons seldom reaches any great size. Considering the known range of *P. tremula*, and the closely related *P. tremuloides* in America, it is hard to believe that the whole of Great Britain is climatically unsuitable for the growth of this tree.

The Balsam poplars, as long as they remain free from canker, grow well in all parts of the British Isles, though they are probably slightly slower in the colder regions. Provided the soil conditions are reasonably good this tree appears to appreciate the high rainfall found in the mountainous areas. The largest trees of *P. candicans* and *P. tacamahaca* are in Scotland, but this may reflect the comparative absence of canker there and the consequent ability of the trees to continue undiseased growth, rather than any particular suitability of climate. Among the White poplars, *P. canescens*, at any rate, grows well in the north.

It would appear that the safe extension of poplar cultivation to the higher ground in the north of England and Scotland rests mainly on the possibility of finding White or Aspen clones or hybrids, of improved growth, of finding a canker resistant strain or hybrid of *P. trichocarpa*, or of using Black × Balsam hybrids, which combine the disease resistance of the first with the climatic adaptability of the second. Among the many new hybrids and selections made during the last twenty years a number of clones are available, which may well be found to satisfy the needs expressed above.

Situation and Soil

The best site, at any rate for the Black hybrid poplars, is on a loamy soil, in a sheltered situation, with the water table never less than two or three feet below the surface and never more than four or five. But of course in practice poplars can be grown on a much wider variety of sites, and in Great Britain the ideal site is the exception rather than the rule. Poplars can be grown on any soil from sand to clay, but growth on the more extreme types is likely to be slower. Acid peats appear, on present evidence, to be quite unsuitable, and heath soils are normally too dry as well as too acid. Poplars have been successfully established on fairly moist *Calluna* (heather) soils in Germany by ploughing and dressing the ground with a heavy application of basic slag, but it remains to be seen whether trees started in this way will continue to flourish. The alkaline peats of the fens and carrs of East Anglia are quite suitable for poplar growing, provided they are properly drained. Much more evidence is needed on the question of acidity, but on present evidence any soil with a pH between 5.0 and 5.5 should be used with caution and any with a pH of 5.0 or less avoided.

Most of the best poplar ground lies on the alluvial soils occurring in river valleys, and the actual area of such land in the British Isles is quite considerable ; but owing to the prior demands of agriculture, the amount available for poplar cultivation is comparatively small. A certain amount of such ground is at present too badly drained for agricultural purposes, but normally, if it can be drained sufficiently to allow the planting of poplars, it will then be good enough for farm crops. Where, however, it is already covered with carr woodland of willow, alder, etc. or with derelict osier beds it would not pay to drain and clear for agriculture, but it might very reasonably be drained and used for poplar cultivation. Apart from existing woodlands there are often odd corners, which, because of difficulty of access or for some other reason, are unsuitable for agriculture, and remembering that poplar can be grown in lines, or individually as well as in plantations, such areas can well be utilized.

The use of poplar along the margins of fields is a matter about which there is much difference of opinion. Some hold that the roots interfere considerably with the growing crops and others that such interference is negligible. Undoubtedly the degree of interference depends considerably on the type of soil, and in a shallow soil or in a wet clay, where the roots tend to run near the surface, the effect is likely to be much more extensive than when the trees are growing in a deep loam, sand or alkaline peat. Apart from the effect of the root competition on the crops, there is also the possibility of the larger roots causing trouble when the ground is ploughed. Provided the land in question is ploughed yearly, there is likely to be little trouble ; but if it is being run on a ley system the roots formed while the land is under grass may well cause difficulty, when it is ploughed again. On permanent grassland, which still frequently occurs in river valleys liable to flooding, there is no objection to line planting along the sides of fields as the injury to grass is negligible, and the shelter may well be of value for stock. When interference with crops does occur it is primarily due to root competition, rather than to shading, as the amount of shade cast by a poplar is relatively small. In Italy, where of course the sunlight is rather brighter, agriculture is carried out for some years after planting in strips between fairly widespaced rows of poplars (Peace 1948), and when the shade becomes too great for crops the land is grassed down and used for grazing. It is not suggested that such practices would be acceptable in England, especially since they limit the use of machinery to some extent, but it is possible that in low-lying fields poplar growing might be combined

with grazing, once the trees were large enough to be safe from stock.

Poplars can also be planted in lines along the sides of rivers and drains, a position in which they are likely to do well, especially if the water is moving. It is advisable to plant the trees several feet from the edge to improve their root anchorage, which otherwise would be very one-sided. It is pointed out later, that poplars should not be planted on river banks, in places where the water level in the river is sometimes above the surrounding land. The risk of the trees blowing over when the river is high and the bank is sodden, and thus breaking the bank, is too great. There is no evidence of poplars blocking open drains, but they should not be planted near tile or mole drains. Most drainage authorities have by-laws prohibiting the planting of trees within a specified distance, usually 10 or 15 feet, from all water courses for which they are responsible. The object of this is to provide working space for drainage machinery. It is advisable therefore to seek the advice of the appropriate drainage authority before planting poplar in such situations.

Except on clay soils, poplars can be safely planted along roads. On such soils they are liable to cause shrinkage of the clay, by excessive extraction of water during the summer, and consequently to damage the road foundations (Croney and Lewis 1948). Obviously such vigorously growing trees as poplars should not be put near buildings, lest their surface roots interfere with the foundations. A minimum distance of twenty yards is advisable on any soil, and considering the height to which poplars grow, and the risk of wind breakage as they get old, an even greater distance is advisable. On clay soils the question of shrinkage again arises (Ward 1948) and it is generally considered that poplars together with elms are the worst trees from this point of view. On clay a minimum distance of forty yards from any building of value is advisable.

It has already been stressed that poplar is essentially a tree for the small plantation, the odd corner, or for the margins of land used for other purposes. Apart from this, of course, it can be used for shelterbelts, for which purpose its rapid growth is an advantage, but the subsequent freedom from branches of its lower trunk is a difficulty, unless other slower growing, better furnished trees are included in the belt. Lines of poplar along the field margins have been found to prevent the blowing of fen peats in dry seasons, and thus to prevent loss of seed and blockage of the drains with the blown soil.

The optimum conditions for poplar have already been mentioned, and it is fairly easy to describe the type of ground unsuitable because of bad drainage, owing to the occurrence of typical plants in the vegetation. Land with a heavy growth of reeds (*Phragmites communis*), reed grass (*Phalaris arundinacea*), or sedges (*Carex paludosa*) etc., is definitely unsuitable. Vigorous growth of marsh marigold (*Caltha palustris*), wild iris (*Iris pseudacorus*) or great water dock (*Rumex hydrolapathum*) usually indicates that the water table is too high. Areas carrying a high proportion of meadowsweet (*Spiraea ulmaria*) are also open to doubt. Whether such sites can be brought into a fit state for poplar cultivation by drainage depends less on the vegetation than on the lie of the land. If there is a reasonable outfall for the drains, so that the winter water table can be lowered to at least two feet below the surface, then poplar can be planted. If this is not possible, then however numerous the drains, poplar cultivation will still be impossible. Sites which are marginal from the drainage point of view can sometimes be partially utilized by planting poplar only along the drains, where they will have the benefit of some movement of the soil water, and of a slight raising of the ground surface owing to the spoil from the drains. These conditions apply even more forcibly to rivers, and it is often possible to plant a single row of poplars along a river or stream bank, although the land behind may be undrainable. Some caution however is advisable in a situation of this kind, since if the poplars lean over the water, felling will be very troublesome and, if a tractor cannot be used on the boggy ground, extraction may well present equally difficult problems.

When we come to consider drier sites it is far more difficult to decide what land is suitable and what unsuitable for poplar cultivation. Leaving out shallow dry sands such as occur in parts of East Anglia and in Surrey, it is safe to state that they can be grown on any soil including *deep* sand that could be used for agricultural crops, if cleared and ploughed. It is not intended to recommend the planting of poplars on land already in use for agriculture, except, as already suggested, in odd corners, along hedges and roads, and as shelterbelts, but rather to indicate that land being considered for poplar planting should be viewed more on an agricultural than a forestry basis. There are many woodlands in the country which would make good agricultural land if they were cleared of trees, and there are other areas which are woodland because the steepness or irregularity of the contour makes cultivation impossible. In considering such sites, however, it should be borne in mind that poplar, like ash, is a somewhat exacting tree, and that while large stretches of agricultural land in wide valleys could certainly be planted with poplar if they were not required for more lucrative purposes, in woodlands very often only part of the ground is really suitable for poplar, and it is to that part that it should

be restricted ; even if this leads to a considerable irregularity and discontinuity in the planting.

Much more experimental work is required before it is possible to say what part poplar can play in the replanting of derelict woodlands. There is no doubt that competition with existing coppice for moisture renders establishment rather difficult, and greatly reduces the rate of growth for the first few years. Also, since it casts such a light shade, poplar is slow to suppress the coppice, and may never do so completely, a serious defect in what should serve as a cleaning crop. Even at the widest spacings—say 30 feet each way—surprisingly little coppice can be left standing between the plants without risk of depriving them of light. On the other hand the wide spacing that can be adopted greatly reduces the costs, both of preparation of the ground for planting, and of subsequent weeding. The acidity of many woodland soils may also prove a barrier to their use for poplar.

The soil requirements of the aspens are apparently rather less exacting, and *P. tremula* is certainly able to grow on much more acid soils, and on clays so heavy that the establishment of Black hybrids would be a long and difficult process, though they might grow reasonably well once established. It is hoped that aspen hybrids will show similar latitude in their soil requirements. If they do, and if they grow to a larger size in Great Britain than *P. tremula*, they will greatly extend the commercial range of poplars not only climatically, but also from the point of view of soil. There is also some evidence that the Balsam poplars will grow under more acid conditions and will stand more competition than the Black poplars.

Intending planters of poplar should always look around and see how poplars are growing in their neighbourhood. For although the number of poplar plantations in Great Britain is certainly very small, the number of individual trees, that have been planted for ornament, screening or shelter, is quite large. Making due allowances for variety, these will often form a valuable guide to the possibilities of any given neighbourhood for poplar growing.

NURSERY PRACTICE

Choosing a Site

For a poplar nursery, of course, the best site available should be chosen, even if this means some trouble over cultivation, fencing, or access. The main points to remember are that the soil must be reasonably deep, and easily worked ; sandy soils are only suitable if the water table is fairly high, otherwise they are not sufficiently water retentive. Heavy soils appreciably increase the cost of lifting the plants. Shelter is quite desirable, but shading or root competition from surrounding trees should be avoided. Old garden soils, unless they have been kept in good heart, are usually only suitable after heavy humus manuring. It is essential to avoid acid soils, so that woodland or heathland nurseries, so suitable for conifers, are unsuitable for poplars. If the site chosen is near a river care should be taken to ascertain how often and for how long it may be flooded. Such flooding will not damage the trees, unless the water washes the soil away, but it may seriously hamper nursery work. The area required can be worked out on the basis of the number of plants it is required to produce per year, using the spacings given later in this section and allowing an extra quarter of the total area as fallow.

Manuring

Poplars are heavy feeders and respond in the nursery stage to planting in manured fertile soil. On an average soil the application of farmyard manure or compost at twenty tons to the acre is desirable both for the rooting of cuttings and for transplanted stock. Under such conditions, and providing the soil is naturally in good heart, no artificial fertiliser treatment is necessary. If such heavy dressings of compost or farmyard manure are impossible the deficiency can be made good to some extent by a normal dressing with a " complete" chemical fertiliser, but a reasonable amount of humus in the soil is absolutely essential. If there is any suspicion of acidity, lime should be applied during the winter. Though no definite advice can be given, it seems almost certain that poplars would respond to mulching, and if any suitable material such as manure, compost, grass clippings or leaf mould is available during the summer, it should be put around the plants. If an acid mulch such as leaf mould is used, the addition of lime may be required.

Recent evidence suggests that on a good site heavy manuring plus a good growing season may result in growth which is too lush to ripen properly, leading to subsequent damage by autumn and winter frost, and attack by the fungus *Dothichiza populea.* This should be borne in mind if the nursery is situated on a fertile valley loam, and manuring modified to keep growth rates within reasonable limits.

Propagation

Poplars for planting can be raised from stem-cuttings, root-cuttings, layers, or seed ; alternatively sets, which are branches of a size large enough for immediate planting, may be used.

Stem cuttings

This is the most usual method for all the Black and Balsam poplars and their hybrids, and can be used with the White poplars and some of their hybrids, though in that case the proportion of cuttings which strike may be much lower. A few of

the new Black hybrids and selections are hard to root, but all the older hybrids and all the Balsam species appear to root with equal ease. The average take is over 80% under normal nursery conditions.

The method described below is that which has been practised in Forestry Commission nurseries for a number of years, and has been found to give very satisfactory results. It is also practised by the Belgian Match Company. Certain other methods will be discussed later. The practice recommended is to take cuttings eight to nine inches in length, from well ripened one year old wood. (Fig. 13.) Thin and succulent material should be discarded. Shorter cuttings seven inches in length might be used on moist sites, but four inch cuttings have been known to fail completely where the annual rainfall was in the region of twenty-six inches. The cuttings should be of sufficient length to prevent drying out, but not longer than nine inches or they will be damaged in lifting, as the most vigorous roots are found at the base. The best material is obtained either from properly managed stool beds or from the shoots of one year old rooted cuttings. The latter are usually cut back to the root collar in any case before transplanting at the end of the first growing season. From each shoot four or five cuttings can frequently be obtained. It is not essential that there should be a bud at the apex of each cutting, although this is desirable. The diameter of cuttings, that will normally produce vigorous shoots, should not be less than pencil thickness, and should normally be rather thicker. Cuttings from older wood do not generally root so readily and tend to produce weaker shoots. It will usually be found that the buds at the base of vigorous one year shoots sprout during the first season, so that while cuttings made from the middle of the shoot (the top should be discarded in any case) have normal buds, those made from the basal part will apparently have no buds after the little side twigs have been pruned off. In view of this it has often been suggested that they should not be used for cuttings. In practice, however, auxiliary buds do make their appearance, although there may be some delay. These basal cuttings often produce good plants, but should not be used if other material is available.

Cuttings can be taken at any time after growth is complete and the wood ripened. Those taken relatively early in the autumn can be heeled in thinly so that the tops are flush with ground level to prevent drying out, or completely buried in moist sand, until required for insertion. Cuttings are usually taken with a knife, but a sharp pair of secateurs is equally effective. They should be inserted vertically in well cultivated soil at a spacing of nine inches apart within, and eighteen inches between, the rows. The distance between the rows can be reduced to twelve inches if space is limited, but this makes lifting harder and except on a moist soil tends to produce a restriction in growth during a dry season. The entire length of the cutting should be inserted so that the top is flush with the firmed surface of the soil, care being taken not to peel the base. The use of a mechanical cultivator to loosen the soil as insertion proceeds is an advantage, the soil around the cutting, however, requires to be well firmed. If large quantities of cuttings have to be planted, the leather protective device, known as a sailmaker's palm and obtainable from ships' chandlers, makes insertion much easier. Insertion is probably best delayed until at least part of the hard winter frosts have passed, to avoid frost lift. In practice from the end of January up to the beginning of March is the best period.

The shoots which arise from the cuttings must be reduced to one when sufficiently developed. This should be done when the young growths are approximately nine to twelve inches in length, when the best placed shoot can be easily selected. Further attention is not usually necessary during the remainder of the first growing season. Shoots from one to eight feet can be expected with most varieties by the end of the first year (Fig. 12).

At the end of the first year rooted cuttings are stumped or cut back to within one inch of the root collar (Fig. 14), leaving at least one bud on the current year's growth (the tops providing material for the supply of the next season's cuttings). The object of a stumping at the end of the first season is to produce a well developed vigorous shoot with a balanced root system, suitable for planting in the field without additional support. The shoots from stumped plants may be no taller than those from cuttings, but they are usually stouter and straighter. Stumping must be low or an awkward crook will result at the base of the plant (Barth 1942). In practice it is best if the plants are lifted before stumping, the roots pruned to a length of four to six inches, and transplanted in manured ground at a wider spacing. The retention of tops makes bundling, handling and planting much easier ; they can be cut off after the plants are in place. The distance apart will vary according to the fertility of the soil, and the age at which the trees are to be used for planting in their final positions. On fertile soil, growths from six to eight feet can be expected at the end of the first year following stumping. Under such conditions a spacing of 2½ feet within, and three feet between, the rows, if the plants are to be lifted after one year, or three feet within, and three feet between, rows if they are to be lifted after two years, is probably sufficient. Wider spacings than this are wasteful and give no real improvement

in the plants ; and, while narrower spacings will produce trees of equal height, they will lack the stoutness and rigidity which are so desirable when they come to be planted out. This apparently wide spacing is of great assistance when the trees are lifted for planting out. In addition it permits mechanical cultivation for the eradication of weeds between the rows.

The shoots produced by the stumped plants are reduced to a single one in the same way as those from cuttings. If the first year shoots are strong and straight, it is possible to transplant without cutting back, and this is the usual practice in Holland. Further treatment during the summer involves pruning occasional branches which might impede the development of the leading shoot, together with the removal of lower branches to about one third of the height.

The trees are lifted either at the end of the first or second year after transplanting and stumping (Fig. 15), and care should be taken to ensure that the plant is supplied with adequate root spread to provide suitable anchorage when planted in the field. The best root form is usually obtained at the end of the first year after stumping when the plants are also more easily lifted ; and, provided the plants are over five feet in height and have a stout main stem, there is no reason why they should not be used at this age. It must be admitted that information on the best size for planting is very meagre. On the basis of what little information is available, it is suggested that a minimum of five feet and a maximum of ten feet is reasonable.

The use of plants smaller than five feet in height is at the moment under investigation, and they may well prove satisfactory on sites where there is not too much competition from vegetation, and where mounding or mulching is resorted to. Large plants, especially if growth was very rapid during the last year in the nursery, are prone to attack by *Dothichiza populea* after planting, and should only be used on favourable sites, or for roadside planting, where their large size helps to lessen damage from passing vehicles and stock.

Experimental work has recently been started on the possibility of producing plants suitable for planting out in the field after only one year in the nursery. The cuttings were inserted at a spacing rather wider than normal (18 inches × 24 inches is the only spacing so far tried and others may give better results) and were root pruned in mid-season by inserting a spade to its full depth, about six inches from the stem. By this means a plant was produced, which generally had a slightly stouter and taller stem than one transplanted for a year after stumping, and had an extremely fibrous root development at the severed ends. It may well be that a plant possessing a root system such as this could be planted out in the field in the normal manner, without the necessity of cutting back and transplanting.

Certain drawbacks do exist, however, in that only soils moderately free from stones would allow a spade to be driven sufficiently deep and cleanly to ensure proper severance of most of the roots. In addition, it is possible that in heavy soils the fibrous roots would be partially stripped by indifferent lifting. Wilting of a few of the experimental plants after root pruning, despite a moderate rainfall immediately after the operation, suggests that it should only be done when the soil is moist, or, if possible, should be followed by a heavy watering.

At the moment, until more information becomes available of the behaviour of this type of plant in the field, it is not intended that wider spacing of cuttings and root pruning should be adopted as general practice. For obvious reasons, however, such a plant would have distinct advantages over transplanted stock, if only because of the large saving in nursery space and the production of plants suitable for the field in one year, instead of the more usual two or three.

Before planting, it is best to reduce the branches, thereby lessening transpiration and the risk of die-back during the first season in the field, and to reduce the resistance to the wind. This reduction can be done in a variety of ways, and it is not possible on present evidence to say which is the best. The alternatives are (*a*) the removal of all the branches, (*b*) the removal of most of the side branches, leaving a few of the less vigorous ones for later pruning, and (*c*) the shortening of all branches to within a distance of three to six inches of the main stem (Fig. 16). The last mentioned method, of course, involves double pruning, since the stubs must be removed later. In most instances they sprout again, but sometimes they die, in which case there is the risk of their forming a means of entry for fungi such as *Dothichiza populea* into the main stem. On the whole methods (*a*) and (*b*) are to be preferred. There appears to be some risk of the wounds on three-year-old plants, which will have larger branches, being infected with *Dothichiza* if pruning is carried out at the time of lifting. It may be possible to avoid infection by pruning earlier in the season, say in August ; but the whole question of pruning is still under investigation.

It is suggested that nursery stocks when lifted should be heeled back in the hole from which removed, in an upright position, where they can remain until transported to the planting site. This prevents undue damage to leading shoots, and does away with the necessity for digging deep trenches, which frequently bring the subsoil to the surface. Whenever possible transport by road from the nur-

sery to the planting site is suggested ; terminal buds and leading shoots are easily damaged by careless handling. Plants should be carefully protected and if necessary moistened during transit, and if they have to be heeled in on the planting site this should be done very carefully. For short periods, standing the trees with the roots in flowing water is quite permissible.

In some countries (Anon. 1948 B, Bull and Muntz 1943) cuttings are used for direct planting, but it is considered that this would only be feasible in Great Britain on fertile, moist sites, which were large enough to be completely ploughed before planting, so that competition with weeds would be reduced to a minimum. Where it has been tried on ground carrying vegetation the results have been very patchy, and many of the cuttings have formed very weak shoots indeed, or in unfavourable seasons have failed to take root at all.

Practically every kind of cutting has been used in some country at some time, but it appears generally that the stout eight to nine inch cutting gives the best results. If it is desired to propagate from an individual tree, the most rapid results can be got by rooting branch material, even up to several inches in thickness, using it not for the direct production of plants, but to produce stools for the subsequent production of cuttings. Only the most vigorous shoots from the crown of the tree, or strong epicormic shoots arising from the main stem, will give good cutting material straight away (Hoffman 1938).

For difficult varieties burying the cuttings upside down in moist sand for the whole of the winter has been recommended (Vogelsang 1941). Hormone treatments have not generally improved the percentage rooting. Soaking the cuttings in water for forty-eight hours before planting (Müller 1949) has also been suggested with some varieties. Actual rooting in water appears to increase the take, but very careful planting out and subsequent watering is required. For very rapid propagation from a selected tree, green summer cuttings can be used (Miron 1939), but this practice is not suitable for general use with the Black and Balsam poplars. It is, however, a good method for the propagation of aspen and aspen hybrids. Very small shoots should be taken from young plants and rooted under double glass in a greenhouse or propagating frame.

Stool beds for the production of cuttings can be made by putting in cuttings or plants at a spacing of four feet apart in the rows by four to five feet between them and cutting them back to one bud. This wide spacing is to allow sufficient space for the summer development of the stools and mechanical cultivation between them during the winter and spring. Normally there is no need to thin the shoots on the stools, which should be cut back to the ground each winter. In some places stools cut at various heights up to three feet above the ground are used, but results with high stools are not so good. After four or five years, even with cultivation, which is essential, and manuring, the stools will probably decrease in vigour, mainly owing to the production of too large a number of shoots. Replacement stools should then be started and the old stools scrapped before the proportion of weak shoots becomes too large. It is usually best to run a stool bed on a rotation system, removing a few stools at one end each year and fallowing the ground, while adding a few new ones at the other.

Root Cuttings

This method is only used for difficult varieties, in particular for the aspens. Roots, preferably from young trees and varying in thickness from $\frac{1}{8}$ to $\frac{1}{2}$ inch, are dug up in the forest, or taken from lifted plants in the nursery during the autumn, and are buried in moist sand in a well protected place during the winter. In the early spring the roots are cut into pieces about four inches long, and are placed one inch apart end to end in drills at about three inches deep. At the end of the summer the plants are moved to a wider spacing, and kept in the nursery till large enough to be used for planting. There is some evidence that aspen reacts to cutting back at the end of the first year in the same way as the other poplars, that is to say by the production of a better shoot (Gray 1949). It must be admitted that propagation by root cuttings is more difficult in practice than it appears on paper, and it is probably best to use it only for a clone that cannot be increased in any other way.

It is possible to use a greenhouse for this method, placing the cuttings in boxes or in a prepared bed. If soil heating is available better plants can be produced by removing the shoots from the parent roots, as soon as they have formed a few leaves, and rooting them as stem cuttings (Johnsson 1942).

Layering

A method of propagation by layering which has been elaborated in Germany (Hesmer 1951) is said to be useful with aspen and other poplars normally hard to root. A young plant is bent over or planted on its side, so that most of the stem, except the growing tip, can be covered with a low mound of soil. The buds on the stem grow up through the soil and take root in it. When well established the parent stem is cut into sections, each bearing roots and a shoot.

Propagation by Seed

The use of seed as a means of increase is certainly the easiest method for the aspens, but of course it

produces a mixed, not a clonal, population. The technique has recently been fully described (Gray 1949, Miron 1939). Perhaps the most important points are the necessity of sowing the delicate seed (250,000 seeds per lb.) (Engstrom 1948) on a very fine seed-bed, the remarkably quick germination, and the need for very careful watering in the early stages. It is probably that spraying (Engstrom 1948) is really more appropriate than watering for this purpose. Under greenhouse conditions the seed can be sown on blocks of peat, and pricked out at a very early stage, or on quartz sand watered with a nutrient solution (Johnsson 1942). Poplar seed can be stored for periods of several years if carefully dried to a low moisture content, and kept at low temperatures in air-tight bottles (Sato 1949). It is possible to store poplar seed or to send it from one continent to another in ordinary packages, but it is safer where possible to sow it as soon as shed.

Although propagation by seed is usually confined to the aspens, it has been used in America for raising *P. deltoides* (Bull and Muntz 1943). It is of course the second stage in the raising of hybrid poplars of any kind. For once the cross has been made the resulting seed must be grown, before the seedlings can be selected and propagated vegetatively. According to the vigour of the variety, seedlings may attain heights of from six inches to two feet in the first year, but naturally they will not produce one year plants of the vigour that can be raised from cuttings.

Propagation by Sets

A set is, in practice, a large cutting consisting of a whole branch, and roughly the same size as a standard plant ready for use in the field. Sets are used for direct planting in the field, and, provided they are of good quality, the soil is reasonably moist, and they are planted correctly, results may be as good as those attained by the use of plants. A great deal of discussion has taken place on the rival merits of sets and plants (Houtzagers *et al.* 1941) and the general conclusion is that given above, namely that they are as good as plants on the best sites, but should not be used on the more difficult ones. For instance in the Argentine (Anon. 1948 B) sets are recommended for use on good ground with an abundance of water for irrigation, and they are suggested for use on American bottomlands (Bull and Muntz 1943).

But even more important is the difficulty of getting sets of good quality, unless they are specially grown, and the ever present temptation to take sets, which will inevitably be of poor quality, from standing or recently felled trees (Fig. 4). Apart from the extreme top of a fairly young tree, it is almost impossible to get really straight sets, eight to ten feet high, from the branches of a tree. Any crookedness in the set is likely to be perpetuated in the butt of the new tree and will greatly reduce its value. Also far too much pruning of side branches is required to make even a fairly shapely set from a branch, and the pruning wounds may well serve as means of entry for fungi. If sets are to be used it is far better to produce them from a stool bed run on a two-year instead of a one-year rotation, as for cuttings. The longer rotation may, with advantage, be combined with some reduction of the number of shoots, three to eight sets being grown, according to the vigour of the stool.

PLANTING

Spacing

In choosing the best spacing there are various points which need to be considered. First, we are dealing with a tree that in all stages of its growth requires plenty of light and plenty of root space, particularly the former. Second, poplar thinnings, if too small for veneering or for cutting into boards, cannot always easily be disposed of. Third, it is not possible to leave poplars to lose their side branches naturally ; if they are planted sufficiently close for this to occur, growth will be severely restricted. It will be seen therefore that poplar should never be planted so close as to require early thinning, and that planting at the final spacing, so that no thinning whatever is required, is quite a reasonable proceeding. It should also be borne in mind that in such a widespaced crop it is very difficult to thin, except on an automatic basis, i.e. by removing every second or every third tree. Any attempt to fell the smaller or more crooked stems will be apt to produce far too much irregularity in the spacing of the final crop.

In the more progressive poplar growing areas there is now a strong tendency to plant at a spacing which will allow the crop to be left untouched until it is ready for its final felling. But a very wide variety of spacings have been recommended in the past, and comparatively close spacings are still in use in many districts. One of the closest spacings recommended is in South Africa (Schiemer 1940, Anon 1949) where 8 ft. by 8 ft. is used for *P. deltoides*. This close spacing is justified on the ground that in Europe other species such as alder were used as nurses, and that no suitable nurse is available in South Africa, that the strain of *P. deltoides* used is a branchy one, which requires close planting to restrain branch formation, and that open grown trees make too rapid increment to be of good timber quality.

It is suggested in the South African publications that the trees should be thinned to 200 per acre, in the 10th year (giving an average spacing of about 15 ft. by 15 ft.), but even this would still leave them

very close. Similarly close spacings, 6 to 8 ft. by 10 ft. (500-700 trees per acre), have been suggested for plantings of Cottonwood, *P. deltoides*, in the United States (Anon. 1947, Bull and Muntz 1943), and it is considered that at this spacing the first thinnings will be large enough for pulpwood, for which of course there is a ready market in America. Even closer spacings, justified on the grounds of suppression of competing grass, have been used in America for hybrid poplars grown for pulpwood ; it would appear likely that any advantage gained by grass suppression would be more than offset by competition between the poplar themselves.

In Europe much wider spacings are now recommended for hybrid poplars. In Belgium (Herbignat 1949 A) 26 ft. apart each way (64 trees per acre) is regarded as a desirable minimum, and this spacing can be increased to 33 ft. by 39 ft. or even 50 ft. each way, if it is desired to continue grazing under the trees. It is considered also that the minimum distance could be reduced to 23 ft. each way (84 trees per acre) for × *P. robusta* and other poplars with narrow crowns, and this view is supported by Wijkstrom (Wijkstrom 1947). In Belgium × *P. robusta* has reached a sufficient size for match veneering grown without thinning at a spacing of 21 ft. each way (100 trees per acre). But it seems fairly certain that this is the minimum for an unthinned crop. In Italy the usual spacing is 20 ft. each way (109 trees per acre), but a great deal of poplar is used for pulping, the complete crop often being cut for this purpose, so that small sizes can be utilized. Very often in Italy (Piccarolo 1948, Peace 1948) this spacing is altered to allow cultivation of crops between the rows during the early years of the plantation, typical spacing in this case being about 10 ft. by 27 ft.

In France (Pourtet 1950) it is now considered that 23 ft. (84 trees per acre) is a minimum distance for useful produce and satisfactory increment. The reasons given for this figure are the low value of thinnings and the high risk that greater densities will retard the growth of the final crop trees. In fact, many growers in northern Europe are rapidly coming to the conclusion that the value of thinnings in poplar is more than offset by the cost of planting and tending them, and the risk of their interfering with the final crop trees.

Despite this there are many, particularly in Germany, who argue that close spacings are necessary in order to make proper economic use of the ground, and that a ready market will be available for the thinnings as pulpwood.

In Great Britain, the market for small poplar thinnings is comparatively poor, although boxwood provides a good outlet for poles down to a five-inch top. There is a good deal to be said, therefore, for planting at final spacing, i.e. at distances varying from 22 to 24 ft. each way (90-70 trees per acre), according to the size of the crown of the variety used. On no account should a spacing of less than 18 ft. each way (134 trees per acre) be adopted. Wider spacings than 24 ft. may give more rapid growth in the later stages, but the number of plants per acre is rather low.

There is some evidence that *P. trichocarpa* is less affected by crown competition than other varieties, possibly because naturally it is more of a woodland tree than the Black poplars. If a canker-resistant variety or hybrid of *P. trichocarpa* is discovered, it may be possible to use rather closer spacings than those recommended for Black hybrids, without appreciable reduction in the rate of increment.

As regards line planting the situation is somewhat different, since all the trees will have free growing space in two directions ; even with double rows there is freedom of growth on one side. This of course enables a closer spacing to be used. In Italy, where the trees are intended for pulp, they may be planted as close as 6 ft. in single rows (Peace 1948). In Belgium (Herbignat 1949 A) 17-20 ft. is recommended as a suitable spacing for single or double lines. General opinion seems to be that 20 ft. in the lines is a desirable minimum, and that there is no great virtue in using a much wider spacing. Of course thinning in line plantings is most undesirable, since it can only be done by removing every other tree. The suggested spacing of 20 ft. will allow the production of veneering size logs without thinning.

Methods of Planting

Unfortunately very little experimental work has been done on methods of planting, and in many cases early establishment has proved far more difficult than the quality of the plants and the site suggested. It is definitely known that the establishment of poplars is much easier if competition with other vegetation is reduced. This has been conclusively demonstrated in America (Schreiner 1945) by planting cuttings of two hybrid poplars (*a*) direct in grass, (*b*) in patches from which the grass had been removed, and (*c*) in patches from which the grass had been removed, but dug in again at a depth of 8 in. The average height of the plants in the three treatments at the end of four years was 1½ ft., 6 ft. and 15 ft. respectively. This suggests that ploughing would be the best soil preparation for the planting of poplars, if possible combined with the burying of some of the turves in the bottom of the planting hole. In view of the wide spacing used, complete ploughing would probably be wasteful, and ploughing strips would be quite sufficient. But of course such a treatment would only be possible

1. × *Populus robusta* in a fertile valley in Bagley Wood, near Oxford. The trees were planted in the winter of 1940-41 when three years old and 6-9 feet high ; the photograph was taken in May, 1948, after seven seasons growth, when the average height was 33 feet.

2. × *Populus serotina* at de Selys Longchamps in Belgium. This tree, which has a quarter girth of 55 in., illustrates the large size which this hybrid can reach.

3. Part of a collection of selected natural hybrids of poplar, Villafranca, Piedmont, Italy. The trees are only fourteen years planted, which illustrates the extremely rapid growth possible on a good site in a favourable climate.

4. × *Populus serotina*, narrow-crowned variety, in the Marais Poitevin, France, pruned in order to get sets for planting. (This is not the recommended method of procuring sets).

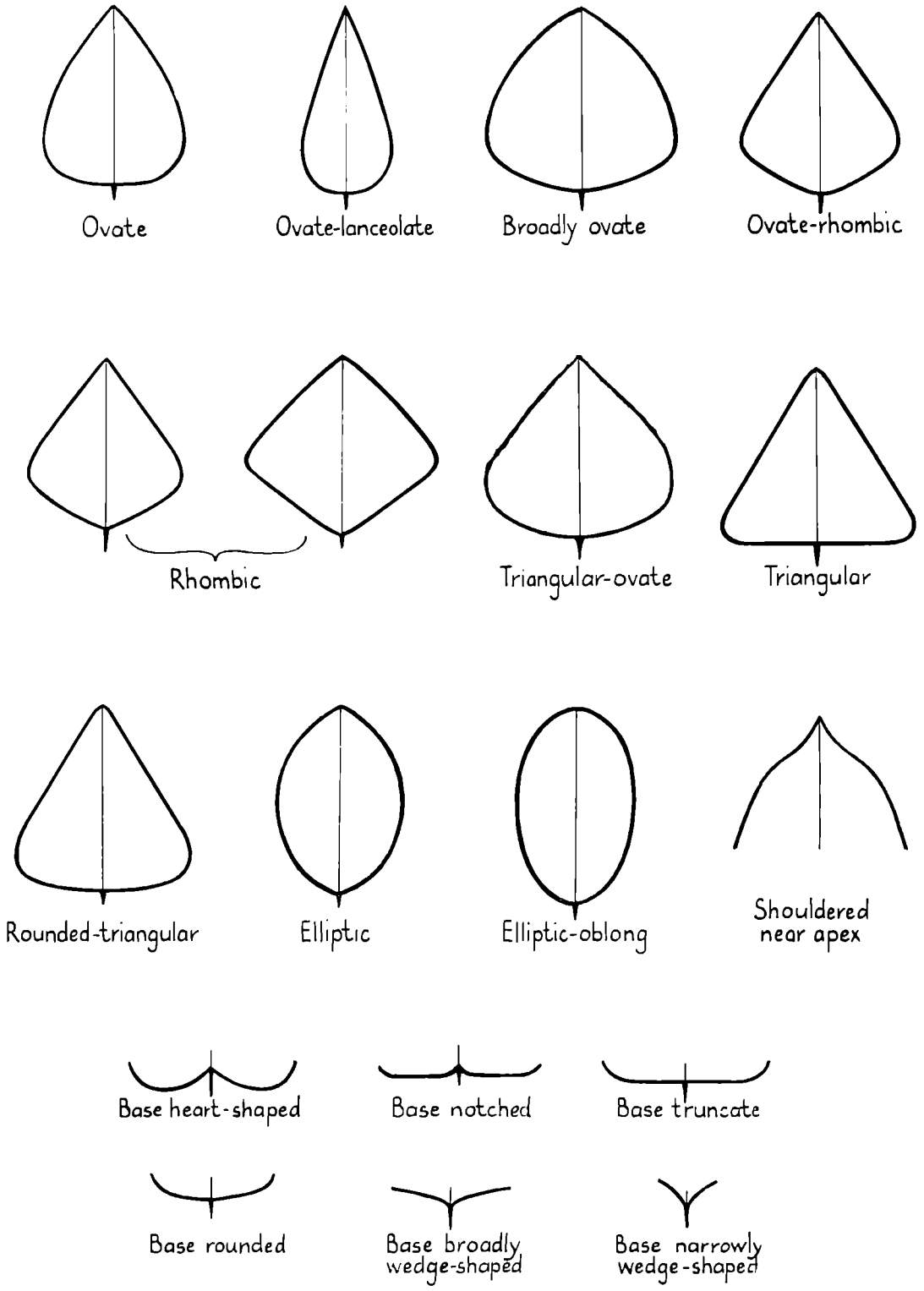
5. × *Populus robusta* four years planted, Pays de Waes, Belgium.

6. × *Populus serotina* along the side of a road near Coupar Angus in Scotland. Pruning would have improved the appearance of these trees.

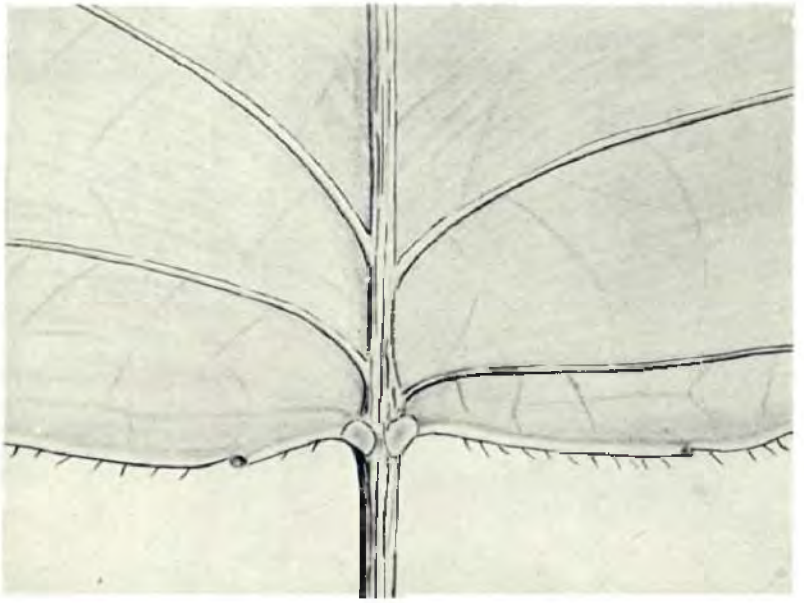
7. × *Populus gelrica* along the side of a field in Holland.

8. × *Populus rasumowskyana*, a poplar allied to × *P. berolinensis*, at Yardley Forest, Northamptonshire. Planted in the winter of 1936-37, photographed July 1950, after fourteen seasons growth. Growth on heavy clay with intense weed competition is slow.

9. × *Populus robusta* the first summer after planting, Yardley Forest, Northamptonshire. Such elaborate protection is not normally required.

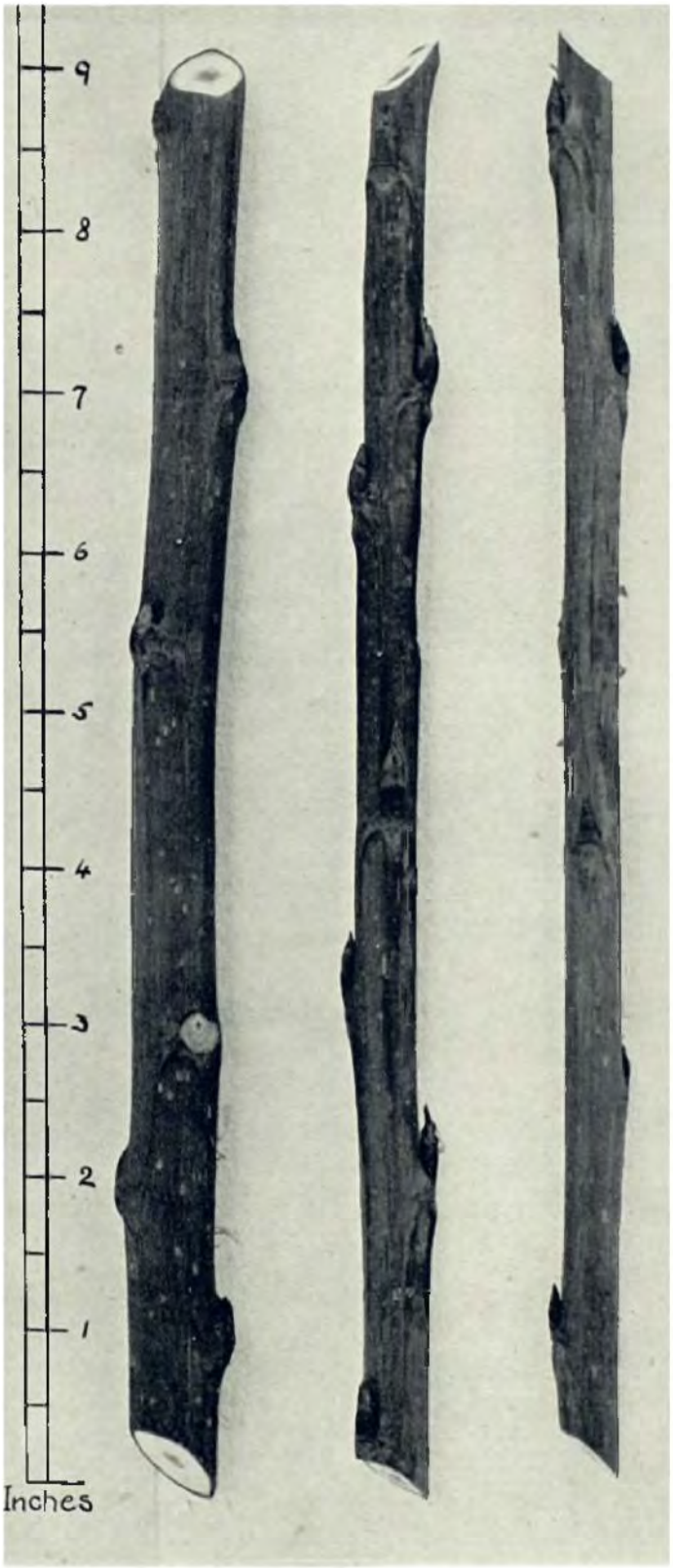


10. Diagrammatic outline of leaves and leaf-bases to illustrate the terms used in the key.

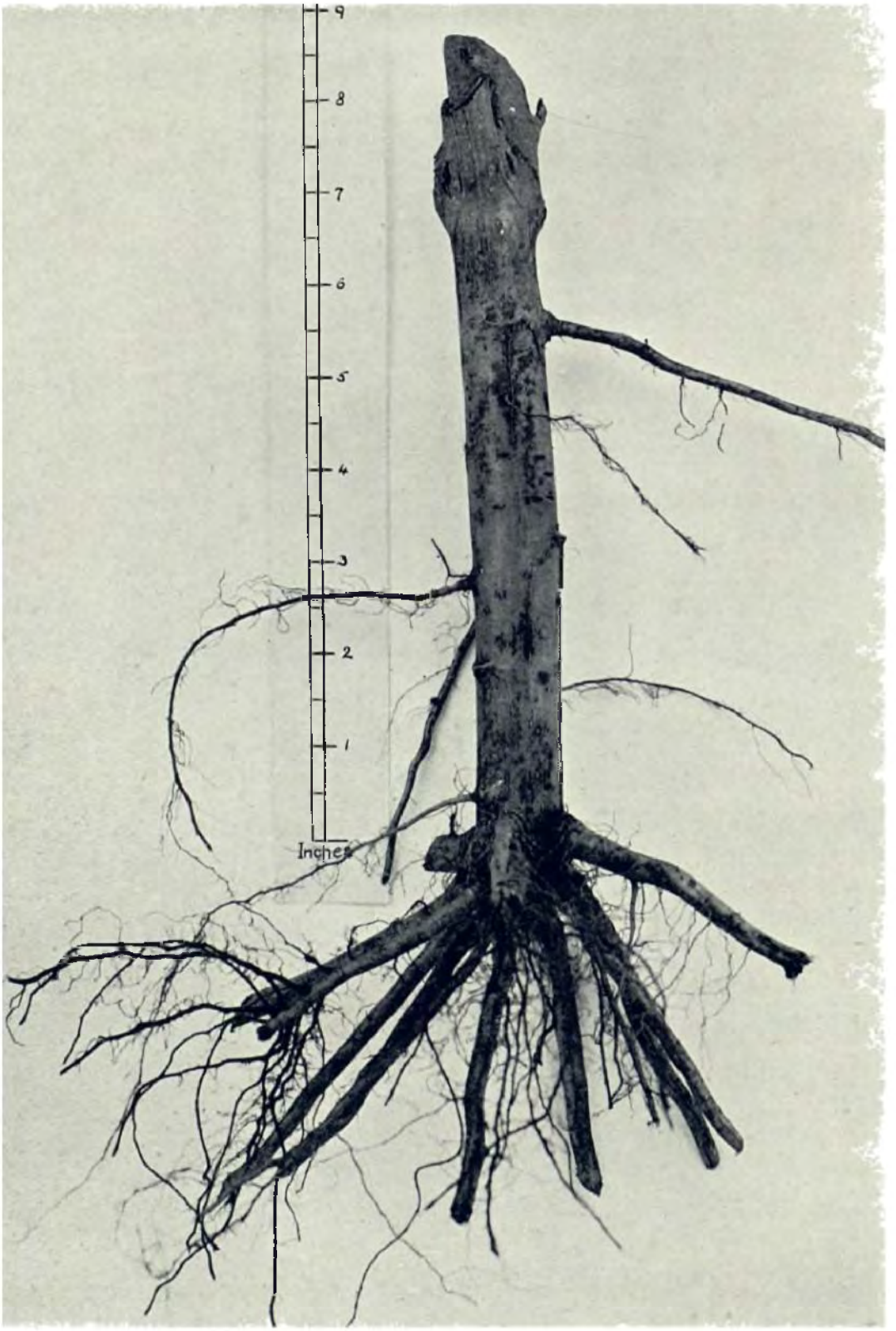


11. Diagram illustrating glands at the junction of leaf-stalk and blade, translucent margin, and marginal ciliation.

12. One-year rooted cuttings at Kennington Nursery, spaced nine inches by twelve inches, photographed September, 1948.



13. Typical good quality cuttings of one-year-old wood.



14. Rooted cutting lifted and cut back at the end of the first year.

15. Plants ready for lifting at Kennington Nursery. They were raised from cuttings cut back at the end of the first year, and replanted at their present wider spacing. They have been two years in their present position.

16. Newly planted poplars at Yardley Forest, Northamptonshire. This shows mound planting and the severe pruning given before planting.

17. The tree-bicycle in use for poplar pruning in Switzerland.

18. Pruning poplar in Belgium using a Swedish sectional aluminium ladder and a billhook.

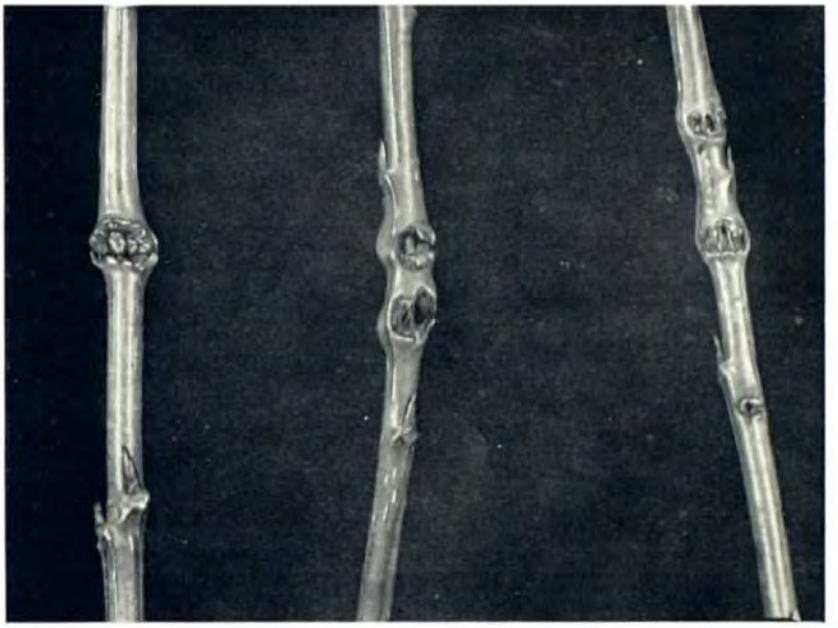
19. Large Poplar Longhorn Beetle, *Saperda carcharias* L. ; adult beetle. ·. 3.

20. Work of the Large Poplar Longhorn Beetle larva. Ejected frass in heap at foot of infested tree.

21. Large Poplar Longhorn Beetle. Larvae in tunnel exposed by removal of bark and outer layer of timber.

22. Bark of tree infested with Large Poplar Longhorn Beetle, showing canker development. 1.

23. Larval tunnels bored by Small Poplar Longhorn Beetle, *Saperda populnea* L.



24. Galls caused by Small Poplar Longhorn Beetle.

26. Red Poplar Leaf Beetle, *Melasoma* (*Chrysomela*) *populi* L. Larva. 1.

25. Young poplar shoots, damaged by *Barypeithes* (*Exomias*) *pellucidus* Boh.

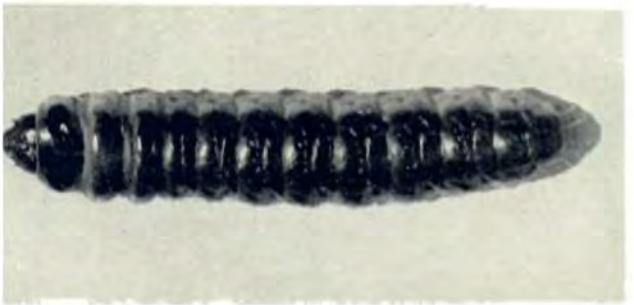
27. Red Poplar Leaf Beetle, *Melasoma* (*Chrysomela*) *populi* L. Adult. 1.

28. Hornet Clearwing Moth. *Sesia* (*Trochilium*) *apiformis* Cl. Adult. × 2.

29. Poplar bark showing emergence holes, and pupal skins of Hornet Clearwing Moth, *Sesia apiformis*. ½.

30. Base of a poplar tree with a portion of bark and wood removed to expose larval tunnels of Hornet Clearwing Moth, *Sesia apiformis*.

31. Goat Moth, *Coccus coccus* L. (= *ligniperda* F.) Adult. 1:1.



32. Goat Moth, *Coccus coccus* L. Larva. 1:1.

33. Goat Moth, *Coccus coccus* L. Pupa. 1:1.

34. Base of young poplar with part of the bark and wood removed to expose tunnels made by Goat Moth larvae.

35. Wood Leopard Moth, *Zeuzera pyrina* L. Moth in resting position on bark. × 2.

36 Wood Leopard Moth, *Zeuzera pyrina* L. Larva. × 1.

37. Pupal skin of Wood Leopard Moth, *Zeuzera pyrina* L. projecting from exit hole. 1.

38. Larva of Puss Moth, *Cerura* (*Dicranula*) *vinula* L. 1.

39. Lichen-covered cocoon of the Puss Moth in a crevice of poplar bark. 1.

40. Parasitised pupa of Puss Moth, revealed by removing the covering of the cocoon shown in Fig. 39. 1.

41. Scars on poplar bark resulting from damage caused by *Cimbex* Sawfly. X 1.

43. Surface of poplar veneer showing larval tunnels of Poplar Cambium Borer, *Agromyza carbonaria* Zett. (Actual size.)

44. Galls on leaf stalks of aspen, caused by Poplar Gall-midge, *Diplosis tremulae* Wtg.

45. Galls on leaf stalks of poplar, caused by Gall-forming Aphid, *Pemphigus bursarius* L.

46. Galls on leaf stalks of poplar, caused by Spiral-gall Aphid, *Pemphigus spirothecae* Pass.

47. Bacterial canker of poplar on × *P. eugenei* near Farnborough, Hants ; *P. nigra italica* on the right is unaffected.

48. Bacterial canker of poplar on × *P. eugenei* near Farnborough, Hants.

49. Bacterial canker on a set of × *P. eugenei* planted for testing purposes.

on level ground free from stumps, and very often poplar will be planted under conditions where ploughing would be out of the question.

Any action which will lessen the competition with surrounding vegetation during the first few years after planting is beneficial. One method of doing this is by mounding at the time of planting (Fig. 16). The tree is planted first in the normal way and then a mound of soil is thrown up around the base of the stem with the intention of smothering the competing vegetation, and acting as a mulch to the tree. Such mounds, which have the additional advantage of holding the tree firm so that no staking is necessary, should be much greater in area than in depth. If they are made too high there is a grave risk that in a dry season such rainfall as does occur, will not penetrate the mound to the roots underneath. It is probable that mounds will be most useful on sites with a high water table, where their effect will be merely to suppress the vegetation around the newly planted trees. If mounds are used on drier sites they should certainly be flat topped and shallow, and made of soil or leaves, not of turves or long vegetation, which might well act as a waterproof thatch over the developing root system. Another method is to put on, after planting, a mulch of cut grass, bracken, or straw. During the first year at least, application of a mulch or the use of a mound increases percentage survival, gives rise to healthier plants and generally results in increased height growth as compared with unmulched or unmounded trees. Investigation is certainly needed to discover whether the money spent on mounding or mulching would not be better used to provide more buried humus at the time of planting, fertilizer to promote rapid early growth, or in the suppression of the competing vegetation by some other means, such as hoeing. It is unfortunate that so little information is available on these matters.

In America hoeing before planting (Bull and Muntz 1943), and hoeing after planting (Anon. 1946) has been recommended, though its high expense is admitted. An alternative aid to establishment suggested is the application of two ounces of ammonium nitrate per tree. In Italy manuring with a mixture of artificial fertilizers containing nitrogen, potash, phosphate and calcium, at the time of planting, has been reported. The suggested rate of application is calculated to add nearly 1/- to the cost of planting each tree. Certainly the application of artificials, probably in the form of a complete fertilizer at the time of planting, or particularly as easily available nitrogen in the summer, is well worth a trial, but the information available is not sufficient for any definite recommendations to be made. It is quite certain that any suppression of competing vegetation during the early years, either by mulching or by cultivation, will be beneficial. How much can be done in practice depends very largely on the nature of the weed growth, and on the labour available. If no work of this nature is done, establishment of the trees is likely to be delayed, especially on more difficult sites.

But none of these considerations offsets the importance of correct and careful planting. Poplar should be pit planted, and the size of the hole dug should be more than ample for the root spread of the tree as trimmed in the nursery. The reason for this is to provide a reasonable volume of loosened soil in which the tree can start its new root system. If possible turves or well rotted rubbish should be placed in the bottom of the hole; if farmyard manure or compost is available for this purpose it is wholly beneficial. The tree should be planted very firmly, but with well-broken soil around the roots especially if neither mounding nor staking is contemplated. Except in badly drained or in very heavy soils there is no reason against planting the tree rather more deeply than it grew in the nursery. On a very wet site the roots may be laid on the surface of the soil and covered with a mound of earth, but the soil underneath the roots must be cultivated and great care must be taken to see that the tree is windfirm. Early in the spring following planting, trees should be inspected, and any that have blown crooked should be re-firmed. If this proves difficult, staking may be resorted to, or a few turves may be placed against the stem to hold it in position If possible staking should be avoided, except for roadside trees, and unless special ties are employed, because of the risk of the tie cutting into the rapidly growing stem. Planting should be completed by the middle of March.

The method for unrooted sets is very similar, and there is little saving in cost on the actual planting. It is necessary to provide the set with loosened soil in which it can form roots, and this can only be done by digging a hole, as for normal planting. In the bottom of this hole a crowbar hole 9 to 12 inches deep is made, and the base of the set is pushed into it and thoroughly firmed; this serves to hold the tree in place. There is no evidence that this buried butt, which often dies, has subsequently any detrimental effect on the health of the tree. The soil is then put back as in normal planting. Any other treatment given should be on exactly the same lines as for a rooted plant. In fact the set will appreciate reduction of competition with weeds to an even greater degree.

The use of mechanical post-hole diggers is worthy of investigation in connection with the planting of poplars, especially sets, which can be planted in a hole of lesser diameter.

Mixtures and Underplanting

On the continent, unless the intervening ground is required for agricultural purposes, poplars are very often grown with an understory of hardwoods, usually alder. In some cases this is considered to justify even wider spacings, and in Germany poplars have been planted at 40 ft. apart each way, but interplanted with alder, ash and sycamore, with *Robinia* on drier sites. In Russia a variety of trees and shrubs are recommended for planting in mixture with poplars (Miron 1939). It has been suggested that mixture with alder, presumably owing to the fixation of nitrogen by its root nodules, and the heavy mulch which the fallen leaves make, is actually beneficial to the growth of the poplar, and figures have been published which appear to support this view (Herbignat 1949 B). On the other hand, of course, alder underplanting is only practised on moist soils, where competition for water is unlikely to be an important factor.

All the evidence available in Great Britain suggests that competition between the poplars and the other species is likely to occur in mixed plantings. Several instances are known where the largest poplars occur in those parts of a mixed plantation where, owing to early failure or suppression, the secondary species has failed to grow, and where the poplars are markedly undersized in all parts where the secondary crop is fully stocked. It must be admitted that most of these examples are on sites which were not optimal for poplar, and results on soils with a maintained high water table might well be different. Norway spruce, which might be underplanted for the Christmas tree trade, produces even under such light shade a lax habit, which renders it unsuitable for its destined purpose. Most hardwood crops will only have reached small pole size by the time the poplars are felled. It is very difficult to fell poplar without seriously damaging the understory. On the continent the small poles are faggoted and sold for firewood, but no such market is available in Great Britain. Under present circumstances it is considered that underplanting should not be attempted, except on an experimental scale, even though the amount of unoccupied ground may appear excessive.

MAINTENANCE

For a year or two after planting it is necessary to make sure that the trees are not shaken about by the wind ; and of course during the first few years any steps that can be taken to reduce the competition with vegetation around the roots will certainly be beneficial. Such work should take the form of hoeing or mulching. Mere cutting of the weeds around the base of the trees is not likely to do any appreciable good. On coppice areas the shoots from the old stumps must not be allowed to overshadow or whip the poplars. In fact, coppice shoots should be cut back for a considerable distance round each poplar, for even side shade is most detrimental to these light-demanding trees.

But by far the most important work throughout the life of the tree is pruning, which should be done so that about half the total height of the tree is completely free from branches. In young trees up to five or six years from planting the proportion of clean stem may be rather less, and in older trees it may be rather more than half, though of course a point will be reached beyond which it is impracticable to prune, and from then on the proportion of crown to clean stem will increase as the trees continue to grow taller. Ideally, pruning should be carried out every year ; every third year may be regarded as the absolute maximum, but it must be done more frequently than this for the first few years after planting, and even after that period, the more frequent the pruning the better will the results be. After planting, pruning should not be started until the tree is well established. When the tree is small secateurs can be used, and later as the branches become stouter a billhook is the best tool. Green poplar wood does not saw particularly well, but small pruning saws of the " Bushman " type may be safer than billhooks in unskilled hands. When the branches to be cut can no longer be reached from the ground, the work can either be done using a ladder and a billhook, or else pruning chisels can be adopted. These should be of the type with a main cutting blade at the top and a secondary blade on one side at the bottom (Wolryche-Whitmore 1950). The main stroke is given by sliding the blade quickly up the tree and into the bottom of the branch to be removed, a second downward stroke onto the top of the branch with the secondary blade usually completes the cut. There are two essentials if this method is to be used, the branches must be removed while they are still alive, and before they are too large. Chisels of this kind can be used with poles up to 12 or even 15 ft. long, so that a clean stem of 20 ft. is fairly easily procured. Pole saws can be used, but not so high up the tree as chisels. Pruning to a greater height than this is usually carried out with ladders, though in Switzerland the so-called tree-bicycle (Fig. 17) has been used for this purpose. In Belgium sectional aluminium ladders are now being used (Fig. 18) ; with these the climber carries additional sections up the tree with him slung to his belt, the actual pruning is done with a billhook. It is hardly possible to use pole pruners from a ladder, as the balance necessary for a strong two-handed thrust cannot be maintained in this position. Therefore, if pruning is to be carried to a greater height than can be reached by pole pruners, some

form of ladder or climbing apparatus to reach the full height will be required.

A special form of pole pruner has been elaborated in Belgium (Dubois 1949). The first push up the tree embeds the cutting blade in the bottom of the branch ; the head of the pruner is so constructed that it is then possible, leaving the blade in the branch, to slide the pole down and push it up, each upward stroke knocking the blade further into the branch, until it is finally severed. In use it appears somewhat heavy, but efforts to produce a lighter type of pruner embodying the same hammer principle might be worth while.

After pruning, epicormic shoots are likely to appear on the trunk, especially in open grown trees ; they arise mainly from the bases of pruned branches. They should be removed at the next pruning. If pruning is neglected, and then a large number of whorls of branches are removed at one time, a very large number of epicormic shoots will be produced. Regular pruning results in far fewer epicormics.

If poplar has been sufficiently widely spaced no thinning will be required, but if spacings closer than 24 ft. each way have been adopted (unless a narrow crowned type has been used), thinning at least once will be required to produce a properly grown final crop. It has already been pointed out that it is very difficult to thin a crop already so wide-spaced except by the removal of a definite proportion of the trees on a geometrically arranged basis, i.e., every second tree in every second row, or some arrangement of that kind. Every effort should be made, by minor adjustments of the method, to include the smaller and more crooked trees among those removed, but it will be found that there are strict limits to the extent to which this can be done. Thinning should be carried out as soon as the crowns begin to meet. If thinning is left till there has been real crown competition, recovery of growth afterwards is likely to be delayed. A closely planted and badly underthinned plantation may fail to respond to thinning, and windblow may be the only result of the operation. It needs to be stressed that delay in thinning poplar is a very serious matter. More than half the poplar plantations already in existence in Great Britain have been spoilt by under-thinning, and many others have been seriously damaged.

COSTS OF ESTABLISHMENT

Before considering the yields that can be expected from poplar it may be well to discuss briefly what little information is so far available on costs. It is generally considered that on 1951 costs (basic agricultural wage 100s. per week) it should be possible to produce a three-year-old plant for 1s 8d. Planting is likely to cost about 1s. 4d. per plant, this includes removing turf, digging holes, planting, and mounding, as well as overheads, but does not include any special soil preparation such as ploughing, or any application of manures. This compares with a figure of 1s. given in Italy, where labour costs are probably lower. Sets will be cheaper to produce but are likely to cost nearly as much to plant as rooted plants. Unfortunately, no reliable figures are available for the cost of pruning, which is likely to increase slightly year by year as greater heights are reached. At a very rough estimate weeding and pruning should not cost more than 7s. 6d. per tree for the whole rotation. Fencing against stock and rabbits may add a further 1s. to 1s. 6d. to the cost per tree.

Government planting grants are at present (1951) available in Great Britain for poplar planted either in plantation form, or in rows, the rates being £8 per acre for plantations, and 2s. per tree for rows. Copies of the current regulations may be obtained from the Secretary of the Forestry Commission, 25, Savile Row, London, W.1.

RATE OF GROWTH AND YIELD

The volume production per acre of poplar can never be high owing to the wide spacing required, so that the productiveness is dependent mainly on the short rotation, which enables two or three crops of poplar to be harvested from one piece of ground in the same time as is required for only one rotation of a coniferous crop. On a very good site, final crop yields of about 4,000 cu. ft. per acre, quarter girth over bark, can be expected. A number of typical examples in Great Britain and abroad are given in the Table 4. Comparative volume data are not yet available for the different varieties. The figures given below, therefore, should be regarded merely as throwing some light on the general behaviour of the faster growing hybrids, and should not be used for comparisons between the different poplars included.

The data for Belgium were kindly supplied by the Union Allumetiere S.A. In Italy (Piccarolo 1948) individual tree volumes of 22-34 hoppus feet are said to be reached after 12-15 years' growth.

It will be noted that in general the yields are rather low, this is a reflection partially of the number of immature plots included, and partially of the number of English plots which have been badly treated or are on second-rate sites. The figures from Ryston and Brahan Castle give some idea of the possibilities on a good site, and the latter is certainly encouraging as regards Scotland. The effect of under-thinning on the volume of the tree is clearly seen by comparing the two × *P. robusta* plots at Ryston, on the two plots at Hainin, in Belgium. The plot at Léau in Belgium has been

Volume Production of Poplar

TABLE 4

Quarter-girth measure, over bark

Place	*Species*	*Age (years) from planting*	*Height (feet)*	*No. of trees per acre*	*Volume per acre (cubic feet)*	*Volume per tree (cubic feet)*	*Volume removed in thinnings (cubic feet)*	*Remarks*
Stagno, Lombardo, Italy	Black hybrid	6	—	180	1,250	7·0	—	Never thinned
Stagno, Lombardo, Italy	Black hybrid	12	—	150	3,150	21·0	—	Never thinned
Léau, Belgium	× *P. regenerata*	17	63	164 (approx.)	1,640	10·0	1,020	Twice thinned
Hainin, Belgium	× *P. regenerata*	17	64	295	2,600	8·8	—	Never thinned
Hainin, Belgium	× *P. robusta*	18	86	90	1,862	20·7	—	Never thinned
Ryston, Norfolk	× *P. robusta*	21	—	In line 30 feet apart	—	38·0	None	—
Ryston, Norfolk	× *P. robusta*	23	—	237	2,750	11·6	?	Badly under-thinned
Ryston, Norfolk	× *P. robusta*	24	—	74	2,500	33·8	?	—
Dawyck, Peebles	*P. trichocarpa*	25	55	540	2,395	4·4	Very little	Seriously under-thinned
Rendlesham, Suffolk	× *P. serotina* and a few × *P. eugenei*	28	80	56	1,066	19·0	1,332	Too dry a site and × *P. eugenei* is cankered
Marne Valley, France	*P. deltoides monilifera*	30	95 (approx.)	505	4,400	80·0	—	Never thinned
Brahan Castle, Ross-shire	× *P. regenerata*	? 30–35	85	100 (approx.)	4,150	20–90 (average 41)	None	The trees are grouped round a swamp, so irregularly that the number per acre can only be an approximation
Ladywood, Raby Castle, Dur.	× *P. serotina* ?	35 ?	64	280	2,080	7·4	Probably none	Mixed with 320 Norway spruce per acre and also under-thinned
Ladywood, Raby Castle, Dur.	× *P. serotina* ?	35 ?	67	160	1,074	6·7	Probably none	Mixed with 410 Norway spruce per acre and also under-thinned
Mundford, Norfolk	× *P. serotina*	43	66	In line 31 feet apart	—	26·7	Negligible	On a very dry site, and recently in severe competition for water with neighbouring Scots pine
Cologne, Germany	× *P. serotina*	45	95	5	915	183	None	Open grown with grazing between

thinned twice, but the effect of the original close spacing shows clearly in the small individual volume of the standing trees. The big volumes given by the older plots at Brahan Castle and in the Marne Valley show the rapid increase of volume which can be made by poplars between 20 and 30 years of age, growing freely on a good site.

Naturally the desirable rotation will vary according to the quality of the site, but it is suggested that for the southern half of England rotations from 24 to 30 years will probably be satisfactory, and for the north rotations from 30 to 36 years.

It is often suggested that it might be possible to grow poplar for pulping in Great Britain on

rotations of ten to fifteen years, but on the best sites this would only produce volumes of 1,500-2,000 cu. ft. per acre, even with close planting. Provided the trees are given sufficient growing space there should be little falling off in the width of the annual rings or in height increment during the first 25 years. If these are both maintained the actual volume increment will increase as the tree grows older, for an equal thickness of wood will be laid down each year over a bigger area of stem. Thus the volume per acre will increase much more between 15 and 20 years of age than it did between 10 and 15. Even for pulpwood, therefore, the longer rotation should give better returns.

Yield tables for poplar have been recently published in Germany by Hesmer (Hesmer 1951) and limited selections from them are quoted below. The high volumes extracted in thinnings are due mainly to the high initial density of 650 plants per acre, though this is reduced to 320 at five years in the case of Quality Class I and II, and at ten years in the case of Quality Class III, without of course producing any thinning yield. The tables then envisage halving the number of trees every five years till the final density of 40 trees per acre is reached at 25 years for Quality Classes I and II, and at 30 years for Quality Class III. It seems fairly certain that the yields given in the table for Quality Class I could only be reached on the very best sites, and with enormous care over thinning, so that there was no check in growth.

Yield Table for Poplar Plantations

(From Hesmer 'Das Pappelbuch')

TABLE 5 *Quarter-girth measure over bark*

Quality Class	*Age (years)*	*Height (feet)*	*No. of trees per acre*	*Volume per acre (cubic feet)*	*Volume removed in thinnings (cubic feet)*
I	20	95	80	2,221	3,703
	25	111	40	2,221	5,475
	30	118	40	3,456	5,475
	35	125	40	4,892	5,475
II	20	79	80	965	1,750
	25	92	40	1,010	2,558
	30	102	40	1,660	2,558
	35	108	40	2,525	2,558
III	20	59	160	808	1,167
	25	72	80	808	1,817
	30	82	40	696	2,378
	35	89	40	965	2,378

Very similar tables (though with different heights for comparable ages and quality classes) are given for poplars in single rows ; some figures from these are given in table 6.

Volumes of individual Poplar Trees grown in Rows

(From Hesmer ' Das Pappelbuch ')

TABLE 6 *Quarter-girth measure over bark*

Quality Class	*Age (years)*	*Height (feet)*	*Volume per tree (cubic feet)*
I	20	79	38
	25	92	71
	30	102	111
	35	108	144
II	20	74	27
	25	87	51
	30	97	81
	35	103	112
III	20	69	17
	25	82	37
	30	92	61
	35	98	88

Both tables are based on measurements of hybrid Black poplars.

Of rather less direct interest to foresters in Great Britain is the yield table for aspen given by Mathiesen (Mathiesen 1949). This table is for heavily thinned aspen stands on the best soils in the experimental forest at Peravalla in Estonia. Some figures selected from this table are given below. They show clearly the much slower rate of growth of aspen as compared with hybrid black poplars, even on a good site.

Yields for Aspen in Peravalla Experimental Forest, Estonia

TABLE 7 *Quarter-girth measure over bark*

Age (years)	*Average height (feet)*	*Volume per tree (cubic feet)*	*Number of stems per acre*	*Volume per acre (cubic feet)*	*Volume removed in thinnings (cubic feet)*
20	36	2·5	485	1,235	90
25	42·5	4·1	388	1,570	214
30	49	6·1	300	1,852	360
35	55	10·5	229	2,423	551
50	70·5	24·3	144	3,520	1,518
60	79	36·2	115	4,170	2,217

Chapter 3

DISEASES AND PESTS

I. DISEASES CAUSED BY INORGANIC AGENCIES

Considering the exposed situations in which poplars are often planted they cannot be regarded as particularly susceptible to damage by wind. When it does occur, wind damage usually takes the form either of complete uprooting of the tree, or breakage of the upper crown or limbs. On most soils poplars are able to establish a good hold owing to their extensive root systems, but where the water table is very high or on fen peats, which become slimy and fail to hold the roots when wet, extensive windblow can occur. The possibility of windblow and consequent disturbances of the soil should be borne in mind when planting poplars along canals or drains in which the water level may be higher than the surrounding countryside. Breakage of the crown occurs in some of the varieties with large leaves, particularly in × *P. generosa*. It seems probable that those varieties with smaller branches will suffer less from crown and branch breakage. With most varieties, however, wind damage to the crown or branches is associated with old age, and does not often occur in trees grown on a normal rotation.

The question of resistance to exposure is rather complex. Most poplars seem able to stand considerable exposure to inland winds provided general growing conditions are suitable. Some varieties lean away from the wind to a considerable extent, if planted in exposed positions; × *P. serotina* is particularly prone to do this. Naturally this results in some loss of straightness and therefore of timber value. Exposure to sea winds is a different matter, and the Black poplars certainly seem unhappy when planted near the sea, whereas *P. alba* is salt-resistant and might well be used more freely for coastal shelter. More information on varietal resistance both to sea and inland winds is badly needed.

Apart from some of the Asiatic varieties, poplars seldom suffer any injury to the twigs or buds from winter frost, however severe it may be. In this connection it is interesting that in Wisconsin, where the winters are much colder than in Great Britain, (Kuntz and Riker 1949) a fungus *Cytospora chrysosperma*, which will be discussed later, is considered to be a much more important cause of dieback than is winter injury. Unfortunately, however, poplar is occasionally subject to frost crack. This is apparently due to unequal expansion of the wood on freezing and thawing, and occurs most frequently on the south side of the tree, where alterations of temperature are most rapid. The cracks extend deep into the wood, and entirely spoil the trunk for veneering purposes. During the summer the efforts of the tree to heal the wound result in a raised ridge of bark above the crack, and it is at this stage that frost crack is most readily detected. It is not a sufficiently common phenomenon for any information to be available on the relative susceptibility of different varieties, nor is there any definite evidence for associating its occurrence with site factors, such as a particular soil type.

As regards spring frost, poplar can be considered a fairly hardy tree, though there is considerable variation between different varieties, associated to some extent with the date of coming into leaf. In the severe May frost of 1935 (Day and Peace 1946) *Populus* varieties regarded as a group were placed in the category of hardy trees on the basis of 80 records, 61 of which indicated complete freedom from injury. Few of the records gave the variety, so that no comparative information on frost susceptibility could be gained from them. Subsequent experience has indicated that there is a greater tendency for the varieties leafing early to be damaged, but there is no direct relationship between date of leafing and susceptibility to damage. Considering that many otherwise good poplar sites are in frost valleys the amount of real damage is slight; this is due not only to their fairly high resistance to frost, but also to their strong powers of recovery. Frost canker is quite commonly found on the stems of young poplar planted in frosty sites (Day 1948). It can be distinguished from bacterial canker, which is described later, because it causes much less swelling, and because it is normally confined to the lower parts of the main stem, whereas bacterial canker is found to a greater extent on the twigs and branches. It is seldom serious and tends to disappear as the canopy closes. The effect on wood quality is slight, since the cankered tissue is in the core of the log, which is usually rejected after veneer peeling. Frost is really only serious on weak plants, to which either in the nursery or on newly-planted ground it can cause serious delay of growth.

Poplars should not normally be planted on sites where they are liable to drought; on such sites they are particularly liable to early leaf-fall and consequent reduction of growth. On the other hand they can stand seasonal drought without permanent damage, and cottonwood (*P. deltoides*)

has been used as one constituent of shelterbelts in the dry regions of the mid-western United States. However, two avenues of × *P. serotina* on a dry site in East Anglia have been examined, where it was observed that growth fell off progressively as competition for water with a neighbouring young plantation of Scots pine increased. Eventually lack of water caused crown dieback, and apparently predisposed the trees to attack by Goat Moth, so that they had to be felled. This did not occur, however, till they had reached timber size at the comparatively late age of 43 years. Dieback due to competition for water has been reported also from the drier parts of America, where growth was quite satisfactory till the poplars started to compete with one another.

Sun scorch of the bark of young poplars has been known to occur when they were suddenly exposed to full sunlight by the felling of a tree crop, which had previously sheltered them from the south. Such damage is not likely to be of frequent occurrence, and poplars always grown in full sunlight are quite safe from it.

The effect of too much water in the soil has already been stressed when choice of site was considered. It is known that poplars can stand considerable periods of flooding, especially when dormant. It is important, however, that the flood water should finally flow off, slow disappearance by evaporation and seepage into the soil will almost certainly result in dieback, since the roots of the trees will suffer from lack of oxygen in the stagnant water.

As already stated, poplars are rather demanding as regards soil nutrients, and their reaction to poor soils and particularly to acid soils might almost be regarded as coming under the heading of disease. Their requirements of the rarer minerals are not known, but chlorosis (yellowing and mottling of the foliage), a symptom often associated with lack of one or more minerals, is sufficiently common to suggest that their requirements are not always met by the soils in which they are grown.

Poplars are generally regarded, quite rightly, as resistant to smoke and fumes, and this renders them particularly suitable for planting in or near industrial towns. On the other hand, their rapid growth somewhat limits their usefulness in such situations. There is no information to indicate any difference between varieties on their resistance to smoke and fumes.

II. DAMAGE CAUSED BY MAMMALS

Poplar is particularly liable to injury by domestic animals, not because they have any particular preference for the foliage and shoots, though it is obvious that they relish succulent poplar shoots in the late spring, but because the tree is so often grown in places to which farm animals have access. For a year or two after planting the main risk is browsing of the foliage, from then until the trees reach a reasonable size, damage may be caused by the animals rubbing against the trees. Occasionally bark is stripped from older trees, but generally it is safe to let in cattle, horses or sheep when the poplars have reached four to five inches in diameter. In Holland (Houtzagers *et al.*, 1941), it has been suggested that the trees can be protected by painting them with a mixture of lime and cow dung diluted with water to a thin paste. Protection against rubbing can be afforded by tying thorny branches of hawthorn, blackthorn or bramble loosely around the stem. For individual trees, cattle guards can of course be provided, but these are too expensive for use on a large scale, even for a long line-planting. There is no doubt that in the case of cattle and horses a temporary single strand barbed wire fence is by far the best protection. It should be set well away from the trees, so that the animals cannot reach over it, even if this means a temporary loss of ground. Sheep are less liable to do damage, especially if large plants are used, and in most cases no special precautions will be necessary.

Among the wild animals, rabbits are undoubtedly the most troublesome, and in any area where they occur in quantity complete rabbit fencing, or the individual encirclement of each tree with a 3-ft. sleeve of netting is essential. If the area to be planted is compact in shape, complete fencing is probably cheaper, but for irregular areas, and certainly for line or belt plantings, the sleeve method, which has the additional advantage that old netting can be used, is undoubtedly the cheaper. Grass or herbage should be tucked inside the top of the wire netting to stop chafing the stem. A cheap protection, when rabbit attack is not intense, but one that requires some skill, is to tie a bunch of reeds round the stem, with a withy, or with binder-twine, which rots fairly quickly and so does not constrict the growing stem.

Deer will certainly attack poplars, but there are few areas where poplar is planted that are likely to be heavily populated with these animals. As far as is known there are no records of severe injury by grey squirrels to poplar, and, as in the case of deer, squirrels are not likely to occur in large numbers on normal poplar sites. Voles, on the other hand, can cause serious damage by eating the bark at the base of newly planted trees, though once the trees are established it is probable that their rapid growth will enable them to heal over the wounds quite quickly, if they have not actually been girdled. Protection with mouse netting would be too expensive, and in any case voles can climb and attack above the netting level. It has been suggested

that vole damage might be prevented by painting the bottom 18 in. of the stem with a half and half mixture of tar and cow dung, which has also been found to protect poplars from rabbits for two years. Fortunately, voles tend to reach a peak population and decrease in any one area, so that a heavy attack seldom continues from year to year.

Their rapid growth, and the systematic pruning of the lower branches, keeps poplars reasonably free from wanton damage by hooligans, even when planted along roads. Great care must be taken if anything is tied round or fastened to the stem, since the rate of growth is so fast that it will quickly be overgrown by the tree. If the trees are staked, the ties must be loosened periodically. Labels should be tied on side branches, not on the main stem, and of course fence wire should never be attached to standing trees ; if left only for a short time it will become impossible to remove.

III. DAMAGE BY INSECTS

In some localities, a very large number of insects may occasionally be found feeding on the foliage of poplars ; the majority of these are omnivorous species normally associated with other broad-leaved trees and shrubs. Only those insects which habitually attack poplars will be dealt with here. Of these, the species with wood-boring larvae are considered to be of the greatest economic importance, but some of the insects which destroy foliage or bark may from time to time develop to pest proportions and cause considerable damage. For further information on the classification of these insects the reader is referred to a General Text Book of Entomology (Imms 1948). Coloured illustrations of the moths (South 1948) and of their caterpillars (Stokoe and Stovin, 1948) will be found in the Wayside and Woodland Series published by Messrs. Warne.

There is little existing evidence on the partiality of poplar feeding insects for any particular variety. Undoubtedly in a few cases, particularly with the leaf feeding insects, such preferences do exist.

Order : Coleoptera

Family: Cerambycidae

The Large Poplar Longhorn Beetle, *Saperda carcharias L.*, is widely distributed but is somewhat local in its occurrence. In localities where it does occur, it is generally the most destructive insect pest of poplars.

The adult insect (Fig. 19) is a little over an inch in length. The antennae are eleven-jointed, as long as the entire body in the female and rather longer in the male. The ground colour is black with a dense covering of fine ochreous-yellow hairs. The thorax is short and cylindrical ; the elytra or wing cases have prominent shoulders projecting beyond the base of the thorax, and taper rapidly towards the apex. Each elytron or wing case has two transverse bands of lighter yellow hairs, a broad band near the middle and a narrower one nearer the tip.

The beetles are active during June and July and eggs are laid singly in slits cut by the female in the bark of the lower portion of the stem of the tree. The larva is a legless, pale yellow grub with almost parallel sides. The upper and lower surfaces are furnished with pad-like protuberances which act as organs of locomotion. The larva feeds for a time just inside the bark where it excavates a large chamber in the surface of the wood. A hole is made in the bark through which wood fibres and excrement are ejected. The larva then proceeds to excavate a vertical tunnel in the timber, generally extending to upwards of a foot in length. As this work proceeds, the hole in the bark is enlarged to facilitate the ejection of frass. When full-grown, the larva is nearly one and a half inches in length and over a quarter of an inch in thickness and the tunnel, which is kept clear of litter, is maintained at a corresponding diameter throughout. The activities of the larva can readily be detected by the heap of ejected wood fibre or frass lying at the foot of the infested tree, at a point immediately below the hole in the bark, as seen in Fig. 20. Fig. 21 shows the same tree with a patch of bark and wood chopped off to expose the larval tunnel with the larva *in situ* near the top of the tunnel. Some infested trees may have several larval tunnels and the base of the tree may be almost surrounded by heaps of frass. On completion of its development, which may extend over a period of from 18 months to upwards of two years, the larva pupates within the excavation and the beetle ultimately emerges through the hole made by the larva.

The frequent use of the hole in the bark for the ejection of frass prevents occlusion during the period of activity, and a certain amount of sap exudation takes place at this point. In some cases this exuding sap becomes infested with the larvae of a species of Dipterous fly, and the activities of the maggots, probably supplemented by bacteria, give rise to fermentation of the sap, causing further delay in occlusion, and sometimes resulting in the development of a canker as seen in Fig. 22.

The Small Poplar Longhorn Beetle, *Saperda populnea L.*, is very numerous in some localities in the south of England and the midlands, but is less frequently found further north. Aspen is the chief host plant, but other species of poplar and willows are attacked.

The adult beetle is about half an inch in length,

and the antennae, which are clothed with grey hairs for about-two-thirds of their length, are almost as long as the entire body. The ground colour of the insect is pitchy-black with a covering of greyish-yellow hairs. The thorax has three longitudinal yellow bands and each elytron (wing case) has from three to five, but more frequently four spots or small patches of yellow hairs.

The beetles are active during the latter part of May to the end of June. The eggs are laid singly in niches cut in the bark of small branches, but sometimes the leading shoot is utilised. As a rule the attack is concentrated on small trees. Around the spot where the egg is laid, several slits are cut in the bark roughly in the form of a horse-shoe. During the first season the larva burrows a semi-circular tunnel between the bark and the wood, and a gall-like swelling develops around the point of attack. The larva subsequently burrows into the wood and bores a hole one or two inches in length along the centre of the stem (Fig. 23). In some cases several galls (Fig. 24) may be formed on the same branch or stem and subsequent breakage may result. The life cycle extends over two seasons from egg-laying to the emergence of the beetle.

Family: Curculionidae

The Osier or Willow Weevil, *Cryptorrhynchus lapathi L.*, is widely distributed but local in occurrence in Britain and is most frequently found in the south of England. It normally breeds in alder and willows, but sometimes attacks young poplars and is capable of considerable destruction. The insect is a potential pest where poplars are grown on a large scale.

The adult weevil is from a third to nearly half an inch in length. The ground colour is black, with a covering of black, pink and yellowish white scales. The thorax is black with a sprinkling of paler scales ; the basal two-thirds of the elytra are black, with a transverse band of pinkish scales, and the apical third is pinkish. Dense tufts of bristle-like scales occur on the thorax and elytra. The snout is rather thick and strongly curved ; the antennae, which are attached about the middle, are elbowed. When not in use the snout is tucked away in a groove between the front legs beneath the thorax.

The adult insect is active from the middle of April and throughout the spring ; the eggs are laid singly in holes in the bark, excavated by the snout of the weevil. The larva is a legless, yellowish white grub with a light brown head and dark jaws. On hatching from the egg the larva burrows for a time between the bark and the wood, sometimes completely girdling the stem, and later, burrows a tunnel two to four inches long in the wood. The life cycle may be completed in from one to two years, and the weevil over-winters in the larval tunnel.

The Short Snouted Weevils, *Barypeithes (Exomias) pellucidus* Boh. and *Barypeithes (Exomias) araneiformis* Schr., are similar in general appearance, and are about one-sixth of an inch in length ; pitch-brown to black in colour with a shiny surface sparsely covered with grey hairs ; the antennae and legs are yellowish-red, the thorax is rounded at the side and closely punctated and the elytra are oblong-ovate with deep, punctured striae.

The insects are normally associated with bracken-covered land, flood debris and other decaying vegetation. They are active in late spring and early summer, and are greatly attracted by forest nurseries in which heavy applications of bracken compost have been used. The adult weevils attack and destroy the bark of young trees just above ground level. Cases have recently been recorded where extensive damage was caused by the insects completely stripping the bark from the base of poplar shoots in nursery lines (Fig. 25).

Family: Chrysomelidae

Several species belonging to this family cause appreciable damage to the foliage of poplars, particularly in nurseries and young plantations. They are brightly coloured beetles, and in shape somewhat resemble ladybird beetles of the closely related family *Coccinellidae*, but can readily be distinguished by the absence of spots and other characteristic markings of the latter.

The Red Poplar-leaf Beetle, *Melasoma (=Chrysomela) populi* L. The adults of this species vary considerably in size and are from one-third to nearly half an inch in length. The head, thorax and scutellum are shining blue-black in colour, and the wing cases, or elytra, are brick red with black tips, and are strongly convex. The antennae are short, compressed, and thickened towards the ends.

On emergence from hibernation in the spring, the beetles lay yellowish-white eggs in batches of about ten or twelve on the underside of poplar leaves. The larvae are plump, greyish-yellow in colour, have three pairs of legs, and a row of black tubercles on each segment, and also white lateral projections on the second and third segments. If disturbed, they extrude rows of bead-like glands and secrete an acrid fluid with an odour like bitter almonds.

The larvae, which " skeletonize " the leaves by eating the surface layers, complete their development in three or four weeks, and pupate attached to the leaves. The adult beetles emerge about the end of July or beginning of August, and feed by biting irregular holes in leaves. The larva and adult beetle are shown in Figs. 26 and 27. In some

localities, particularly in the south of England, a second generation occurs during the autumn, and the beetles hibernate throughout the winter.

A closely allied species, *Melasoma* (*Chrysomela*) *longicolle* Suffr., occurs in some localities. This species is very similar to the above but is smaller and narrower, is without black tips at the apex of the elytra, while the punctures on its elytra are coarser.

The Blue Poplar-leaf Beetles, *Phyllodecta* species, are often referred to as willow-beetles, because they are frequently found feeding on willow foliage and shoots, but they are equally fond of poplar foliage and are often very destructive. They are small, bright beetles with a blue-black metallic lustre, with shades of bronze to green, particularly on the underside, and range in size from one-eighth to about one-sixth of an inch in length. The three British species may be distinguished as follows :

Phyllodecta vulgatissima L. has the punctured striae of elytra irregular and is blue in colour.

Phyllodecta cavifrons Thoms. has the punctured striae of elytra regular, the front of the head broadly excavated and the antennae fairly long ; the colour is dark blue.

Phyllodecta vitellinae L. has the punctured striae regular, the front of head with only a slight depression, not excavated and the antennae shorter than in the preceding species ; the colour is, as a rule, bronze.

Phyllodecta vulgatissima and *P. vitellinae* are both widely distributed and are destructive species. *P. cavifrons* is more limited in occurrence, but is a potential pest in localities where it occurs. All three species cause damage in both the larval and adult stage by skeletonizing leaves, and the beetles cause further destruction by gnawing the tender young shoots.

The beetle on emergence from hibernation in the spring, lays white eggs in batches of ten to twenty or more, on the underside of leaves. The larvae resemble those of *Melasoma* in general appearance, but are more elongate in proportion to their width. They feed in regular formation side by side, and on completing their development, pupate in the soil. The beetles emerge about the beginning of August and produce a second generation during the autumn. Because of the greatly increased numbers, this second generation is often more destructive than the first. The winter is spent in hibernation in crevices of the bark of trees, under stones, or in other sheltered places.

Family: Halticidae

The Flea Beetles, *Crepidodera aurata* Marsh and *C. helxines* L., are generally distributed, and are both destructive pests of poplars and willows in many localities. Like closely related species which are well-known agricultural pests, they get their name from the habit of jumping like fleas when disturbed. They feed on leaves in both larval and adult stages, and, as they are rather less than one-eighth of an inch in length, often escape notice until they become extremely numerous and cause serious damage. They may be recognised and distinguished by the following descriptions.

C. aurata is ovate in shape, and the thorax is reddish-golden or coppery in colour, very finely punctured and with rather deep basal furrow or transverse depression ; the elytra (wing cases) are green or violet, with regular rows of deep punctures, and the interstices are convex and very finely wrinkled. The legs are reddish, with the thighs of the hind pair brown.

C. helxines is very similar to the above in general appearance, but is somewhat larger and more robust in build ; the thorax is more convex, with a shallower basal furrow ; the sides are more rounded, the posterior angles are obtuse, and the elytra are broader and more convex.

Family: Scolytidae

The Poplar Bark Beetle, *Cryphalus* (*Trypophloeus*) *binodulus* Ratz. (= *asperatus* Gyll.), is rather less than one-twelfth of an inch in length, black and shining and scantily clothed with short hairs ; the antennae and legs are yellowish. It is widely distributed in England and Wales, and breeds in the bark at the top of poplars suffering from attacks of wood-boring insects and defoliators, where it may turn the scale and precipitate dieback. It is possibly of considerable importance in facilitating the development of bacterial and fungal diseases.

Order: Lepidoptera

(i) MOTHS WITH WOOD-BORING LARVAE

Family Sesiidae

The Hornet Clearwing Moth, *Sesia* (= *Trochilium*) *apiformis* Cl., is widely distributed and is numerous in many localities. It is a destructive enemy of poplars and willows, and occasionally breeds in lime and ash trees. The adult insect has a wing span of about an inch and a half, and, as its name implies, somewhat resembles a hornet, particularly when seen at rest on the bark of the tree from which it has recently emerged.

The head is yellow, and the thorax brown, with four yellow spots ; the abdomen is yellow, with the first and fourth segments black, and clothed with brown pubescence. The other segments are bordered with black, and the last three are brown on the back, with a line of the same colour on the sides. All the wings are transparent, with the borders, the nervures, and a transverse stripe on the fore-wings, rusty-brown. The fringes are tawny. (Fig. 28).

The moths are active during June and July, and lay their eggs in crevices in the bark at the base of the tree. The young larvae burrow into the bark and feed for a time in the bark and cambium, then excavate a cavity in the outer layer of wood. Later, they burrow into the wood at the base of the stem or into the buttresses of the roots, over-wintering while still in the larval stage, at the end of the first season. After burrowing in the wood during the second season, they pupate in cocoons at the entrance of their tunnels. The larvae are pale yellow in colour, with brown heads and dark brown, rather small, legs. When full-grown, the larva is a little over an inch in length.

The pupa is of a bright chestnut colour, with the wing cases, and rather long antennae free from the body. When the moth is about to emerge, the pupa wriggles until the front portion projects through an aperture in the bark, and the empty pupal skin remains in that position after the emergence of the moth (Fig. 29).

When a tree has been heavily infested over a period of years, the outer layers of wood become honeycombed with the larval tunnels, as may be seen in Fig. 30 where the bark has been removed to show the larval tunnels. Heavily infested trees tend to dieback from the top, and are sometimes killed outright.

Family : Cossidae

The Goat Moth, *Cossus cossus* L. (= *ligniperda* F.), is widely distributed, but is more numerous in the south of England than further north. It is a large, stout-bodied moth, with a wing-span of about two and a half to three inches in the male, and from three to three and a half inches in the female. The thorax is brown and grey, with a curved black transverse stripe ; the abdomen is dark grey with rings of a paler shade. The wings are a variable combination of shades of grey and brown, with transverse black streaks and irregular dark lines.

The insect breeds in the stems of poplars and many other kinds of broad-leaved trees, and often causes considerable damage to trees selected for attack. Unfortunately, it does not confine its attention to sickly trees, but seems to prefer isolated trees, or trees growing in avenues, on the margin of woods, or in open formation, although trees growing in close stands are sometimes attacked.

The female is very prolific and generally lays several hundred eggs which are deposited in batches in crevices in the bark, generally within a few feet of the base of the stem, during June, July or August, according to locality and other factors.

On hatching from the eggs the larvae burrow into the bark and excavate irregular chambers in which they over-winter. In the following spring they disperse, each burrowing its own tunnel in the wood. The larval stage extends over two to three years, during which time the larvae burrow oval-shaped tunnels of increasing diameter. From time to time they bore tunnels to the surface and eject frass and excrement. In spite of the large number of eggs laid, relatively few larvae attain full development. The high rate of mortality is generally attributed to cannibalism ; nevertheless, in heavily infested individual trees large numbers of fully developed larvae may be present.

When full grown, the larva may be quite three and a half inches in length. The head is black, and on the first segment there is a dark shield ; the sides and underpart of the rest of the body are pale yellow, and the upper part is shiny dark red ; the body is sparsely furnished with bristly hairs. The larvae normally pupate in coarsely made cocoons near the surface of the wood, but in cases of heavy infestation some of the larvae may leave the tree and pupate in the soil. The pupa is reddish-brown with lighter stripes on the abdominal portion. The larva, pupa and adult moth are shown in Figs. 31 to 33.

Although large or medium sized trees are often selected for breeding purposes, quite small trees are frequently utilised, and in these cases the central portion of the timber may be completely destroyed by the larvae. Fig. 34 shows the stem of a Black Italian poplar about four inches in diameter just above ground level, with the bark and outer layers of wood cut away to expose the infested portion. This tree was in full leaf and, judged externally, was still apparently quite healthy.

The Leopard Moth, *Zeuzera pyrina* L. (= *aesculi* L.), is numerous in the south of England, but occurs less frequently in other parts of the country.

The female moth has a wing-span of about two and a half to two and three-quarter inches, and the male is smaller. The fore-wings are white with numerous blue-black spots ; the semi-transparent hind-wings are also white with fainter spots. The thorax is white with three pairs of large spots ; the abdomen is long, slate coloured, and, in the female, furnished with an ovipositor (Fig. 35).

The moths are active from June to August, and lay their eggs singly in the bark of poplars and many other species of broad-leaved trees, as a rule attacking stems of small diameter. During the first season, the larvae burrow in a circular direction in the superficial layer of wood ; during the second season they burrow a vertical tunnel in the inner wood six to eight inches in length. When small diameter stems are attacked they tend to snap off at the point of injury.

The larva when full-grown is one and a half to two inches in length, yellowish white in colour, with

black spots. The head is rather small and almost black ; the segment behind the head has a black shield, and the last segment is black (Fig. 36).

The life cycle extends over two to three years. When full-grown, the larva pupates in a chamber near the surface. When the moth is ready to emerge, the pupa works itself partly through the exit hole to facilitate emergence, and the empty pupal skin may be found in this position (see Fig. 37).

(ii) MOTHS WITH LEAF-EATING LARVAE

Family : Notodontidae

The Puss Moth, *Cerura* (*Dicranura*) *vinula* L., is common in most parts of Britain where poplars and willows grow. The popular name refers to the furry appearance of the moth when at rest. It is light grey in colour, with dark transverse marks and numerous zig-zag lines towards the hind margin of the fore-wings. The hind wings are almost white in the male ; grey in the female. The thorax is lightly tinged with green, and has two pairs of large black spots. The abdomen is grey with two longitudinal black lines. The tarsi (the lower part of the legs) are black, ringed with white. The female has a wing-span of about three inches, the male somewhat less.

The eggs are laid in May or June, and sometimes the larvae almost completely defoliate small trees. The caterpillar is a very conspicuous object and is remarkable both in colour and shape. The head is pale brown, and a purplish band of variable shade and irregular width with a white border extends along the entire upper surface, spreading to the sides in the middle of the caterpillar, like a saddle, while the rest of the body is green ; the third segment is raised in the form of a distinct hump. Instead of a pair of anal claspers, the last segment is furnished with a pair of tube-like processes, with telescopic tips from which purplish-red whip-like filaments can be protruded at will. These are used to protect the larva against the attack of parasitic insects and other natural enemies.

When full-grown (Fig. 38) the larva excavates a hollow in the surface of the bark and constructs a strong cocoon, in the composition of which fragments of bark are incorporated. Pupation takes place within this cocoon, with the head near a specially prepared thinner area through which emergence of the moth is subsequently effected, facilitated by a solvent which it ejects.

When constructed in the crevices of rough bark, the cocoon is almost imperceptible (Fig. 39). Nevertheless it can be located by parasitic insects, and the thin-walled portion is utilised for oviposition. Fig. 40 shows the same cocoon with a portion of the surface removed to expose a batch of Hymenopterous parasite larvae feeding on the remains of the host larva.

Sometimes the cocoon is constructed in the bark of a young stem, in which case the preliminary excavation forms a weak spot, at which the stem may subsequently snap.

The Poplar Kitten, *Cerura hermelina* Goeze, is a closely related but much smaller insect of relatively minor importance. The larvae of this species also feed almost exclusively on poplar.

Family : Sphingidae

The Poplar Hawk Moth, *Smerinthus populi* L., which is comparatively large, is found about midsummer in most localities where poplars grow. It has a wing-span of about three to three and a half inches, and is very variable in colour, ranging from dove-grey to light purplish-brown, with darker bands and transverse lines ; the fore-wings have a white crescent-shaped spot near the middle ; the hind-wings are rusty-red at the base.

The larvae feed almost exclusively on poplar foliage during July and August, but are seldom sufficiently numerous to cause serious damage. They are green with oblique pale-yellow stripes ; the last segment has a yellow " horn ", tinged with blue at the base, and the front of the head is blue, bordered with yellow. When full-grown, they are about three inches long, and pupate in the soil.

The larvae of an allied species, the **Eyed Hawk Moth,** *S. occellatus* L., are also frequently found feeding on poplar foliage. They are somewhat similar to the above, but can be distinguished by the longitudinal white streak on the thoracic segments, while the oblique stripes on the sides of the body are white, and the " horn " is bright blue. The fore-wings of the moth are grey tinged with rose-colour, with brown areas and waved streaks ; the hind-wings are carmine-red with a grey margin, each with a large eye-spot.

Family : Lymantriidae

The White Satin Moth, *Leucoma* (*Liparis, Stilpnotia*) *salicis* L., is one of the worst pests of poplars and willows in some countries. This insect was formerly common in this country, but during recent years has been found only in a few localities. It is, however, a potential pest of importance and should not be neglected.

The moth is white with a satin lustre ; the antennae and the legs are black, the latter with white rings. The female has a wing-span of about two inches, and is active during July, laying from 100 to 200 eggs in batches on the stems of poplars or willows. Each batch of eggs is overlaid with a fluid which quickly solidifies, forming a pearly

surface, under which the eggs usually over-winter, the larvae appearing in April.

Occasionally the young larvae hatch out during the autumn of the same year, in which case they spin themselves up and over-winter in crevices of the bark. From April to June they feed on the foliage, at first eating only the surface tissues, but later they consume the entire leaves except the mid-ribs, and where the larvae are numerous large trees may be completely defoliated.

When full-grown, the larvae are about one and a half inches in length, with black heads and dark grey bodies, with large pale yellow spots along the back ; each segment bears three pairs of bright red tubercles with long hairs. In June each larva spins a loosely constructed web in which pupation takes place ; these may be in crevices of the bark, attached to twigs, or among remnants of foliage.

Other Defoliating Larvae of the Lepidoptera

In addition to the species referred to above, larvae of a great variety of moths belonging to several families may be found feeding on poplars in some localities, but the majority normally feed on the foliage of other broad-leaved trees and shrubs, and cannot be regarded as specific pests of poplars, although in the aggregate they sometimes cause considerable defoliation. This is particularly liable to occur when poplar is planted adjacent to deciduous high forest.

Order : Hymenoptera

Family: Tenthredinidae

The Poplar Sawfly, *Cladius* (*Trichiocampus*) *viminalis* Fall., is widely distributed and numerous in many localities. The female sawfly has a black head, thorax, and antennae ; while the abdomen is orange red, the legs yellow, and the wings transparent with light brown veins and stigmata (triangular spots). The entire body is rather more than one third of an inch in length, with a wing-span of about three quarters of an inch. The male is similarly coloured but the antennae are brown ; with a body about one quarter of an inch in length, and a wing-span of a little over half an inch.

The eggs are laid in slits in the leaf stalks of poplar, causing regular swellings on each side. The young larvae are pale green and hairy, later they become light-yellow in colour, and when full-grown they are orange with black spots. They feed side by side, close together in short rows, on the underside of the leaves, which they skeletonize during the process. A second generation occurs during the autumn.

The Birch Sawfly, *Croesus* (*Nematus*) *septentrionalis* L., is commonly referred to as the Birch Sawfly, but the larvae are also frequently found feeding on poplar and willow foliage. The insect is common in all parts of the country.

The head, the thorax, and the first three and last two segments of the abdomen are black, while the intermediate segments are reddish-yellow ; the tibiae and tarsi (middle and lower parts) of the hind legs are broad and flattened. The female has a wing span of about an inch ; the male about two-thirds of an inch.

The eggs are laid in slits in the veins of the leaves. The newly hatched larvae are pale-green with black legs. When half-grown they are green with black and yellow spots, and when full-grown, greenish-yellow with prominent black patches, and rather more than an inch in length. They feed on the edges of the leaves, generally with the rear portion of the body held erect. There are two generations a year.

Family : Cimbicidae

The members of this family are large, conspicuous sawflies, some of which are brightly coloured. They may be recognised by their clubbed antennae. The larvae feed on the foliage of various broad-leaved trees including poplar, but seldom cause appreciable damage. They have eight pairs of abdominal feet, and generally construct double cocoons, the outer one being of a leathery consistency.

A certain amount of damage is caused by the adult insect. One species, *Cimbex variabilis* Klg., gnaws the bark of poplar shoots, forming deep spiral grooves about one twenty-fifth of an inch in width, sometimes completely surrounding the young stem in several places. Subsequent occlusion leaves a scar with a very characteristic appearance (Fig. 41).

Order : Diptera

Family : Cecidomyidae

This family is comprised of a large number of fragile and often very minute insects with long antennae bearing conspicuous whorls of hairs ; the wings have few longitudinal veins, generally unbranched and with no obvious cross-veins.

The various species exhibit very diversified habits. Some are among the most destructive agricultural and horticultural pests, while the larvae of several species are predaceous and therefore beneficial. The family includes a large number of gall-forming species, some of which attack willows. One species, the **Poplar Gall-midge,** *Diplosis tremulae* Wtg. (Connold 1901), forms galls on the leaf-stalks of poplar (Fig. 44). Aspen is the host plant most frequently attacked.

Family Agromyzidae

The members of this family are small compact flies with transparent wings. There is a very wide

range of variation in size, some species are very minute, while others are almost as large as the common house fly, to which they bear a slight resemblance in shape and general appearance. They also vary considerably in their habits, and their economic status. The larvae of some species are predaceous and are useful factors in the control of certain insect pests. Many have leaf-mining larvae ; *Napomyza* (*Phytagromyza*) *populi* Kalt., mines extensive galleries in the leaves of poplars, while the larvae of other species tunnel in the cambium of various broad-leaved trees.

The Poplar Cambium Borer, *Agromyza carbonaria* Zett., causes damage of great economic importance. This insect is widely distributed, and numerous in many localities. The eggs are deposited singly in punctures made in the bark during late spring, and the larvae bore long irregular burrows in the cambium of the stem throughout the summer months. The larvae are opaque white, long and narrow, and when full-grown are about three quarters of an inch in length, and one twenty-fifth of an inch in width. On completing their development in the autumn they leave the bark, enter the soil and form dark reddish-brown puparia about one quarter of an inch in length, in which form they over-winter, and transformation is completed during the following spring.

The excavated larval tunnels become infested with bacteria, and the frass and injured tissues become discoloured and turn brown. As the growth of the stem proceeds, the larval tunnels are covered with a layer of new wood and ultimately become embedded in the timber, a new series of larval tunnels being formed each year while the infestation lasts.

If a previously infested stem is cross-cut, the larval tunnels in section appear as small brown spots of varying width, irregularly spaced and occurring in concentric rings corresponding with the boundaries of the annual rings (Fig. 42). These brown spots are generally referred to as "pith flecks", and used to be regarded as characteristics of the species of timber concerned. If the log is sawn or split lengthwise, the larval tunnels appear on the radial surface as narrow streaks, varying in length according to the angle of incidence. When logs are peeled as veneers, the larval tunnels appear on the surface as brown marks about one-twelfth of an inch in width, of irregular pattern and varying length (Fig. 43). These frass-filled tunnels with their damaged cell tissues constitute lines of weakness in the wood structure and render the material unsuitable for the manufacture of matches or plywood.

This species also attacks the cambium of willow trees, and is of particular importance in the case of trees intended for the manufacture of cricket bats, as the timber from trees which have been heavily infested may be rendered quite useless for making first-class bats.

A closely allied species, *Dizygomyza barnesi* Hendel, attacks the bark and cambium of osiers and renders the rods unsuitable for the manufacture of first quality baskets, and similar purposes. It has been shown (Barnes 1933) that stems infested by this insect may be attacked by bacteria resulting in canker formation.

Order : Hemiptera

Family : Aphididae

Several species of aphides are injurious to poplars ; some attack the bark of young shoots, others the leaves, and a few species cause the formation of galls.

The complete life-cycle of some species is still imperfectly known ; some may confine their attention to poplars and willows, but in others the individuals assume quite different habits and migration takes place from one host plant to another. Some species which cause gall-formations on poplars, also have root-feeding forms which produce one or more generations on entirely different types of plants, such as lettuce and buttercups.

It is known that some species of aphides act as vectors of virus and bacterial diseases, and some facilitate the attack and development of fungus diseases (Leach 1940). Little definite information is available as regards this aspect of the economic status of aphides in relation to the diseases of poplars, but it is a subject which merits further investigation.

The Gall-forming Aphid, *Pemphigus bursarius* L., causes the formation of pear-shaped or purse-like galls on the leaf-stalks of poplars, and occasionally on the mid-rib of leaves. The gall is formed by the queen aphid puncturing the tissues, causing a swelling the edges of which envelop the insect. Reproduction takes place within the gall which may develop to more than half an inch in length (Fig. 45). The young aphids feed and develop within the galls and on emergence, during the latter part of August, they disperse over the surface of the leaves where they continue to feed, often producing heavy secretion of " honey-dew ".

One form of this aphid (*P. lactucarius*) formerly regarded as a separate species, migrates to the roots of lettuce where it reproduces and may remain in the soil for upwards of a year, the progeny usually migrating back to poplars. This lettuce-root form (Theobald 1926) sometimes causes great destruction to lettuce ; and it is probable that the insect can develop and spread on lettuce in the absence of poplars.

The Spiral-gall Aphid, *Pemphigus spirothecae* Passerini, is a closely allied species, which causes the

formation of spiral-shaped galls on the leaf-stalks of poplars (Fig. 46). This insect is sometimes numerous in the south-east of England, but appears to have a somewhat restricted distribution. In some localities a large proportion of the leaf-stalks may be galled. So far as is known it has no alternate host, and confines its attention to poplars.

The Leaf-gall Aphid, *Pemphigus* (*Thecabius*) *affinis* Kalt., causes considerable malformation of the leaves of poplar; the attacked leaves curl and form gall-like pouches in which the insects produce a winged generation in late summer. These winged aphids migrate to buttercups (*Ranunculus*) where two generations are formed, chiefly on the roots, but occasionally on the underside of leaves near the ground. This form of the insect is known as *P. ranunculi* (Kaltenbach) and was formerly regarded as a separate species.

In October or early November, winged viviparous females, which are asexual and produce their young alive, and which form the second generation of this root breeding form, migrate back to poplars, and produce sexual females. These in turn lay eggs in which form over-wintering takes place. At the same time, over-wintering may also take place in the form of nymphae (partly developed aphids) on the roots of *Ranunculus*.

In the spring, the new life-cycle on poplars begins with the hatching of the overwintering eggs from which the "fundatrix" or "mother queen" develops, and new leaf galls are formed.

The Poplar-bark Aphid, *Pterochlorus saligna* Gmelin., is a large aphis, which is common and widely distributed. The winged viviparous (asexual) female varies in general colour from greyish-brown, ochreous-brown, to dark-brown; the body has rows of transverse black spots and a dark dorsal mark. The cornicles or honey tubes are dark, large and cone shaped.

The apterous (sexual) female is dark ochreous-brown, with a dense covering of fine, shiny grey hair. The dorsal surface of the abdomen has rows of small transverse black spots and a large characteristic black horn-like process. The cornicles are the same as on the viviparous female.

This species often occurs in dense colonies on the branches and twigs of poplar and willow trees, also on osiers and sometimes on the bark of young poplar shoots. The colonies sometimes measure upwards of a foot in length with a width of two or three inches, and may consist of several hundred individuals. Each colony is started by a single female aphid, and the rate of growth of a colony may be very rapid. The wingless aphis are grouped side by side with their heads pointing upwards. Full-grown winged specimens are about one sixth of an inch in length and have a wing-span of about half an inch.

The Willow-bark Aphid, *Melanoxantherium salicis* L., also attacks the bark of poplars, forming large-dense masses, sometimes individual colonies contain several thousand individuals. The insect is widely distributed in Britain and is abundant in some localities.

The winged female is dark grey to black, the abdomen having two or more dorsal, and several lateral, grey to almost white patches. The wingless females have a paler greyish or greyish-blue dorsal median line, in some specimens this is almost white. The insect is easily distinguished from the previous species by its bright orange-red cornicles (honey-tubes), legs and antennae.

Both this and the previous species cause considerable damage to willows and osiers by stunting the growth, and by causing stained wood where the bark has been heavily infested. It is somewhat erratic in its appearance on these plants, and its occurrence on the branches of poplar trees seems to indicate that migration takes place between willows and poplars. It also seems possible that both these species of aphids may be associated with the occurrence of bacterial, or fungoid diseases of the branches or crowns of poplar and willow trees.

The Poplar-leaf Aphids. Several species of small aphids may be found feeding on the leaves of poplars. Of these *Chaitophorus populi* L. is probably the commonest and most widely distributed. In spring and early summer it sometimes clusters in large numbers on leaves and young shoots.

This species has three distinct types of female, and two types of male. The winged viviparous (asexual) female has the head and thorax black, the abdomen green with black transverse bands, and dark lateral patches, the cornicles black, and the whole body hairy. The wingless viviparous female is yellowish-green, mottled with dark green. The wingless oviparous (sexual) female, however, is various shades of green, mottled with dark brown.

The winged male is brownish-black with yellow rings on the abdomen, in some specimens the abdomen is almost entirely yellow; the antennae are about as long as the body. The wingless male has antennae much longer than the body.

In late summer the oviparous females lay eggs near leaf buds. The larvae are at first almost white, mottled with green. The nymphae (partly developed aphids) vary from yellow to dark brown. The adult insects are about one-twelfth of an inch in length.

A closely allied species, *Chaitophorus leucomelus* Koch., fairly numerous in some localities, causes the formation of blisters or bladder-like swellings on poplar leaves, and reproduces in the cavities. This species is probably associated with the occurrence

of the fungus *Taphrina aurea*, the bright gold-coloured fructifications of which often clothe the concave surface of the blisters.

Control of Insects on Poplars

In considering the subject of control, it is necessary to remember that several species which attack poplars are equally fond of willows ; many also attack fruit trees, and other broad-leaved trees. The effective protection of poplars may therefore be contingent on the simultaneous destruction of insects on other infested host plants in the immediate vicinity. Attempts to control certain types of insects, particularly wood-boring species, may be rendered futile if facilities for unlimited increase exist in other parts of the locality. Similarly, the successful control of bacterial, and certain fungus diseases, may well depend on the effective control of insect pests.

Injurious insect populations may be kept in check by biological, cultural, mechanical, or chemical control methods, or by a combination of these.

Biological Control

Potential insect pests are normally controlled at a low level of population density by their natural enemies, including birds, bats and other insectivorous mammals ; spiders ; parasitic and predatory insects, and in some cases by disease-producing organisms. Climatic and physical conditions also play an important part in the development and control of insect populations, and may also adversely affect their natural enemies, particularly birds. The absence or scarcity of one or more important biotic control factors may result in abnormal increase of any particular type of insect.

Much may be done to facilitate the natural control of injurious insects by fostering or helping to preserve and encourage their natural enemies, as for example by the provision of nesting boxes for birds, or the creation of suitable natural nesting conditions, by providing water during periods of prolonged drought, or food during very severe winters. Benefit may also result from the provision of suitable roosting places for bats, and the protection of hedgehogs and other insectivorous mammals. A careful study of the resident population of parasitic and predatory insects may reveal the absence of one or more very important species which may be introduced and established. The local parasite and predatory insect population may also be augmented by the cultivation of suitable food plants, on the flowers of which the adult insects feed.

Cultural Control

Risk of damage by injurious insects may be reduced by careful selection and cultivation of strains less attractive, or more resistant, to insect attack, though unfortunately our information on this matter is very limited. It is certainly important to make a correct choice of soil and site for plantations, and to give proper attention to drainage. It is also important to exercise careful management, including protection from damage to the bark and roots by fire, human agencies, live stock, rabbits and other animals, and generally to prevent any form of damage which may reduce vitality and predispose the trees to insect attack.

Mechanical Control

Mechanical control measures include the collection and destruction of eggs, larvae, pupae and adult insects before egg-laying takes place, also the removal and destruction of insect-infested stems and branches ; and the use of tree banding materials, light traps such as those used for catching moths, and similar devices.

Chemical Control

In most cases the insect pests of poplars may be controlled by the methods already referred to, but in certain cases the use of insecticides may be necessary. Numerous proprietary products are readily obtainable from well-known pest control organisations, or their selling agents ; who should be consulted as to the most suitable kind to use for any particular type of pest.

Great care is necessary in the large scale application of some insecticides because of their poisonous character, and their possible toxicity to the tree if applied in excessive quantities. It should also be noted that unrestricted use of insecticides may result in the wholesale destruction of parasitic and predatory insects and may create conditions under which a more severe type of infestation may develop. In all cases the prescribed instructions for use should be carefully carried out, and where large scale application is considered necessary it is advisable to enlist the services of a reputable pest control organisation, equipped with the necessary appliances, trained technical staff, and expert knowledge of the problem and its possible implications.

Control Measures for Various Types of Insects

Methods of control are related to the various types of insect concerned, they may be grouped as follows :—

INSECTS WITH WOOD-BORING LARVAE

This group includes some of the most destructive pests of poplars. Of these the Large Poplar Longhorn Beetle is one of the most important. The eggs are laid singly and each larvae burrows a long vertical tunnel in the outer layers of wood with a

hole opening to the exterior (Figs. 20 and 21). The larvae may be destroyed by pushing a long wire through the external aperture and up the burrow, or by inserting potassium cyanide or some other strong fumigant, and plugging up the hole.

The larvae of the Small Poplar Longhorn Beetle generally burrows in the wood of branches or young stems (Figs. 23 and 24) forming galls which should be cut out and destroyed during the first year of development while they contain larvae. The weevil *Cryptorrhynchus* also breeds in the wood of branches and small stems, and should be destroyed in the same way.

The Hornet Clearwing Moth breeds in the timber at the base of poplar trees. The same trees may be used by the insects for many years, and in some cases the bases of the trees become " honeycombed " with larval tunnels, (Fig. 30). The moths emerge during June and July when they may be seen clinging to the bark near the base of infested trees, and should be killed before eggs are deposited. As the life-cycle extends over more than one year, larvae may be present at all times, and they can be destroyed by fumigation as described above. Heavily infested trees may be in a dying condition, in which case they should be felled and the larvae destroyed, including any that may be present in the stump and roots.

The Goat Moth breeds in the timber of the stem generally within a few feet of the ground, and the same tree may be used over a period of many years. A single tree may contain large numbers of larvae and the central portion of the stem may be completely ramified with larval tunnels. Sometimes quite small trees are attacked (Fig. 34). Heavily infested trees should be felled and the larvae destroyed. Willow, ash, elm and oak are also attacked and any in the vicinity should be examined.

The Wood Leopard Moth generally breeds in the wood of small stems and branches. The eggs are laid singly and each larva occupies a separate tunnel. Infested stems and branches should be cut out and the larvae destroyed. From June to August the adult moth may be seen clinging to the bark of trees (Fig. 35). Ash, beech, birch and other trees are also attacked and if growing near infested poplars should be examined.

Old pollard willows ; trees growing in coppice thickets, overgrown hedges, and neglected mixed woodlands constitute the chief breeding places for wood-boring insects, and form centres of infestation from which they spread to attack trees in neighbouring plantations. Control measures should have as their objective the location and eradication of these breeding grounds.

DEFOLIATORS

This group consists of leaf-eating beetles and their larvae, sawfly larvae, and a great variety of moth larvae. The defoliators are of relatively greater importance in nurseries and young plantations than in the case of large trees. Many of the leaf-eating beetles produce two generations a year, one in the spring and the other during the autumn. Destruction of the first generation may prevent the development of more severe infestations later in the year. Where young trees in the nursery are concerned, the beetles may be destroyed in the spring when feeding on the leaves either by being shaken into collecting trays and dropped into paraffin, by the application of a " Flea-beetle Dust," or by a suitable spray.

Many species of sawflies attack poplar leaves, the two most common species each produce two generations in the course of the year. The larvae at first feed in colonies and may readily be destroyed by hand-picking. If this is done in the spring, a stronger infestation later may be prevented. Sawfly larvae may also be destroyed by the application of a suitable spray, and moth larvae may be dealt with in the same way. The large moth larvae which appear in late summer are easily collected by hand.

APHIDS

Most of the aphid pests may be controlled by insecticides during early spring, but subsequent applications may be necessary throughout the season. Gall-forming species may be controlled by collecting the galls.

CAMBIUM-BORERS

The *Agromyzid* cambium borers are most vulnerable to attack in the autumn when the larvae leave the trees to form puparia in the soil. They may then be destroyed by the application of " Wire-worm Dust " on the bark at the base of the tree, and among the surface litter and soil in the vicinity.

WEEVILS IN NURSERIES

Bark-eating weevils including *Barypeithes* spp. may also be controlled by the application of a surface dressing of a " Wire-worm Dust," at the rate of 1 oz. per sq. yd., or by dusting or spraying the plants with D.D.T.

IV. DISEASES CAUSED BY FUNGI AND BACTERIA

Over the world as a whole, poplar suffers from a considerable number of fungal and bacterial diseases. Fortunately very few of these are generally distributed. They can be conveniently considered according to the part of the tree that they attack, falling into four categories,

(i) Leaves and succulent shoots,
(ii) Twigs, branches and trunk,
(iii) Roots,
(iv) Heartwood.

Diseases of Leaves and Succulent Shoots

Melampsora Rust

By far the commonest and most widely distributed leaf disease of poplars is that caused by the Rust fungus, *Melampsora*. When poplars are attacked by this disease the under surfaces of the leaves become thickly covered with small bright orange-yellow fructifications which appear from mid-summer onwards. After a time the infected leaves wither and fall, so that a heavy attack leads to premature defoliation and consequent reduction in growth. This premature defoliation seems to prevent the proper ripening of the attacked shoots, which are subsequently damaged by autumn frosts. It is necessary to regard this as a group of diseases rather than as a single disease, because a considerable number of species of *Melampsora* are concerned. The *Melampsora* on poplar, like many other rust fungi, have two host plants, spending part of their life cycle on one and part on the other, and their classification is partly dependant on the hosts on which they occur. The species known to occur in Great Britain are (Grove 1913) :—

Species	*Alternate Host*	*Poplar Host*
Melampsora allii-populina Kleb.	*Allium* (onion) species.	Black and Balsam poplars.
Melampsora larici-populina Kleb.	*Larix decidua* (*europaea*) (European larch).	Black and Balsam poplars.
Melampsora larici-tremulae Kleb.	*Larix decidua* (*europaea*).	Aspen and White poplars.
Melampsora pini-torqua Rostr.	*Pinus sylvestris* (Scots pine).	Aspen and White poplars.
Melampsora rost-rupi Wagner.	*Mercurialis perennis* (Dog's Mercury).	Aspen and White poplars.

It is probable that further study, particularly on poplar, might lead to further elaboration, but for our purposes they can, with the exception of *M. pinitorqua*, be grouped simply as poplar rusts, and this is almost inevitable since they are hard to distinguish on poplar, and those on Black and Balsam poplar, at any rate, can maintain themselves indefinitely without the alternate stages which are comparatively rarely found. They occur in all parts of the British Isles. There is considerable difference in susceptibility to rust among the different poplar varieties, and on certain poplars, notably × *P. generosa*, severe attacks occur with such regularity as seriously to interfere with growth.

Information on rust susceptibility of poplar in Great Britain is still very incomplete, but information on some of the older varieties is summarized below in a table which combines observations made over several years at Kennington Nursery, Oxford, and at Lt. Col. Pratt's Arboretum at Ryston, Norfolk, with those made for two years at Alice Holt Research Station on the borders of Surrey and Hampshire. There are often wide differences in the reaction of one variety in different years, and even in different places or different parts of the nursery in the same year. These differences are much more marked in some varieties than in others, and in List A it has been necessary to introduce a special category for varieties which show consistently wide variations in susceptibility. All varieties are to some extent variable and this makes the introduction of degrees of susceptibility and resistance impossible.

LIST A.—RESISTANCE OF POPLARS TO MELAMPSORA RUSTS

Resistant	*Susceptible*
P. deltoides	P. candicans
× P. laevigiata	P. tacamahaca
P. nigra betulifolia	P. maximowiczii
× P. marilandica	× P. berolinensis group
× P. regenerata	P. yunnanensis
× P. gelrica	× P. generosa

Varying from Resistant to Susceptible

P. trichocarpa
P. nigra var. italica
× P. eugenii
× P. robusta
× P. serotina

The aspen and White poplars are not often attacked, because the rusts to which they are susceptible are not so generally distributed. When they are attacked by their particular rusts the damage is normally much less severe than that which occurs on susceptible Balsam and Black poplars. It is interesting that while many clones of *P. trichocarpa* are markedly susceptible, a number of hybrids of this species with *P. tacamahaca* all fall on the border of the resistant and susceptible classes, showing generally higher resistance than either parent. It is not known whether there is any difference in susceptibility to rust between the two strains of *P. eugenii*, which differ in resistance to bacterial canker.

The American hybrids of Stout and Schreiner vary in rust resistance, but an unduly high proportion of them are susceptible and a number seriously so. The Italian selections, on the other hand, while showing nearly the same range of variation are mostly in the resistant class.

It is interesting to compare the above table with information given for one locality in Scotland (Cameron 1936). In this case the order of susceptibility was :

× P. generosa
P. trichocarpa
× P. serotina
× P. robusta
× P. regenerata
× P. eugenii

the last named being virtually free from the disease. Van Vloten (Houtzagers et al. 1941) gives × *P.*

robusta and × *P. generosa* as particularly susceptible, while he regards × *P. serotina*, × *P. regenerata*, × *P. marilandica*, × *P. eugenei*, and × *P. gelrica* as resistant. It is obvious that it is not possible to be completely sure of the behaviour of some poplars such as × *P. robusta*, and × *P. serotina* with regard to rust.

Unfortunately this information, even though it may be confirmed by subsequent observations, cannot be regarded as of permanent value. It is known that different species of *Melampsora* occur on poplars in other countries, especially in the Americas, and if these were introduced they might well prove to have different varietal preferences. In addition it has been proved (Van Vloten 1944) that hybridization in the fungus is possible. This may lead to the production in nature of new varieties of *Melampsora* with different host ranges. It is certainly fortunate that this is not a killing disease.

Melampsora pinitorqua must be regarded from a rather different angle, since the fungus causes severe shoot distortion and die-back in Scots pine (Peace 1944). It occurs only where the alternate host, usually aspen, is present. Deliberate mixture of the two species is of course unlikely, but Scots pine has often been planted near aspen or on ground where aspen suckers form part of the weed growth. Under such circumstances damage to the Scots pine is almost inevitable, but can be mitigated by early removal of the aspen shoots in weeding. This disease should be borne in mind when planting either species, so that they will not be put close together. Corsican pine (*Pinus laricio*) and Maritime pine (*P. pinaster*) are apparently highly resistant to this fungus, and can be used instead of Scots pine on aspen infested sites.

It is probably not worth while trying to control poplar rusts by spraying, and no experiments have been done on its control. Even if a susceptible variety were kept free in the nursery, it would still suffer after it had been planted out, when spraying would no longer be practicable. Since most of the valuable varieties are not usually severely attacked, the disease need cause no real concern, provided highly susceptible varieties such as × *P. generosa* and some of the new American hybrids are avoided.

Other Leaf Diseases

No other leaf diseases are of any real importance in this country, though the fungus *Taphrina aurea*, which causes bright yellow blisters and a certain amount of distortion on the leaves, is quite commonly met with. In Italy poplars suffer badly from the so called " spring defoliation " caused by the fungus *Venturia tremulae*, (Servazzi 1935, Goidanich 1937), which causes a withering of the foliage and young shoots soon after growth has started. This fungus has been recorded from Denmark (Jorstad 1936) where apparently it has done severe damage on poplars of several varieties, and rather doubtfully in Great Britain associated with die-back of aspen.

Diseases of Twigs, Branches and Trunk

Bacterial Canker

By far the most serious disease of poplar in Great Britain, or indeed in Northern Europe, occurs on the woody parts of the tree. This is the so-called bacterial or weeping canker (Figs. 47, 48, and 49). A great deal of work has already been done on this disease (Koning 1938, Regnier 1943 A and 1943 B, Lansade 1946). It seems from recent unpublished work by Sabet that the initiation of the cankers is due to one bacterium, *Pseudomonas syringae* forma *populae*, though other bacteria and fungi, including *Nectria*, may be concerned in the subsequent extension of the cankers. It has been suggested (Day 1948) that frost may play an important part in the initiation and subsequent extension of these cankers, but this seems unlikely in view of the very wide range of sites, many of them certainly not frosty, in which bacterial canker occurs. The cankers have been well described and illustrated (Koning 1938) and only a brief description will be given here. The first signs of the disease are small cracks in the bark of young twigs from which in the spring, particularly in April and May, pale brown bacterial slime exudes. It is possible to produce canker in other poplars by inoculating wounds with this slime or, according to Sabet, by inoculating with *Pseudomonas syringae* provided it is accompanied by a sterile filtrate of the slime. Sometimes the affected twigs are girdled and die back, but often, as the twig grows, it attempts to heal over the affected area and canker formation starts. It is these repeated efforts on the part of the tree to heal the wound, and repeated extensions of the wound by bacteria and later probably also by fungi, that give rise to the rough and swollen cankers, which are characteristic of this disease. As the disease progresses the cankers may girdle and kill quite large branches or even occasionally the trunk, so that a diseased tree is distinguished not only by the numerous cankers and the slime exudation in the spring, but also by a greater or lesser number of dead twigs and branches. The disease sometimes kills the tree, but more often cripples its growth and, if cankers occur on the main stem, lowers the value of the timber.

The distribution of the disease is not yet fully known. It occurs in places over the whole of England and Wales, and as far north as Inverness in Scotland. But within this area it is quite possible to find susceptible varieties free from canker ; and,

though the disease may eventually attack them, this often does not happen till the trees are ten to fifteen years old. Occasionally susceptible varieties may reach timber size without becoming infected. This is particularly the case with *P. trichocarpa*. This suggests that the disease is not yet generally distributed over the whole countryside, but takes a variable time to reach trees planted in hitherto canker-free districts. It was first brought to public notice in Great Britain in 1934 (Day and Peace 1934); but it had certainly been established for a good many years before that date. In Europe it is known in Holland, Belgium, north east France and Germany, but does not appear to extend further south. It is not known how far it extends into Eastern Europe. The method by which the bacteria get from tree to tree is unknown, though insects are naturally suspect, nor is the means of entry of the bacteria into the tree understood. Canker is usually associated with a certain degree of orange staining in the wood, and this supports the suggestion that once a tree is infected the bacteria can spread internally, producing cankers all over the tree from a limited number of original infections, but there is no proof of this. Further knowledge of the mechanism of transmission and infection might well throw more light on the reasons for the present distribution of the disease, and also on the question of the resistance and susceptibility of different varieties, which is discussed below.

No cure is known for this disease, and once a tree has become heavily attacked it must be regarded as worthless. The proper method of dealing with the disease is by the use of resistant varieties, and these are listed below. Nevertheless cankered trees should be felled and destroyed. If this action were generally taken, it would not only greatly improve the look of many poplar plantings, but it might well save some surviving healthy trees of susceptible varieties until they were big enough for felling, allow small quantities of desirable but susceptible varieties such as *P. trichocarpa*, to be planted with less risk, and above all do away with the chance of propagating material being taken from cankered trees. Normally the disease does not occur in the nursery, and the objection to the use of propagating material from cankered trees lies mainly in the possibility that it might be used to form stool beds, from which large numbers of apparently healthy trees might be raised and sent out, which later would fall victims to this disease. But unfortunately cankered trees are so widely distributed, and so many of them belong to persons not really interested in forestry, that the hope of "cleaning up" the country is remote. Nevertheless all who have the interests of poplar cultivation at heart should fell such trees, and encourage others to do so. In Holland, where this policy has been enthusiastically followed, bacterial canker, which about 1935 was commonly met with, is now seldom seen.

The serious interest which the Dutch show in this disease, is demonstrated not only by their policy of felling diseased trees, but also in the work they have done on the resistance and susceptibility of numerous varieties (Koning 1941, ter Pelkwijk and Brink 1946). Very large numbers of inoculations using the bacterial exudation from young cankers have been made, and although the results in different years have been somewhat contradictory at times, a great deal of valuable information has been collected. In practice it has been found that any poplar, which is not highly susceptible to inoculation, can safely be used for planting under normal conditions. The information given in List B below is based on Dutch work, supported by observational data on natural infection of trees growing in various parts of England and Scotland. Inoculation trials in England have only just been started and few results are yet available.

LIST B.—RESISTANCE OF POPLARS TO BACTERIAL CANKER

Highly Resistant

P. nigra betulifolia
P. nigra italica
× P. gelrica

Resistant

P. alba
P. canescens
× P. eugenei, canker-resistant form (further testing is required)
× P. serotina
× P. serontina narrow-crowned var.
× P. berolinensis group
× P. laevigiata

Resistance Doubtful

(Under this heading are grouped varieties, which have given contradictory results under test or in the field or both. On present evidence they can mostly be planted with reasonable confidence.)

P. maximowiczii
P. simonii
P. deltoides. (Testing of many more clones is required before this can be regarded as reliable)
P. tacamahaca
× P. marilandica. (Usually canker-free in Great Britain)
× P. regenerata. Some forms. (Not safe until the relatively resistant varieties have been definitely separated)
× P. robusta. (One case in Great Britain and evidence from the Dutch trials indicate a measure of doubt about this hybrid)

Susceptible (Therefore unsafe except for very small-scale planting)

P. tremula. (Though natural cases of canker are rare in Great Britain)
P. lasiocarpa
P. candicans
P. koreana
P. trichocarpa
P. laurifolia

× P. brabantica
× P. eugenei. Canker-susceptible strain
× P. regenerata. Some forms. (These certainly include the variety going under the names *P. carrieri* or *P. carriereana*, which appears to belong to Houtzager's *P. regenerata erecta*
× P. generosa
× P. tremula × tremuloides. (It is not known how this will behave in the field)

These results are generally supported by French evidence (Regnier 1943 B) but × *P. eugenei* is there regarded as resistant. The resistance of × *P. robusta* is thought to be somewhat doubtful, but it is considered sufficiently safe to be used for planting.

It has already been stated that several of the American hybrids have proved susceptible in the Dutch tests and that two of the Italian selections have been found to be reasonably resistant. But further and more extended trials of all the more promising varieties are required, and it is certainly not fair to condemn all the American hybrids or recommend all the Italian selections on the basis of results referring only to certain varieties.

It has often been suggested that bacterial canker is affected by the environment in which the poplars are growing, but the evidence for this is not very convincing. Serious outbreaks of this canker have been recorded under almost all the conditions in which poplar can be grown. It is considered that a number of particularly bad outbreaks of canker on very badly drained sites were largely due to fungi, notably *Dothichiza populea*, which is discussed below, attacking trees weakened by the stagnant conditions and adding their effect to that really due to the bacterial canker. Perhaps the best evidence that exists in favour of the influence of site on this disease is provided by the difficulty of getting canker to persist on cankered sets planted under nursery conditions. It was hoped to use lines of such sets to provide natural infection to varieties on trial planted between them ; but in practice very few new cankers have been formed on the sets and their canker-free growth has been remarkably vigorous. In Great Britain bacterial cankers have never been observed on planting stock in the nursery, even though susceptible varieties were concerned. It does not follow, however, that the disease cannot exist under the fertile conditions usual in a nursery. It is possible that an insect vector does not feed on such young trees, or that some other method of infection fails to function under nursery conditions. It is quite certain, at any rate, that young trees can be infected, since they have been used in most of the Dutch work. It is equally certain that in older trees, even if the degree of canker development can be affected by environment, the disease cannot be avoided by any choice of site or cultural practice.

Other Stem Diseases

Other stem diseases of poplar in this country have never been properly investigated. Die-back of poplar, which could not be attributed to bacterial canker, occurs quite frequently, and at least three fungi, *Dothichiza populea*, *Cytospora chrysosperma*, and *Nectria coccinea*, which have been associated with poplar die-back in other countries, are known to occur in Great Britain. All the evidence available in this country suggests that *Cytospora chrysoperma* usually occurs on twigs that have died from some other cause, or have been so weakened that invasion by the fungus is made easy. Its conspicuous orange tendrils of exuding spores may often be seen on dead poplar twigs, or newly-planted trees which have died from drought, or on twigs killed by bacterial canker. In America rather more significance has been attached to this fungus (Kuntz and Riker 1949), though even there it is admitted that it is often secondary (Schreiner 1931).

The little red pin-head fructifications of *Nectria* may be seen in larger bacterial cankers, and it would appear that it is often secondary to the bacterial disease and may help to extend the cankers ; but it can act as a parasite in its own right (Koning 1938). Its real significance in Great Britain has never been evaluated.

The third of the fungi mentioned above, *Dothichiza populea*, is certainly the most serious of the three. In northern Europe it is regarded as a grave source of loss, though it usually occurs on trees that have been weakened by some other cause, such as bad drainage, drought, or transplanting. It is particularly feared as a cause of die-back in newly-planted trees (Anon. 1946). In Italy (Goidanich 1940, 1941), where it has been described under the name *Chondroplea*, it is also considered to be dangerous only when other factors are operating against the tree. The fungus, which eventually produces pin-head sized fructifications from which cream coloured tendrils of spores emerge, causes both canker and die-back, though the cankers, which originate as sunken areas, in contrast to the swellings associated with the early stages of bacterial canker, never become as pronounced as those caused by bacteria, and are therefore not so noticeable.

Little is known about varietal susceptibility to this disease, but preliminary tests in Holland (Van Vloten 1938) indicate that in general the Balsam poplars are more susceptible than the Black poplars, and that the Balsam susceptibility extends to some, though not all, of the new American hybrids. Of the Black hybrids tested, × *P. robusta* and the tree sold in Holland under the incorrect name *P. deltoides missouriensis*, are the most susceptible. It is known that this fungus occurs widely in Great Britain, but it is not known to what extent it can be

blamed for various cases of die-back that cannot be attributed to bacterial canker. It has been found associated with die-back in a mixed plantation of Black hybrids on a badly drained site, and it is considered that it may be associated with the die-back that commonly occurs on *P. alba* var. *pyramidalis*, and rather less commonly on *P. nigra italica*, which has been reported as susceptible to this fungus in America (Waterman 1946). On the Continent, however, this disease of Lombardy poplars has been attributed to other fungi, namely *Dothiorella populea* and *Venturia tremulae*, which latter has already been discussed. *Dothichiza* can, on occasion, do severe damage to over-lush newly planted trees, especially if pruning wounds are available for infection. On this account over-manuring of nurseries should be avoided, and pruning of larger plants destined for transplanting should be done earlier in the season, not at the time of lifting. Using these precautions, *Dothichiza* can probably be avoided on most varieties by correct choice of site, and by proper treatment, especially at the time of planting.

Probably the most important of a number of other fungi causing canker and die-back abroad is *Septoria musiva* (Waterman 1946), which is found in parts of Canada and the United States. It is normally a leaf fungus, producing negligible damage to native poplars, but has caused severe canker and consequent damage to hybrid poplars, especially those of the × *P. berolinensis* group (Bier 1939). It has also been reported causing injury to some of the new American hybrids (Davis 1942), and on × *P. serotina*. In the initial stages cankers caused by this fungus are sunken, like those due to *Dothichiza populea*, but later, as they develop, they become scarcely distinguishable from those due to bacterial canker. Since *Septoria* is confined to America and bacterial canker to Europe, great care should be taken that they are not spread from one continent to the other. This is particularly important since the varietal susceptibilities of the two diseases appear to be so different. There are several other fungi supposed to be associated with canker and die-back of poplars in America, but a great deal of the damage there is due to causes which are still unexplained. In America, as in Europe, more work is needed before the causes of the complex of die-backs and cankers are properly understood.

In the North of England and in Scotland there is a tendency for Black hybrid poplars to be rather sparsely leaved, and to show a certain amount of die-back. This has never been investigated, but it appears likely that it is climatic rather than fungal. It does not appear to prevent the trees reaching quite a large size, though it may well be associated with rather slower growth.

Diseases of Roots

Poplars are not particularly susceptible to root fungi, though Honey fungus, *Armillaria mellea*, occurs occasionally. It is found comparatively rarely, so that it is not a serious factor in poplar cultivation. Affected trees should be felled, and time allowed for the stump to decay thoroughly before any other poplars are planted near. It is interesting to note that poplar wood decayed by *Armillaria* is particularly apt to show phosphorescence, a phenomenon occasionally associated with Honey fungus attack on other timbers.

Diseases of Heartwood

Felled timber of poplar is very prone to decay, but standing trees very seldom suffer from heart rot until they are past the normal rotation. This freedom from decay is, in part, only a reflection of the short rotation on which poplar is normally grown. On older trees, particularly on those over 60 years of age, decay-causing fungi do often occur. Among the species likely to be found are *Ganoderma applanatum*, *Fomes ignarius*, *Fomes fraxineus*, *Pholiota heteroclyta*, *Pleurotus ostreatus* and *Polyporus sulphureus*. These are fully described in a publication by Cartwright and Findlay (Cartwright and Findlay 1946) dealing with decay in timber. The possibility of attack by such fungi introduces a risk into the growing of poplar to large sizes. But provided all the trees of a similar age on any one site are felled as soon as any one tree shows visible signs of attack, such as a fungus fructification at the base, losses are not likely to be heavy.

Stereum purpureum, the cause of silver leaf in plums and other fruit trees, occurs quite commonly, growing on the sapwood of dead poplar branches. It does not appear to be capable of causing any disease on poplar, but if the trees have been planted as an orchard shelterbelt, as poplars often are, care must be taken to cut out dead wood, lest it be attacked by this fungus and serve as a source of infection for the orchard trees.

By far the most serious trouble affecting the heartwood of poplars is a dark brown stain, the cause of which still remains obscure. It is always confined to the heartwood, and normally has a circular outline coinciding more or less with the annual rings. No fungi or bacteria have been associated with it. It appears that it must be chemical or physiological in nature. There is no evidence that it leads to subsequent decay, though it is often assumed that this must be the case, and stained timber is referred to as being "rotted". Where it does occur it tends to affect a high percentage, or even all, of the trees felled. This suggests that it may have some connection with site or with variety. There is not enough evidence available

to prove or disprove these suggestions. It has been found on a large scale both on × *P. serotina* and × *P. robusta*, as well as on other varieties. It has been found on dry sand, really far too dry for poplars, and on moist fen peat ; it occurs on first class poplar soils in Belgium, where it is said that affected wood is very slightly weaker than unstained but is still utilizable. The most unfortunate thing is of course the discolouration, which renders the wood much less valuable for certain purposes. In match manufacture, however, the loss is mitigated to some extent by the fact that the stain is invariably in the centre, so that a considerable length of veneer can be cut before the stained core is reached, and some of the stain will remain in the core, which cannot be cut into veneer in any case. An investigation of the true nature of this stain, and reliable information on the sites and varieties on which it is liable to occur, are badly needed.

V. DISEASES CAUSED BY HIGHER PLANTS

Mistletoe (*Viscum album* L.), is the only green plant likely to cause injury on poplar, and in Great Britain it very seldom occurs in sufficient quantity to do harm. In parts of France, however, the quantity of mistletoe on commercially grown poplars is enormous, and it is hard to believe that it does not affect the health of the trees. On the other hand it provides an additional source of revenue, and it is obvious that the rate of growth of the trees is not seriously lowered.

The other higher plants, such as honeysuckle and ivy, which are sometimes troublesome in the forest, do not usually occur on poplar sites. Should they do so they can easily be dealt with at the time of pruning.

Chapter 4

PROPERTIES AND USES OF POPLAR TIMBER

GENERAL DESCRIPTION OF THE WOOD

The timbers of the various species and hybrids of poplar grown in Britain have certain essential features in common, but the quality varies considerably according to the conditions and habit of growth and the attention given during cultivation. Poplar wood is light in weight, about 55 lb. per cu. ft. in the green condition and about 28 lb. per cu. ft. seasoned (15 per cent. moisture content) ; the recorded range in the seasoned condition is from 23 to 34 lb. per cu. ft. The wood is odourless and light in colour, white, greyish, pale brown or reddish, generally with little visual distinction between sapwood and heartwood. It is usually straight-grained and inclined to be woolly, but has a fine, even texture due to the uniform structure and lack of contrast between springwood and summerwood. Poplar is one of the lighter and softer home-grown timbers but its strength properties, especially toughness, are relatively high when its density is taken into consideration.

The anatomical features for all the varieties are so similar that a single description will suffice. The following features may be observed on a clean-cut surface. Annual rings are fairly distinct, their boundary marked by a narrow band of soft tissue and a zone of denser, summerwood, contrasting with the succeeding broad zone of coarse-textured springwood. Pores are indistinct to the naked eye on end-surface but clearly visible under a hand lens ; they are very numerous and evenly distributed, rather smaller in aspen than in the other poplars. Vessel lines on longitudinal surfaces are visible as fine scratches. Rays are very numerous and very fine, not clear even with a lens on the end-surface. They may be observed on the radial or quarter-sawn surface as silvery lines, and are just visible to the naked eye and clearly visible with a lens. Pith flecks, probably due to insect attack, are sometimes present, especially in aspen, but are not a constant feature. Small dark marks, possibly due to the occlusion of epicormic shoots, may be present in some species either as isolated dots or in groups.

The various poplars cannot be separated with any degree of accuracy by the anatomical features of their timbers ; but this does not mean, however, that they are identical in general quality and technical properties. Of the principal groups the white poplars alone show a contrast between the light-coloured sapwood and the pink or reddish heartwood. Aspen, the Black poplars, and the Balsams generally have uniformly white or greyish wood although that of the Black poplars is sometimes slightly streaked.

As already indicated, the poplar timbers produce a woolly surface in sawing and sometimes tend to

bind the saw. They air-season and kiln-season well and fairly rapidly, although knots are liable to split when subjected to high temperatures. Local pockets of moisture are apt to remain in the timber. Considerable shrinkage occurs during seasoning, and green timber cut into planks warps badly if not carefully stacked. Once properly seasoned, however, it is stable and there is little liability to serious warping during manufacture. The seasoned wood is somewhat tough in working, with the exception of aspen which compares favourably in its properties with lime. Sharp, thin-edged tools are required to obtain a good finish. The wood usually glues well, takes stain readily, although sometimes with rather patchy results, and takes paint, varnish and polish satisfactorily. Poplar wood is easily dented but does not readily splinter, and there is a tendency for small holes to close up. Most varieties of poplar, if of sufficient size, can be cut as a rotary veneer without any previous softening treatment ; veneers of good quality and varying thicknesses from 1/50″ to 1/8″ have been obtained by this method. Physical tests show that the wood burns quickly, with little resistance to flame penetration, and it has, in general, low fire-resistance properties. Owing to its rapid burning and low density it makes rather poor firewood.

Seasoned timber is liable to attack by Common Furniture Beetles (*Anobium striatum*), but it is immune to Powder Post Beetle (*Lyctus*) attack. It is classed as perishable, being very liable to decay under conditions favourable to fungal attack. In common with most timbers the sapwood of poplar is readily impregnated with preservatives by the open-tank process and as a large proportion of the timber from small trees consists mainly of permeable sapwood, thinnings yield suitable material for use, after preservative treatment, for fence posts, stakes etc. The heartwood, however, is resistant to impregnation even under pressure and does not lend itself to preservative treatment. (Anon. 1941, Houtzagers 1941).

UTILISATION OF POPLAR TIMBER

Among the more important uses of poplar timber are veneer and plywood manufacture, matches and match boxes, pulp for paper and cellulose products, and wood wool. For matches, match boxes, veneers and plywood only the best quality timber can be used. It must be substantially free from knots and irregular grain, discolouration and other defects. Aspen is the timber preferred for match manufacture, and large quantities of European aspen (*P. tremula*) and the closely allied American aspen (*P. tremuloides*) are imported from the Baltic countries and Canada respectively. But, during the 1939-45 war, when the European source of supply was cut off, substitutes were sought and other species of home-grown poplar successfully used. Match splints are made by peeling the log and obtaining a veneer about one-eighth of an inch thick. For this operation a log as near cylindrical and as straight as possible is required. A diameter of 15 in. is favoured, with a maximum size of 24 in. and a minimum top diameter of 8 in. Considerable quantities of home-grown poplar, notably × *P. serotina* and × *P. robusta*, have been utilised in Great Britain for match splints during the past ten years. × *P. robusta* and × *P. regenerata* have been used on a large scale by the Belgian Match Co. for matches and match boxes, and various hybrids have been found satisfactory in France (Meunier, Guinier and Regnier 1947). Thus there is good evidence that other forms of poplar, provided they are well-grown and of suitable size, can be used to supplement, or even replace, supplies of aspen for this purpose.

For veneer and plywood much the same considerations apply. Owing to limited supplies of the home-grown timber, poplar has not been used to any great extent for the manufacture of plywood in the United Kingdom, but it is recognised as a standard timber for this purpose in North America (under the name of cottonwood) and on the Continent. In this form it is employed principally for general utility purposes and as a base for decorative veneers. Veneered poplar furniture is light in weight and easy to handle. Another common use for peeled poplar is in the manufacture of chip baskets for soft fruits ; for this purpose poplar has certain outstanding advantages including its clean appearance, light weight, lack of odour and freedom from resinous or oily products likely to exude and contaminate the fruit. Moreover the peeled veneer can be bent at right angles without breaking. For chip baskets a high-class product is not required ; occasional knots are tolerated and relatively small material can be utilised as the logs are peeled down to a core of 4 in. diameter.

Other uses for poplar are recorded below under the descriptions for each group. For many purposes poplars from the various groups are used indiscriminately and while preferences may exist, to conclude that one variety alone is suitable for any particular purpose may be quite erroneous. Choice is limited by the selection available and the frequent references to Black poplar, for example, may be a reflection of the fact that the Black hybrids are more commonly grown for timber.

Our knowledge of the relative merits of the different kinds of poplar as timber, especially as grown in Britain, is still very imperfect, but it may be laid down as a general rule that, except for the roughest kinds of work, it would be better to market

the various species and hybrids separately. This practice would be much easier, if pure stands, of one hybrid or species alone, were established on the planting area. Such planting would ensure the uniformity of quality so necessary for the manufacturer and would lead, in time, to a better knowledge of their relative merits for different purposes; but would be open to grave criticism in view of our limited knowledge of the best varieties for different conditions, and their resistance to disease. In practice it is better for each estate or forest to use two or three different varieties.

Aspen

This is the most useful species of poplar, with present day demand far exceeding the supply. It is relatively slow in growth, and produces a wood which is white, straight-grained, and splits cleanly and easily. It is comparatively soft but possesses, for its weight, fairly good bending strength and toughness. The standard type of match was made almost exclusively from imported aspen until war conditions necessitated substitution of other timbers. The larger dimensions are most profitable for the match industry, but wood of smaller diameter or less perfect trees can be used for pulp for the manufacture of paper and for cellulose.

Wood wool is another useful product and although large quantities are manufactured from spruce, that made from aspen is of superior quality. In America it is marketed under the name " excelsior " and large quantities of American aspen are used in this form for such purposes as packing material and as a stuffing for upholstery. On account of its fine, even texture, and freedom from warping and checking, aspen is favoured for carving, turnery and marquetry work. Its ability to withstand rough usage without splintering, its light weight and the ease with which it may be painted, make it suitable for toys. Practically white in colour, odourless and free of resin, it is used for kitchen utensils, pails, ladles and similar articles. For similar reasons it is esteemed for dry cooperage and boxes, especially those intended for food. Aspen is one of several hardwoods used experimentally for the manufacture of wooden stoppers to replace bottle corks (Vandersee 1939).

White Poplars

Two species, *Populus alba* and *Populus canescens*, are commonly included in this section, although the timber of the two trees should be marketed separately. *P. canescens* is one of the slower growing species but produces a higher quality timber than × *P. serotina*. It is described as one of the finer-textured poplars and will take a good finish. The heartwood is reddish-brown in colour and contrasts with the sapwood which has a lighter, more pinkish tint. The wood of *P. alba* is harder than that of the black poplars, but the surface is inclined to be woolly. Sapwood and heartwood are distinct, the former white, the latter reddish. Both species can be utilised for many of the purposes for which aspen is used, but, as the heartwood of old trees is distinctly coloured, it is not suitable for objects where a clean white wood is required. As *P. canescens* grows to a larger size than aspen the timber can be used for purposes for which that tree is too small, and it enters into wheelwrights' work, box manufacture, furniture production and carving. It is eminently suitable for coach-building on account of its stability, light colour and ease with which it may be stained or painted. It is popular for floor boards, especially for kilns and similar drying places, on account of its stability, resistance to shock, non-splintering properties and clean appearance. Timber from comparatively young but not too quickly grown trees is suitable for work that entails splitting into small dimensions.

Black Poplars

As at present applied in this country the term " Black poplar timber " includes timber of any poplar other than *P. tremula*, *P. alba* and *P. canescens*, and probably includes the Balsam poplars, but most of the black poplar is provided by large trees of the native *Populus nigra betulifolia*, and particularly by the hybrids × *Populus serotina* etc. Little distinction between the timbers obtained from the different species and varieties has been recognised in this country, but on the Continent the comparative properties have to some extent been studied (Meunier, Guinier and Regnier 1947); but more work is required before it can be assumed that these results, which are preliminary in any case, are applicable to the soil and climatic conditions of Great Britain.

The practice of mixing different varieties of Black poplar is mainly responsible for the variable quality of the timber supplied to manufacturers. Thus, although the relative value of the different kinds of timber produced is still uncertain, the marketing of the timber of each kind separately to ensure a uniform product is very desirable. There is good reason to suppose that, provided the trees are satisfactorily managed, the principal varieties of Black poplar recommended in this Bulletin are capable of producing clean, white, straight-grained timber, reasonably free of defects and of good merchantable quality. Black poplar of this type is suitable for cutting into veneers for plywood and for matches, or as core-stock and the interior parts of furniture. Owing to its ability to stand rough usage without splintering it is in demand for cart

bottoms, wheel barrows and for the colliery tubs in which the coal is brought from the seam to the surface. It has more specialised application for glass polishing, and there is quite a large demand for poplar timber for brake blocks for colliery tubs and horse-drawn carts. The homogeneous nature of the wood, combined with its softness, make it suitable for drawing boards, as compass and drawing pin points are easily inserted and withdrawn, and the holes tend to close again. As with poplars in general, it is eminently suitable for crate and box making as it is odourless and resin-free ; nails and screws are held firmly, and the wood withstands rough handling. Material down to five inches diameter can be used for this purpose.

Its light weight, clean appearance and the ease with which it can be worked and stained or painted, make it a valuable general utility timber for purposes where no great strength is required. Minor uses include turnery, the manufacture of toys, pulleys, clogs, shoe heels and boxes. As is the case with other kinds of poplar, the Black poplars have been found suitable for the manufacture of wood pulp for cellulose and paper.

Balsam Poplars

Populus trichocarpa appears to have been used in America for most of the products which are made from poplar. It has been suggested on occasion that it is rather inferior to the Black poplars and aspens. This may be due in part to its profuse production of epicormic shoots, the knots from which would naturally render it less attractive for rotary-cut veneer. In Great Britain it has been tried on an experimental scale for matches and proved suitable.

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