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BULLETIN No. 17

THE CULTIVATION OF THE CRICKET BAT WILLOW

LONDON: HIS MAJESTY'S STATIONERY OFFICE
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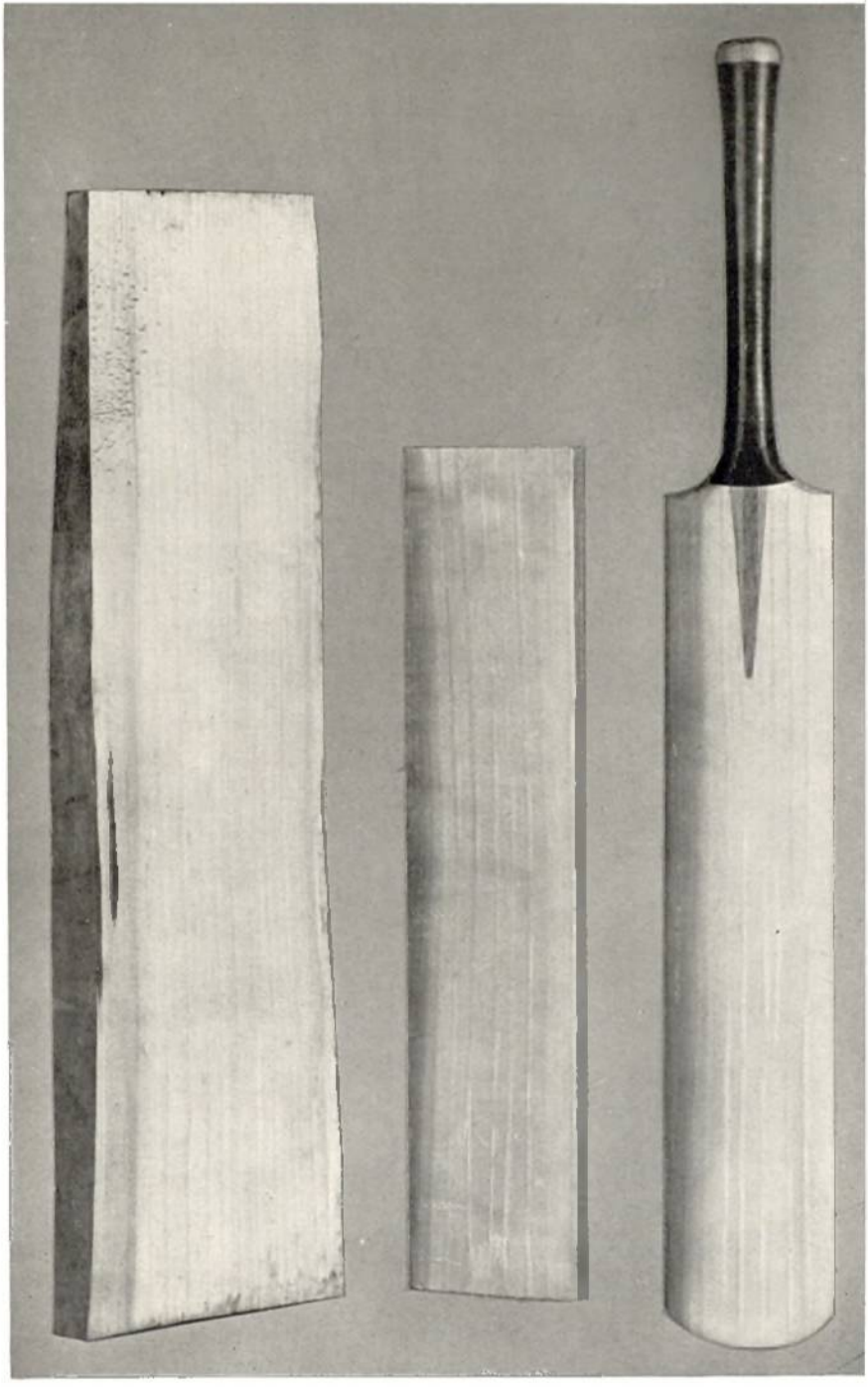

Three stages in cricket bat manufacture. (i) Willow cleft. (ii) Cleft sawn to shape. (iii) The finished bat.

(By permission of the Director, Forest Products Research Laboratory.)

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(*Reprinted* 1950)

PREFACE

The greater part of this Bulletin is the work of Dr. J. Burtt Davy and Mr. W. R. Day of the Imperial Forestry Institute, Oxford. They are joint authors of the most important sections, namely, those on the selection of suitable sites and the propagation, planting and tending of willows. Individually each has written a further section—Dr. Burtt Davy being responsible for " Systematy " and Mr. Day for the mycological section. The chapter on " Insect Pests " has been contributed by Dr. R. N. Chrystal, and for those parts of the work which deal with the character and uses of willow timber the Commissioners are indebted to the Director, Forest Products Research Laboratory, Princes Risborough.

To a considerable extent the Bulletin is the result of the combined experience of willow growers who for many years have given close attention to the cultivation and utilisation of the cricket bat willow. The Commissioners particularly wish to acknowledge assistance received from Mr. H. P. Hutchinson of the Agricultural and Horticultural Research Station, Long Ashton, a recognised authority on willows whose notes and published works on the subject have been consulted. Mr. Hutchinson has been good enough to read the Bulletin in manuscript form and a number of his suggestions have been incorporated.

Among others whose experience has been drawn upon are Colonel Pratt, Ryston Hall, Norfolk; Mr. C. P. Ackers, Huntley Manor, Gloucester; Mr. A. S. Winterbotham, Stonehouse Court, Gloucester; Messrs. L. P. Foreman & Sons, Chelmsford; Mr. E. J. Strutt, Hatfield Peveril, Essex; Mr. G. H. Watts, Bungay, Suffolk and the British Basket and Besto Co., Ltd., Irlam, Manchester.

Thanks are also due to a number of bat makers for information regarding the process of manufacture and the methods employed by the trade in the selection of suitable trees for utilisation. In this connection Messrs. Gradidge have been particularly helpful.

The extraordinarily high prices occasionally obtained for single trees have awakened a great deal of interest in willow cultivation and have led to enquiries regarding the type best suited for the purpose. In this Bulletin these matters are discussed from the tree planters' point of view. Emphasis is laid on the necessity of careful selection of the right kind of willow—this being the *Salix alba* var. *caerulea*. When properly planted and tended this tree may attain the dimensions required by bat manufacturers in twelve to eighteen years. Such a short rotation is attractive to those who insist on a comparatively quick return, and it is also claimed for willows that they can often be grown without interference with the productivity of the land for agricultural crops. Considerable diversity of opinion exists among practical men as regards the cultural methods which should be adopted, and the authors of this Bulletin put forward their recommendations with some diffidence. The technique of willow production is quite distinct from ordinary forestry practice and it is readily admitted that further research is required. The conclusions arrived at are, however, the result of very careful investigation.

The planting procedure is not particularly difficult but exceptional vigilance is necessary to keep the willow stems clean and straight from start to finish. Without this, defects appear in the timber which cause it to be rejected for cricket bats. Apart from bat-making there is a very limited demand for willow timber and as the percentage of defective material is often large an element of speculation is present which should be carefully borne in mind by prospective planters.

The claims of poplars as quick-growing trees for planting under much the same conditions as those suitable for willow are worth consideration in districts where poplar timber has an assured market.

R. L. ROBINSON,
Chairman.

Forestry Commission,
25, Savile Row,
London, W.1.

July, 1936.

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INTRODUCTION

Tree willows may be divided into two groups, according to the purpose for which the wood is to be utilised. In one group the trees are pollarded with a view to the production of poles used principally for hurdles and rough fencing. In the other group, timber of larger size is aimed at, and under this category the most important manufactured product is the cricket bat.

In the valley of the Thames, pollards (Plate I, fig. 1) form one of the most characteristic features of the landscape; they are characteristic also of other lowland localities such as the Somersetshire marshes and the levels of the Bedfordshire Ouse.

Trees intended for conversion into cricket bats require much more careful treatment than pollards, at every stage in their growth. Selection of the most suitable sort is the first consideration. At one time the timber willow was grown with little regard to origin of the stock, but to-day, to an ever-increasing extent, the demand is for *Salix alba* var. *caerulea*. Just as the preference for this variety has been a matter of gradual development, so also the methods of cultivation have gradually been refined and improved. The process of improvement is still going on and many methods of propagation and planting may be seen, from the most primitive to the most highly developed. Whereas there is no definite indication that the market for willow timber is increasing, the number of trees planted annually is undoubtedly becoming greater, no doubt on account of the high price obtainable for the best quality timber.

The cultivation of the willow is not actually difficult, but close attention to detail is necessary, especially during its early life. Many growers fail to realise sufficiently the requirements of the tree, and are accordingly disappointed in the product obtained. The large amount of timber of poor quality now produced is partly the result of lack of attention.

This publication does not deal with osiers for basket-making; readers who wish information on this subject may refer to Bulletin No. 89, " Osiers and Willows," issued by the Ministry of Agriculture and Fisheries, or to the Ministry's Advisory Leaflet No. 108, " The Cultivation of Basket Willows."

SUITABLE CONDITIONS FOR CULTIVATION

Important conditions for successful cultivation of the cricket bat willow include a favourable situation as regards moisture and drainage, good soil and suitable climate.

Situation

Bat willows like to be near to running water (Plate I, fig. 2) but it cannot be too strongly stressed that badly drained soils (Plate II, fig. 1) are inimical to the production of good timber. An ideal site is the bank of a running stream, from 2½ to 4 ft. above the normal water level; occasional flooding does not matter provided the flood water drains off quickly.

Marshy lands producing a vigorous growth of reeds (*Phragmites communis* Trin.) or sedges (*Carex paludosa* auct., (aggr.), etc.), are definitely too wet, causing slowing down of growth, and eventual " die-back ". Tussock grass-marsh marigold (*Deschampsia-Caltha*) and rush-marsh marigold (*Juncus-Caltha*) communities, though less wet than the former, also indicate unfavourable sites.

Vigorous growths of any one or more of the above, or of wild iris (*Iris pseudacorus* L.), figwort (*Scrophularia aquatica* L.) or great water-dock (*Rumex hydrolapathum* Huds.) indicate a water-table higher than is safe for successful planting with tree willows.

Areas having a dense growth of meadow-sweet (*Spiraea ulmaria* L.) are suspect, but such sites may be improved by draining with open ditches; such treatment sometimes results in changing the dominant ground flora from meadow-sweet to willow-herb (*Epilobium hirsutum* L.) and in the production of well-grown bat willows.

A favourable site often produces a dense growth of nettles (*Urtica dioica* L.) and ground ivy (*Glechoma hederacea* L.) with mixture of one or more of the following:—comfrey (*Symphytum officinale* L.), lady's smock (*Cardamine pratensis* L.), goose grass (*Galium aparine* L.), cow parsnip (*Heracleum sphondylium* L.), angelica (*Angelica sylvestris* L.), and a sprinkling of meadow-sweet (*Spiraea ulmaria* L.) and willow-herb (*Epilobium hirsutum* L.). Not all of these need be present in the same place, to indicate suitable conditions.

Climate

The bat willow has been cultivated as far north as Argyllshire, but in spite of a high rainfall and mild winter temperature the tree is not suited to a wind-swept humid coastal climate. Excessive humidity of the atmosphere encourages the growth of lichens on the bark, a condition correlated with retarded growth; also the development of adventitious roots high up on the stem produces defective wood. One may say, however, that in most districts places can be found in which the climate will permit of the tree's successful growth. Limiting climatic factors occur, but it is often difficult to tell whether adverse conditions in the soil are not acting at the same time. From the point of view of cultivation for timber, wind, periodic droughts, and frost are the chief adverse meteorological factors. Whether a limiting factor is to be found in the temperature, expressed as mean annual or mean summer temperature, is not known, nor, it is believed, are any data available to determine this. South-eastern England, being the region of highest summer temperature and greatest amount of sunshine, is that in which the cricket bat willow succeeds best, other things being equal. This may be the reason

why the willow-growing area has, up to the present, occupied mainly the basins of the rivers of Essex and the lower Thames, where soil of good quality with abundant subsoil water occurs over wide areas, and a high summer temperature is maintained longer than in most parts of the country.

A low rainfall undoubtedly acts as a limiting factor in that it prevents the extension of willow cultivation to some of the lighter loams or loamy sands. It is probable, however, that the occurrence of periodic droughts is of still greater importance, and as these are liable to occur in the wetter as well as in the drier parts of the country, the effect of differences in average annual rainfall is much diminished.

As regards wind it may be accepted that for the production of fast-grown timber a certain amount of natural shelter is essential. Liability of the locality to frost is a matter of much importance. The cricket bat willow is not markedly frost tender but there may be injury from late frosts in situations where cold air accumulates or it is exposed to cold winds.

Soils

Lowland Sites.—The soils of the lowland sites are either of mineral origin or peaty in character. The former are the more important and may be alluvial or derived directly from the underlying solid formation—usually consisting of clay, rich in plant food but often difficult to drain. When the clay soils are unalleviated by downwash from lighter land they usually produce trees of slow growth. Of the lowland alluvial soils the gravels are seldom suitable, partly because of their poverty and partly because of their liability to drought. On sandy soils of good quality, provided there is sufficient moisture, satisfactory growth may be obtained, much depending on the richness of the soil. These alluvial gravels and sands are usually arable, and light arable soil should always be regarded with suspicion for willow cultivation. The alluvial loams, if well drained, undoubtedly provide most of the best willow sites. Being as a rule deep, fertile, retentive of water and yet draining freely, they allow of strong healthy root development. The clay soils and the alluvial loams are generally utilised for pasture, and some indication of their potential value for willow growing is given by the richness of the grass they produce. It will be found that where but little supplementary feed is required for the fattening of cattle, willow of good quality can usually be produced.

Peaty soils on lowland sites are of widespread occurrence, although, except in certain districts, they are of limited extent. In the form of fens and low moors there are extensive areas of this type in the fenland in eastern England and in Somerset. Both acid and alkaline peats occur and the soils vary much in productivity; the acid heath peats are quite unsuitable. Broadly speaking the cultivation of the bat willow on fen or moorland is successful only if the land has been carefully drained and brought into agricultural use.

Most willow growers have to deal with only small areas of peat or peaty soil, such as those alongside rivers in Suffolk or Hampshire, or where the ground is marshy. Usually these places are of little or no use for agricultural purposes, owing to defective drainage, and there is a strong temptation to plant them with bat willow. The tree never grows well in such situations, unless effective drainage is assured. Even then the timber produced is usually somewhat indifferent in quality.

There are certain sites in which the soil is intermediate between the peat and the mineral type, and on these fast-grown willow is obtained. They consist of small areas of rich, moist soil containing a large proportion of

humus, and are usually subject to occasional flooding. If ungrazed, they bear a rich, lush, and often very varied, vegetation in which plants indicative of bad drainage are rarely present and never in great abundance. Artificial soils of this type are formed from the dredgings of the effluent ditches on sewage farms, or of canals or canalised rivers. Under the most fertile conditions willow may grow so fast on such soils that the wood is too light and spongy to be of the best quality.

Upland Sites.—Upland sites devoted to the cultivation of the bat willow are at present, rather restricted in area. They occur in the east of England, and principally in Essex where the soil is formed from glacial drift. The drift is variable in nature; it may be sand, gravel or clay, more or less pure, or mixed in any proportion. In the parts of East Anglia concerned, the underlying solid formation is either chalk or clay. Willow cultivation is here confined to the soils designated as boulder clay and to the more fertile sandy loams. The boulder clay is the more important; it is almost entirely arable, with the fields usually bounded by open ditches. The soil is fairly heavy, flinty and, although more permeable than a pure clay, sometimes requires drainage. Willow appears to be grown on the uplands only where the boulder clay, or other glacial drift, overlies the London clay. The trees are planted round the edges of the fields, a little way down the side of the ditches (Plate IV, fig. 2). Generally willow grows more slowly on the uplands than in the valleys, but very good quality wood is produced, a fact which indicates that the cultivation may be extended out of valleys under certain circumstances.

Drainage.—Soil may hold a superabundance of water, largely owing to its physical character; this is true, for example, of peat or clay. In most cases, however, excessive wetness is caused by lack of drainage; the physical character of the soil is then of secondary importance. It is a matter of common observation that willow roots grow out into the water of streams or ditches, and because of this it is thought that any wet place is suited to them. It is necessary, however, to distinguish between well- and badly aerated water. Running water is always well aerated; even slowly moving or stagnant water in a ditch may be in summer, owing to oxygen given off by water weeds during daytime. So long as water contains sufficient oxygen, willow roots will grow healthily in it. In a bog or marsh, however, matters are very different; the movement of soil water is usually slow or absent and there is nearly always a mass of partly decayed and putrefying vegetation which, of itself, results in a lack of sufficient oxygen to allow healthy root development. In this case, lack of proper aeration rather than excess of water is the cause of disease; a healthy state may be produced by adequate drainage.

On drier sites, the tree will grow quite healthily, providing it can establish itself. The type of locality will be reflected in the rate of growth and the depth of root development. There are sites where there is sufficient water during an average, or wet season, but not during a dry one; examples of this occur where gravelly or sandy drift overlies a clay. It is on these soils, with a variable water-table, that willows suffer most from drought; each dry season acts as a check to growth, a severe one often causing die-back of the crown. This is one of the main reasons, apart from their general poverty. why the gravel soils frequently found in river valleys so often fail to produce good willow.

As, in some places, sites occur which are intermittently too dry, so there are others that are intermittently too wet. In such places better growth is obtained than in permanently sodden marshy sites, but during the periodic

wet times die-back of the root occurs, either because of the bad physical conditions temporarily prevailing, or because of parasites whose growth is favoured by them.

Both in sites which become temporarily too dry or too wet, improved drainage is the key to the maintenance of favourable soil conditions. On those which are drier it encourages deep root development by lowering the water-table during the wet seasons; on the wetter, it removes surplus water during such times, thus preventing root suffocation and decay.

Summary.—It may be said that good physical conditions for growth seem to imply a soil which has the power of water retention but is well drained. This being so, loams provide the best class of soil. Soils derived purely from clay are unsatisfactory owing to defective drainage. Gravels tend to be unsuitable owing to lack of retentive power and consequent liability to drought; sands are also likely to cause failure for this reason. Peaty soils usually occur in badly drained places; if well drained, as in the Norfolk fens, they form a light open soil, the physical properties of which are only moderately favourable.

It should be observed that soils cannot be rigidly classified into clays, loams, sands, etc., although it is usually convenient to speak of them as such. All graduations between the various types of soil occur and each has to be considered on its merits.

Good drainage in the case of willow growing is synonymous with good aeration. Given favourable physical conditions, the rate of growth depends on the amount of available food material in the soil. The application of farmyard manure, top dressing with the remains of weeds dredged from rivers and the dredgings from the effluent ditches on sewage farms, result in very fast growth. Soils made up in this way contain a large quantity of humus rich in plant food. It is unusual to apply artificial manures, but trees bordering on cultivated land often benefit from dressings intended for agricultural crops.

PROPAGATION

The cultivation of willow for cricket bat timber is a more difficult matter than for pollards in that more care is required in propagation, tending and protection.

Propagation is usually carried out by means of tall shoots which, unlike pollard poles, bear their natural head of branches. These shoots are commonly called sets and are produced in various ways: they may be cut from a pollard, or from a low stool like that used to produce osiers, or they may be grown from short cuttings. In the latter case they are always rooted before planting out; in both of the former they are usually unrooted and perhaps, strictly speaking, the term " set " should be applied solely to these.

Poles from Pollards as Sets

Large unrooted sets, or poles twelve feet or more in length cut from pollards, were formerly used universally for propagation, and this method is still met with, although it is not a good one. When planted the poles usually stood from ten to fifteen feet out of the ground and were of sufficient thickness to do without support. Where there was a shortage of poles it was customary to take the straighter portions of ends of branches from felled trees as substitutes. The sets or poles were planted to a depth sufficient to keep them wind-firm without staking. A particular point was made of retaining the head of branches at the time of planting, so that the tree might grow normally and the trunk be less subject to decay, the side branches only being

cut off to a height of at least six to seven feet from the ground. As the trees developed, pruning was often, unnecessarily, taken up to ten, twelve, or even sixteen feet. During the whole life of the tree, any new shoots that developed on the pruned part were rubbed off, so that timber free from side branches might be produced.

The chief objection to this method of propagation lies in the type of set. Sets cut from pollards are frequently crooked and heavily scarred by the removal of side branches (Plate II, fig. 1). These irregularities which are perpetuated in the grain make the wood of low value for bat manufacture. Numerous defects such as " trapped bark," twisted grain and certain types of " stain " are apt to develop from pruning scars.

Sets from Low Stools

The chief aim of good growers at the present day is to produce a set which is nearly faultless in being (i) straight, (ii) free from side scars, (iii) stout enough to stand erect without a stake and (iv) long enough to give a clear bole 7ft. 6 in. to 8 ft. long. Several methods have been evolved, using either unrooted or rooted sets. The method of producing sets on low stools (Plate III) after the manner of osiers, is an improvement over that of using poles from pollards. To obtain straight sets in this way the stools should not be more than 3 ft. apart. Each stool consists of a single stem grown from a cutting, and cut back to the height desired, which may vary up to 4 ft. but need not exceed eighteen inches. A low stool has the advantage of reducing to a minimum the curve at the base of the shoot, though it does not eliminate it altogether.

Shoots not thinned out.—The simplest of the methods followed allows the shoots to grow for three to five years in unrestricted competition, with little thinning out and no pruning; the grower depends on the dense growth of the shoots to suppress those which are weakly and to kill the side branches of the stronger, which dominate and form a canopy. Usually, however, most of the sets produced are imperfect. Under perfect conditions some very good sets may be grown in this way.

A moist and fertile soil, preferably combined with irrigation and heavy manuring, is necessary to obtain satisfactory results by this method. Much depends, in fact, on the growth obtained in the first year. The terminal bud of the willow usually dies at the end of the growing season, and the shoot is continued by one of the side buds immediately below. Sometimes this bud is next to the terminal one, and so close that the shoot continues straight in growth during the next season, but commonly it is lower down and emerges at an angle, forming a kink in the otherwise straight set. On poor soils, where a growth of only six or seven feet occurs in the first year, the second year's shoot may not grow perfectly in line with that of the first year, with the result that crooked sets are produced. Thus it is often difficult to obtain satisfactory sets by this method.

Shoots thinned out.—Bearing the above in mind, consideration has been given to obtaining better methods of set production by paying greater attention to the set while growing on the stool. In this revised practice the stool itself is usually kept quite low, being a foot or less in height, and undue competition between the shoots on any particular stool is avoided by reducing the number on each to between two and four. In this way greater height and strength are obtained and a larger number of the first year's shoots reach the height required, nine and a half feet, to give three bat lengths in the stem, two feet being allowed for insertion in the ground on planting. Irrigation and manuring are still needed, however, if the best size and quality of set are to be obtained from the shoots.

It is evident that where the shoots are thinned out they will have room to form much stouter side branches than under the more crowded conditions, where there is little or no thinning, so pruning becomes necessary. This may be done in two different ways. (i) According to one method the side shoots, which always develop in willow during the first year's growth, are pruned off at some time between autumn and spring. If the terminal bud has died back the tip is carefully cut to the bud which is to form the leading shoot for the next growing season, so that this will have a favourable opportunity of growing straight. If the pruning of the first year's shoot has been well done the amount of disbudding, or rubbing off of the young shoots, is reduced to a minimum. The leading shoot produced in the second year is treated similarly, at least up to the height required to produce the desired length of clean timber. It is not usually necessary to continue this pruning process to the third year's shoot, and the growers who have adopted this method of production rely on obtaining a set large enough to plant at the end of two years. (ii) An alternative method of preventing the development of side branches on the lower part of the stem, is known as disbudding, that is, pinching off each side shoot (below its lowest leaf) while still soft (Plate IV, fig. 1). The stump of the branchlet dries up and either falls off, or is easily knocked off at the end of the season. The advantages of this method are that no knife wounds are made and less skill is required. The disadvantage lies in the production of weak, whippy rods when the shoot is not sufficiently vigorous. Some growers try to avoid this by shortening the laterals during the growing period, removing them finally at the end of the growing season.

Rooted Sets

The use of rooted sets has never been a general practice in willow cultivation. It is still uncommon because the use of unrooted sets is cheaper and better adapted to farm practice on account of the ease with which sets can be produced and the simplicity of planting them.

For the production of rooted sets the maintenance of a nursery is necessary, and to small growers this presents certain difficulties.

In their propagation small cuttings seven to nine inches long, and a half to one inch in thickness, are used. These are planted in the nursery six to nine inches apart in lines, there being a space of two feet between the lines. The cuttings are almost wholly buried in the soil and planting in January or February gives the best results. Only one shoot should be allowed to grow from each cutting; the treatment of this is as described above for the production of unrooted sets. At the end of the first year the plants are lifted and graded according to the length of shoot produced. They are then replanted in lines, there being 18 to 24 inches between the plants in the lines, and three feet between each line. The largest plants can be set out when two years old; the others remain three or even four years in the nursery.

Alternative methods are: (i) to cut back the cuttings when lifted (at the end of the first season) to about an inch above ground level, and to re-line as above. In the succeeding season only one shoot is allowed to develop and this time, owing to a root system having already been formed, much stronger growth is obtained and a better type of set produced. The usual distances in such cases are two feet between the plants in the lines and three feet between each line. It is by this method, if rightly followed, that it should be easiest to produce the right type of shoot. (ii) One-year-old unrooted sets 8 to 10 ft. long are planted in rows 2 to 3 ft. apart, and from 1 to 2 ft. between the plants. Two-year-old sets may also be used satisfactorily. These may be planted out after one year if good growth has been made.

The Advantages of the Various Methods

The advantage of the unrooted set is that it is easily raised; no special nursery is needed, and the method of planting is simple; a straighter set, free from scars, involves a certain amount of nursery work. The chief cultural disadvantage of unrooted sets is their susceptibility to drought in the year of planting, resulting, frequently, in heavy losses.

The rooted set is more troublesome to lift and plant, but if the operation is carried out at the right season, there is a greater prospect of success than if unrooted sets are used. Also, owing to the small size of the cutting used in propagation, the end in the soil rapidly heals over and the danger of stain or decay entering the stem is reduced to a minimum. In an unrooted set on the contrary, the lower end is so deeply placed that even on light well-aerated soils it is slow to heal over; on heavy soils it may never heal. Stain or decay entering in this way is only serious locally.

The advantages and disadvantages of the various types of set are tabulated below for ease of comparison:—

Type of Set.	Disadvantages.	Advantages.
Unrooted sets.		
From pollards ..	Often very crooked and with large pruning wounds or branch snags.	Easy and cheap to raise. Do not require staking.
Low stools in beds—		
(*a*) Shoots not thinned.	Many sets not straight, often bearing large pruning wounds. Sets tend to be too short, weak, and to require staking.	Easy to raise; little if any more trouble than pollards. Many sets straighter and requiring less pruning than those from pollards.
(*b*) Shoots thinned out.	Cost of production is raised appreciably, more skilled labour being required.	Straight and good sets are produced, on the whole. Pruning wounds are either insignificant or absent.
Rooted sets from short cuttings.		
(*c*) If the plant is not cut back on re-lining.	Cost of production is higher than in any of the above; skilled labour is required. Sets frequently require staking.	Better root development is possible; early formation of a fibrous root system is secured, and loss from drought is reduced. Shorter length of clean stem is required than with the above.
(*d*) If the plant is cut back on re-lining.	Costs are high, as in (*c*), skilled labour being required.	The advantages of (*c*) in regard to root system and length of clean stem are secured. The required length of stem can be produced in a single growing season and is usually straighter and free from wounds.
Rooted sets from long cuttings.		
(*e*) 1- to 2-year-old sets are struck before planting out.	Danger of loss in the nursery during drought; loss of length on planting.	An easy and inexpensive method of raising rooted sets.

Given suitable conditions the best results follow the use of short cuttings, which are given one year in a nursery and then, after cutting back to within an inch of the ground, and re-lining, are allowed to develop one shoot only

(method *d*). An objection to this method is its cost, but it is considered that this is more than repaid by the higher quality of the timber produced. Where conditions are not favourable for this method, that lettered (*b*) may be used.

Many growers, including some with long experience, may not admit that the additional expenditure involved in careful cultivation and pruning is remunerative. The view is often advanced that as there is a core of about three inches diameter in the centre of the stem, which does not enter into the manufacture of bats, and that, as by the time this is formed the scars will be healed over, no special care need be taken in reducing the size of pruning wounds on the set or in eliminating them. This contention is disproved, however, by a comparison of trees raised from sets produced with and without the supposedly unnecessary care. The result of such a comparison leaves the matter beyond doubt. As explained further on page 30 defects in the set definitely influence the timber of the bat clefts; trees from the better sets are of superior quality and command a higher price.

PLANTING

Planting Distance

It is characteristic of the tree willows that they grow well only when given plenty of room for crown development; accordingly, a very wide planting distance should be adopted. In practice it is found that the best results are obtained when there is a space of at least thirty feet between each tree in a single row. As abundant light is necessary for the production of fast-grown timber the planting of trees in single or double rows is preferable to assembling them in plantations. Although a spacing of thirty feet may be sufficient in single rows, in double rows the trees should be placed a little wider apart, say thirty-five feet, and in plantation form still more widely, up to forty-five feet.

The rate of growth depends not only upon the space available for crown development but also on the suitability of the site. Where the soil is specially fertile willow of sufficiently fast growth can be obtained from trees planted more closely than where conditions are less favourable. On some of the richest sites complete freedom of growth may, indeed, produce a timber that is not quite first-class owing to excessively wide annual rings. Such very fertile sites are however exceptional.

Planting Methods

Without Mounds (Plate V, fig. 1)

Until recently the usual method of planting the unrooted set was to remove the top spit of soil with a spade; a crowbar or ironshod stake was then driven into the soil for about eighteen inches. Into the bottom of the hole thus made a little fine soil was dropped and the set then inserted and rammed firmly home. When the crowbar is used it is difficult to ensure that the soil is firmly bedded round the set; moreover the soil at the sides of the hole is apt to become too hard and firm, and there is danger of the bark at the extremity of the set becoming torn and ragged. This often makes satisfactory root development difficult, so that in dry seasons recently-planted sets suffer severely. Nowadays the holes for unrooted sets are more frequently made entirely with the spade; the extra labour required is found to be warranted by results, and the faults referred to do not readily arise. The depth of planting should be sufficient to keep the set quite firm, preferably without staking; it varies between eighteen inches and two feet six inches according to size of set.

The rooted set is planted by the method known as pitting, in the same way that forest trees are often planted. A hole is dug sufficiently large to take the roots when spread out; its depth should be such that the top of the cutting from which the set grew is no higher than the surface of the soil, preferably just a little lower. Some growers plant more deeply than this in the belief that better root development is thereby obtained, but the wisdom of the practice is questionable.

Mound Planting

Some growers are adopting the method of planting in a mound of earth (Plate V, fig. 2). This gives sufficient stability with a shallower hole; it provides a supply of well-drained soil in which rooting may start, and it suppresses weeds for at least the early stages of growth of the young tree. This system is specially suited to localities where drainage tends to be inadequate, or weed growth particularly rank; it may not have any advantages where conditions are more favourable. The mound should be sufficiently large to prevent excessive lack of moisture in a dry season; a diameter of six feet has been recommended as a minimum.

Direct Planting of Short Cuttings

In areas having adequate soil-moisture, unrooted cuttings at times have been planted *in situ*, with apparent success. It is probable that this method will fail unless the soil is moist, fertile, and kept free from weed growth; it has not yet been adequately tested.

Planting Season

Unrooted sets should be planted during the months of January, February and March; it is dangerous to delay until April unless copious watering is possible and even then earlier planting ensures better root development. It is found that rooted sets are best planted in late winter, preferably in February; at this season new root growth begins.

Newly planted trees need protection from cattle, rodents, etc. (see page 18). Soft shoots on the lower part of the stem should be removed by rubbing whenever they appear. This should be done every two or three weeks during the growing season; neglect leads to the young shoots becoming woody, in which case pruning with a knife is necessary and scars remain.

Young sets may require staking for the first year or two in order to give them sufficient rigidity. The bark of young willows is very tender and great care in binding is necessary to avoid the development of bark galls. Pads of some suitable material, such as pieces of old tyre tubing, may be used to advantage for the protection of the stem from rubbing against the stake, or from being constricted by the tying material.

Manuring and Irrigation

It is not often that irrigation or manuring is carried out in connection with the cultivation of the bat willow. There are, however, certain exceptions, as on sewage farms. The trees are planted along the banks of the ditches through which the effluent flows; sometimes on the effluent beds, or on fields periodically flooded. The water supply is thus provided by a periodic and more or less regular irrigation. Futhermore, the effluent beds and the banks of the surrounding ditches are subject to regular manuring,

in the first case with the deposit from the effluent and in the second with the dredgings from the ditches. Providing the drainage is sufficiently good, the rich manuring and abundant water supply make the production of fast-grown willow not only easy, but almost inevitable under free conditions for growth.

More or less regular manuring occurs also along the banks of canalised rivers. These are dredged periodically to clear out the weeds and silt; the dredgings are often deposited on the bank not used as a towing path, and in such cases very fast-grown willow is usually obtained. Owing to the maintenance of a constant water level by the canalisation there is always sufficient water available in such situations, once the roots of the trees are established.

The application of farmyard manure at the time of planting is not uncommonly practised; the advantage lies in the stimulus given to the young tree to make good the damage done by transplanting and to overcome the resulting check in the growth. Farmyard manure is applied most satisfactorily in a well-rotted condition, and well mixed with the soil.

On soils of a light, dry nature, cultivation may be made possible, in some cases, by means of irrigation, where no expensive outlay for pumping, etc., is involved. The water is led into shallow ditches between the rows of trees. It is worth consideration whether, in some cases where running water is plentiful, land which has hitherto been considered unsuitable might not be utilised in this way.

Whenever irrigation is practised the greatest care is required to maintain a well-regulated and continuous supply during dry periods. The danger of water-logging must be avoided.

TENDING THE TREES

Mulching Young Trees

Before the root system of the newly planted tree has had time to develop, some protection of the soil is desirable; this may be given easily and cheaply by mulching with cut herbage or such material as dry bracken. This serves to prevent the soil drying out, or freezing, and helps to form a good tilth; it serves, also, to prevent undue compaction of the surface. Mulching may be continued with advantage during the first year or two of the life of the tree, preventing injurious weed growth and the consequent formation of adventitious roots at the base of the trunk; the mulch acts also, to a certain extent, as a fertiliser.

Disbudding

During the early life of a willow tree there is a tendency to develop buds where lateral branches have been removed, these forming stem-shoots. In order to produce timber free from knots all shoots developing from such buds must be removed up to a height of eight feet, before they become woody. This (Plate II, fig. 1; Plate IV, figs. 1 and 2) is done by rubbing off the buds by hand at intervals of about two weeks as long as new shoots appear which is mostly during the spring and early summer. If this has been done early and often enough on the set in the nursery, very few stem-shoots will appear on the young trees. If stem-shoots are neglected, and have to be pruned off with a knife, the development of others is encouraged, and faults in the wood result. Some growers disbud a much greater length of stem than eight feet; this is unnecessary and checks the growth of the tree.

Topping the Crown

The crown of a tree may be left without any pruning, with entirely satisfactory results. Some growers adopt the practice of cutting out the leading shoot, thus preventing the development of a single main stem, which is replaced by two or more main branches.

At least three methods of " topping " are practised.

(i) After two years the leading shoot is cut back at a point above 8 ft. (ii) The main branches of the tree so treated are cut back in a subsequent year, so that a thick head of branches is eventually produced. (iii) The whole of the top above 8 ft. is removed, producing a tree like a pollard.

The fundamental idea behind these practices is that by following them, wood will be formed in the bole, which would otherwise go to a continuation of the main stem; this appears doubtful and requires experimental confirmation. Another reason advanced is that trees so treated present less surface to the wind, but as a matter of fact they form a denser crown, which is structurally less well adapted to resist a gale than a tree with a straight main stem and slender crown. This was clearly shown in the severe gales of 1935, when topped trees exhibited a decided tendency to split.

Removal of Branches

Sometimes the grower prunes his trees to a greater height than 8 ft. (Plate VI). This is a mistaken practice, adding to the cost of production without commensurate return, lengthening the rotation and reducing the rate of growth and value of the tree. Pruning wounds permit the entry of organisms which cause stain and decay and leave permanent scars in the healing of which an irregular growth of wood is produced which is useless for cricket bats.

Cutting Back of Crooked or Damaged Trees

Young trees which are either crooked or damaged may be cut back to ground level in late winter; the strongest of the shoots which develop subsequently is then selected to form a new stem; disbudding below 8 ft. must be practised, as in the case of sets. This practice is not free from objection because the young, tender shoot is more liable to frost injury than is a more developed plant, and is also more susceptible to damage from weed growth and from pests. Nevertheless when sets of a bad shape have been established, cutting back in this manner provides an excellent means of producing a new straight stem free from defects.

Thinning

Thinning is not required if correct planting distances have been adopted. It is necessary, however, to deal with cases where trees have been planted too closely. Where this has been done thinning should be carried out as soon as possible, while the trees are still immature and before there is danger of injury by suppression of crown development, or interference with the root system of those which are to remain. In the case of older well-established plantings, it will be well to consider whether it would not be more profitable to clear-fell at once and replant, rather than to thin trees if their crowns are so small that satisfactory recovery within a reasonable period is improbable.

Fencing

The bark of young willow is green, tender and sweet, and is attractive to grazing animals, especially horses. More than most trees, therefore, willows require protection. In the healing of wounds caused by bark injury, defective

and useless wood is developed which cannot be made into bats. Nor infrequently the whole of one side of a tree may be stripped of its bark, and ruined. Rubbing by livestock is also injurious.

Various methods of protection are employed, some of which, however, ultimately result in injury to the tree. Where rodents are likely to do damage, each tree should be surrounded by a guard of wire-netting of small mesh high enough and buried deeply enough to protect the bark.

Against livestock a strong fence should be erected, and maintained throughout the life of the trees (Plate II, fig. 2). The tying of thorns or other brushwood round the tree trunk is usually ineffectual and sometimes injures the bark.

DAMAGE CAUSED BY VARIOUS AGENCIES

Frost

Ill effects due to bad climatic conditions are usually brought about by either frost or drought. Injury from other factors, such as wind, lightning, or sun scorch is much less common.

The indigenous tree willows are probably not to be regarded as very frost susceptible, but they may suffer serious damage in places where exceptionally severe late frosts occur. This is partly to be accounted for by the fact that they are trees with a long growing season, and occupy low-lying land. The buds begin to burst in March, well before the spring frosts are over, and, especially on young shoots, growth continues until the end of the summer. Damage to the leaves, flowers and young shoots is undoubtedly of common occurrence. It was, for example, widespread after the " blackthorn winter " of April, 1933. This was an early season, and over the whole of the southern part of England bat willows suffered from injury to catkins, young leaves, and to some extent, to soft, developing shoots. There can be no doubt that a severe die-back of the twigs can occur in this way, but it does not seem to be usual.

Once the willow stems have formed rough bark they are not usually susceptible to frost damage, but stems with smooth, green bark may be affected very seriously. The damage done varies in appearance according to the severity of the injury.

The less severe injuries, that can be seen externally, result in the death of the outer tissues of the smooth, green bark on young stems. The dead bark cracks and, as a result, rough patches develop (Plate VII, fig. 1) which may be large or small, and which simulate in appearance the normal rough bark which would develop later. This abnormal rough bark may be conveniently called " frost " bark. If the injury takes place after new wood has started to form, a " frost ring " will occur at the beginning of the annual ring, beneath the frost bark. A frost ring is a zone of discoloured tissue which develops in the wood, owing to frost injury.

Frost bark, in itself, does little damage to the tree, but where it occurs frost canker is always liable to develop. This canker does not appear to be common, but it is very widespread and sometimes causes severe injury. It is most dangerous during the first few years after planting, when the main stem is small. Soil conditions appear to be very closely connected with susceptibility to this type of injury, and in all the really severe cases so far examined the soil has been unsuited to good growth, chiefly owing to lack of drainage, but sometimes also because of poverty. Trees growing on good soil and escaping injury may be adjacent to, and on much the same level as, those severely cankered.

Canker is most common within six to eight feet of the ground; that is, on the part of the tree which is of most value commercially. Sets may be affected while still on the stool, and low stools are more liable to this type of injury than are pollards. It is characteristic of frost canker that the part of the stem near to a bud or side branch is particularly liable to injury and frequently, but not necessarily, the damage is confined to small areas around such places. Because frost canker develops early in the life of the tree, localities in which it occurs badly are soon discovered. Almost invariably they are low lying and usually ill drained. Often little can be done to mitigate the conditions prevailing, which usually arise from cold air collecting in a hollow, or on low, flat areas. It will be found, however, that the effective draining of the soil, where this is feasible, reduces the amount of damage, or so improves conditions for growth that the injury is of much less consequence.

Sun Scorch

Young trees sometimes suffer from sun scorch, especially when larger ones which previously shaded them are felled. A long strip of bark is killed on the south side of the tree, which is thus rendered useless for bat willow timber; sometimes this may take place early in the year, frequently during April. This type of injury is not common. There is no remedy for it but to avoid the sudden exposure of the stems of young trees or to plant them in such a position that they receive full sunlight from the beginning.

Wind

Wind does not cause any appreciable damage, as a rule, but occasional instances of wind-throw occur. A very shallow root system, such as will be induced by impermeable sub-soil, or by a very high water-table, predisposes trees to this danger.

Unsuitable Soil Conditions

Given ample space the tree's rate of growth, and to a large extent its general freedom from disease, depend on the condition of the soil. The bat willow appears to have a very adaptable root system, it is deep rooted or shallow rooted according to the conditions prevailing. The depth to which its roots develop is probably controlled chiefly by the water level and aeration of the soil; the better aerated the soil, the deeper the roots go. Within limits it does not matter whether the root system is shallow or deep; in either case good health may be maintained; the important point is that rooting conditions shall be reasonably constant. Much disease is due to excessive variation in soil conditions, and its true cause is often overlooked because of the difficulty, or impossibility, of observing the state of health of the root. Even when the crown is not obviously unhealthy, bad rooting conditions are frequently responsible for a slow rate of growth. Much of this ill-health takes the form of periodic dying back of the smaller roots. Within limits, and if confined to a part of the fine rootlets, this may be regarded as a normal phenomenon: only in excess does it become pathological. It is probable that parasites are associated with this type of disease, but it is certain that its development is made possible by the adverse state of the soil. Nothing is more important, therefore, than to realise what conditions are necessary to maintain a healthy root system. Shortly stated, these are:—good aeration, and an ample but not excessive water supply, which is also reasonably constant. Much incorrect planting is done because growers do not realise this, or wrongly estimate the conditions that prevail in the soil of the site chosen. Good drainage is generally the key to improvement.

Die-back may be produced in trees growing either on too dry soils or on those which are too wet. Such soils are avoided by willow growers. Sites occur, however, where there is sufficient water in an average season, but not during a dry one; examples of this are found where a gravel or sand overlies a clay. The opposite condition may occur where the soil is water-logged in a wet season. In both cases die-back of the roots follows the occurrence of the unfavourable condition. The remedy lies in better drainage; in the case of the drier site this allows the root system to extend more deeply during an average season, and to draw its water supply from a greater depth during a dry one. On the wetter site, drainage removes the surplus water and prevents the roots being suffocated in wet seasons.

Where trees are thus injuriously affected by unfavourable conditions, and their vigour is reduced, infection by fungi is particularly liable to occur. One of the most common parasites is the honey fungus, *Armillaria mellea,* which attacks the root system, often killing the tree. Fungi infecting the crowns of trees, under such conditions, are commonly not vigorous parasites, and usually cease their attack if the adverse physical causes are removed, as already indicated.

Diseases of Unknown Origin

A number of pathological phenomena develop in willows, the cause of which is at present unknown. Of these the most serious is the defect known as " stain," " bar stain," or " butterfly mark." This appears as a dark, horizontal bar across the bat; brown wings of rather lighter stain go out from the sides of the bar (Plate VII, fig. 2). In a standing tree the position of any large patch of stain in the wood is shown by the presence of a swelling or slight burr on the back. This burr is usually cracked horizontally (Plate VIII, fig. 1). If the stem is suitably split and cross cut the stained wood shows as a sector of the transverse section, but it extends only for a short distance up and down the tree. The dead bark in the burr is thicker than normal (Plate XI, fig. 2) and the outer surface of the wood is slightly sunken. At the beginning of each annual ring, within the central bar of the stain, there is a zone of abnormal tissue consisting largely of wood parenchyma. Opposite this bar of stain, and also opposite the abnormal woody tissue, the live bark is exceptionally thin, owing to the fact that parts of the living tissues have been killed each year. The dying of the bark, in this way, seems to correspond with the formation of the abnormal tissue at the beginning of the annual rings. Sometimes the injury is more severe than has been described, and the cambium is killed instead of being stimulated to form abnormal wood. In this way hidden cankers arise, the presence of which cannot usually be recognised from the outside (Plate VIII, fig. 2). If the bark is stripped off a stained stem the hollows where the stain occurs can be seen. In a bad case these can be very numerous, far more so than the burrs, which only occur outside the larger stains.

The examination of stained trees shows that in most cases this defect appears at points in the callus of pruning or other wounds. Though it usually arises where there has been an injury, it does not seem necessary for its development that any definite wound should occur. Certainly the continued formation of the stain takes place without there being any further wound. One expects to find most stain in localities subject to early and late frosts; there is no present proof that frost is its cause, but the anatomy of the injured tissues suggests this.

The cause of the discoloration is due to killing and browning of the medullary ray cells, and the diffusion of colouring matter from them. The

ray cells are killed within the dark central bar only; the brown wings appear to be formed by the staining of the cell walls with the colouring matters that diffuse from the rays.

Until the cause of stain is known with certainty, control measures cannot be suggested with complete confidence. The most important thing is to avoid pruning wounds on the stem of the set; even the pruning of one-year-old branches is dangerous. Wherever rough bark forms unduly early, and especially in small patches around buds, twigs or wounds, stain is to be expected. The early formation of rough bark is usually, if not always, caused by frost, and apart from the avoidance of recognisably frosty sites, frost is to be countered chiefly by good drainage and stimulation of growth.

Some growers consider that certain strains of the cricket bat willow are specially susceptible to stain. Careful enquiry has provided no confirmation of this; it is a matter which can only be determined by experiment.

Bacterial Diseases

There is one important bacterial disease of the tree willow; this is the so-called " watermark disease " ([10], [12a]). It is widespread throughout the counties of Essex, Suffolk, Hertfordshire and Norfolk, being especially prevalent in the first three. A very similar if not identical disease on *Salix alba*, has been described in Holland([18]), but in no other country, so far.

Diseased trees may be recognised in the latter part of May, or in June, by the presence of wilted and browned leaves on one or more branches. Sometimes, but only rarely, the whole of the crown is affected. Trees attacked in previous years have a part of the crown dead (Plate IX, fig. 1) and appear to be stagheaded. On cutting through an affected branch, the typical stained appearance of the diseased wood is seen (Plate IX, fig. 2), and from this, in freshly affected specimens, bacterial slime exudes. Insects are probably the chief agents for carrying disease, although this has never been proved. Trees of all ages and conditions may become diseased, although there is a decided tendency for those growing on well-drained sites to be less affected than others.

The only method of control known up to the present, is the felling and destruction of the trees. This should be done as soon as the disease is recognised; the tops should be burnt and the larger parts split up and allowed to dry out. Orders for the destruction of diseased trees are at present in force in Essex, Suffolk, and parts of Hertfordshire and Middlesex, the principal willow-growing counties. (See Appendix, p.45.) There is evidence from large estates, where such destruction has been carried out for some time, that it is an effective means of keeping the disease in check.

The cricket bat willow, *Salix alba* var. *caerulea*, is the most susceptible tree; it is also the most numerous and valuable tree throughout the affected area. *Salix fragilis*, and the hybrid x *Salix viridis* are rarely attacked.

For a fuller account of this disease, see Forestry Commission Leaflet 20, *Watermark Disease of the Cricket Bat Willow* (H.M.S.O. price 2d.)

Fungal Diseases

Diseases affecting the Root

The only important parasite known in this connection, is the honey fungus, *Armillaria mellea* (Vahl) Quèl.([4]) Trees are usually attacked when established and of some size. They do not invariably die; indeed part of the root may be killed without the crown being visibly affected. Dying trees come into leaf in the spring, but fail to develop the full foliage. When the bark

is removed at the base, the thick white mycelium of the fungus may be seen, and if the soil is dug up, the long black rhizomorphs may be found. As the tree dries out, rhizomorphs develop under the bark. The light brown rather honey-coloured fructifications appear at or near the base of the trunk: they are, however, not infrequently absent.

The usual means of control recommended are the grubbing-out of the roots of dead trees or the excavation and removal of the affected roots of those still living. In actual practice it is very difficult to excavate the whole of an infected root, and, apart from the not inconsiderable cost, the attempt is not always effective. There is probably no direct means of control available[2] losses may, however, be reduced or avoided, if it is remembered that the fungus may be unable to kill a tree unless the way is prepared by adverse conditions affecting its health. Usually these conditions are to be found in the soil; trees are most liable to be affected where drainage is bad or the soil is too dry. Such bad conditions usually prevail intermittently; at other times healthy growth is quite possible. In the control of the honey fungus it is therefore most important that in any area planted special attention should be paid to the soil conditions and in particular to proper drainage.

Diseases affecting the Bark

A fungus, *Cytospora chrysosperma* (Pers.) Fries, commonly found on dying twigs and branches, will colonise and rapidly kill back any tree that is in a seriously weakened condition. It is, thus, the common fungus on newly planted sets suffering from drought and, in very dry years, it appears on the crowns of large trees. This fungus produces minute black spots (fructifications), buried in the bark, from which orange-coloured spore-threads are extruded, especially in the later months of the year. There is no evidence that it is ever a virulent parasite on vigorous trees; the removal of unfavourable conditions, *e.g.*, by copiously watering during drought, usually stops the course of the disease.

Black canker, ascribed to *Physalospora miyabeana* Fukushi, attacks the leaves and the ends of the young twigs; it may spread down the petiole from the leaf and cause a canker on the stem. It has been noted chiefly in connection with osier willows, on which much damage may be caused. Material of the tree willows has occasionally been received bearing this type of damage. Bat willows of some size are rarely affected to any extent, but in set nurseries occasional severe attacks may occur. Spraying with Bordeaux Mixture in the spring has been recommended to prevent infection. Canker on willow rods or small branches has also been attributed to *Physalospora gregaria* Sacc., *Fusicladium salaciperdium* (All. and Tub.) Tub. and *Marsonina salicicola* Bres.

On the tree willow, at least, it is sometimes difficult to distinguish the damage caused by these fungi from that caused by frost.

Diseases affecting the Leaves

No serious fungal leaf diseases of the tree willows have come under notice; far more damage appears to be caused by insects than fungi. The silver-leaf disease, caused by *Stereum pupureum* Pers., chiefly known in connection with plum trees, attacks an occasional willow, however. Should a tree be affected it may, for safety, be felled, the tops burnt and the trunk split up and taken away; the fungus is, however, a common saprophyte, occurring with great frequency on the dead wood of some other trees including poplar, sycamore and beech. It is often the first fungus to fructify on the cut surface of a branch stub, or a tree stump.

Wood-rotting Fungi

In the Standing Tree.—Bat willows do not as a rule suffer from heart rot. This is probably because they are grown on a very short rotation, in most cases, and the decay has not time to develop. In trees of about eighteen years of age or more, heart rot has been observed, however, extending into the trunk, both from the crown and the root. Of those fungi which enter through dead branches in the crown, only *Trametes suaveolens* (Linn.) Fr., a fungus whose fructification, when fresh, smells of aniseed, has been observed as a cause of heart rot in a young unpollarded tree. In older trees and in pollards this fungus and also *Fomes igniarius* (Linn.) Fr. and *Polyporus sulphureus* (Bull.) Fr., commonly occur; doubtless a number of other species may also be found.

Heart rot occurring half way up the tree, with both top and bottom remaining sound, has been reported as a common occurrence in tall trees grown too closely together.

In the Cleft while Seasoning.—If the stacking of clefts during seasoning is done properly there is little or no loss from fungal infection. Sometimes clefts are found in which a portion of heart rot has been included; under damp conditions both rotting and staining fungi may be present. The value of bat willow wood depends so much on its good appearance, as well as upon its freedom from weakness owing to decay, that care is usually taken to see that seasoning conditions are good. It is sometimes found necessary to treat the clefts while seasoning, with disinfectant, to prevent the development of stains.

Mechanical Injuries

Wounds of any kind are liable to cause defects in the timber. Mechanical injuries are chiefly of three types: those caused by pruning, by farm implements and by animals. As shown in a previous section large wounds resulting from pruning may be avoided by proper care in the cultivation of sets, and so should not occur. In practice, however, it must be admitted that most wounds actually encountered have their origin in pruning. Injury from agricultural implements may be prevented by the erection of suitable fences or otherwise. Protection from animals must be provided. When sets are planted in, or very near to a hedge, the swaying of the bushes is often sufficient to cause small injuries to the bark, which reduce the quality of the timber.

Treatment of Wounds

If wounds occur they should be treated to ensure rapid healing and the prevention of decay. Torn bark should be cut off close to the stem with a sharp knife to avoid further tearing. Exposed wood may be treated with a good lead paint, which is one of the best materials. Grafting wax can be applied to small wounds, and there are a number of other preparations on the market which may be used. One of the objects sought is to cover the wound completely with a smooth weather-proof surface, which will not crack; Stockholm tar, though a good preservative, fails in this.

INSECT PESTS

Insect pests of tree willows can be divided into two well-defined groups, (*a*) those feeding upon the leaves, or causing galls on the main stem, shoots or branches and, (*b*) those burrowing in the wood itself.

Dicranura vinula L., the puss moth, is a large, thickset insect with a fluffy or downy body, the ground colour of which is grey with darker bands on the abdominal region. The wing spread is 2·5 to 3 inches, and the general colour is grey, the wing veins standing out yellowish or blackish. The eggs are laid in May and June on the leaves of willow or poplar. They may be laid singly, or in groups of two or three. The caterpillars which appear a few days later, and feed until September, are green, have a pale brown head, and an area of purplish brown covering the back, the edges of which are marked with a yellowish line. The body is humped at the third segment behind the head, and at the hind end there are two long tubes which are elevated when the creature is at rest. These tubes can be extended or withdrawn at will. Pupation takes place in a cocoon made out of bark and wood chips, the cocoon being firmly attached to a branch or similar support. Pupation actually takes place in the spring, the caterpillars passing the winter in the cocoon. The life-cycle may occupy two years in certain cases. The full-grown caterpillars are two inches long and easy to see; hand picking is therefore an easy method of control in the case of young plantations. Arsenical sprays can also be used during the feeding season, but these should be applied when the caterpillars are young.

Willow sawflies (*Croesus* and *Nematus*) belong to the family Tenthredinidae (*Hymenoptera*). Their caterpillars differ from those of the *Lepidoptera* in possessing a greater number of pro-legs on the abdominal segments. When feeding, they also have the habit of curling the body either over their heads, or round the plant below them. Many of the caterpillars are conspicuous on account of their bright coloration.

Croesus septentrionalis Leach. This sawfly measures $\frac{1}{4}$ in. in length, and has a wing span of $\frac{3}{4}$ in. The general colour is black, some of the abdominal segments being reddish yellow. The tibiae and first tarsal joints of the hind legs are broad and flattened. The caterpillars are greenish yellow, with black patches, and measure one inch in length. They attack the leaf margins and feed with the hinder portion of the body raised in the air. The species is often abundant locally, and attacks poplar and hazel as well as willow.

Nematus salicis Lep. This species defoliates willow in the south, and the adult is easily recognised by its bright orange-coloured abdomen. The caterpillar measures 1 in. in length, with a shining black head; the first part of the body, and the last segment, are reddish brown to orange, and the rest of the body is bluish green. The eggs are laid on the underside of the leaves, and the young caterpillars feed in companies at the leaf edges. They feed from July to October, and occur on such species as *Salix alba, S. fragilis,* and *S. caprea*. The pupa lies in the soil in a brownish black cocoon.

These sawflies are most injurious to nursery plants and young trees. The caterpillars are only slightly attacked by birds on account of the distasteful fluids which they eject from certain abdominal glands. Parasitic insects sometimes effect a certain amount of control. Hand picking of eggs or larvae can be practised, or spraying can be employed. The caterpillars are susceptible to an arsenical spray when in the young stage.

Leaf-feeding beetles (*Chrysomelidae*). Two species attacking willows are worthy of note though neither is known to attack the cricket bat willow:—

Galerucella lineola F. These beetles measure one fifth of an inch in length, and are straw yellow with occasional darker markings on the wing covers. They hibernate under dead bark, in old posts, or under vegetable refuse. In the winter they can endure a considerable amount of exposure to

wet conditions. They lay their eggs in May and early June. These are white and lie conspicuously on the terminal leaves of the shoots. The caterpillars are plentiful by the end of June. They pupate in the soil, and the second brood emerges during the first week of August. Both adult and larva feed on the willow, attacking buds, leaves and stem. The adults devour the whole leaf up to the midrib, the larvae skeletonise the leaves, eating epidermis and mesophyll. Severe attack entails complete defoliation. The insect is often a severe pest of basket willows, and the following sprays are recommended:—pyrethrum emulsion —2 gallons to 100 gallons of water;—Nicotine emulsion—nicotine $\frac{3}{4}$ oz., soft soap 1 lb., to 10 gallons of water;—Lead arsenate —1 lb. to 10 gallons of water combined with an efficient spreading agent. The spray should be applied in early June when the larvae are young. The insect attacks *S. triandra* and its varieties.

Phyllodecta vitellinae L. The adult beetle is smaller than *G. lineola,* oblong oval in shape, and bronze green in colour. The beetles hibernate in a similar manner to the latter species. They emerge from hibernation from April to the end of May, feeding for a certain time before pairing. Egg-laying begins at the end of May and lasts until the third week of June, unless interrupted by adverse weather conditions. The white eggs are laid in batches of 10 to 30, on the undersides of the leaves. Each beetle lays from 200 to 300 eggs. The eggs hatch in about a fortnight, and the young larvae feed in companies for a period of 15 to 25 days when they are full grown. They are typical chrysomelids, with well-developed legs, and the body covered with regular rows of black, spiny, chitinized (horny) areas, some bearing glands, which secrete a fluid which affords efficient protection against sprays. The pupal stage is passed in the soil and lasts two weeks, the second brood appearing in the second week of August. The greatest amount of adult damage is done at this time. The adults attack the terminal shoots, and bushy growth results. They feed mostly on the upper surface of the leaves. In late seasons they often do much damage by feeding on the unopened buds. The larvae skeletonise the lower leaf surfaces. Control is difficult, as natural enemies are unknown, and pyrethrum emulsion is only effective against the young larvae. Lead arsenate, combined with an efficient spreading agent, kills the larvae, and deters the adults from egg-laying.

Willows vary in susceptibility to attack. Much damage is done to some of the osiers. *S. fragilis* is only very slightly affected and *S. alba* var. *caerulea* is not attacked at all.

The following gall-making species are worthy of note. *Rhabdophaga terminalis* Lw., the bat willow gall midge, is a small fly belonging to the dipterous family Cecidomyidae. The larvae attack the terminal leaves, curling and wrinkling them, thus preventing proper unfolding. The gall formed is reddish at first, but turns black later. Blister galls also occur on the midribs. Attacked terminals cease to grow. The insect chiefly attacks the bat willow, and may cause serious damage. Where sets are grown, formation of side shoots on the young rods at heights between 7 and 10 ft. constitutes one form of damage. This often occasions considerable financial loss.

One of the most common sawflies is the bean gall sawfly, *Pontania gallicola.* This gall is reddish and occurs on the leaves. The adult lays her eggs on the willow leaves in May and the larvae are full grown in the galls by the end of June. They cut their way out of the gall and pupate in a bark crevice near the ground, a second brood appearing later in the summer. The species is common on *S. triandra, S. alba,* and *S. fragilis.*

Pontania salicis Christ, is a spherical gall, common on the leaves of many species, $\frac{1}{3}$ to $\frac{1}{2}$ in. in diameter.

Nematus pentandrae Ratz, gives rise to woody galls in the young stems of willow and poplar.

Mites of the genera *Phyllocoptes* and *Eriophyes* deform the catkins of willow and cause hypertrophy of the reproductive organs. The floral bracts are enlarged, adventitious buds developing at their bases, the whole forming a " witch's broom " type of gall.

Wood Borers

The small poplar longhorn beetle, *Saperda populnea* L., belonging to the coleopterous family Cerambycidae, is better known as a borer in poplar shoots, on which it causes galls. The beetle measures almost half an inch in length, and is yellowish grey in colour with three longitudinal yellow stripes on the prothorax, and three or four spots of the same colour on the wing covers. The eggs are laid in slits cut in the bark of young branches, each of which produces a horseshoe-shaped scar. In the case of the willow there is little or no gall formation, but the young stems are weakened at the point of attack, and breakage often occurs there. The larva is white or yellowish white, with a dark brown head, and three pairs of rudimentary legs on the thoracic segments. It makes its first tunnels under the bark, but soon enters the wood, finally penetrating to the pith. The life-cycle lasts two years. The larvae are much sought after by woodpeckers, and are also attacked by insect parasites.

Cryptorrhynchus lapathi L., the poplar and willow borer, belongs to the family Curculionidae, the beetles having the head prolonged into a snout of varying length which is hidden from view when the insect is at rest, as the name *Cryptorrhynchus* denotes. The insect measures from $\frac{1}{3}$ to $\frac{1}{2}$ in. in length, is elongate-oval in shape, and has the body densely clothed with pale, black scales, intermingled with long, black bristles. There is a band of pale, pinkish scales at the tip of the wing covers; these are repeated at the base of the wing covers, on the underside of the prothorax, and on part of the legs.

The beetles hibernate in the wood, emerging in spring to lay eggs in punctures made by their snout in the bark. The larva is a yellowish white, legless grub, with a curved body, the head region being dark brown. The first tunnels are made just below the bark, and the tunnel in the wood measures from 2 to 4 in. in length. The pupal chamber lies at the end of the tunnel in the wood. The life-cycle lasts from one to two years. The removal and destruction of infested stems is the best measure of control, but in the case of valuable trees, carbolineum emulsion has been recommended as giving efficient results. The beetle sometimes damages the bat willow, and is suspected of being an agent for the spread of vascular bacterial disease.

Aromia moschata L., the musk beetle, belongs to the family Cerambycidae, and has received its popular name on account of the musk-like odour emitted by the adult, which measures about 1 in. in length, and varies in colour from sapphire to peacock green. Its larva is yellowish white, with a dark brown head, and is found boring in willow stems to which it sometimes does considerable damage. The insect is often locally abundant and the adults are in flight during the month of September.

The willow wood midge, *Rhabdophaga* (*Cecidomyia*) *saliciperda* Dufour, is a tiny fly, less than $\frac{1}{4}$ in. in length. In the spring it lays its orange-yellow eggs, chain-wise, on the bark of willow branches. The larvae, which are yellow or orange red, bore into the bast region, and overwinter there.

The damage is covered at first by the thin bark, but this soon breaks up leaving the punctured sapwood exposed. The pupae are bright yellow, and lie in the same chambers as the larvae. Successive attacks gradually extend the injured area, and the stem is often encircled by the scar (Plate XII, fig. 2). Damage is usually most severe on trees growing on poor soil, such trees showing poor foliage and bark discoloration. Destruction by cutting and burning is the best control measure, but the application of a lime wash to injured trees will discourage egg-laying. Many willow species are attacked.

Two insects are associated with " speck " or " fleck ". These terms are applied by the trade to timber damage in willow. This damage is widely distributed and, according to some observers, is more commonly found where the soil is sandy. This association is so marked that merchants often refuse to buy trees which have grown on such soil. The occurrence of this defect is, however, not inevitable, as perfectly clean trees are often produced on soils of this type, and the injury is found in trees growing on soils of a very different character. Examples of the latter are, the Fen region by the River Wissey, where the soil is Fen peat with only a little sand, and the banks of the River Ter in Essex where the soil is an alluvial loam but not of a sandy type.

One of the insects suspected of giving rise to speck is the dipterous cambium-miner, *Agromyza carbonaria* Zett, the larvae of which tunnel in the cambium, their tunnels being covered over by successive wood rings, and leaving specks or marks in the wood (Plate XII, fig. 1); another is *Dizygomyza barnesi* Hendel, a fly belonging to the same family, which tunnels in the cambium of basket willows. This insect has recently been studied by H. F. Barnes of Rothamsted, who calls attention to the fact that infected stems are attacked by bacterial rots which induce cankerous growths. Speck is a form of damage which occurs on many species of willows.

The goat moth, *Cossus cossus* L., is one of the largest British moths, with a wing span in the female of 3·5 in. The fore wings are pale brown, mottled with ashy grey, and show irregular transverse, dark coloured streaks and markings. The hind wings are greyish brown. The abdomen is grey with well-marked rings of a lighter colour. The eggs are laid in June and July at the bases of the trees. The caterpillar, when fully grown, measures over 3 in. has a dark brown head, the dorsal surface of the body purplish brown, and the rest of the body flesh-coloured. The first part of its life is spent boring between the bark and wood, after which it enters the wood. The tunnel in the wood is irregular and the duration of the larval life varies from 2 to 4 years according to locality and other conditions. The pupal stage is passed in a cocoon made out of wood chips and excrement; the cocoon may lie in the wood, or in the soil at the base of the tree. Damage to willow by this species is often of a transitory nature; when severe, the damage is important as it involves the basal portion of the trunk.

Zeuzera aesculi L., the leopard moth, is also a large species, the wing span of the moth being 2 to 3 in. The species is easily recognised by the white wings, marked with dark, bluish black spots. The caterpillar, measuring from 1·5 to 2 in. when fully grown, is yellowish white, with a dark spot on the dorsal surface of the head, the first thoracic segment, and the last abdominal segment. The eggs are laid on the stem and branches from June to August. The caterpillar bores first under the bark, and then within the wood, making a vertical tunnel 6 to 8 inches long. The life-cycle varies from 2 to 3 years, and the damage usually affects the crown and branches rather than the main stem.

Clearwing moths are easily recognised by their transparent wings. The species which attacks willow is the hornet clearwing, *Sesia* (*Trochilium*) *apiformis* Cl., an insect with a wing span of 1·5 inches, and a yellow and black scheme of coloration which gives it a marked resemblance to a hornet, especially in respect of the black and yellow banding of the abdomen. The caterpillars tunnel in the bark and sapwood at the tree base and in the roots, the life-cycle lasting for at least two years. The insect is well known also as an enemy of poplars and when attacks are severe large trees may be killed.

Destruction by cutting and burning of infested stems is usually the only possible control measure for wood borers. In the case of species like the hornet clearwing, which burrow in the roots, the latter also must be destroyed. Valuable trees which have been attacked may have small pieces of potassium or sodium cyanide inserted into the tunnels. This method of poisoning the larvae is, however, tedious and the substances used must be handled with care. Paradichlorobenzene is another fumigant which has been recommended. It is crystalline, insoluble in water, and non-poisonous. It volatilises slowly between 55 and 75 degrees Fahr., but more rapidly at higher temperatures. The vapour is heavy, hence it is a valuable fumigant for use against species which bore in the basal portions and roots of the tree.

Other Insect Pests

Pterochlorus saligna Gmelin, is a large, dark brown aphid, sometimes reported as damaging willow. The insect clusters in colonies on the stem and branches. These colonies sometimes measure over 1 foot in length and several inches in breadth. They are composed of winged and wingless forms, and a feature of the attack is the large amount of honey-dew produced by them. This, falling upon the foliage, attracts numbers of wasps, which feed greedily upon it. The insect attacks many species of willow but in varying degrees. Sometimes the damage is confined to discoloration and premature leaf-fall; at other times, however, willows may be killed and there are records of trees 30 to 40 feet in height succumbing to attack. The wood is often stained a dark brown colour at the places where the insects have been feeding and this damage in osiers ruins the rods for the purpose of basket-making. The insect is usually spasmodic in its appearances, being very abundant in some seasons and practically absent in others.

Chionaspis salicis L., the willow scale, often forms a thick covering on the bark of the stem and branches. The scales which are white are of two kinds; those of the female insects are broad and pear-shaped, those of the males elongate and parallel-sided with a central, raised keel. The presence of this species in quantity is indicative of ill health, probably ascribable to other more fundamental causes than the attack of the insect.

CHARACTER AND USES OF WILLOW TIMBER

The willows together with the closely related poplars, produce a well-defined group of timbers, light in weight, fairly easily cleft, and able to resist considerable shock without splintering. *Salix alba* var. *caerulea,* the cricket bat willow, produces the most valuable timber of any of the numerous native willows ([12]); but others, notably *S. fragilis* and the hybrid x *S. viridis,* are more widely distributed and provide a certain amount of timber and large quantities of poles.

The following are the general characters of willow timber. The wood is soft and light, the average weight when freshly felled being about 44 lb. per cubic foot, and when air dry (approximately 15 per cent. moisture content)

about 28 lb. The wood of well-grown cricket bat willow is appreciably lighter than that of other sorts; its weight commonly varies from 21 to 26 lb. per cubic foot in the air dry condition. Willow timber is straight-grained (see Frontispiece) and of fine and even texture. The sapwood is almost white and the heartwood red-brown; the colour of the heartwood varies considerably, and is not a reliable means of distinguishing between different willows. The annual rings are distinct on all clean-cut transverse surfaces, except near the centre of the tree. The boundary of the annual ring is marked by a fine but distinct light-coloured line of parenchyma, on the outside of a dark band of summer-wood. The pores (vessels in cross-section) are small, hardly to be seen by the naked eye, numerous, and occur singly, or in short radial groups of 2–4; their size and distribution are even (" diffuse-porous " type) except that they are smaller near the outer edge of the annual ring. On longitudinal surfaces the vessels appear as fine lines. The rays are very fine and numerous, and usually indistinct even with a lens.

To the eye of the expert, willow is easily distinguished from other woods, with the possible exception of poplar. In poplar the heartwood is often streaked with grey, but in some species, *e.g. P. canescens,* it is red-brown, and the distinction from willow, by colour alone, is not always reliable. There are also slight anatomical differences which distinguish willow from poplar wood.

Of the home-grown timbers with which there is a possibility of confusion, silver fir and spruce are distinguishable from willow by the absence of pores; sycamore, birch and lime, by their broader rays; and horse chestnut by its smaller pores. Alder can be distinguished by its radially grouped vessels and by the presence of a few irregularly spaced broad (aggregated) rays.

Those used to handling bat willow timber can generally recognise the wood of *S. alba* var. *caerulea* with reasonable certainty by its appearance and manner of working. It is difficult, however, to point to any one feature of clear diagnostic value, and to describe the characteristic behaviour of the wood under various tools. Some microscopic features may possibly be of value, but at present the separation of the wood of the various willows by this means is a matter of uncertainty.

Under conditions favourable for the production of bat willow the annual rings may exceed one inch in width; the average growth-rate of selected trees examined at the Forest Products Research Laboratory, Princes Risborough, was, however, $2\frac{1}{2}$–3 rings per inch. For bats of the best quality, sapwood only is used, and it is desirable to produce as great a width of this as possible with annual rings up to one inch wide. Generally speaking the greater the rate of growth the wider is the sapwood; in trees 12 to 18 years old the width of the sapwood may exceed 8 inches.

Wood of the last-formed annual ring, *i.e.* the outermost layer of the sapwood, is of inferior quality to the inner sapwood, at least in the case of trees which have been summer-felled, and it is usual for this outer layer to be removed in the process of manufacture. Besides being distinguishable by its brighter shade of white, this layer contains an abundance of starch, which renders the wood liable to attack by *Lyctus* beetles. The practice of removing this outer portion before the bat clefts are stacked for seasoning has, therefore, the added advantage of reducing this type of insect damage.[31]

In the trade it is recognised that the best quality of bat timber is obtainable only from one sort, the true cricket bat willow, *Salix alba* var. *caerulea*. The wood of the crack willow. *Salix fragilis,* is recognised as unsuited for bat-making. Of the numerous hybrids between these two, and

possibly other species, little is known except that, so far, their wood has been found inferior in quality. It is used for the manufacture of low-priced bats, toys, etc.

Although there are many uses to which willow timber may be put, the manufacture of cricket bats is the most important and should determine the policy of the grower and the type of tree he raises; the best part of the tree is taken for this, and the remainder has to be used for other purposes. The importance of finding additional outlets for wood not suitable for cricket bats should be recognised.

Only a short length of the bole is suitable for cricket bats and the best quality is obtained only from the lowest " round." Willow logs are sawn into sections variously known as " rounds," " rolls " or " bolts " of 2 ft. 4 in. in length (Plate X, fig. 1); the cross-cutting is usually done immediately after the tree is felled; only three or four rounds are cut from each log. Owing to the inferiority of the timber further up the stem, growers do not keep the trees clean of branches for more than seven or at most ten feet from the base. The wood on the south side of a tree is considered better than that on the north.

If the wood has to be sent some distance to the manufacturer it may be despatched in the round, but frequently it is split into clefts on the spot. The clefts are made by splitting the rounds radially with a wedge, or axe, and a maul. On the outer tangential surface the clefts are about $4\frac{1}{2}$ in. wide; some eight pieces can be obtained from a round of 11 in. quarter-girth, overbark measurement, depending partly on freedom from shakes or other defects.

The radial cracks or shakes which commonly appear in the end of a round, thus provide places down which splitting must take place, and the number of clefts obtainable from a round may be partly decided by them. The bark is removed and the split clefts are roughly shaped either with axe or saw; they are then stacked in the open for seasoning (Plate X, fig. 2). The stacks are built up on wooden foundations, the clefts being laid criss-cross on each other, usually in pairs, without any intervening " stickers." At the end of about twelve months the clefts are placed under cover, in a shed with open ends; they remain there for about three months, when they are ready for working-up. The whole of the seasoning is normally carried out in the manufacturers' yards.

Defects have already been described in the sections on pathology and insect pests, and only brief reference to those which specially affect the utilisation of the timber need be made here. Some defects are evident in the standing tree, others only when the tree is felled; others again do not reveal themselves until the timber has been split into clefts. Incidentally this explains the function of the middle-man or merchant, from whose stock the bat-maker can select the best quality for his purpose.

Defects noticeable in the standing tree include wounds and snags, indicated by irregularities in the bark, and by horizontal cracks which are evidence of stain (Plate VIII, fig. 1). Trees from which branches have been pruned, and those with buttress roots, are likely to produce defective wood. Groups of small knots known as " grape " (Plate XI, fig. 1) and bits of " trapped bark " (Plate XI, fig. 2) due to wounds with healed surfaces, often cause rejection of clefts otherwise quite sound. When the rate of growth has been either excessively slow or extremely fast, or has been irregular, this is shown in the width of the rings, indicating an inferior quality of wood. Speck or pith fleck (Plate XII, fig. 1) is another serious defect which only shows

itself after felling; it is caused by insects boring in the living tree; the borings become filled with plant tissue, which turns brown and produces streaky discoloration.

The qualities most desired are lightness, resilience, strength or toughness, white colour throughout, silkiness of texture, and straightness of grain. Some of these qualities are dependent on rate of growth, which in turn is affected by soil and situation. The rate of growth should be sufficiently rapid to produce not more than two annual rings per inch. Some buyers object to willow grown on sandy or black fen soils as these are particularly associated with the occurrence of pith fleck. Flinty, gravelly or heavy clay soils are regarded as seldom capable of producing the best class of wood.

It is difficult for bat-makers to define precisely the characteristics of good timber. Strength, from this point of view, implies toughness and ability to withstand the compression to which the surface of the bat is subjected in manufacture. Very soft wood is compressed too easily and is liable to splinter in play; very hard wood requires a greater force of compression and is liable to splinter in the making. One of the difficulties of willow cultivation is to produce wood which has a proper balance of mechanical qualities. Straightness of grain is important; curving or wavy grain adversely affects the playing quality. Straightness of grain is determined by the straightness of the set from which the tree has been grown. The light colour preferred for the best bats can only be obtained from sapwood, and sapwood of sufficient width presupposes a reasonably fast-grown tree.

Various factors affect the prices of bat willow. A grower known by experience to produce consistently good timber free from faults tends to attract buyers and to command good prices, whereas other growers, and even whole districts, where experience has been less satisfactory, tend to be avoided. The first or virgin cut in any particular lot of trees usually obtains a higher price than the trees cut subsequently, probably because it has been faster grown.

In 1936 an enquiry extending over at least ten counties was made as to prices paid for willow trees; they usually ranged from £4 to £10 per tree, most of the trees being between 12 inches and 14 inches quarter-girth (48 to 56 inches circumference). Only twice was any price mentioned higher than £10; in one instance a few exceptionally good trees were sold for £25 each, and in another, out of a lot of 60 trees, the best brought £20 and the worst 10s. On two occasions a price of £10 was obtained for the first selection; trees felled three years later, though planted at the same time, were sold for £7. Prices lower than £4 were usually for trees less reliable as to quality, or entailing much expense in extraction and transport. At the lowest end of the scale is a record of 700 trees bought at 1s. each, but these were infected with watermark disease.

A grower who is known to have only the right sort of willow on his estate, commands the confidence of buyers because the quality of his timber will be uniform, provided it shows no blemish or defect; buyers can afford, therefore, to offer him the top price. Although buyers continue to purchase from growers who have mixed stocks, it is known that they pay lower prices in such cases.

In the manufacture of bats, the seasoned and roughly trimmed cleft may be worked almost entirely by hand, or may be prepared largely by machinery. In the latter case the cutting of the face, and to a great extent the shaping of the back, are done by revolving knives, against which the bat is passed. The face and sides are left slightly thicker and wider than the final size and are finally reduced by compression beneath a roller, this compression being applied in three stages to avoid damaging the wood. The process is completed

by sand-papering. The handle is made up of square pieces of cane glued together and is fitted into the bat before it is shaped. A very close fit is made, so that it is extremely difficult to pull a properly fitted handle out of a bat, even if it is not glued in. The final balancing is always done by hand and is the most skilful operation in the whole process: it is done by shaving the back. The shaping of the handle and the finishing processes are then carried out; after marking and polishing, the bat is ready for sale. Much of the skill of the maker lies in producing bats of a proper weight and balance: balance is especially important. The weight of the finished bat varies from 2 lb. 2 oz. to 2lb. 7 oz.

Other Uses of Willow

Willow wood is tough, and there is a tendency to woolliness in working if it is converted while green. It works easily and well when seasoned but in planing and dressing the edges of cutting tools should be thin and sharp. It has wearing qualities which cause it to dent, rather than split or break, under rough usage. It is light in weight, capable of taking a good polish, is without objectionable odour or taint and free from resinous matter.

The bottoms of carts, barrows, wagons, and lorries are frequently made of willow which is also used to some extent as weather-boarding for barns. It is well suited for brake drum cleading (plank covering), lagging for the winding gear of hoisting engines for mining, and in other situations where heat may be generated by friction. It makes good brake blocks for vehicles fitted with steel wheels or tyres and is suitable for crates, barrels, boxes, honey-comb frames, and other containers for foodstuffs, also for such domestic utensils as knifeboards.

It is employed in the manufacture of trug baskets for gardeners, for saddle-trees, shoe-lasts, clogs, and bent-work. There is a small but steady demand for the wood of *S. alba* var. *caerulea* for artificial limbs, on account of its combined lightness and toughness. It readily gives a fine surface which can be stained and polished, or given a smooth coating of enamel. Toy-manufacturers use quite small sizes. It is also used for broom and brush heads and for skittle, polo, coco-nut shy, and other balls which are subjected to hard knocks. Charcoal of fine texture may be produced from it.

Material from pollarded trees of *Salix fragilis* (Plate I, fig. 1) cleaves easily; this species is grown to provide the poles which are made into gate hurdles (Plate XIII), crates, baskets, woven garden hurdles, sieve rims and hoops for slack cooperage. The material is used also for stakes; for this purpose it is desirable that the butt should be treated with creosote, as willow is not durable in contact with the ground.

Willow wood of good quality is also accepted for the manufacture of matches.

An outlet of some importance to the growers of cricket bats, which has recently been developed, is for the making of paper pulp. For this purpose any reasonably sound wood is acceptable; it need not be straight or of a large diameter, and therefore branchwood or stems rejected for bat manufacture are suitable. The pulp mills that take willow are situated in the London area, and the value of the material justifies transport within a radius of one hundred miles from that centre.

Use of Willow in the Manufacture of Veneer Packages

Over half a million cubic feet of round timber, mainly willow and poplar, are consumed annually in the British Isles for the production of veneer containers (chip baskets, punnets, etc.) for marketing strawberries, cherries, apples, tomatoes, watercress, salads and many other foods.

The containers range in size from the 2-oz. cress punnet to the 12-lb. plum and tomato basket. When adequate supplies of timber are available, tub-shaped " Bonnets " of 12, 24 and 28-lb. capacity are manufactured, mainly for apples, pears, etc.

All these containers (40,000,000 per annum) are made from veneer obtained by the rotary peeling of round timber. The timber is first cross cut to lengths of up to 60 in. and the bark is then removed. The log is gripped at each end in a veneer lathe (peeling machine) by spindles which rotate the log against long hollow-ground knives. As soon as the log is cylindrical, the veneer comes off the machine in a long sheet and the log diminishes in diameter until it measures from 4 in. to 6 in., when further peeling is impossible. The resulting log cores have many uses, notably crate and wood wool production.

After peeling, the veneer (which is sometimes " scored " for bending at right-angles) is cut to the required widths and shaped by automatic guillotines.

The various component pieces of the packages are partly assembled by hand, but from this point, the production of the container is highly mechanised. The machinery used is specially designed for the trade. The bending qualities of willow make this timber particularly suited to veneer package production and its colour is usually excellent.

It will be gathered from the paragraph on rotary peeling that the timber used must be of regular growth (round and straight), reasonably free from knots, and must be sound; any heart rot, splits, ingrown bark, shakes, etc. render the timber useless for veneering. Although the best quality of bat willow is not called for, the specification required means a fairly rigorous selection. Minimum lots of 100 cubic feet are accepted and contracts are placed for quantities up to 50,000 cubic feet where available.

All timber is required to be topped at a minimum of 10 in. diameter, maximum butt diameter is 40 in. Minimum length of log accepted is 7 feet. Buyers usually inspect on site in the first instance to agree selection and prices and then merchants often send supplies to factories without further inspection by the buyers. Where necessary, however, buyers will inspect and agree prices for each and every parcel to suit merchant's wishes in this respect. The address of the Federation of Veneer Package Manufacturers is 986 Hertford Rd., Waltham Cross, Herts.

It should, however, be born in mind that the primary purpose of growing *Salix alba* var. *caerulea* is for the production of cricket bats. The alternative uses outlined above serve mainly to absorb trees which, for one reason or another, are not of sufficiently high quality. If trees are being grown for these markets alone, poplar is to be preferred on account of its larger trunk and greater volume production.

SYSTEMATY OF THE CRICKET BAT WILLOW AND ITS ALLIES

The willows growing wild in Britain number about 94 named kinds, most of which are natives. Only some 20 of these are recognised as distinct species, the others being treated as " varieties " or " forms," or as hybrids between two or more species. Of the total number, only about 25 are trees, and of these several often fail to attain more than the habit and size of shrubs. Of the strictly shrubby species, some are cultivated as osiers, used principally in basket-making.

Excluding the osiers, the willows employed commercially are timber trees, and include the cricket bat willow (*Salix alba* var. *caerulea* Smith), the crack willow (*Salix fragilis* L.), and a group of hybrids between them, known collectively by the name x *Salix viridis* Fries. There is considerable doubt

as to the identity of the tree passing in this country under the name *Salix alba* L. Of these the cricket bat willow is the most important.

Confusion of Species and Hybrids

The hybrids referred to are frequently mistaken for the parent forms; they cause trouble and financial loss because the rate of growth is sometimes slow, and the timber differs in quality from that of the parent species. Growers have too often failed to distinguish between *S. alba* var. *caerulea* and its hybrids.

In Suffolk, the crack willow, *Salix fragilis,* has been found planted to refill gaps in a row of cricket bat willows. A young plantation of bat willows in Hampshire contained many male trees of x *S. viridis*. An estate in Hertfordshire was growing trees of *S. viminalis* mixed with *S. alba* var. *caerulea*. On an estate in Buckinghamshire almost the whole crop (over 500 fifteen-year-old trees), which ought to have been ready for sale, was rejected by buyers as useless, and proved on examination to represent a well-known and widely distributed hybrid.

It is of practical importance that such confusion should be cleared up, and that the differences between the species and hybrids concerned should be defined in such a way that people can recognise them.

There is one, and only one, true cricket bat willow, *S. alba* var. *caerulea,* which furnishes the required quality of timber; all the others, so far as is known, produce inferior timber. It is a mistake, therefore, to grow any of them for the purpose of bat-making.

Hybridisation

To deal with the systematy of the several forms of *Salix alba, S. fragilis* and *S. viridis* would be an easy matter but for the fact that they cross-pollinate with each other so freely that many hybrids are produced. The descriptions of these hybrids have often lacked adequate precision, which has led to confusion.

Willows are nearly always dioecious, *i.e.* the two sexes are usually borne on separate trees; when seed is produced, the female flower has been fertilised with pollen from another tree; the pollen is carried by wind and by bees. Where the male tree pollinates a female of the same species, the offspring are of that species also; where the pollen has been derived from a different species the result is a " hybrid " progeny. Not all species of willow will hybridise with one another. *Salix alba* and *Salix fragilis,* the two most common of our tree willows, hybridise between themselves freely, and as these two species favour the same habitat, and often grow near to each other, hybrids between them are common. *Salix alba* will, also, cross with *Salix pentandra* and with *Salix triandra.*

Diversity of Character in Hybrids

The number of possible hybrid forms among the willows is very great; those of the same parentage are not always alike. Hybrids between two species are called " di-hybrids "; when di-hybrids of the same parentage cross with each other, or when they back-cross with the parent species, the resulting progeny may be very diverse in appearance and character, the distinguishing characters—or some of them—being separated and re-arranged in different combinations. Hybrids between *S. alba* and *S. fragilis* may

themselves hybridise with several other species, producing " poly-hybrids "; as many as six species may be represented in a single willow hybrid. In such cases the progeny are likely to be still more diverse than those of a simple di-hybrid.

A hybrid is not always intermediate in appearance between its parents; it may resemble either, to a greater or lesser degree; it may differ from either; or it may show reversion to an earlier ancestral type. Some, however, are intermediate between the two parents, in appearance and character. In the second and subsequent generations there is a segregation of characters such that some of the progeny usually resemble one of the parents in certain features, some resemble the other of the two parents, while others, again, are intermediate between them.

The timber produced by *Salix fragilis* differs materially from that of *S. alba* var. *caerulea,* and, in consequence, the timber of these species is used for different purposes. That of the hybrids has not been investigated, but it may be expected to have the qualities of either of the parents, or it may be intermediate in character, owing to the varying degree of intermixture of one or other parent, or of other ancestors. We may expect, also, from the known behaviour of hybrids in general, that a *Salix alba* x *fragilis* hybrid resembling *S. alba* in general appearance, may have timber more or less like that of *S. fragilis,* and vice versa.

Thus it is likely that the wood of the hybrids will be variable and unreliable in quality; that produced by known hybrids is always classed as inferior to that of the bat willow.

Characters used in Identification

The following characters are used in the identification of species of willow. The bark: whether rough or comparatively smooth, persistent, or flaking off as in a plane tree. The leaf appendages (stipules): their size, shape, and marginal toothing, and their relative duration (persistent or deciduous). The leaf-stalk (petiole): its relative length and the presence or absence of glands near the apex. The leaf blade: its shape and relative size; the shape of the apex and of the base; the absence or presence, and the character, of any hairy covering (indumentum); the size and relative number of the stomatal dots on the leaf surfaces; the character of the leaf margin, whether toothed or free from teeth (entire), and if toothed, then the character of the toothing (whether serrate or dentate), and whether glandular or not. The flowers of the willow are produced in spikes (catkins) bearing many flowers, which are subtended by scale-like bracteoles; the stalk of a catkin is known as a peduncle; the catkins of different species differ in their relative length, thickness, and density of flowering, in the relative length of the peduncle, and in the shape, length, colour and hairiness of the bracteoles.

There is no obvious calyx or corolla in the flowers of the willows. As already mentioned (page 34) the reproductive organs, male (stamens) and female (carpels) occur in separate flowers, and (usually) the stamens are borne on one tree and the carpels on another; in such cases the sexes are said to be dioecious. The male flower consists of two or more stamens, each comprising a stalk or filament, and an anther (the portion which contains the pollen); differentiating characters are found in the number of stamens, the hairiness or otherwise of the filaments, and the number and shape of the glands (nectaries) at their base. The female flower consists of a solitary ovary with stigmas; the ovary is stalked (stipitate) in some species, or stalkless (sessile) in others; in some species the stigmas are borne on a stalk

(style), in others the style is absent or nearly so; in the female flower, also, the number and shape of the glands (nectaries) at the base of the ovary, may be of use in identifying species.

Description of the Species, Varieties and Hybrids

In the following brief account of the species, varieties and hybrids discussed in this Bulletin, their distribution in Great Britain and Ireland has been indicated, but owing to confusion in the nomenclature the records are very incomplete and unreliable.

(*a*) *S. alba* var. *caerulea* Smith (1828); *S. caerulea* Smith (1812); *S. caerulea* Henry (1913). Cricket bat willow. A shapely tree, occasionally reaching a height of 100 ft. and 15 to 18 ft. girth. It differs from typical *S. alba* L. and from x *S. viridis* Fries in its conical form and erect branching, the young branches arising at an acute angle of about 30° (Plate I, fig. 2; see also Plate XIV). The bark is much smoother (" closer ") than in *S. fragilis,* but differs little from that of varieties of x *S. viridis* (Plate XVII). In the leaves (Plate XV) it differs from them in losing most of the silky hairs from the under-surface early in the season, which gives it a bluish green or bluish grey appearance instead of the whitish aspect of some other forms and hybrids of *S. alba.* The leaves are distinguishable also by their translucency; when viewed against the light with a lens, the tertiary venation is always plainly visible. The leaves in some forms of x *S. viridis* resemble those of *S. alba* var. *caerulea* in colour and translucency, but are larger and more coarsely serrate on the margin (suggesting a strain of *S. fragilis* in their composition), and in habit the trees lack the characteristic upright branching of *S. alba* var. *caerulea.*

The original description of *S. alba* var. *caerulea* was based on the pistillate (female) tree, the staminate (male) being then unknown. Henry[14] states that " apparently no staminate tree " of this variety " exists "; Bean[1] observes that " only the female tree is known "; Forbes, however, as far back as 1829[9, 13], described and figured a male tree as " *S. caerulea.*" Moss[21] recognised the existence of a staminate tree, for he observes that " the staminate tree does not appear to be cultivated for the best cricket bat timber." Several staminate trees have been found in East Anglia, having the same habit of growth and characters of *S. alba* var. *caerulea*[9], so that it is no longer correct to speak of it as being only a female tree.

The female catkin of *S. alba* var. *caerulea,* as compared with those of x *S. viridis* var. *elyensis* and of *S. fragilis,* is relatively short and dense-flowered. (Plate XVI).

Salix alba var. *caerulea* was first discovered by Mr. James Crowe, F.L.S. (1750–1807), a surgeon of Norwich, " who found the female plant wild in Suffolk," and propagated it for several years in his salicetum at Norwich. It is a lowland species grown principally in Essex, Suffolk and Norfolk, but also in many other counties. It prefers the banks of running streams, and obviously dislikes a water-logged soil. Moss remarks that " *S. alba* demands a soil richer in mineral content than *S. fragilis* "; probably he referred to " *S. alba* " in the aggregate sense, including its varieties and hybrids, for there is some doubt whether typical *S. alba* L., as known in continental Europe, occurs wild in the British Isles.

(*b*) x *S. viridis* Fries. (= *S. alba* x *fragilis*). This name has been applied promiscuously to the polymorphous progeny of *Salix alba* L. x *S. fragilis* L.

The *S. alba* x *fragilis* segregates show a wide range of intergradation between the parental forms, due, perhaps, to backcrossing with the parents. These may be grouped under two varietal names according to their resemblance to *S. alba* on the one side (var. *albescens*) or to *S. fragilis* on the other (var. *fragilior*). In addition, a third distinct form (var. *elyensis*), whose suspected hybrid origin is not yet established with certainty, is provisionally placed here.

(*c*) x *S. viridis* var. *albescens* (Anderss.) includes those *alba* x *fragilis* segregates which show stronger resemblance to *S. alba* than to *S. fragilis*. These forms differ from *S. alba* var. *caerulea* in the more spreading branches (Plate XIV); in the twigs being usually more brittle; in the buds being earlier glabrescent; in the leaf blades (Plate XV) being rather less silky from the first, lighter green, variously glabrescent, and somewhat more coarsely serrate; in the stalks of the ovaries, which are eventually about 1½ times the length of the nectaries, and in the ovaries themselves, which are less gradually acuminate, and do not taper into the moderately long styles (Plate XVI). The male catkin is shorter than in *S. fragilis* and narrower than, but much the same length as, that of var. *fragilior*. The bark differs but little from that of *S. alba* var. *caerulea* (Plate XVII). Under this name may be included the so-called " Norfolk strain " which had provisionally been called *S. alba* var. *rystonensis* Burtt Davy, ined.

(*d*) x *S. viridis* var. *fragilior* (Host) includes such hybrid segregates as approach more closely to *S. fragilis* than to *S. alba*. The original *S. fragilior* Host (1828) cannot be precisely indentified in the absence of original specimens; Teopffer (1915) refers it to *S. fragilis*, but Dr. Floderus suggests " influence from another species, probably *S. pentandra* L."

Those forms of x *S. viridis* which approach *S. fragilis* differ from it in the less spreading branches, the more flexible and tougher branchlets which less readily snap off at the base, and the longer and more pubescent buds; the leaf blades are always somewhat silky when young, are darker and duller green, with more persistent hairs when mature; the leaf margin is less coarsely serrate; the bracteoles of the female catkin are less pilose on the upper part of the outside; the ovaries are 4 to 5 mm. long, ovate-conic, obtuse, not tapering into the styles; and the style and stalk of the ovary are shorter. The male catkin is relatively short and thick.

(*e*) x *S. viridis* var. *elyensis* Burtt Davy. This is a tree attaining about 50 ft. in height, with slender, slightly drooping branchlets (Plate XIV, fig. 3) and somewhat yellowish twigs. The leaves are much as in *S. alba* var. *caerulea* Smith. The catkins are longer, with much longer bracteoles (usually 3·5 to 4·5 mm. long), considerably exceeding the styles at the flowering period. The ovary is borne on a short stalk (Plate XVI) as in var. *albescens*, and it has a distinct style. These characters seem to indicate that *elyensis* is a distinct *alba* x *fragilis* segregate.

This variety is said to have been brought into cultivation from the Isle of Ely, but whether it was wild there, or had been introduced from elsewhere, is not known. It is now met with not infrequently in cultivation in East Anglia, Hampshire, etc., where it has been planted as a bat willow. It appears to be of slower growth than *S. alba* var. *caerulea*, and as far as is known its timber commands a lower price, being used only for the cheaper classes of cricket bat, but no record appears to have been kept by the sellers or purchasers, as to the relative value, or the quality of wood obtained. Tests of its relative rate of growth and the quality of its timber would be of interest.

(*f*) *S. fragilis* L. Crack willow. A handsome bushy tree when not pollarded or otherwise mutilated, attaining 80 to 90 ft. in height, but largely grown as a river bank pollard; the bark is roughly " corrugated " (Plate XVII). The young branches of normal trees are more wide-spreading than in *S. alba,* usually emerging at an angle of 60° to 90°; the bark of the young shoots is smooth. The leaves (Plate XV) are lanced-shaped, long and narrow (up to 7 in. long and ¾ in. broad), tapering at the base, and with the apex drawn out into a long slender point; when mature they are dark green and hairless above, distinctly bluish and almost hairless beneath, distinctly and irregularly toothed with coarse, usually incurved teeth ending in a large, dark gland. The stomatal dots on the upper surface of the leaf are larger and farther apart than in *S. alba* var. *caerulea* (approximately 50 to the sq. millimetre, instead of 100 as in the latter). The catkin bracteoles are nearly as long as the stamens or ovaries. The ovary is long and gradually tapering.

S. fragilis is a tree of the lowlands, but is said to ascend to 1,350 ft. in Allendale. It is recorded from every botanical vice-county in England*; from all but four in Wales and from all but six in Scotland. Linton considered it " doubtfully indigenous " in Scotland; Druce treated it as " native north to Inverness." In Ireland it is said by Linton to be " frequent in the south," " rare in the north, probably introduced in all localities ".

Beyond Britain it is reported from Europe generally and from Asia Minor, Syria, Persia, Caucasus, Armenia, and western and central Siberia.

The crack willow is valued for the rapidity of its growth, and its handsome appearance. It is extensively planted here as a pollard; thousands of trees may be seen on stream banks in the Midlands. The wood is reddish and splits much more readily than that of *S. alba* and its varieties.

(*g*) *S. fragilis* forma *latifolia* (Anderss.) Leaf blades broader than in the typical form, 1 to 1½ in. wide, subcuspidate: stamens usually 2, sometimes 3. This name may be used for all broadleaved forms of *S. fragilis* except such as are here included under x *S. viridis* var. *fragilior.* It has been found in Huntingdonshire and probably occurs elsewhere.

* For the study of plant distribution the counties of Great Britain and Ireland are subdivided into botanical "vice-counties."

KEY TO THE SPECIES, VARIETIES AND HYBRIDS

All of the willows discussed in this Bulletin belong to the group known as Section *Vitisalix* (sometimes called *Amerina*). These are either trees or large shrubs. The leaves are dimorphic (*i.e.* of two kinds) :—(1) the early or pro-leaves, sometimes called spring leaves, borne on the peduncles or on short barren shoots, and (2) the adult or summer leaves, produced chiefly on the long-shoots. The adult (or summer) leaves usually appear later in the season, on the later-formed barren shoots ; they are usually larger than the pro-leaves, more or less different in shape, and often glandular-serrate on the margins. The catkins are borne at the ends of new leafy short-shoots produced from lateral flower-buds formed the preceding year ; these short-shoots bear pro-leaves. In *Vitisalix* the catkins and their pro-leaves usually appear before the adult leaves, and usually (but not always) fall away together. The bracteoles of the catkins are pale-coloured (whitish or greenish), concolorous (*i.e.* not darker towards the tip except, perhaps, in some hybrid forms). The nectaries are 2 (rarely 3 or 4) to each staminate flower, and 2 or 1 only to each pistillate flower ; they may be free from each other, or slightly united at the base ; when there is only one, it is pitcher-shaped (urceolate). The stamens vary from 2 to 6 in number (rarely more), the filaments and anthers are free. The style is short, with bifid or notched stigma. The capsule is glabrous.

The Section *Vitisalix* is divided into three subsections, names :—(1) *Fragiles*, (2) *Amygdalinae* (sometimes called *Triandrae*), (3) *Pentandrae*. Only the *Fragiles* are dealt with here.

Subsection *Fragiles*

Summer leaves (but not necessarily the pro-leaves) when young, silky with silvery hairs*, sometimes becoming hairless or nearly so in age : apex of petiole sometimes glandular, sometimes not : bracteoles of the catkins yellowish, falling off before the capsules are mature : stamens usually 2 (varying up to 6), free : capsules sessile, subsessile, or stalked.

The following is a Key to the species, varieties and hybrids :—

To use the Key satisfactorily, it is necessary to examine the summer leaves, as the pro-leaves of the different species and forms show too little variation, and have not, therefore, been taken into account in the preparation of the Key. It should be borne in mind that no Key to the willows is likely to prove workable on incomplete or abnormal material.

The characters are described in contrasting pairs, each pair bearing the same letter (*e.g.* a, a, or b, b, etc.). The specimen should be compared first with the characters a and a ; if it agrees with the first a (p. 39), it should then be compared with the two b's, and so on, till it is run down to one of the species. If, on the other hand, it agrees with the second a (p. 40), it should then be compared with the characters described in h and h, etc., in the same way.

a. Mature summer leaves with the upper surface green and usually shining, and when mature, glabrous or nearly so, green or glaucous and quite or nearly glabrous beneath ; leaf blades relatively long (up to 5½ in. long and 1½ in. broad) ; the leaf margin not ciliate, *b*.

b. Branchlets not drooping, usually ascending or somewhat spreading : capsules long and narrow, tapering, on long stalks (*i.e.* stalks up to twice or thrice as long as the nectaries), *c*.

c. Leaf margins with coarse, irregular serrations which are not close together ; leaf blades usually broadest rather below the middle, 4 to 5½ in. long, ¾ to 1½ in. broad, glabrous except for a few scattered hairs : young branchlets pubescent, easily snapping off at the base : ovary with a longish stalk (2 to 3 times as long as the nectary, in fruit), *d*.

d. Colour of fresh young branchlets and shoots in winter and spring green or greyish to dark olive brown (neither yellow nor red), *e*.

e. Teeth of leaf margins remote (about 12 to 14 per inch), the gland large and usually incurved ; stomatal dots on the upper surface of the leaf blade large and relatively few in number (about 50 per square mm.) ; stipules large, half-cordate, deciduous : staminate flowers with long yellow bracteoles fringed with long hairs, their nectaries broader than in *S. alba* ; pistillate flowers with stalked ovary, the capsule long (up to 6 mm.), tapering, stalked, *f*.

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* The young leaves of *S. triandra* and of x *S. undulata* are sometimes more or less hairy, but not silky with silvery hairs.

f. Leaf blades up to ¾ in. broad. 1. *S. fragilis* L.

f. Leaf blades 1 to 1½ in. broad. 2. *S. fragilis* forma *latifolia* (Anderss).

e. Teeth of leaf margins closer (about 18 per inch), the gland usually smaller and often straighter; stomatal dots intermediate in size and number between those of *S. fragilis* and *S. alba* (*e.g.* about 75 per square mm.); capsule shorter (about 4·5 mm. long), ovoid, less tapering. 3. x *S. viridis* var. *fragilior* (Host).

d. Colour of fresh young branchlets and shoots in winter and spring yellow to "brilliant orange" or "rich red," the bark becoming "very polished, even varnished" in appearance in the second year. 4. *S. fragilis* var. *decipiens* (Hoffm.) Koch.

c. Leaf margins with fine rather regular serrations which are closer together than in *S. fragilis*, about 24 (ranging from 22 to 26) to the inch; leaf blades usually broadest a little above the middle, in shape approaching those of *S. alba*, but larger (up to 5 in. long and 1¼ in. broad); young branchlets sometimes reddish or yellowish in winter or spring; bracteoles falling off early, yellow, thinly clothed (especially towards the base) with white hairs; stamens usually 6 (but varying from 4 to 6); ovary subsessile (its stalk about as long as the nectary). 5. x *S. hexandra* (Ehrh.) Anderss.

b. Branchlets, and often the branches also, long drooping: styles longer than in other British members of the Section *Vitisalix*: catkins not infrequently androgynous (*i.e.* bearing both staminate and pistillate flowers). Weeping willows, *g.*

g. Branchlets glabrous (or slightly silky only when very young); leaf blades 3 to 4 in. long, about ½ in. broad, when mature glabrous or nearly so, "blue grey" beneath; apex long and slender. Sensitive to frost. 6. *S. babylonica* L.

g. Branchlets silky when young; leaf blades rather broader (½ to ⅞ in. wide), on first expanding silky-hairy beneath, becoming glabrous and "bluish white": only the pistillate sex known. Hardier then *S. babylonica*. 7. x *S. salamonii* (Carr.) Bean.

a. Summer leaves more or less densely silvery-silky with appressed hairs, at least beneath (in some forms becoming glabrous above in age), the margin ciliate; leaf blades relatively short (2 to 3 in. long, rarely longer) and narrow (⅜ to ½ in. broad), *h.*

h. Bracteoles of the centre of the catkin 2·5 to 2·75 mm. long, sometimes as long as the ovary at its receptive stage, but shorter than the capsule and stamens: branchlets olive green in winter and spring, *i.*

i. Leaf blades persistently clothed on both surfaces with silvery-silky hairs, but most densely on the whitish under-surface; stipules very small, ovate-lanceolate, deciduous. Wide spreading trees, the branches sub-erect (but the angle of divergence less acute than in var. *caerulea*), the branchlets spreading or more or less drooping: nectaries of the staminate flower narrower than in *S. fragilis*; ovary and capsule subsessile (or sessile ?): capsule obtuse, *j.*

j. Leaf blades 15 to 20 mm. (½ to ¾ in.) broad; stipules very small, ovate-lanceolate, deciduous, *k.*

k. Leaves in age thinly silky-hairy. 8. *S. alba* L.

k. Leaves with an intensely silvery hue, and conspicuous at long distances, by their shining whiteness, due to the dense covering of silky hairs. 9. *S. alba* var. *argentea* Bean.

j. Leaf blades 7 to 14 mm. broad. 10. *S. alba* var. *stenophylla* Fraser.

i. Leaf blades rather less silky from the first, becoming more or less glabrous above at maturity; buds sooner becoming glabrous, *l.*

l. Branchlets tough and pliable (not brittle as in *S. fragilis* and x *S. viridis*) sub-erect, the branches arising at an acute angle (approximately 30°) giving the tree a somewhat "pyramidal," "conical," or rhomboid outline, especially when young, the terminal branchlets almost erect; leaf blades bluish grey or bluish green (not white-silky) beneath, thinner in texture than in typical *S. alba*, and more translucent, the veins showing plainly on the undersurface, ovary and capsule almost sessile (*i.e.* only very shortly stalked if at all). 11. *S. alba* var. *caerulea* Smith.

l. Branchlets usually (but not always) brittle, snapping off easily as in *S. fragilis*; branches and branchlets more spreading than in var. *caerulea*; buds sooner becoming glabrous; leaf blades intermediate in size between those of *S. alba*

and *S. fragilis*, often larger, less blue green, with margin rather more coarsely serrate than in *S. alba* var. *caerulea* : nectaries very variable : ovaries more gradually acuminate, but not tapering into the style as in *S. fragilis* ; capsule with a longer stalk, and bark of young trees rougher (more " open ") than in *S. alba* var. *caerulea*. 12. x *S. viridis* var. *albescens* (Anderss).

h. Bracteoles of the centre of the catkin longer and relatively narrower than in *S. alba* and the above varieties, exceeding the stamens, ovary, and capsule, rather persistent ; branchlets more or less yellowish in spring, *m*.

m. Bracteoles of centre of pistillate catkin 3 to 4 mm. long : young branchlets bright yellow to orange-coloured : leaf blades " shorter and broader " than in *S. alba*. 13. *S. alba* var. *vitellina* (L.) Stokes.

m. Bracteoles 4 to 6 mm. long : young branchlets yellowish green : leaf blades as in *S. alba* var. *caerulea*. 14. *S. alba* var. *elyensis* Burtt Davy.

SUMMARY

1. One of the first points to be considered in the cultivation of the cricket bat willow is the selection of areas with suitable climate and soil. A warm and moderately dry climate is the most favourable. A deep, permeable and rich loam, preferably near to running water (either as a stream or as subsoil water) gives the best results; waterlogged soil is inimical to the production of good bat timber.

2. Reproduction from sets is still in an experimental stage. Two principal methods are practised:—(1) from unrooted sets; (2) from rooted plants. The unrooted sets are raised on stools after the manner of osier cultivation; these should not be less than 9½ feet long. The rooted plants are grown from short cuttings.

Whether rooted, or unrooted, the sets should be free from branchlets for a height of 8 feet above ground level when planted. As pruning wounds are frequently a source of defective timber, no branchlets should be removed at a greater age than one year.

3. The best distance for planting, in single rows, is 30 ft.; in double rows about 35 ft., and in plantation form about 40 ft. The unrooted set is planted to a sufficient depth to ensure stability against wind. Where staking is necessary, protection from rubbing and from cutting by the material used in tying, is essential. The best time for planting is during open weather in the latter part of winter (usually January and February). Frequently trees are manured at the time of planting, and mulched afterwards. On dry soils irrigation is sometimes practised.

4. The 8 ft. bole of the tree must be kept clear of stem shoots, by rubbing off the buds while still soft. Various methods of crown pruning are practised, but without any obvious advantage. Injury by live stock and rodents, and from contact with farm implements, is a common source of loss to growers; adequate protection from injury is, therefore, of vital importance, and this must be maintained throughout the life of the tree. Any wounds which occur should be treated to ensure rapid healing.

5. Certain diseases are specially liable to occur where conditions are unfavourable to growth; some—*e.g.* canker of the young stem—can be caused by frost. Waterlogging is specially conducive to disease; lack of moisture, on the other hand, is a not infrequent cause of die-back. Watermark disease is the most serious trouble of parasitic origin and is highly infectious; the only known method of control is destruction of infected trees. The honey fungus is another common cause of death; it is most destructive in sites unfavourable to the tree, owing to variations in soil conditions; rejection of such sites is the best known preventive.

Diseases of leaves and young stems are not usually important.

6. Among insect defoliators of willow, certain sawflies belonging to the order *Hymenoptera,* and leaf beetles belonging to the coleopterous family Chrysomelidae, are noteworthy. Of the larger woodboring species the beetles *Cryptorrhynchus lapathi,* and *Saperda populnea* are sometimes of local importance, as is also the musk beetle, *Aromia moschata.* Certain gall midges belonging to the dipterous family Cecidomyidae, are of importance as their larvae are cambium-borers and are suspected of being connected, in some manner not yet clearly understood, with the spread of the disease

known as " fleck " or " speck " in willows. Artificial control of insect attacks on willows is only practicable in the case of valuable trees and particulars of the substances used in eradicative measures are given.

7. The manufacture of cricket bats is briefly described, with notes on defects in the wood; the general characters of willow wood are given, the uses of willow for purposes other than bat manufacture are mentioned.

8. The differences between the true cricket bat willow, *Salix alba* var. *caerulea,* and other willows often confused with it, are described, and a key to the species, varieties and hybrids of the group is given.

BIBLIOGRAPHY

For convenience of reference it has been considered desirable to include here references to various scattered papers dealing more or less directly with the subject of this Bulletin. Although the information contained in them, as far as relevant, has been included, there is little matter in the Bulletin which is not based on the personal observation of the authors.

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APPENDIX

WATERMARK DISEASE

STATUTORY RULES AND ORDERS

1938 No. 677

DESTRUCTIVE INSECT AND PEST, ENGLAND

THE WATERMARK DISEASE (ESSEX) ORDER OF 1938
DATED JULY 12, 1938

The Forestry Commissioners by virtue and in exercise of the powers vested in them under the Destructive Insects and Pests Act, 1877 and 1907(a), and the Forestry Act, 1919(b), Section 3 (2), and of every other power enabling them in that behalf, order as follows:—

Powers of Appointed Officer

1. An Officer appointed by the Local Authority for the purposes of this Order (hereinafter called " the appointed officer "), upon production if so required of his appointment, may at all reasonable times enter upon any premises in the district and examine any willow trees thereon, and all reasonable facilities for carrying out the examination shall be given to him.

Prevention of Spread of Infection

2. The Local Authority on being satisfied by a report from the appointed officer that the disease exists in any willow trees on any premises within the district,

(*a*) may serve upon the occupier of the premises or upon any other person in whose control and management the trees may appear to be a notice requiring him within such time as may be prescribed in the notice to treat the willow trees in such manner as may be prescribed in the notice. The notice may require the person upon whom it is served:—

(1) To cut down to the ground level all such trees as are affected with the disease.

(2) To remove and destroy by fire all the branches and twigs of such trees.

(3) To remove the bark from the trunks thereof.

(4) To destroy by fire the trunks thereof, and

(5) To take such other steps as may be prescribed in the notice.

(*b*) Nothing in this Order shall prevent any person upon whom a notice has been served under sub-paragraph (*a*) hereof, completely destroying by fire or otherwise any trees in respect of which a notice has been served upon him, and if he does so destroy them, he shall be deemed to have complied with the notice.

(*c*) Where a notice has been served under sub-paragraph (*a*) hereof, the appointed Officer shall, if so directed by the Local Authority, ascertain whether the notice has been complied with.

(a) 40 & 41 Vict. c. 68 and 7 Edw. 7. c.4. (b) 9 & 10 Geo. 5. c. 58.

Reports and copies of Notices to be sent to the Forestry Commission

3. The Local Authority shall furnish to the Forestry Commission a report of any action taken by it under this Order and a copy of any notice served under Article 2 (*a*) hereof.

Service of Notices

4. For the purpose of this Order, a notice shall be deemed to be served on any person if it is delivered to him personally or left for him at his last known place of abode or business, or sent through the post in a letter addressed to him there, and a notice purporting to be signed by the Clerk to the Local Authority shall be prima facie evidence that it was signed by him as Clerk to the Local Authority.

Appointment of Officers

5. The Local Authority my appoint such persons as the Local Authority may deem desirable to be appointed Officers for the execution of this Order.

Penalties

6. Every person shall be liable, on conviction, to a penalty not exceeding ten pounds, or in the case of a second or subsequent offence, to a penalty not exceeding fifty pounds, who

(i) fails to comply with any notice served under Article 2 (*a*) of this Order; or

(ii) fails to give an appointed Officer all reasonable facilities as required by this Order; or

(iii) wilfully obstructs or impedes an appointed Officer in the exercise of his powers under this Order.

Definitions

7. " The District " means the Administrative County of Essex, the County Borough of Southend-on-Sea, and the Boroughs of Barking, Chelmsford, Colchester, Harwich, Ilford, Leyton, Maldon, Saffron Walden and Walthamstow.

" Local Authority " means:— ;

(*a*) in the Administrative County of Essex and in the Boroughs of Barking, Chelmsford, Harwich, Maldon and Saffron Walden, the Council of the administrative County of Essex.

(*b*) in the County Borough of Southend-on-Sea and in the Boroughs of Colchester, Ilford, Leyton and Walthamstow, the respective Councils of these Boroughs.

" The disease " means the die-back of willows commonly known as " water-mark disease ".

Enforcement of Order

8. The provisions of this Order shall be enforced by the Local Authority.

Notification of Order

9. This Order shall be published by the Local Authority in accordance with any directions given by the Forestry Commissioners.

Revocation of Order

10. The Watermark Disease (Essex) Order of 1934(a), is hereby revoked; provided that such revocation shall not:—

(i) affect the previous operation of such Order or anything duly done or suffered under such Order; or

(a) S.R. & O. 1934 No. 1066.

(ii) affect any right, privilege, obligation or liability acquired, accrued, or incurred under such Order; or

(iii) affect any penalty incurred in respect of any offence committed against such Order; or

(iv) affect any investigation, legal proceeding or remedy in respect of any such right, privilege, obligation, liability or penalty as aforesaid;

and any such investigation, legal proceeding or remedy may be instituted, continued or enforced, and any such penalty may be imposed as if this Order had not been made.

Short Title

11. This Order may be cited as the Watermark Disease (Essex) Order of 1938.

Commencement of Order

12. This Order shall come into operation on the first day of September, Nineteen hundred and thirty-eight.

Interpretation of Order

13. The Interpretation Act, 1889(a), applies for the interpretation of this Order as it applies for the interpretation of an Act of Parliament.

In witness whereof the Official Seal of the Forestry Commissioners is hereunto affixed this twelfth day of July, Nineteen hundred and thirty-eight.

(L.S.) *A. G. Herbert,*

Secretary of the Forestry Commissioners.

(a) 52 and 53 Vict. c. 63.

COPY OF NOTICE SERVED UNDER THE ORDER

COUNTY OF ESSEX

DESTRUCTIVE INSECTS AND PESTS ACTS, 1877 AND 1907 FORESTRY ACT, 1919. SECTION 3(2)

THE WATERMARK DISEASE (ESSEX) ORDER OF 1938

To .....

of .....

NOTICE IS HEREBY GIVEN that the Essex County Council as the Local Authority for the Administrative County of Essex for the execution of the Watermark Disease (Essex) Order of 1938, dated 12th July, 1938, requires you, as the occupier of the premises described in the First Schedule hereto or person in whose control and management the willow trees growing thereon appear to be, to take in relation to such of those trees as are affected by Watermark Disease, the steps specified in the Second Schedule hereto in order to prevent the spread of the disease.

First Schedule

The following fields situate in the Parish of.....and County of Essex:—

O.S. No. ... (... trees)
O.S. No. ... (... ,,)
O.S. No. ... (... ,,)
O.S. No. ... (... ,,)
O.S. No. ... (... ,,)
Total ... trees.

Second Schedule

(*a*) Each diseased tree to be cut down to the ground level.

(*b*) The trunks to be removed from the property or to be destroyed by fire.

(*c*) The branches and twigs to be destroyed by fire.

The above to be carried out to the diseased trees on the premises described in the First Schedule hereto within three weeks from the date hereof.

Dated this.....day of.....

(Sgd.) .....
Clerk of the County Council.

Note.—Nothing in the above Order operates to prevent any person upon whom a Notice has been served under sub-paragraph (*a*) of Article 2 thereof from completely destroying by fire or otherwise any trees in respect of which a notice has been served upon him, and if he does so destroy them, he shall be deemed to have complied with the notice.

(94272) Wt. 2490 K.6 9/50 Hw. (TS.20671)

FIG. 1.
Pollards of crack willow. Near Thame, Oxford.
Photo : L. A. Clinkard.

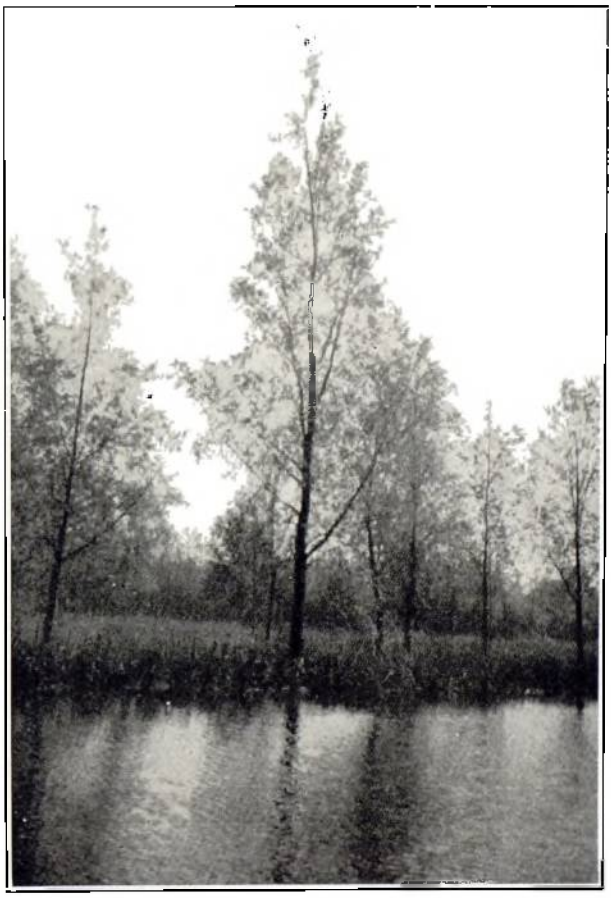


FIG. 2.
Cricket bat willows showing habit of growth and correct spacing. River Ouse, St. Neot's, Huntingdonshire. *Photo : J. Burtt Davy.*

PLATE II.

FIG. 1.
Unsuitable waterlogged site. The set is crooked and the young shoots have not been rubbed off. Nazeing, Essex.

FIG. 2.
Good site, properly fenced against live stock, but trees too closely planted. Near Chelmsford, Essex.
Photos : J. Burtt Davy.

PLATE III.

FIG. 1.
Stool of cricket bat willow bearing unpruned sets, one year old.

FIG. 2.
The same after pruning.

FIG. 3.
Set two years old, ready for cutting.

Photos : H. P. Hutchinson.

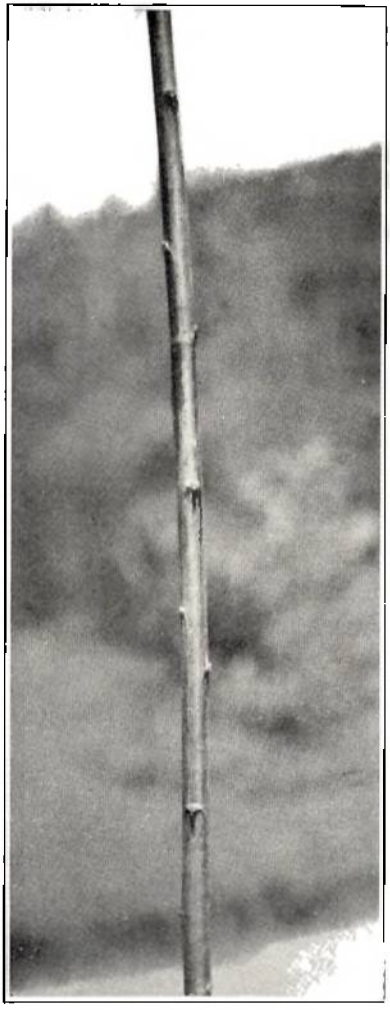


FIG. 1.

Stem of one-year-old cricket bat willow produced by stumping. Buds removed by pinching off, thus avoiding pruning wounds. Oxford.

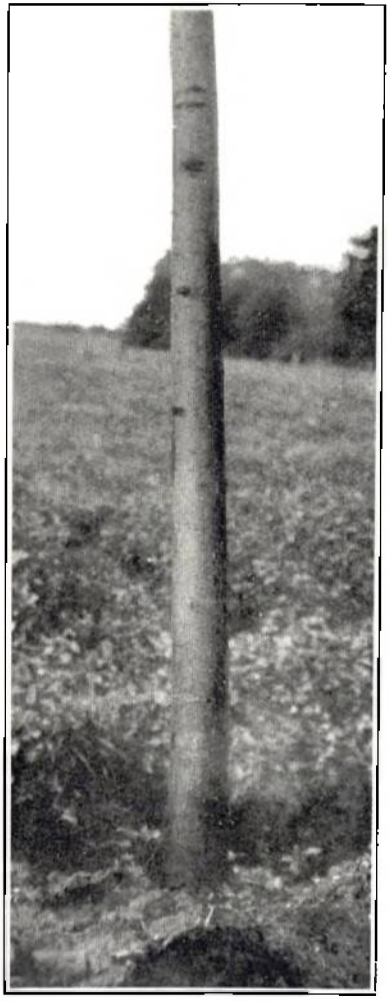


FIG. 2.

Three-year-old tree with perfect stem, growing near drainage ditch, on boulder clay. Near Terling, Essex.

Photos : J. Burtt Davy

PLATE V.

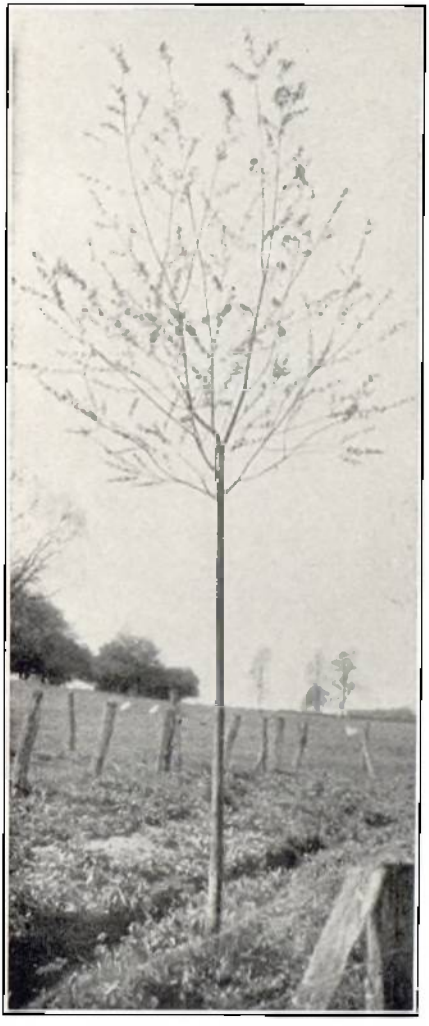


FIG. 1.

Three-year-old willow of high quality showing clean, straight stem; crown forked as a result of topping. Witham, Essex.

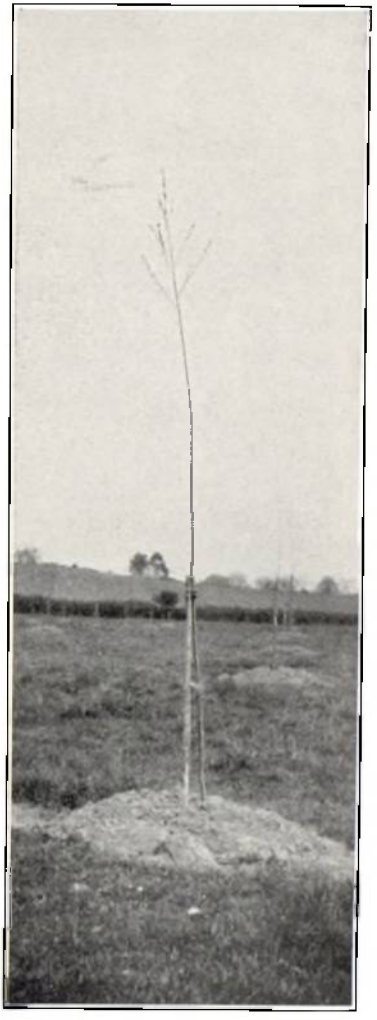


FIG. 2.

Mound planting of new sets. Huntley Manor, Gloucestershire.

Photos : J. Burtt Davy.

PLATE VI.

Plantation of three-year-old cricket bat willows, on a favourable streamside site.

Photo: H. P. Hutchinson.

PLATE VII.

FIG. 1.

Set injured by frost. In the long wound the inner bark has been killed.

FIG. 2.

Willow cleft showing bar stain in the lower half, butterfly mark above, and small knots in the centre.

Photos : L. A. Clinkard.

FIG. 1.
Burr on stem giving rise to bar stain underneath. This defect follows an old pruning wound, indicated by the circular marks.

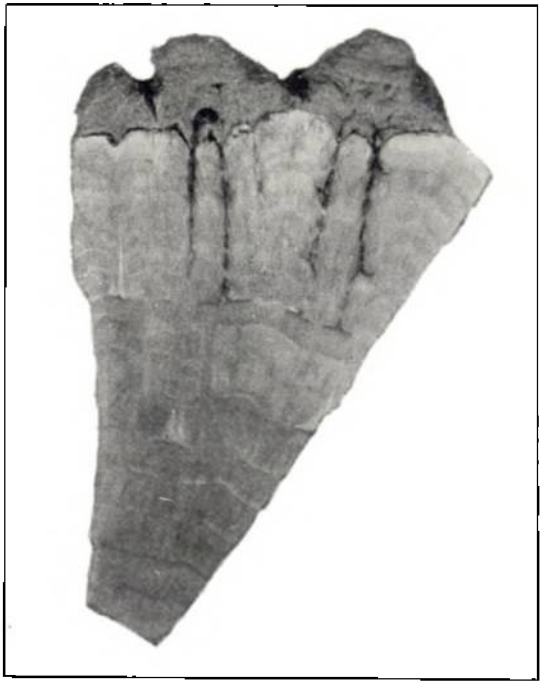


FIG. 2.
Section through burr, exposing stain and hidden canker.
Photos : L. A. Clinkard.

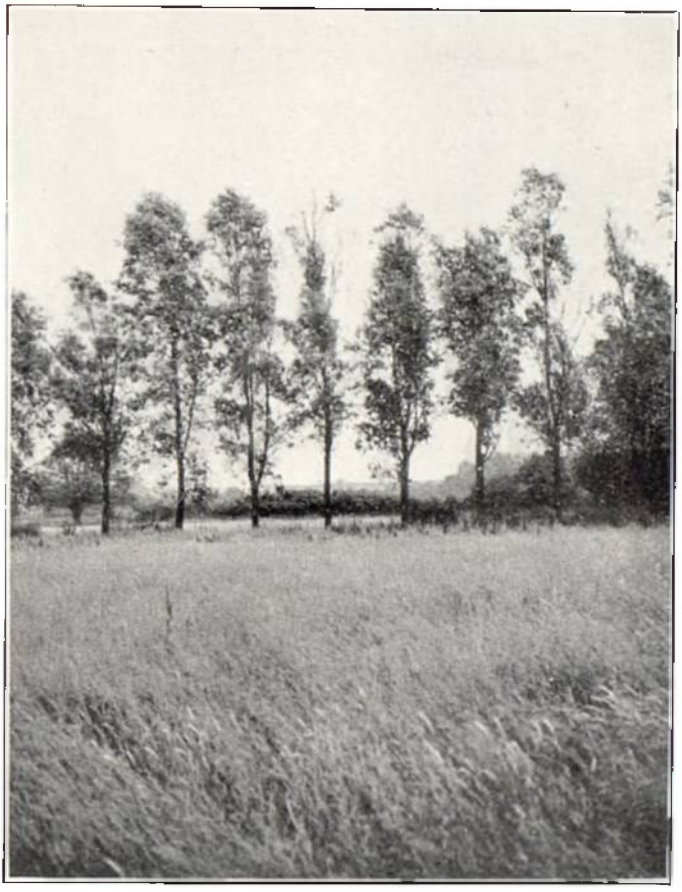


FIG. 1.
Trees showing effect of watermark disease. Near Maldon, Essex.

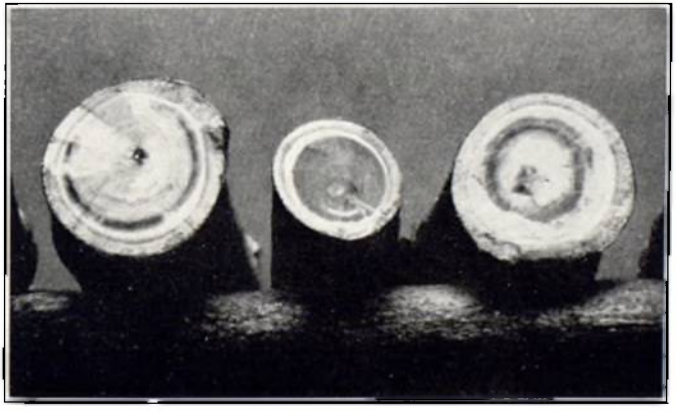


FIG. 2.
Branches showing typical markings of watermark disease.
From Oxford Forestry Memoir No. III, by courtesy of the Clarendon Press.

FIG. 1.
Trees cut into rounds for cleft ing. Stonehouse, Gloucestershire.

FIG. 2.
Stack of clefts seasoning in the open. Stonehouse, Gloucestershire.
Photos : Miss Hammond.

FIG. 1.
Cleft showing clusters of small knots, known as grape marks.

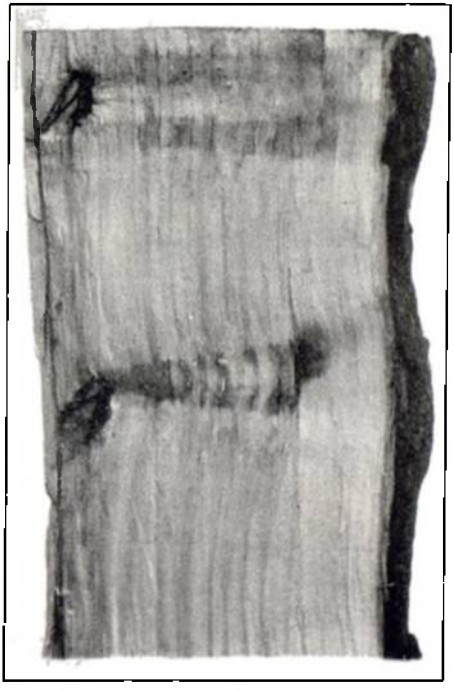


FIG. 2.
Bar stain associated with pruning wounds.
Photos : L. A. Clinkard

PLATE XII.

FIG. 1.

" Pith fleck " or " speck " damage on face of cricket bat.

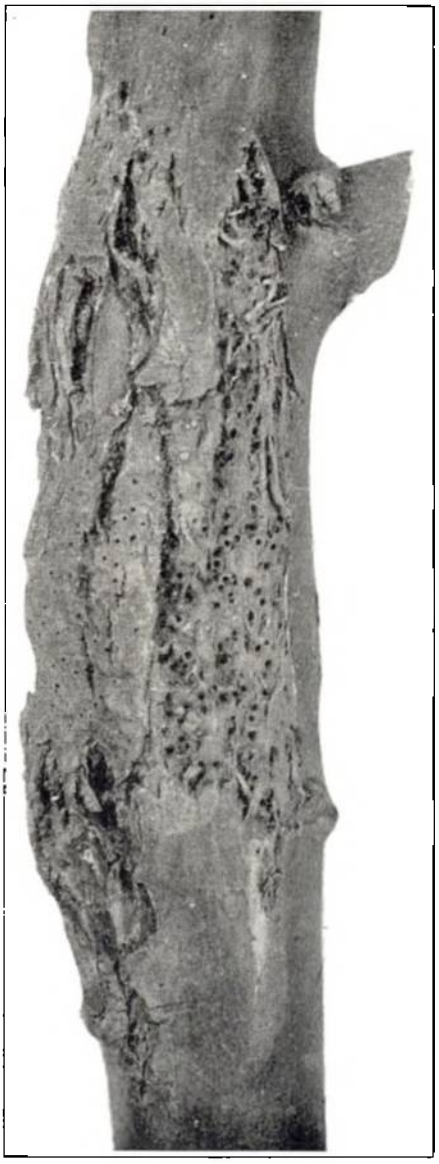
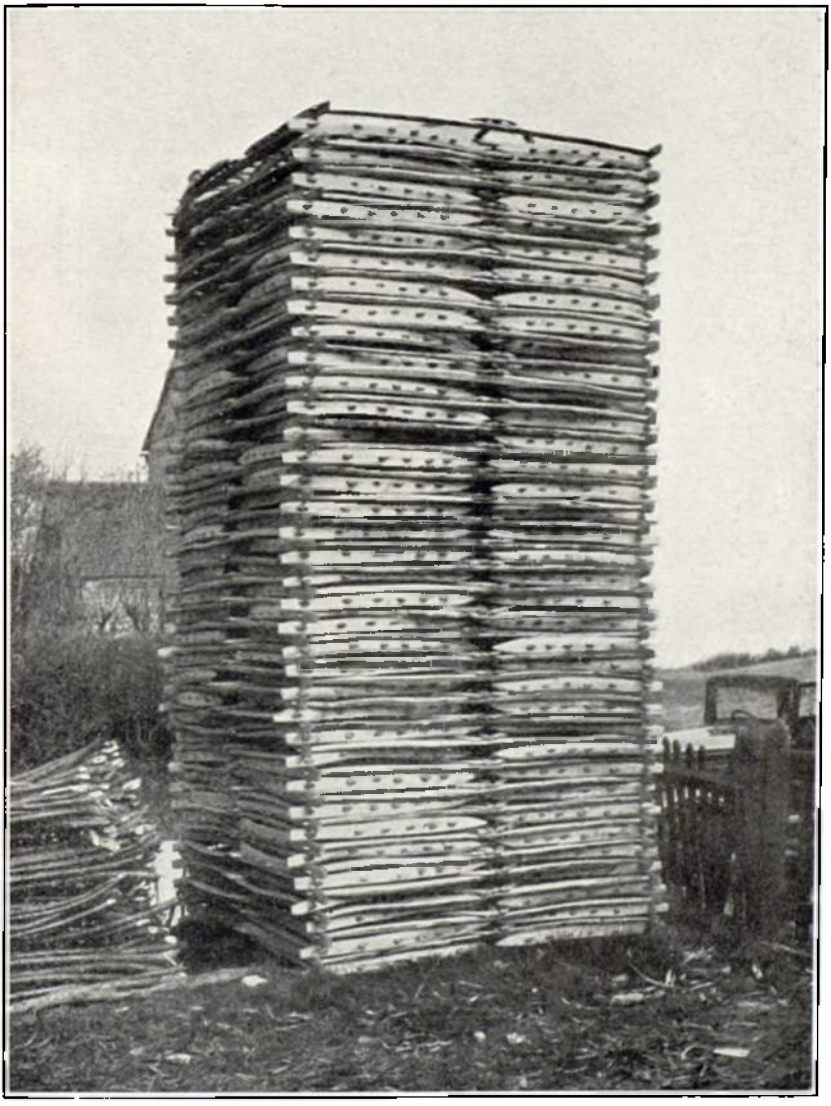


FIG 2.

Willow stem showing swelling caused by the gall-fly, *Rhabdophaga* (*Cecidomyia*) *saliciperda*. The exit holes of the flies can be seen dotted about over the central portion of the stem.

Photos : L. A. Clinkard.



Stack of hurdles made from poles of crack willow. Watlington, Oxford.
Photo : L. A. Clinkard.

PLATE XIV.

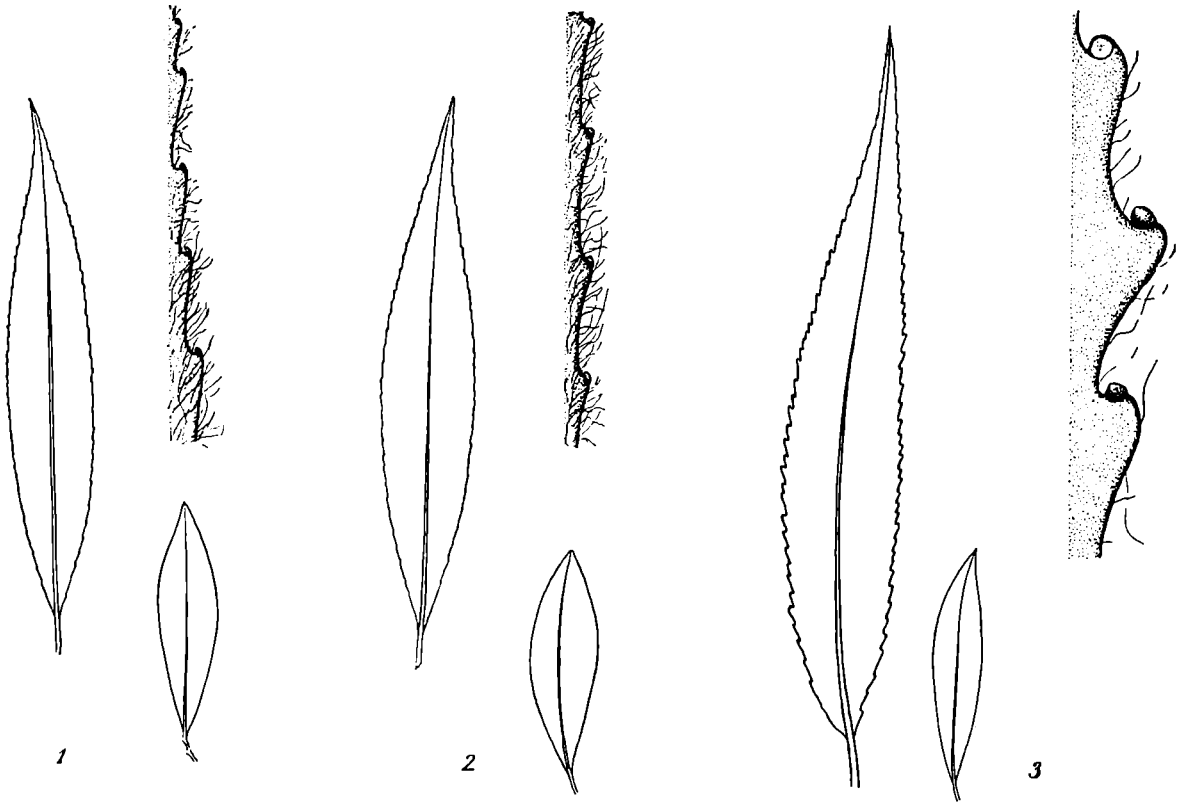
FIG. 1.
x *Salix viridis* var. *albescens* (female). Lavenham, Suffolk.

FIG. 2.
Salix alba var. *caerulea*. Copped Hall, Essex.

FIG. 3.
x *Salix viridis* (male). Lavenham, Suffolk.

Photos : J. Burtt Davy.

PLATE XV.

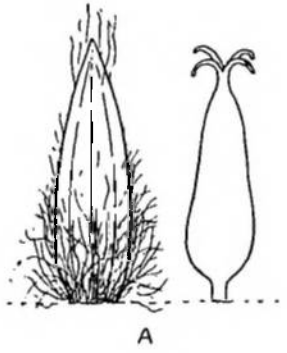


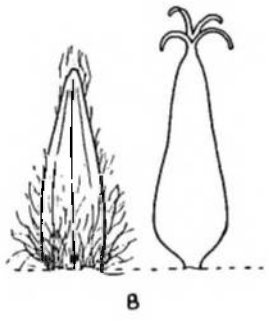
Summer leaf, pro-leaf and leaf-margin of :—

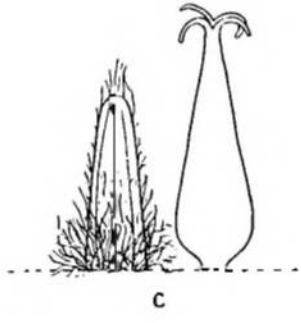
1. *Salix alba* var. *caerulea.* 2. x *Salix viridis* var. *albescens.* 3. *Salix fragilis.*

(The pro-leaves are the smaller of the two in each case.)

PLATE XVI.

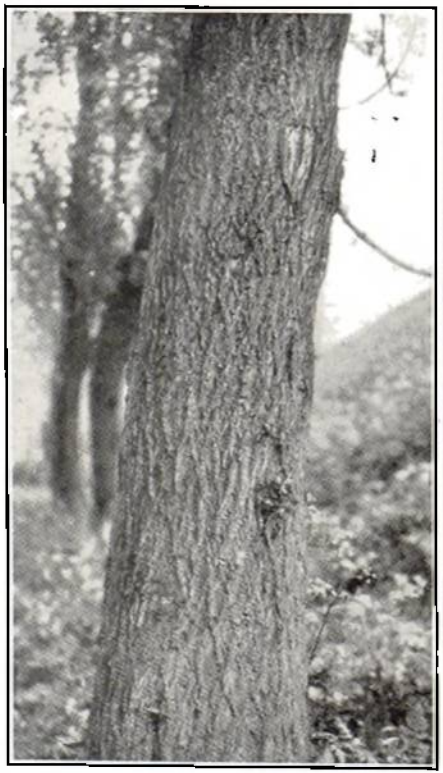


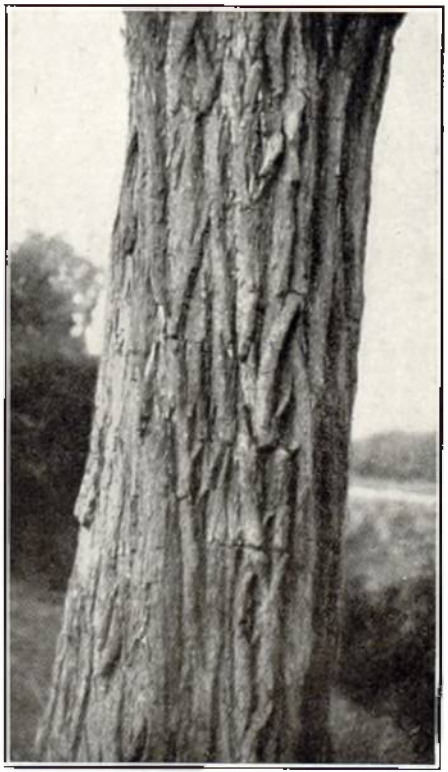




Catkins and diagrammatic drawings of bracteoles and ovaries of :—

A. x *Salix viridis* var. *elyensis*.
B. x *Salix viridis* var. *albescens*.
C. *Salix alba* var. *caerulea*.





Typical specimens of bark.

FIG. 1. x *Salix viridis* (male).
Photo : J. Burtt Davy.

FIG. 2. *Salix alba* var. *caerulea*.
By permission of the Director, Forest Products Research Laboratory.

FIG. 3. *Salix fragilis*.
Photo : J. Burtt Davy.

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