THE WILLOW TREE (*Salix* sp.)

By ALEXANDER L. HOWARD

"There is a willow grows aslant a brook
That shows his hoar leaves in the glassy stream"
SHAKESPEARE.

AMONG the many trees which adorn the countryside of Britain, this tree is one of the best known, and especially to those whose lives have been spent from earliest childhood in the country. A great many people have earned their livelihood in one way and another from its products, but those who have interested themselves in conserving or replenishing the stock are far too few, and almost entirely confined their attention to the bat willow, although perhaps with the exception of the ash tree the willow is one of those which will repay the planter within the least number of years. The fisherman, the basket-maker, and the gipsy are very intimate with the particular species which they know about, the first-named because of his continued controversy with the overhanging branches which interfere with his sport, but the latter since it has contributed to their livelihood.

It is unnecessary to describe the leaf or appearance of the tree, as it is so well known. Indeed, the narrow-pointed leaf, unlike most of our broad-leaved trees, is so prominent that its name has been borrowed for the description of other trees, such as the willow oak (*Quercus phyllus*), etc.

Everyone must be quite familiar with what we know as 'the willow pattern' of Chinese and Japanese origin in pictures and china ware; and also with the blue willow pattern of our own china, and more lately when a great designer made use of this attractive medium by the introduction of it into wall-papers. The Morris willow pattern also has become a well-known and admired addition to our domestic art. Whether the original Chinese, etc., pictured the willow as we know it is in some doubt. It has been suggested that perhaps the tree *Koelreuteria*, also a native of China, inspired the original willow pattern. While it would be interesting to decide the point, the beauty and likeness of both these trees is the principal subject of our interest.

The willow tree is regarded by different people with strangely opposite views: some think it a dull tree and take little interest in it, while others are delighted with the graceful form of the foliage and leaves, and its association with the banks of streams and rivers. The silvery blue presented by the leaves of many trees waving in the breeze adds greatly to the beauty of the landscape in those parts of the country frequented by the heron, the snipe and the duck. By the banks of streams, and in osier beds and the like, the willow figures more as a bush than a tree, and here it serves the purpose which it shares with the alder, of consolidating the banks, preventing erosion.

If care, and the study and practice of scientific measures are adopted, the tree will yield a very satisfactory financial result to the grower; but to succeed, diligence and study are required.

General knowledge is limited to two or three kinds, but Elwes mentions more than a hundred and sixty species, and Loudon more than two hundred. Many of these have been introduced from other countries.

The male and female trees of the original indigenous kinds have become the progenitors of numbers of hybrids. I shall limit my remarks to seven kinds

which are the better known and most prominent, namely: white willow, cricket bat willow, goat willow, bay willow, crack willow, golden willow, and the weeping willow.

White Willow (*Salix alba*)

In single form this tree will attain a height of more than 100 ft., with a girth of 25 ft. 6 in., but generally speaking large-sized trees are not common. The white willow (*S. alba*) with its close relative *S. alba coerulea* are by far the most important, as these two yield the best wood for the making of cricket bats. *Salix alba* may easily be recognized by 'witches brooms'—a formation caused by a mite (*Eriophes salicis*).

Elwes mentions:

"a tree at Bury St. Edmunds, figured by Strutt . . . as the Abbot's willow, is one of the largest white willow of which we have record. It was measured . . . in 1822, when it was 72 ft. high by 18½ ft. in girth, and was estimated to contain 440 ft. of timber".

Inquiries at Bury St. Edmunds to-day (1944) fail to reveal any information about this tree, and for many years it has been inquired for with no better results.

Cricket Bat Willow (*S. alba coerulea*)

This is a tree the origin of which would seem to be obscure, but it has been known in Great Britain since the beginning of the nineteenth century. It will attain a height of perhaps 100 ft. Of this Elwes says:

"Many trees of remarkable size, but comparatively young, have been felled for conversion into cricket bats. One of the largest was a tree at Boreham, Essex, which was planted in 1835, and felled in 1888, when it was 101 ft. high and 5 ft. 9 ins. in diameter. It weighed upwards of 11 tons, and was perfectly sound. It was felled by B. Warsop & Sons, who made from it no less than 1,179 bats".

Elwes was not often mistaken; but it would seem doubtful if any tree could make such growth in fifty-three years, as would equal more than one inch for every year.

He also says:

"Mr. Stuart Surridge purchased for £25, in 1910, a tree near St. Albans, which was about 80 ft. high and measured 5 ft. in diameter at 3 ft. from the ground. Judging from a photograph, it had a clean stem of about 16 ft. He states that the largest tree known to him grew at Robertsbridge, in Sussex, and measured 21 ft. in girth. This was felled in 1902, and produced over 1,000 cricket bats".

Mr. D. N. Bridger informs me that one of his workmen well remembers this tree being cut down and cleft. Mr. Bridger says that all the trees of *S. alba coerulea* are female, and he also says that many trees of *S. alba* have provided as good timber for cricket bats as *S. coerulea*. Elwes says, however, that the wood of *S. alba* is used for making cricket bats of an inferior kind. I also recall an occasion when an indignant purchaser of what he thought would prove to be cricket bat quality was informed that he had purchased the product of *S. alba* when he should have purchased *S. alba coerulea*. After exhaustive study I think the best results could be expected from the last-named, but it is quite possible that in the last thirty to forty years the character of the trees which have reached maturity may have altered.

The cricket bat manufacturer has become expert in his selection of the trees, but the same knowledge is not general among those who would find it to their advantage to become planters. Mr. Bridger emphasizes the importance of an abundant provision for the future of the cricket-bat making industry, his estimate of the annual output being in the neighbourhood of 250,000 bats per annum, men's size alone, while others name an even higher figure.

In 1915, it was discovered that in tropical countries, where the white ant has become a major pest, artificial limbs became a prey to these insects, and Prof. Groom and I were asked to find a wood which was immune to this attack. Exhaustive inquiry failed to discover anything except the willow suitable for the purpose, and in reply to an inquiry this year (1944) at the hospital at Roehampton, Mr. A. W. Shaw confirms the opinion, and says:

"willow is still the wood used in relation to wooden artificial legs, and no other wood has yet been found suitable. For metal artificial legs the foot is of willow".

The wood is pinkish-white, with a tough but softish grain, and besides the before-mentioned uses, provides the best-known timber for trug baskets, fruit baskets, linings for carts, barrows, and brakes for railway and other wagons, being especially good for the last-named, as it does not fire so readily as other woods from the friction of the wheels.

Goat Willow (*Salix caprea*)

This tree is naturally regenerated by seed, but can be propagated by cuttings and by sets. Its principal value is for prevention of erosion, and it is used for making fences and sheep hurdles, for trug baskets and for handles of rakes.

Bay Willow (*Salix pentandra*)

This is more noticeable for its attractive foliage than for its uses; it is distinguishable by its broad shining leaves.

Crack Willow (*Salix fragilis*)

This is sometimes called 'open-bark' willow. The wood is of little importance, but the Rev. C. A. Johns tells us that "the roots afford a purple-red dye, and are still used in Sweden and in France to colour Easter Eggs".

Golden Willow (*Salix vitellina*)

This tree is familiar to most people, and can be found in many gardens, parks and pleasure grounds. Fortunately, the nurseryman has found it sufficiently attractive to warrant production in large numbers, so that of late years householders have been able to gratify their inclination to make their gardens ornamental, and in this manner the tree has been justly introduced on a scientific scale. Elwes says:

"we have seen no trees of great size, the finest being probably two trees at Glasnevin, which are about 65 ft. in height and 8 ft. in girth".

The tree should be encouraged for its unusual grace and beauty.

Weeping Willow (*S. babylonica*)

There must be very few who have not enjoyed the beauty of the weeping willow, a tree much more commonly seen half a century ago than to-day, and

one which, if the plans for re-afforestation for the future are limited alone to the economic aspect, may insensibly vanish from our landscape.

It would appear that the first tree introduced to Great Britain was planted at Twickenham, and became famous, for Johns tells us:

"the first tree was planted at Twickenham, either by Mr. Vernon, a merchant of Aleppo, or by Pope. This was a favourite tree with the poet, and after his death became the object of so much curiosity that the possessor of his villa cut it down, to avoid being annoyed by persons who came to see it".

He also says:

"Loudon informs us that this tree was introduced into St. Helena from Britain by General Beaton, 1810. It was planted among other trees on the side of a valley near a spring; and having attracted the notice of Napoleon, he had a seat placed under it, and used to go and sit there very frequently, and have water brought to him from the adjoining fountain. About the time of Napoleon's death, in 1821, a storm shattered the willow in pieces, and after the interment of the Emperor, Madame Bertrand planted several cuttings from it on the outside of the railing which surrounded the grave. As none of these flourished, they were renewed in 1828; and from one of them, which outstripped the rest, were brought most of the cuttings which have been reared in various parts of the country. The oldest now in existence in Europe derived from this stock stands in the garden of the Roebuck Tavern on Richmond Hill".

And again:

"So popular has the weeping willow become as an ornamental tree, that it is said to be commoner in almost every country than in its native habitat, the banks of the Euphrates".

We are accustomed to the introduction of fashions in many directions, but it is curious that this should apply to the planting of particular trees. Sometimes the fashion has been to plant oak, another time acacia, and further instances might be quoted. Following the reign of terror and the Napoleonic era, certainly a wave of fashion spread over Europe, including Great Britain, for the planting of weeping willows, so that almost all the gardens and parks which date from this period included it among their ornamental trees.

Elwes gives some interesting information relating to this tree, and says:

"this was the name given by Linnaeus to the common weeping willow cultivated in Europe, which he erroneously supposed to have been identical with the trees growing by the rivers of Babylon, which are mentioned in Psalm cxxxvii, 1, 2.

"By the rivers of Babylon,
There we sat down, yea, we wept,
When we remembered Zion.

Upon the willows in the midst thereof
We hanged up our harps.

"The latter are, without doubt, a species of Poplar (*Populus euphratica*). . . . The best that I have seen is perhaps a tree on the Promenade, Cheltenham, which was planted about 1860, and is still thriving, although its limbs have been supported by iron rods for some years. It measured in 1911 about 75 ft. by 9 ft. and on 24th November, 1911, after a severe frost, it still retained most of its leaves.

"There are several picturesque trees, but of no great height, growing on the banks of the Cam, behind the Colleges of Cambridge. These are exceeded in size by one

in the Fellows' Garden of King's College, which was about 45 ft. high and 10 ft. in girth in 1912, with the trunk decayed and mended with cement".

The weeping willow is surprisingly distributed. In addition to the numberless places in Asia and Europe where it thrives, Elwes informs us that "it attains much greater size and beauty in warm countries than it does in England" and that he had "seen none finer than in Chile".

THERMODYNAMICS OF SORPTION ISOTHERMS: THE HYSTERESIS LOOP IN CAPILLARY CONDENSATION

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IN any two-component system if m_A, m_B are the masses of the components A and B and g_A, g_B their respective Gibbs free energies *per gram*, then so long as there is equilibrium,

$$SdT - VdP + m_A dg_A + m_B dg_B = 0, \quad (1)$$

where S is the entropy and V the volume of the 'complex' of A and B whatever form it may take. If the 'complex' contains only condensed phases and the pressure is kept substantially constant (say, below 1 atmosphere) we can disregard the second term, and write for isothermal equilibrium:

$$m_A dg_A + m_B dg_B = 0 \quad (2)$$

An advantage of (2) over the more usual form of equation in terms of molecular quantities is that it is immediately applicable in cases where the molecular weight of one of the components (say, A) is large or unknown; it is particularly helpful, therefore, in examining the sorption relations of gels, the interaction between solid polymer and 'plasticizer', and such cases. Supposing B to be a volatile liquid of molecular weight M , and that the 'complex' is at equilibrium with the vapour of B at a pressure p , f being the corresponding fugacity, we have, on substituting $RT/M \log_e f$ for dg_B ,

$$m_A dg_A + \frac{m_B RT}{M} d \log_e f = 0$$

$$g_A^0 - g_A = - \frac{RT}{M} \int_0^p \frac{m_B}{m_A} d \log_e f \quad (3)$$

where g_A^0 is the (Gibbs) free energy of pure A . The right-hand member of this equation can be evaluated experimentally.

The only conditions attached to the validity of (3) are that the structure and composition of A should be statistically uniform (so that m_B/m_A has a definite meaning) and that the same equilibrium should be attained by approach from either side. Primarily, we do not need to ask ourselves whether or not a true chemical compound is formed, whether the 'complex' is to be regarded as a one- or as a two-phase system, whether B is or is not molecularly dispersed (to give a true solution), or whether, supposing surface interactions are involved, these are taking place at plane or at curved surfaces. In fact, however, a large number of cases have come to light where the relation

between $(g_A^0 - g_A)$ and m_B/m_A corresponds to well-recognized two-dimensional equations of state or to a sequence thereof^{1,2,3}. Where this occurs it appears justifiable, *prima facie*, to infer that: (1) B is adsorbed as a film at the surface of A ; (2) A is characterized by possession of a definite surface area (Σ) per unit weight; and (3) that $(g_A^0 - g_A)$ stands for a decrement of surface energy and can be equated to $\Sigma(\gamma_0 - \gamma)$, where γ_0 is the surface energy of A *in vacuo* and γ its value in contact with the vapour of B at p . It is convenient to assign the symbol Π to $(\gamma_0 - \gamma)$ and regard Π as a two-dimensional 'film pressure'; thus

$$\Pi \Sigma = (\gamma_0 - \gamma) \Sigma = \frac{RT}{M} \int_0^p \frac{m_B}{m_A} d \log f \quad (4)$$

Now the sorption relations of many gels are such as to suggest the *filling-up* of capillary spaces, the quantities of different adsorbates at saturation representing roughly equal volumes of the different liquids⁴. According to the well-known capillary condensation hypothesis, the quantities sorbed at pressures below saturation are determined by the distribution of pore radii (the pores usually being considered cylindrical), the surface tensions γ_B of the liquids, and the equilibrium angles of contact θ , the relation between these parameters being the Kelvin equation:

$$p/p_0 = \exp. (-2V_m \gamma_B \cos \theta / rRT), \quad (5)$$

where p_0 is the saturation pressure of the liquid and V its molecular volume. A necessary condition for capillary condensation is that $\theta < 90^\circ$. Several authors have attempted to derive 'structure curves' for pore-size distributions from their sorption data on the basis of equation (5), θ generally being taken as zero. A weak point about this procedure is that, apart from its ability to become wetted by the component B , the only adjunct of A that is allowed to have a determining influence is the single property of curvature: p should thus be uniquely determined by r .

By the use of equation (4), on the other hand, Gregg² has brought to light instances hitherto universally accepted as examples of capillary condensation, but in which the relations between Π and the surface concentration reproduce in detail those of certain insoluble films on water. As the concentration rises, first a 'vapour', then an 'intermediate' and finally a 'liquid expanded' (or 'liquid condensed') film is formed. Thus, at the hands of different workers, the same sorption data may receive mutually incompatible interpretations in terms of film-forming characteristics on one hand and of pore structure on the other. The issue is complicated by the appearance of a hysteresis loop in some of the experimental adsorption isotherms referred to⁵; for over the range of the hysteresis the basic requirement of equations (1)-(4), namely, that the equilibria should be independent of the direction of approach, is no longer satisfied. For this reason we shall resort to the more cumbersome method of argument based on work cycles in the discussion which follows of the tenets of the capillary condensation hypothesis.

We suppose two large enclosures X and Y containing the vapour B at pressures p and $(p - dp)$ respectively, the corresponding fugacities being f and $(f - df)$. Connecting X and Y is a long length of capillary tubing Z of suitable material and of such (uniform) diameter that according to (5) capillary