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Biotechnol. Agron. Soc. Environ. 1997 **1** (1), 59–64

Wood Quality of White Willow

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Received 7 March 1996, accepted 18 March 1996.

Based upon an exhaustive work made by Sacré (1974) and a review of the literature since 1960, the author gathered together the anatomical, physical and mechanical characteristics, the machining behaviour (industrial sawing, planing, surfacing, shaping, mortising and nailing) and wood end-uses of white willow.
Keywords. Machining behaviour, utilisation, white willow, wood quality, *Salix alba*.

Qualité du bois de saule blanc. En se référant à un travail exhaustif de Sacré (1974) et à une revue de la littérature depuis 1960, l'auteur rassemble les caractéristiques anatomiques, physiques et mécaniques, le comportement à l'usinage (sciage industriel, rabotage, dégauchissage, toupillage, défonçage et clouage) ainsi que les utilisations du bois de saule blanc.
Mots-clés. Comportement à l'usinage, qualité du bois, saule blanc, utilisation, *Salix alba*.

DIVERSITY OF WILLOWS

Willows (genus *Salix*) and poplars (genus *Populus*) form the large family of Salicaceae.

The genus *Salix* alone is made up of more than 300 species (CIP-FAO, 1980), of which about thirty may be found in temperate Europe and eleven in Belgium (De Langhe *et al.*, 1978; Dethioux, 1982). Among the last ones, white willow (*Salix alba* L.) is allowed to grow to timber size (25 m height), while many others have a shrub life form.

A general characteristic of willows is their trend to form interspecific hybrids, out of which a large number has been inventoried in Europe and in Belgium. This peculiarity often makes the right diagnosis difficult for many trees.

The Belgian willows may be classified into two taxonomic groups.

– The osiers are characterized by narrow and long leaves and by flexible branches, used in basket making. This is the case of common willow or basket willow (*Salix viminalis* L.), white willow (*Salix alba* L.), almond-leaved willow (*Salix triandra* L.), purple osier (*Salix purpurea* L.), yellow hybrid osier (*Salix* × *rubens* Schrank). The osiers regularly cut back to the stump, in the past, were called "pollard". Within this group of willows having long and narrow leaves, one should also note some species as crack willow or brittle willow (*Salix fragilis* L.), and decorative willows such as cricket-bat willow or close-bark willow (*Salix alba* subsp. *coerulea* Sm.) and weeping willow (*Salix alba* subsp. *vitellina*, cultivar *tristis* Stokes, *Salix babylonica* L.).

– The auricled willows are often bushy, have wider and shorter leaves, fitted at the bottom with leaf appendages (auricle), such as auricled willow (*Salix aurita* L.), sallow willow (*Salix caprea* L.), grey willow (*Salix cinerea* L.) and russet willow (*Salix atrocinerea* L.), which one is exceptional in Belgium but very common in western France and in Great-Britain.

Almost all our homegrown willows are dependent on moist soils (Dethioux, 1982). The osiers are localized on the riverside border of rivers and ponds and tolerate periodical flooding quite well. The auricled willows are much more tolerant with the permanent moistness of soil and inhabit constantly waterlogged soils.

In some countries (Austria, Hungary, India, The Netherlands, New Zealand, Romania, United States, Yugoslavia, etc.), willows growing for timber production is rather important (CIP, 1971). In Belgium, the forest inventory of 1970 includes willows found in coppice and coppice-with-standards. However, statistical data concerning especially willows do not exist yet, so that it is not possible to know the real area occupied by them or the volume involved. At the most, their proportion is not exceeding 2–3% of the total number of poplars (Sacré, 1974b).

Up to now, willow growing in Belgium is unimportant and, at present, willows are dying in our country due to a disease caused by new strains of *Erwinia salicis* (Day) Chester. Ranked as poplar, only white willow may be of some industrial interest because of the sizes gained and its ability to grow on inadequate (moister) soils for poplars.

According to the economical study made by Évrard and Picron (1965) on white willow in Belgium, it is evident that

– willow is infrequent on the market, bought with mixed other species, particularly with grown poplars;

– the age of logged trees is varying between 25 and 80 years, their girth at breast height is fluctuating between 1 and 2 m, and the bole cutting is made around 10 m height;
– in general, the boles show more or less important defects: frost crack, cup shake, large sound knots, sometimes with rotten knots, irregular form;
– the industrial uses would be practically the same as those of poplarwood.

WOOD QUALITY

In reading back the literature since 1960 on wood uses of willow, it appears that a great deal of studies mainly concerned biomass production (Tsanov, Kolarov, 1979; Geyer, 1981; Mosseler *et al.*, 1988) and pulp and paper quality (Uusvaara, Pekkala, 1979; de Guth, Ragonese, 1980; Milea, 1980; de Guth, 1982; Milea, 1982; Kopitovic, Klasnja, 1985; Kopitovic *et al.*, 1988; Deka *et al.*, 1992; Landucci *et al.*, 1992).

Only few studies are dealing with wood quality of willows and their authors will be mentioned hereunder.

In Belgium, Sacré (1974b) fully examined the anatomical, physical and mechanical characteristics as well as the machining behaviour of 4 boles of white willow (*Salix alba*) coming from a planted stand (tree spacing: 5 by 6 m) in the Scheldt Polders within the Province of Antwerp. These four trees, 31 years old, with a mean total height of 23.5 m, had a girth at breast height varying between 1.3 and 1.6 m, as well as a volume to the 10 m cutting height between 1.1 m^3 and 1.8 m^3. The wood quality and machining tests concerned the first 4 m from the butt. The experimental cutting scheme for each tree was the following
– 0–0.25 m and 3.75–4 m: disks for anatomical examinations;
– 0.25–3.25 m: machining tests;
– 0.25–3.25 m: 2 central quarter-sawn boards of 26 mm thickness for mechanical tests;
– 3.25–3.75 m: disks for physical tests.

Macroscopic examination of boles cross sections

Bark thickness is varying between 5 and 20 mm.

Sapwood is yellowish white, lightly pinkish.

Heartwood is reddish brown with thin wavy orange-coloured lines indicating its annual progression on the cross section. The mean surface proportion of heartwood on the cross section fluctuates between 53 and 57%. The proportion of heartwood is more important at the bottom of the bole than at 4 m height.

The pith is often eccentric, mainly at the bottom of the bole. Tension wood, of diffuse type, is abundant on all the sections, with a mean surface proportion ranging from 62% up to 70%.

Anatomical characteristics

Characteristics of vessels and rays are rather the same at the bottom and at the top of the butt log (**Table 1**).

Fibres from the inner part of the bole are significantly shorter than those from the outer part and are also thinner whatever the sampling height may be. These observations were also made by Tompa (1969) on *Salix alba*, by Deka *et al.* (1992) on willow hybrids, and by Sennerby-Forsse (1989) on *Salix caprea* and *Salix pentandra* L. As a consequence, the felting ratio is lower in the inner part than in the outer part of the bole, particularly at the bottom of the stem, while the flexibility ratio is slightly higher in the inner part.

Compared with the results achieved on the three Euramerican poplars *P.* "I.214", *P.* "robusta" and *P.* "gelrica" (Sacré, 1974a), differences in white willow characteristics may be observed:
– the vessels of white willow are thinner, shorter and more numerous;
– its fibres are narrower, shorter and generally thinner; the same observation was made by Kopitovic and Klasnja (1985);
– its felting ratio is lower than in *P.* "robusta", but higher than in the two other cultivars;
– its rays are clearly shorter, involving a smaller number of cells, and narrower than those of Euramerican poplars.

Fibre length in Belgian white willow is similar to that observed by Herpka (1966) on white willow in the Hungarian Danube flood-plain. In any case, fibres and vessels of *Salix alba* appear to be longer and wider than in *Salix caprea* and in *Salix pentandra* (Lehtonen *et al.*, 1978; Sennerby-Forsse, 1989).

The number of rays observed by Sacré (1974b) within 1 mm along the tangential direction is pretty close to the number noted by Tompa (1969) on white willow in Hungary.

Physical characteristics

The specific gravity and the total shrinkage of willowwood are intermediate compared with the figures recorded on Euramerican poplars grown in Belgium during that period of time (**Table 2**).

Heartwood of white willow is as dense as sapwood, like false heartwood of most old clones of Euramerican poplars.

On the other hand, total shrinkage in heartwood (15.0%) is higher than in sapwood (12.9%) within the butt log.

However, willowwood exhibits a far greater longitudinal shrinkage as compared to that of old Euramerican poplar clones. Its other shrinkage characteristics are pretty close to these of *P.* "I.214" and *P.* "gelrica". In any case, willowwood is more stable than the wood of *P.* "robusta". This result has also been observed by Tompa (1969).

Table 1. Anatomical study of white willow (Sacré, 1974a; 1974b) — *Étude anatomique du saule blanc.*

Characteristics		*Salix alba*			*Populus* "robusta"
		Bottom (0.25 cm)	**Top (3.75 m)**	**Butt log (0–4 m)**	**Butt log (0–4 m)**
Vessels	Diameter (μm)				
	Radial direction	92	88	90	138
	Tangential direction	57	56	56	78
	Length (μm)	396	397	397	452
	Number per mm^2	94	105	100	56
Fibres	Diameter *d* (μm)				
	Inner part of the bole	31.4	28.6	30.0	30.7
	Outer part of the bole	31.8	30.7	31.2	34.2
	mean	*31.6*	*29.6*	*30.6*	*32.5*
	Length *l* (μm)				
	Inner part of the bole	884	920	902	1,139
	Outer part of the bole	1,122	1,112	1,117	1,313
	mean	*1,003*	*1,016*	*1,009*	*1,226*
	Felting ratio *l/d*				
	Inner part of the bole	28.1	32.2	30.1	37.1
	Outer part of the bole	35.3	36.2	35.8	38.4
	mean	*31.7*	*34.2*	*33.0*	*37.7*
	Wall thickness *e* (μm)				
	Inner part of the bole	2.5	2.6	2.6	2.9
	Outer part of the bole	3.1	3.0	3.1	3.1
	mean	*2.8*	*2.8*	*2.8*	*3.0*
	Flexibility ratio $100 (d - 2e) / d$				
	Inner part of the bole	84.1	81.8	82.7	81.1
	Outer part of the bole	80.5	80.4	80.4	81.9
	mean	*82.3*	*81.1*	*81.7*	*81.5*
Rays	Number of cells along the height	16	15	16	30
	Cell height (μm)	21.2	21.4	21.3	18.5
	Cell width (μm)	16.6	15.6	16.1	18.6
	Number of rays within 1 mm in the tangential direction	12	11	11	11

Compared to other origins, Belgian white willow proves to be similar in specific gravity than German (Otto, 1989), Hungarian (Herpka, 1966; Tompa, 1969; von Szalay, 1975) and Slovak white willow (Kurjatko, Pozgaj, 1977), but seems to be slightly less stable.

With regard to interspecific differences, it must be noted that white willowwood is lighter than the wood of *Salix caprea* (Lehtonen *et al.*, 1978; Sennerby-Forsse, 1989), *Salix pentandra* (Sennerby-Forsse, 1989) and Canadian willow hybrids (Singh, 1987).

On the whole, white willowwood is very light, with a medium shrinkage, and relatively stable.

Mechanical characteristics

Compared with the wood of old Euramerican poplar clones, white willowwood has a lower compression strength ratio and a lower static bending strength ratio (**Table 3**). Its hardness is intermediate.

However, the wood of white willow has a higher impact bending strength, elasticity and a sensibly higher rigidity (rigidity ratio: 21.5) which was also noted by von Szalay (1976).

The absolute values of tensile strength, splitting strength and shear strength are medium.

With regard to the radial position on the cross section, heartwood seems to be weaker in impact bending and in cleavage than sapwood; the other mechanical properties of both wood sorts are very similar.

On the whole, willowwood compared to old Euramerican poplar clones is softer, weaker in compression and in static bending, more flexible, more resilient and more resistant to splitting, but also higher in shear strength and tensile strength.

Table 2. Physical characteristics of white willowwood — *Caractéristiques physiques du bois de saule blanc.*

Physical characteristics	**Source**	***Salix alba***	***Populus***		
			"I.214"	**"robusta"**	**"gelrica"**
Mean specific gravity	Sacré, 1974	0.388	0.359	0.448	0.352
	Herpka, 1966	0.337			
	Tompa, 1969	0.454			
	von Szalay, 1976	0.380			
	Kurjatko, Pozgaj, 1977	0.368			
	Otto, 1989	0.365			
Total shrinkage (%)	Sacré, 1974	14.0	13.1	15.2	14.6
	Otto, 1989	13.9			
Shrinkage coefficient (%)	Sacré, 1974				
Longitudinal		0.026	0.009	0.015	0.013
Radial		0.060	0.089	0.111	0.085
Tangential		0.233	0.220	0.263	0.225
Volumetric		0.319	0.318	0.389	0.323

These data, observed by Sacré (1974b), were similar to those recorded by Tompa (1969).

MACHINING BEHAVIOUR

Industrial sawing test

Sawing "through and through" freshly cut willow logs at a 26 mm constant thickness with a log band mill proves slow and difficult because of a high proportion of tension wood which generates a woolly covering on band saw blade producing, consequently, perceptible variations in sawn timber thickness.

Inside the logs examined, the grain seems to be more or less wavy.

The output of air-dried (around 15%) square-edged timber, in proportion to the green volume, is getting up to 55%.

The results achieved by Sacré (1974b) show that 1% of sawn timber may be classified in grade I (selected joinery), 15% in grade II (common joinery and carpentry) and 84% in grade III (packaging and boxes-making). The downgrading of 1st and 2d grade sawn timber is due to woolly surfacing (tension wood) and black knots.

After drying, almost all square-edged boards exhibit more or less deformations (bow, crook, cup, twist) and end checks (between 30% and 60% according to the log itself).

The shrinkage measurements on boards width, between green and air-dried conditions, display respectively the following figures:

- quarter-sawn timber: 2.7%;
- half quarter-sawn timber: 3.2%;
- flat-sawn timber: 3.9%.

If sawing green willow logs appears to be difficult, sawing air-dried square-edged timber proves to be far easier—with a band saw as well as with a circular saw—and gives a good surfacing and smooth edges.

Planing and surfacing tests

As a rule, the quality of surface finishing by planing is satisfactory excepted within interlocked grain zones surrounding knots. Surfacing sometimes shows small splinters inside the extremely fuzzy grain parts.

However, it must be noted that the raised grain aspect is almost completely removed from air-dried square-edged timber by planing and surfacing.

Shaping and mortising tests

Generally, shaping and mortising test results are good. The wood is very easily wrought. Nevertheless, fringes of sticky fibers locally appear within grooves and mortises, and some splinters are visible on the edges.

Nailing

The behaviour of willow boards under nailing is quite remarkable because there is no split if a 3 mm diameter nail is driven into the plank at a distance from the edge exceeding two times the nail's diameter. However, without taking great care, the wood dents easily.

CONCLUSION

From the sampling examined by Sacré (1974b), white willow appears to have a good stem form, a relatively short trunk, a normal taper (3 to 4 cm per m) and an extremely variable individual growth, but remaining rather fast (mean

Table 3. Mechanical characteristics of white willowwood (Sacré, 1974a, 1974b) — *Caractéristiques mécaniques du bois de saule blanc.*

Strength characteristics	***Salix alba***	***Populus***		
		"I.214"	**"robusta"**	**"gelrica"**
Compression strength ∥ ($N \cdot mm^{-2}$)				
Heartwood	26.9			
Sapwood	27.1			
Mean	*27.0*	*28.8*	*36.8*	*25.6*
Static bending strength ($N \cdot mm^{-2}$)				
Heartwood	54.0			
Sapwood	54.6			
Mean	*54.3*	*54.3*	*69.7*	*47.3*
Modulus of elasticity ($N \cdot mm^{-2}$)				
Heartwood	5,060			
Sapwood	5,520			
Mean	*5,290*	*5,760*	*8,250*	*4,890*
Impact bending strength ($J \cdot cm^{-2}$)				
Heartwood	2.5			
Sapwood	3.0			
Mean	*2.7*	*1.5*	*3.5*	*1.7*
Tensil strength ⊥ ($N \cdot mm^{-2}$)				
Heartwood	2.18			
Sapwood	2.11			
Mean	*2.15*	*1.77*	*2.21*	*1.88*
Cleavage strength ($N \cdot mm^{-2}$)				
Heartwood	13.0			
Sapwood	11.5			
Mean	*12.3*	*11.1*	*11.4*	*12.3*
Shear strength ($N \cdot mm^{-2}$)				
Heartwood	6.30			
Sapwood	6.33			
Mean	*6.31*	*5.81*	*7.26*	*5.51*
Hardness (Monnin)				
Heartwood	0.84			
Sapwood	0.86			
Mean	*0.85*	*0.76*	*1.03*	*0.71*

annual ring width is ranging between 6.6 and 8.6 mm according to the log).

The wood contains a medium proportion of distinct reddish brown heartwood and a high percentage of tension wood.

That is the reason why the sawing of freshly cut logs is difficult and why defects appear during the drying process but, once air-dried, boards machining is far easier and the shrinkage becomes medium.

The sawing output from white willow is quite good with a normal proportion of second grade boards. The percentage of first grade boards is very low due to natural downgrading of fuzzy grain boards. However, woolly surfaces are completely removed from air-dried boards by planing.

Compared with old Euramerican poplar clones, willowwood exhibits a finer texture and its coloured heartwood has no lower quality. On the contrary, willow heartwood is as dense, almost as tough as sapwood. Its reddish brown and mottle appearance is susceptible to take a nice polish finishing.

Referring to wood quality, willow sawn timber is suitable:

- for nice joinery: decorative panelling, woodwork;
- for common joinery: common furniture (carcass and inner parts), battens and blockboards (Sacré, 1974b; von Szalay, 1975);
- for packaging and pallets making.

In many countries (Hungary, Yugoslavia, United States, etc.) high quality timber of white willow is used by the peeling industry (Otto, 1989; Blossfeld *et al.*, 1990). In connection with that, the tests made by the "Union allumettière" in Belgium were conclusive. Therefore, white willow might be used, as poplar, for veneer and plywood production, for match-making and for light packaging.

Pulp and paper making industry, fiberboard and particleboard industries use willows in the countries where they are well represented. The intrinsic characteristics of white willow make it suitable for these purposes (Tompa, 1969; Lehtonen *et al.*, 1978; Uusvaara, Pekkala, 1979; Milea, 1982; Kopitovic, Klasnja, 1985; Deka *et al.*, 1992).

Finally, the anatomical features (relatively fine texture), the physical characteristics (lightness) and the mechanical properties (elasticity, impact strength) allow the use of white willow for particular purposes, such as: sport goods (cricket bats), playthings, carved wood, tool handles and clog-making for which willow is preferred to poplar in Belgium (Sacré, 1974b).

Briefly, a good white willow clone (rapid growth, straight and high stem) has at least as many qualities as old Euramerican poplar clones. Consequently, white willow stands would be of interest on very moist soils where appropriate draining for poplars is missing.

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