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QUALITY CHARACTERISTICS OF THE SELECTED VARIANT OF *Paulownia tomentosa* (ROBUST4) WOOD CULTIVATED IN HUNGARY

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ABSTRACT

Besides the continuously increasing demand for wood, the significant increase in its price also contributes to the increasingly broader use of fast-growing wood species and cultivars. Newer variants are continue to be cross-bred as a result. In case of a new variant within a species, it is questionable how it would adapt to a particular climatic environment and the quality of wood it would yield. The characteristics of the *Paulownia tomentosa* (Robust4) wood obtained from Hungarian plantations of are generally identical to those of the *Paulownia tomentosa*. The value of the air dry density - as typically for paulownia species- are very low i.e. 273 kg/m^3. Its strength values (compressive strength: 9,6 MPa; tensile strength: 39,3 MPa; bending strength: 41,7 MPa; modulus of elasticity: 4116 MPa; impact bending strength: 1,4 J/cm^2) also reach, and in some cases, exceed those of the *Paulownia tomentosa* (Thunb.) Steud. and the *Paulownia Clone in vitro 112* variant. Based on these, we can expect the same wood quality from the Robust4 version as from the other paulownia variants.

Keywords: Mechanical properties, *Paulownia tomentosa*, Robust4, shrinkage, swelling, wood density.

INTRODUCTION

The current gap between timber demand and supply in the market generates an increasing need for fast-growing species. The various paulownia species are important examples for such.

Nowadays, they are in widespread cultivation in many plantations worldwide, and they have also been cross-bred, resulting in a number of inter-species hybrids with even greater growth dynamics. The rapid growth of paulownia and its resulting high CO_2 absorption is a further advantage. The use of the timber of paulownia species cultivated in short cycles is limited by the log size, which does not permit the production of full size sawntimber and hence, solid wood components (Kozakiewicz *et al.* 2020). Of late, research into the medical properties of paulownia has begun (He *et al.* 2016). In China, species of the paulownia family (*Paulowniaceae*) have been widely used in traditional medicine to treat primarily contagious diseases such as gonorrhea and erysipelas (Adach *et al.* 2021). The ethanol production from the hemicellulosic fraction is another area subject to current research (Domínguez *et al.* 2021). Given the economic significance of the use of paulownia sp. the economic significance of its use, its current and potential prospects and the development of the biotechnological approach to its cultivation are based on the application of micro-breeding technology, which helps the introduction of paulownia in certain countries (Turganova *et al.* 2021). Over the recent decades, a number of laboratories researched paulownia sp. aiming to expand the technology of microclonal reproduction, the study of organogenesis processes, and the elaboration of the protocols of genetic transformation. (Yadav *et al.* 2013). Its cultivation opportunities are being sought in regions referred to as the limits of optimal growth (Icka *et al.* 2016).

Paulownia is one of the fastest growing trees globally, but its wood also known to have one of the lowest density. The use of wood is influenced by several factors, with density standing out as one of the critical parameters. In terms of wood industrial use, air-dry density is a dominant parameter, which for paulownia is 250 kg/m^3 to 300 kg/m^3. A determination of wood-chip bulk density, and from the perspective of pulp production, or particleboard manufacture the determination of basic density may be very important.

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On a global scale, paulownias are used among others for the production of veneer, plywood, furniture, paper and cellulose, packaging materials, modelling material, musical instruments, ships, surfboards, chipboard, insulating materials and decorative objects (Clad and Pommer 1980, Bergmann 1998, Rai *et al*. 2000).

Over the recent decade, interest in paulownias increased significantly in Europe. However, the available scientific publications do not give a complete picture of the properties of the wood. Furthermore, for the various cross-bed variants, reference is often made to the properties of the *Paulownia tomentosa*. Even less information is available on the wood of specific plantations and of variants that grow logs of the industrial size. There are as yet not enough research results available in sufficient depth and volume on what wood quality (the value and variability of density and different physical-mechanical properties) this species, indigenous to subtropical climate zones, would yield under temperate conditions. The objective of the present study is to describe the properties of the wood of the selected paulownia variant Robust4, cultivated in Hungary and already recognised by the state as a cultivar.

MATERIALS AND METHODS

The specimens *Paulownia tomentosa* (Thunb.) Steud, used for the study were cut from three trunks, each four years of age and supplied by plantation (H-7812 Garé). The samples were felled at a section 1 m below breast height. From the examined trunk the following properties were defined based on the relevant standards: density (DIN 68364 (2003)), swelling and shrinkage (DIN 52184 (1979)), compression strength (DIN 52185 (1976)), tensile strength (DIN 52188 (1979)), static bending strength (DIN 52186 (1978)), modulus of elasticity (DIN 68364 (2003)), and impact bending strength (DIN 52189-1 (1981)). The tests were carried out on specimens stored under normal climate conditions (T=20 °C; RH=65 %) until equilibrium moisture was reached. The strength tests were performed using the Instron 4208 universal material tester (Norwood, USA) and Charpy impact tester (Leominster, England). 25 pcs of test samples were used in each and every examination cases.

RESULTS AND DISCUSSION

As for the appearance of Robust4, its heartwood has an observable colour. The heartwood is light yellowish, pink or greyish-brown, while the sapwood has a light yellowish hue. The pith is 2-3 centimetres wide and is divided into chambers inside the log. The lengths of these chambers vary with the height of the trunk, being between 9-25 cm along the section examined (Figure 1).

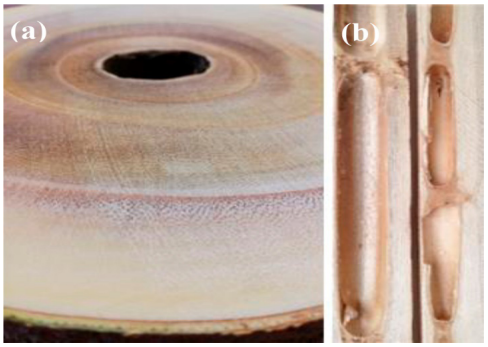

Figure 1: (a) The cross and (b) Longitudinal section of the pith.

The average breast height diameter was 19,3 cm, with an average annual growth of 2,1 cm. Its bark is a few millimetres thick, which is a very advantageous feature in terms of combustion technology. Generally the ash content of the bark is several multiples of that of the wood (Komán 2018, Carrión-Prieto *et al.* 2017, Nosek *et al.* 2016).

Immediately after harvesting the average moisture content (wet basis) is very high, i.e. 63 %. This corresponds in terms of order of magnitude to that of the Shan Tong variety, published by Kozakiewicz *et al.* (2020). However, it is higher than for other fast-growing species - e.g. poplars (Vusić *et al*. 2019, Eimil-Fraga *et al*. 2019).

The test results were primarily compared to those of the *Paulownia tomentosa* (Thunb.) Steud. (Koman *et al.* 2017) and the *Paulownia Clone in vitro 112* hybrid (Koman and Feher 2020).

The density of *Paulownia tomentosa* Robust4, i.e. 273 kg/m^3 is – similarly to that of other paulownia variants (Senelwa and Sims 1999, Flynn and Holder 2001, Minato *et al.* 2005, Kalaycioglu *et al.* 2005, Akyildiz and Kol 2010, Kiaei 2013, Hassankhani *et al.* 2015, Sedlar *et al.* 2020) is very low (Table 1). Its air dry density, an important parameter for industrial use, indicates that the *Paulownia tomentosa* Robust4 is one of the lightest woods of the world. In comparison to samples of the *Paulownia tomentosa* (Thunb.) Steud. also cultivated in Hungary, it is 9 % lower, while it is 15 % higher than that of *Paulownia Clone in vitro 112.* Similar proportions can be observed in case of oven dry and basic density, which are important to know, in regards determination of wood-chip bulk density, pulp production, or particleboard manufacture.

Table 1: Comparison of the obtained results of wood density tests with data from other studies.

Density (kg/m^3)	*Paulownia tomentosa* (Thunb.) Steud. (Koman *et al.* 2017)	*Paulownia Clone in vitro 112* (Koman and Feher 2020)	*Paulownia tomentosa* Robust4			
	Average	Average	Average	Min	Max	St dev
Air dry (u=12 %)	300	232	273	208	352	37
Oven dry (u=0 %)	275	215	251	179	323	32
Basic	264	198	229	179	298	31

u - moisture content of wood (%) basic density - the ratio between the oven-dry mass of a wood sample and its green volume

The planks were dried using the drying schedules used for the similarly low-density wood of poplar species. The wood has very favourable shrinkage values (Table 2). In terms of its dimensional stability, it is among the best wood species. Compared to the *Paulownia tomentosa* (Thunb.) Steud., its dimensional stability is somewhat more moderate while being practically identical to that of the other variant. Both the shrinkage and swelling values are of the same order of magnitude as the results published by Akyildiz and Kol (2010). Shrinkage anisotropy, on the other hand, exceeds 2.

Table 2: Comparison of the obtained results of wood shrinkage and swelling tests with data from other studies.

		Paulownia tomentosa (Thunb.) Steud.[1]	*Paulownia Clone in vitro 112* [2]	*Paulownia tomentosa* Robust4			
				Average	Min	Max	St dev
Shrinkage (%)	Longitudinal	0,7	0,6	0,4	0,1	1,3	0,4
	Radial	2,2	3,2	2,0	1,2	3,2	0,4
	Tangential	3,7	5,0	5,8	3,8	7,4	0,9
	Volumetric	6,3	8,5	8,1	4,8	11,4	1,3
Swelling (%)	Longitudinal	0,7	-	0,4	0,1	1,3	0,4
	Radial	2,2	-	2,1	1,2	3,3	0,4
	Tangential	3,9	-	6,1	3,9	8,0	1,0
	Volumetric	6,9	-	8,8	5,1	12,8	1,5

In accordance with the low density of the wood, the strength values are likewise moderate, not following the order observable for density in each case (Figure 2, Figure 3). The smallest deviation occurs with compressive strength. The value of 19,6 MPa equals that of the *Paulownia Clone in vitro 112*, nearly 11 % lower than the corresponding value of the *Paulownia tomentosa* (Thunb.) Steud. The value of the tensile strength, however, at 39,3 MPa, is 18 % higher in comparison to the *Paulownia tomentosa* (Thunb.) SteudFste. As for the bending strength, the value of 41,7 MPa obtained is identical to the *Paulownia tomentosa* (Thunb.) Steud., being 29 % higher than that of the other variant. The modulus of elasticity (MOE) exceeds the value of the *Paulownia tomentosa* (Thunb.) Steud. and the other variant by 18 % and 8 % respectively. Of the dynamic strength properties, the 1,4 J/cm^2 value of the impact bending strength is about 14 % lower than the corres-

ponding value of the *Paulownia tomentosa* (Thunb.) Steud. examined earlier. The strength values obtained, with the exception of compressive strength are nearly the same to the values found in the relevant literature (Shim 1948, Barton *et al.* 2007, Akyildiz and Kol 2010).

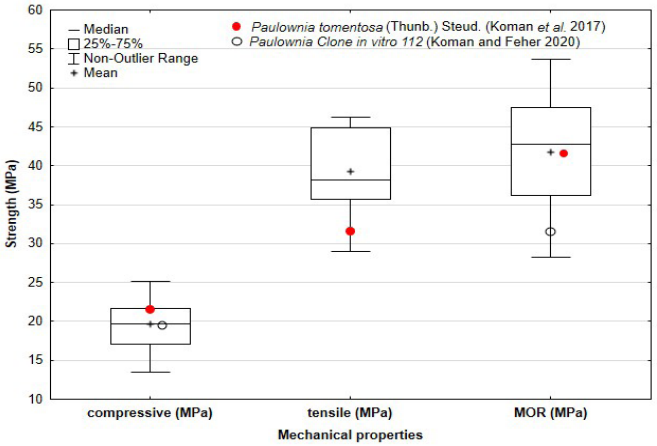

Figure 2: Compressive strength, tensile strength and modulus of elasticity of the examined paulownias.

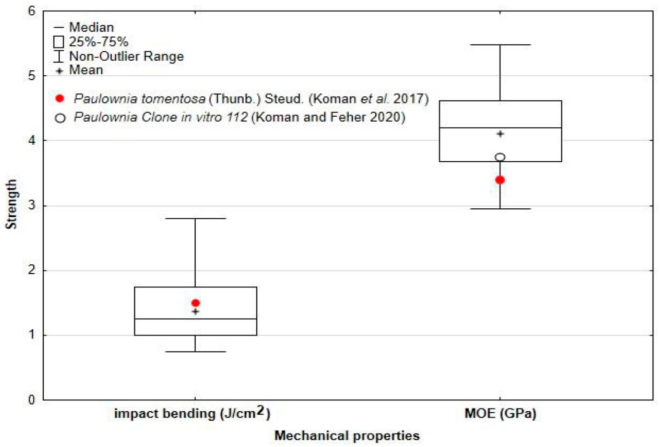

Figure 3: Impact bending strength and modulus of elasticity of the examined paulownias.

CONCLUSIONS

In the case of paulownias, it remains a question whether they can remain under the given climatic conditions– primarily due to sub-zero temperatures – and what growth and wood quality they would yield. From this perspective, the *Paulownia tomentosa* Robust4 is a selected cultivar that has already been tested under Hungarian climatic conditions, which has already become a cultivar recognised by the state. The properties of its wood are identical to those of the *Paulownia tomentosa* (Thunb.) Steud, based on which it can be concluded that the region's climatic conditions do not influence the wood quality. Although its density is somewhat lower, its strength properties nevertheless show no significant deviation from the those of the *Paulownia tomentosa* (Thunb.) Steud., even exceeding them in certain cases, as well as those of the *Paulownia Clone in vitro 112*. Based on the results, the *Paulownia tomentosa* Robust4 grown wood of the same quality as the *Paulownia tomentosa* (Thunb.) Steud., consequently it can supply the same spectrum of application.

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