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SHORT NOTE

PHYSICAL AND MECHANICAL PROPERTIES OF *PAULOWNIA TOMENTOSA* WOOD PLANTED IN HUNGARIA

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ABSTRACT

The Paulownia tree (or to its well-known name Chinese empress tree; *Paulownia tomentosa*) is classified among the most variable wood species of the world concerning usability. Its cultivation in Hungary in form of research plantations has just started in the last decade, first of all for the investigation of energetic properties. Due to this the information related to the physical-mechanical properties of the wood was still not determined, from which aspect this study is essential. The investigated wood with an air-dry density of 0.3 $g \cdot cm^{-3}$ has shown low bending (42 MPa), compressive (22 MPa), shear (7 MPa), tensile (33 MPa) and impact strength (1.6 $J \cdot cm^{-2}$) values, based on which its wooden material properties can be compared to poplars considering tree species in the region.

KEYWORDS: *Paulownia tomentosa*, physical properties, mechanical properties, density,

INTRODUCTION

In Asia and in some European countries Paulownia species are preferred in tree cultivations or agro-forestry plantations of industrial wood purpose, in the latter typically in combination of industrial wood/agricultural crop plant, rarely in mixed culture of other purpose (e.g. energy). For example in the Chinese agriculture Paulownia is cultivated as intermediate plant on almost

1.3 million hectares. The reason for this is that one manages meagre property assets in China, so food production and industrial wood cultivation can be realized on the same ground (Vityi and Marosvölgyi 2012).

Literature data and the results of Hungarian investigations performed present that individual Paulownia species are basically undemanding, have a great yield and can be cultivated relative simply. It can be well reproduced from grain, root cutting (according to some sources also from shoot cutting), under favourable conditions it can reach a trunk diameter of 30-40 cm, the height of 10-12 m and the wood yield of 0.2-0.6 m^{-3} by the age of 10 years. (Under ideal cultivation conditions its growth can be even quicker). (Yang 2004).

Its wide utilization spectrum ranges from industrial applications (furniture and building timber, base material for paper industry, biomass for energy purposes etc.) through apiculture and medical industry (bark, leaf, flower cluster) to decoration function (park tree, base material of exquisite wood-carving). Owing to its machinable timber of decorative texture it is used in Japan as traditional timber, where a high quality log counts as valuable base material. The less valuable base material can be utilized on other areas such as for example chipboard (Kalaycioglu 2005), however it is applied as heat and electric insulation material (AFBI 2008) respectively. From the properties of a wood density is most essential concerning utilization. From this information one can conclude on the strength properties (Kiaei 2013). Typically there is a strong correlation between density and MOR and MOE resp (Zhang 1997). The basic density relates closely to the quality parameters of the final usage, such as e.g. cellulose yield and strength of construction materials (Harvald and Olesen 1987). The tree species of higher density generally have more solid wood than the ones of lower density (Walker and Butterfield 1996).

Paulownia is mainly cultivated on areas with hotter climatic conditions of the world (mainly on the extended plantations of China and USA), where the usage of *P. elongata* has spread. For this reason there is lot of information about this tree species, while one can find much less data related to *P. tomentosa* tolerating also more moderate climatic conditions. The purpose of this research is the discovery of the properties of the wooden material cultivated in Hungary, which is the essential condition of applicability on some utilization areas.

MATERIALS AND METHODS

The Hungarian cultivations were established first of all for the purpose of plantation experiences and energetic researches, for this reason older, more mature wood was not available for investigation. The tree-trunk serving as base material for the specimen required for the examination is situated at an altitude of 70 m; the average annual temperature ranges between 11-12°C, and the long-term total annual precipitation is approx. 608 mm. The examinations have covered the following properties in accordance with the relevant standards:

- *Annual ring structure*

Based on the picture made of the disc cut from the trunk by means of the program Image Pro Plus the annual ring width was determined along the smallest and biggest radius.

- *Physical-mechanical properties*

From the examined trunk the following properties were defined based on the relevant standards: Density (DIN 68364:2003), Shrinkage and swelling (DIN 52184:1979), Compression strength (DIN 52185:1976), Tensile strength (DIN 52188:1979), Shearing strength (DIN 52187:1979), Static bending strength (DIN 52186:1978), Modulus of elasticity (DIN 68364:2003). Impact bending strength (DIN 52189:1981), Brinell hardness (MSZ EN 1534:2000).

The examination were performed under standard climatic conditions (T=20°C; φ=65%) - until equilibrium moisture content - on stored specimens. The strength examinations were carried out with universal material examining device type Instron 4208 and Charpy-impact tester on specimen series of 25 pcs. each.

RESULTS AND DISCUSSION

Due to the eccentric structure of the examined disc along the biggest radius the growth is wider by approx. 30% than the value of the smallest radius. The increase cycle becomes constant beginning from the 5^{th} year (Fig. 1) under the growth ring width value of 1 cm. In the previous years significantly bigger values can be found. The average growth ring width is 14.7 mm along the biggest radius, while 8.3 mm in the direction of the smallest radius .

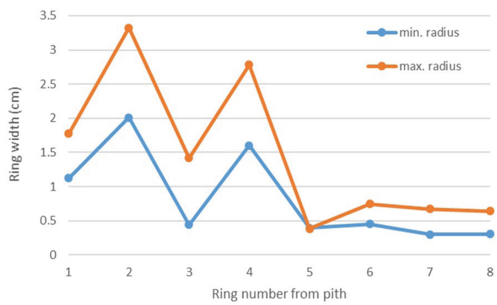

Fig. 1: Growth per year.

Density

Paulownia tomentosa has an expressly light, soft wood, which is proven by the measured density values. The air-dry density (Tab. 1.) received corresponds with the average of the values in the literatures (Kanehira 1933, Senelwaa and Sims 1999, Flynn and Holder 2001, Kalaycioglu 2005, Akyildiz 2010). This low density does not even exceed that of the poplars for example.

Tab. 1: Values of the measured densities (kg·m^{-3}).

Density type	Average	Min.	Max.	St. dev.
Air-dry (u=12%)	300.18	262.33	360.18	26.59
Oven-dry (u=0%)	275.46	240.00	328.15	23.52
Basic	264.2	224.39	309.09	23.04

Shrinking-swelling

In case of the Paulownia tree we have received favourable results (Tab. 2.) from aspect of dimensional change caused by moisture. Firstly the radial and tangential values are very favourable, which almost completely comply with the ones communicated by Meier (2015). However related to the dimensional change of volume higher literature values by more than 20-30% can be found as well (Akyildiz 2010).

Tab. 2: Values of the measured densities.

	Longitudinal	Radial	Tangential	Volumetric
Shrinkage	0.69	2.20	3.89	6.94
Swelling	0.68	2.17	3.73	6.28

Strength

From the low density value of the wooden material it is inferred that the different strength values are not high as well. It is proven by the results received (Tab. 3.), which often have not reached that of the poplars with similarly soft wooden material.

Tab. 3: Mechanical properties (parallel to the grain (MPa)).

Test type		Average	Min.	Max.	St.dev.
Compressive		22.14	19.63	25.24	1.78
Tensile		33.23	21.86	52.96	8.90
Shearing		7.03	6.08	8.00	0.52
MOR (3 points)		41.51	28,65	48.65	4.68
MOE (3 points)		3492	2595	4142	472
Brinell	**Cross**	26.74	20.78	31.89	3.22
	Tangential	9.13	5.59	13.61	2.16
	Radial	9.51	6.53	13.39	2.17
Impact bending strength ($J \cdot cm^{-2}$)		1.59	1.27	1.90	0.17

The strength values of the investigated paulownia correspond in some cases, while in other cases these deviate more or less from the ones indicated by others. The values of bending strength as maybe the most important strength property are practically identical with the values found in some literatures (Akyildiz 2010, Meier 2015, Shim 1948). However regarding flexibility we have received significantly lower values than communicated by other sources (Akyildiz 2010, Meier 2015, Shim 1948).

Regarding compressive strength the average 22 MPa value can be considered as very low, which is however connected to favourable deviation values. The average shear strength value received can be higher by even 20% compared to some earlier researches (Shim 1948, Barton 2007).

The determination of the tensile strength values is generally performed rarely in case of wooden material examination, contrary to e.g. bending or compressive strength. In this case the very high deviation value was connected to relatively low (33 MPa) strength.

The determination of the impact-bending strength – which is already a dynamic strength property - is performed also relative rarely, for this reason values in this regard were not available. The values received are extremely low, even in case of wood species with similar low density.

The Brinell hardness values measured in the main anatomical directions of the wood have produced similar values as the similarly soft poplars. The axial hardness is almost the triple of the side hardness values, which are practically the same.

CONCLUSIONS

The wooden material properties of *Paulownia tomentosa* cultivated in Hungary do not show any significant deviation related to the ones cultivated in other parts of the world. Due to its low density (air-dry: 300 kg·m^{-3}) and strength values it is not suitable for structural purposes; however it can be a serious competition for broad-leaf tree species, first of all due to its growth characteristics. Based on our investigations its properties can be compared first of all to hybrid poplars. The density of hybrid poplars wood is between 300-400 kg·m^{-3}. The cultivation experiences and the current research related to the physical-mechanical properties of wooden material can establish the more significant extension of the species in the region.

REFERENCES

1. AFBI, 2008: Paulownia as a novel biomass crop for Northern Ireland? A review of current knowlwedge, Occasional publication No. 7. Agri-Food and Bioscience Institute, Hillsborough.
2. Akyildiz, M.H., Kol, S.H., 2010: Some technological properties and uses of paulownia (*Paulownia tomentosa* Steud.) wood. Journal of Environmental Biology (31): 351-355.
3. Barton, I.L., Nicholas I.D., Ecroyd C.E., 2007: Paulownia. Forest Research Bulletin No. 231, 9pp. Rotorua, New Zealand, Forest Research Institute.
4. Bergmann, B.A., 1998: Propagation method influences first year field survival and growth of Paulownia, New Forests 16(3): 251-264.
5. DIN 52188, 1979: Testing of wood - Determination of ultimate tensile stress parallel to grain
6. DIN 68364, 2003: Properties of wood species - Density, modulus of elasticity and strength
7. DIN 52186, 1978: Testing of wood - Bending test
8. DIN 52187, 1979: Testing of wood - Determination of ultimate shearing stress parallel to grain
9. DIN 52189, 1981: Testing of wood - Determination of impact bending strength
10. DIN 52185, 1976: Testing of wood - Compression test parallel to grain
11. DIN 52184, 1979: Testing of wood - Determination of swelling and shrinkage
12. Flynn, H., Holder, C., 2001: Useful wood of the world, Forest Products Society. Madison, WI.
13. Jun-Qing, et al. 1983: Studies on the wood propertis of the genus paulownia, I. Scienta Silvae Sinicae 19(1): 57-63.
14. Harvald, C., Olesen, P. O., 1987: The variation of the basic density within the juvenile wood of Sitka spruce (*Picea sitchensis*). Scand. J. For. Res. 2: 525-53
15. Kalaycioglu, H., Deniz I., Hiziroglu, S., 2005: Some of the properties of particleboard made from paulownia, J. Wood Sci. 51: 410-414.
16. Kanehira, R., 1933: On light-weight woods. J. Soc. For. Japan. In: Harzmann, L. J. 1988. Kurzer Grundriß der allgemeinen Tropenholzkunde. S. Hirzel Verlag, Leipzig 255 pp.
17. Kiaei, M., 2013: Radial variation in wood static bending of naturally and plantation grown alder stems, Cellulose Chem. Technol. 47 (5-6): 339-344.
18. Komán, Sz., 2013: Anatomical and physical characteristics influencing the modern utilisation of hybrid poplars for industrial and energy purposes, Doctoral dissertation. University of West Hungary, Sopron.

19. Meier, E., 2015: Wood. Identifying and using hundreds of woods worldwide, ISBN 978-0-9822460-3-0.
20. MSZ EN 1534, 2000: Wood and parquet flooring. Determination of resistance to indentation (Brinell). Test method.
21. Olson, J.R., Carpenter, S.B., 1985: Specific gravity, fibre length, and extractive content of young paulownia, Wood and Fiber Science 17(4): 428-438.
22. Senelwa, K., Sims R.E.H., 1999: Fuel characteristics of short rotation forest biomass. Biomass and Bioenergy 17(2): 127–140.
23. Shim, C.S., 1948: The mechanical properties of *Paulownia tomentosa* and *Paulownia Coreana* in Korea, Report of Forest Product Lab., Dept. of Forestry, Seoul Nat'1 Univ. Pp 1-20.
24. Yang, X., 2004: Paulownia agroforestry systems in China, Poster. Proceedings os the International Ecoagriculture Conference and Practitioners' Fair. Vol. 2: Conference abstracts. Nairobi 2004.
25. Vityi, A., Marosvölgyi, B., 2012: A fajszi kísérleti Paulownia ültetvények újabb kutatási eredményei (Environmental resource management and protection and environmental cooperation), Research Centre Non-profit Ltd, Sopron (in Hungaryan).
26. Walker, J.C.F., Butterfield, B.G., 1996: The variation of the basic density within the juvenile wood of Sitka spruce (*Picea sitchensis*), New Zealand Journal of Forestry 40(4): 34–40.
27. Zhang, S. Y. (1997): Wood specific gravity-mechanical property relationship at species level, Wood Science and Technology 31(3):181-191.

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