



Study on the wettability of Pannónia poplar (*P.x euramericana Pannónia*) from two Hungarian plantations: Győr and Solt

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ABSTRACT

In Hungary, large stocks of plantation poplar reached their cutting age. The present paper is a part-time report of the OTKA project on the wettability of Pannónia poplar samples originating from two Hungarian plantations: Győr and Solt. The main question was whether the different sites of origin have a significant influence on the properties of the boards. Samples from the two plantation sites were collected from different trunks, and laboratory samples with tangential cut were prepared by planing. Wettability was measured by sessile drop method, both with distilled water and diiodomethane, using a PGX goniometer. Surface tension was calculated according to the Fowkes method.

1 Introduction

Spruce and other coniferous species generally involved in glulam production usually manifest densities between 300 and 700 kg/m³. Nowadays in Hungary, large stocks of plantation poplar reach the cutting age, and improving its utilization became a major goal, as poplar is first of all used by the paper industry. Pannónia poplar (*P.x euramericana Pannónia*) has been developed by F. Kopecky in 1961, in a forestry research center at Sárvár, Hungary. It is a fast growing species similar to the I-214 Italian poplar (*P.x euramericana*, "I-214"), but its density is similar to the Robusta poplar (*P.x euramericana robusta*). Nowadays, the Pannónia poplar is the most frequently planted poplar hybrid in Hungary (Molnár 2004). Its growth properties also make it suitable for short, medium or long-term (10–25 years) cultivation (Halupa and Tóth 1988). The Hungarian poplar species can be classified in three density classes (Molnár and Bariska 2002): very low density: $\rho \leq 360$ kg/m³, semi-low density: $\rho = 361$ –400 kg/m³, and low density $\rho \geq 401$ kg/m³. Regarding its density, Pannónia poplar hybrid belongs to the

latter class. Its density of around 411 kg/m³ raises the question whether it is suitable for glulam production. In the frame of the OTKA K 116216 project, a comprehensive study on the physico-mechanical properties (including the analysis of MOE, MOR, bending strength, compressive strength, etc.) of the poplar wood samples and of glulam samples made from poplar was conducted to evaluate the suitability of Pannónia poplar (*P.x euramericana Pannónia*) hybrid, originating from different plantations, for load bearing applications, especially for glued laminated timber production. The aim of this study was to find the answer whether the provenience (site of origin) of the timber trunks has a relevant influence on the wettability of the boards and furthermore, are there sites which could be favored due to the good wettability (and thus a supposedly good adhesion) of their samples.

2 Materials and methods

Pannónia poplar boards were collected from different poplar trunks of two plantations, Győr and Solt and kiln dried to $8 \pm 1.2\%$ MC. The boards were planed and 20 defect free samples of 400 mm × 70 mm × 20 mm size, with tangentially cut surface were prepared. All the samples were conditioned for 30 days prior to measurements at 20 ± 2 °C temperature and $65 \pm 1\%$ RH. (Fig. 1). The samples were freshly planed before contact angle measurements, as in practice, most of the time freshly machined surfaces are glued in the course of the glulam production. Although the samples had been prepared in the same way, their surface

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Fig. 1 Pannónia poplar samples during conditioning for 30 days prior to measurements

roughness was also measured to enable an eventual comparison of these results with other research data. Surface roughness of the samples was determined based upon five consecutive stylus tip measurements, taken on each sample, along a 17.5 mm trace, perpendicular to the grain, (on the same tangential surface as for the contact angle measurements), using a Mahr Perthen SP3 instrument, equipped with a stylus, with diamond head of 2 μm radius. Both R_a and R_z roughness parameters were calculated, as they are considered suitable to describe the status of the surface (Magoss 2000) and are also widely used for. Contact angle of the surfaces was measured using a PGX Goniometer (FIBRO SYSTEMS AG, Sweden), with dynamic method, using a 5 μl test liquid volume. The contact angle was determined in the first second after release, as by this time the drop consolidates. Three measurements were taken on each sample.

The contact angle was determined both with distilled water (DW) and with diiodomethane (DIM). The measurements were taken with two different tube sets for distilled water and diiodomethane.

To evaluate the wettability, Young's equation (Eq. 1) was considered and the Fowkes model (Eqs. 2, 3, 4 and 5) was

used for surface tension (also quoted surface free energy) calculation.

$$\gamma_{SL} + \gamma_{LV} \cos \Theta - \gamma_{SV} = 0 \quad (1)$$

where γ_{SL} is the surface tension at the solid/liquid, γ_{LV} at the liquid/vapor, γ_{SV} at the solid vapor interface

$$W_{sl}^d + W_{sl}^p = \gamma_l * (1 + \cos \theta) \quad (2)$$

where W_{sl}^p is the polar, W_{sl}^d is the dispersive component of work of adhesion at the solid/liquid interface

$$(\gamma_l^d)^{\frac{1}{2}} * (\gamma_s^d)^{\frac{1}{2}} + (\gamma_l^p)^{\frac{1}{2}} * (\gamma_s^p)^{\frac{1}{2}} = \frac{\gamma_l * (\cos \theta + 1)}{2} \quad (3)$$

where “l” stands for the liquid, “s” for the solid, “d” and “p” are the dispersive and consecutively the polar components of the surface tension: γ

$$\gamma_s^d = \frac{\gamma_l * (\cos \theta + 1)^2}{4} \quad (4)$$

According to Fowkes (Eq. 5), the surface tension of the solid (γ_s) is the sum of the polar (γ_s^p) and dispersive (γ_s^d) components

$$\gamma_s = \gamma_s^p + \gamma_s^d \quad (5)$$

First, the calculation of the dispersive component of the surface tension of the solid was performed with a liquid which manifests dispersive forces, and in a second step, the polar component was calculated. Contact angle measurements were taken both with distilled water (as polar component $\gamma_l^p = 46.4 \text{ mN/m}$) and diiodomethane (dispersive component $\gamma_s^d = 50.8 \text{ mN/m}$).

3 Results and discussion

The results of the surface roughness measurements, the contact angle measurements (performed with distilled water and diiodomethane) and the calculated values of the surface tension are presented in Table 1.

The results of the roughness measurements indicate that whilst the average roughness R_a is not significantly different, the R_z values show significant difference (2 sample location Student T test, $p = 0.05$). The difference in roughness is in line with the difference in the surface tension. Since R_z is more sensitive to the real status of the surface than R_a (Csiha 2003), and since the samples were machined and treated in the same way, this difference in the roughness values suggests that there is an effect of the plantation on the quality of the timber. The samples were also investigated under microscope, but no relevant difference in their anatomical structure could be identified. In

Table 1 Results of the Pannónia poplar samples from two plantations: Győr and Solt

	R_a (μm)/SD	R_z (μm)/SD	Contact angle (DW)/SD	Contact angle (DIM)/SD	Surface tension (mN/m)/SD
GYŐR	7.15/1.14	53.52/11.36	72.32/4.51	31.08/7.27	47.17/8.55
SOLT	8.2/2.37	56.38/15.47	68.58/4.88	28.17/5.11	49.97/7.06

spite of this fact, the samples originating from Solt, when soaked in water for a short time, manifested higher swelling than the ones from Győr, leading to the conclusion that there might be differences in their anatomical structure, which need further investigation.

It is characteristic of the samples that the contact angle values measured with distilled water are roughly two times higher than the ones measured with diiodomethane. The higher the contact angle the worse the wettability of the surface is. The samples from Győr show higher contact angle, both with distilled water and diiodomethane, than the samples from Solt, indicating that the samples from Solt have better wettability. The trend of the contact angle's behavior is the same with both test liquids: in case of Solt samples, both the contact angle of distilled water and the contact angle of diiodomethane are lower than the same contact angles of Győr samples. The main conclusion can be drawn that the contact angle values show significant difference (t test, $p=0.05$) between the two investigated plantations, with both test liquids, thus the site of origin may have a major influence on the wettability of Pannónia poplar boards. The surface free energy calculated according to the Fowkes model is also significantly different for the samples of the two plantations: the samples from Solt have significantly higher (t test, $p=0.05$) surface tension values than the samples from Győr. According to the Young-Dupré equation, high surface tension of the solid indicates good wetting. Better adhesion with the same adhesive can be expected on samples originating from Solt plantation. It is still a question, how these results relate to similar values of coniferous species, which are frequently used in glulam production. Brahmia et al. (2020) published data on the contact angle of planed Scots pine (*Pinus sylvestris*) surfaces, measured with the same device and same settings, with distilled water, on the occasion of investigating the wettability of some wood species with different fire retardants. They found that the average contact angle of Scots pine samples is 63.7° . This value is significantly lower than the contact angle values measured on Pannónia poplar samples originating from Győr and Solt (72.32° and 68.58°), leading to the conclusion, that the wettability of Scots pine (and consequently the expected adhesion) is better than the wettability of the Pannónia poplar samples originating from the two investigated sites.

4 Conclusion

The wettability of Pannónia poplar samples originating from two different Hungarian plantations Győr and Solt was investigated in order to evaluate the suitability of their expected adhesion for glulam production and to find which one could be favored due to the good wettability of its samples. The samples from Győr show higher contact angle, both with distilled water and diiodomethane, than the samples from Solt, indicating that the samples from Solt have better wettability. The surface free energy calculated according to the Fowkes model is also significantly different for the samples of the two plantations: the samples from Solt have significantly higher (t test, $p=0.05$) surface tension than the samples from Győr. The better adhesion with the same adhesive can be expected on samples originating from Solt plantation. The results of this study indicate that the site of origin may have a significant effect on the wettability of Pannónia poplar boards. However, both sample batches manifested higher contact angle values measured with distilled water than the Scots pine samples treated and machined in the same way, indicating that probably their expected adhesion does not reach that of Scots pine—which is a frequently used wood species in glulam production.

As these preliminary results show uncertainty regarding the necessary adhesion for glulam production of Pannónia poplar samples, it is planned to test the glulam performance itself with known load bearing structural adhesive. On the other hand, the surface tension of these boards may also need to be increased by choosing a different machining type (e.g. sanding), or by chemical pretreatment (e.g. nano-agents).

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Compliance with ethical standards

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest.

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