Willows in Czech lowlands: variability of density and shrinkage

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Abstract. The objective of the present study was to determine the variability of tree-ring width, wood density and shrinkage of white willow (*Salix alba* L.) growing in the lowland forest of South Moravia, Czech Republic. Six young trees were selected from three plots (18 trees in total). Sample logs were taken at breast height (1.3 m from the ground). All examined parameters i.e., average tree-ring width, wood density and shrinkage were influenced by the locality. Moreover, the results revealed much higher variability among trees per plot than mean values among plots. Average green and dry wood density of white willow was 753.0 kg·m^{-3} and 390.8 kg·m^{-3}, respectively. Average radial shrinkage was 3.59 % and the average tangential shrinkage 8.26 %.

Keywords: *Salix alba*, tree-ring width, radial shrinkage, tangential shrinkage, variability of wood properties.

1 Introduction

Genus *Salix* represents about 450 species worldwide distributed mostly in the North hemisphere (Argus 1997). White willow (*Salix alba* L.) is native to Europe and Asia (western and central). Nowadays, white willow has expanded beyond its original area, e.g. to North America and Australia. In the Czech Republic, the species grows in the floodplain forests in warmer regions (Úradníček et al. 2001). Willows and willow clones are fast growing species preferred for many reasons i.e., environmental restoration work, biomass production for energy purposes as well as timber for wood industry (Kuzovkina and Quigley 2005, Leclerq 1997).

Wood is an exceptional raw material owing to the fact that it is renewable, very strong and elastic despite the low density, easily shaped, ecologically recyclable etc. Nevertheless, wood is not homogenous and it is a highly hygroscopic material. Wood density is a fundamental property featuring the rest of wood properties. Wood density and shrinkage depend on the genus, the locality type, wood defects and mainly on position in the stem. Moreover shrinkage manifests the anisotropic character of wood through different values in the individual directions (Vavrčík and Gryc 2012, Gryc and Horáček 2007).

Our study aimed at (I) analyzing the variability of density and shrinkage of white willow (*Salix alba* L.) among different plots and (II) describing the variability of density and shrinkage among trees in each plot.

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2 Materials and methods

The sampling material was taken from white willows growing in three plots in South Moravia, Czech Republic. All selected plots were located floodplain forest near Židlochovice (180 m a. s. l.). The plots 1, 2 and 3 were classified as *Ulmeto-Quercetum alluviale* (*Brachypodium sylvaticum*), *Saliceto-Alnetum* and *Ulmeto-Quercetum alluviale* (*Aegopodium podagraria*), respectively. Six healthy trees were randomly chosen per plot (mean height 23–25 m, diameter 26–32 cm). Logs (1 m) were cut at breast height (1.3 m from the ground) from each tree. Tree-ring widths were measured on transversal section by using Leica S6D stereomicroscope and the VIAS TimeTable (Vienna Institute for Archaeological Science, Vienna, Austria) measuring system (with accuracy of 0.01 mm). Samples for density and shrinkage (20 × 20 × 30 mm) were prepared uniformly from the entire log.

The wood density was analyzed as (I) immediately after cutting (*green density*) and (II) at moisture content 0 %, when samples were measured after oven drying at temperature 103 ± 2 ºC (*dry density*). The wood density was calculated as:

$$\rho = \frac{m}{V} \text{ [kg·m}^{-3}\text{] (1)}$$

where ρ stands for green and/or dry wood density, m stands for weight of sample (kg), and V stands for the volume of sample (m^{-3}).

The total linear shrinkage in the individual anatomic directions was calculated as:

$$\alpha = \frac{l_{imax} - l_{imin}}{l_{imax}} \text{ [\%] (2)}$$

where l_{imax} stands for size of the tested sample (mm) in the particular anatomic direction at moisture content higher than the hygroscopicity level, l_{imin} stands for size of the sample (mm) in the particular anatomic direction at moisture content 0 %.

3 Results and discussion

2.1 Variability of tree-ring width

The selected trees showed a very similar amount of tree rings, between 17 and 19 at breast height. The tree rings were wider (10–12 mm) during the first years, followed by a gradual decreasing of tree-ring width (2–6 mm) along the stem radius from pith to bark (Fig. 1). The average tree-ring width calculated from all three plots was 7.51 mm, ranging between 6.62 and 8.03 mm (Table 1). Our results on tree-ring widths were in accordance with Sacré (1974), who reported similar values (6.6–8.6 mm) depending on the logs.

Table 1. Descriptive statistics of tree-ring width measured in all three plots.

Plot	1	2	3	1–3
Average (mm)	6.62	8.03	7.71	7.51
Median (mm)	6.40	7.76	7.62	7.38
Standard deviation (mm)	3.43	3.34	3.21	3.39
Minimum (mm)	1.17	2.46	0.91	0.91
Maximum (mm)	14.70	17.04	14.84	17.04
Coefficient of variation (%)	51.69	41.64	41.58	45.05

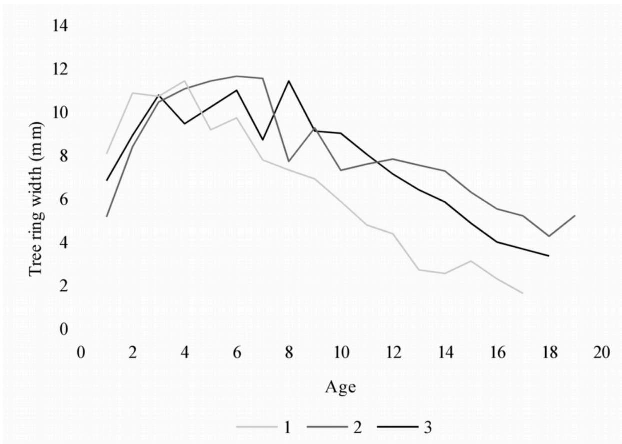

Fig. 1. Variability of tree-ring width along stem radius calculated per plot. All curves represent the mean values of six trees.

2.1 Variability of properties – density and shrinkage

We found significant differences in both average green density and average dry density among plots (Table 2). The differences in case of green wood density among plots were higher (81.46 kg·m^{-3}) than in case in dry wood density (20 kg·m^{-3}). The average dry wood density from all three plots was 390.8 kg·m^{-3} ranging from 278.6 to 631.6 kg·m^{-3}. Kollmann and Côté (1968) reported similar average dry wood density 365 kg·m^{-3} ranging between 320 and 420 kg·m^{-3}. Nevertheless, Wagenführ (2000) stated lower dry wood density 270–330–380 kg·m^{-3} (minimum–average–maximum), while Wani et al. (2014) stated that basic density in *Salix alba* growing in Pakistan is influenced by locality. In our study, we noticed higher variability of dry wood density among individual trees in each plot than in average dry wood density among the plots (Fig. 2).

Table 2. Green and dry density of white willow wood.

Plots	1	2	3	1–3	
Average	695.0	750.1	776.5	753.0	Green density ($kg \cdot m^{-3}$)
Median	682.7	741.6	763.0	749.3	
Standard deviation	132.1	92.1	119.3	122.7	
Minimum	412.0	499.7	424.2	412.0	
Maximum	1044.6	1044.9	1563.0	1563.0	
Coeff. of variation (%)	19.0	12.3	15.4	16.3	
Average	380.3	400.3	387.7	390.8	Dry density ($kg \cdot m^{-3}$)
Median	384.4	399.7	389.3	392.4	
Standard deviation	41.3	31.4	30.7	34.3	
Minimum	278.6	315.7	306.9	278.6	
Maximum	631.6	513.8	461.9	631.6	
Coeff. of variation (%)	10.9	7.9	7.9	8.8	

Average shrinkage in the radial and tangential direction was 3.59 % and 8.26 %, respectively, which coincided with black willow radial and tangential shrinkage i.e., 3.3 % and 8.7 % respectively (Bowyer et al. 2007) (Fig. 2, Table 3).

Table 3. Radial and tangential shrinkage of white willow wood.

Plots	1	2	3	1–3	
Average	3.41	3.86	3.51	3.59	Radial shrinkage (%)
Median	2.99	3.67	3.24	3.31	
Standard deviation	1.45	1.59	1.35	1.47	
Minimum	1.03	1.17	1.11	1.03	
Maximum	7.22	9.03	10.61	10.61	
Coeff. of variation (%)	42.62	41.04	38.52	40.78	
Average	7.46	8.45	8.41	8.26	Tangential shrinkage (%)
Median	7.52	8.54	8.58	8.40	
Standard deviation	1.70	1.62	1.58	1.69	
Minimum	2.20	3.36	1.03	2.20	
Maximum	13.68	13.82	13.17	15.42	
Coeff. of variation (%)	22.77	19.20	18.73	20.43	

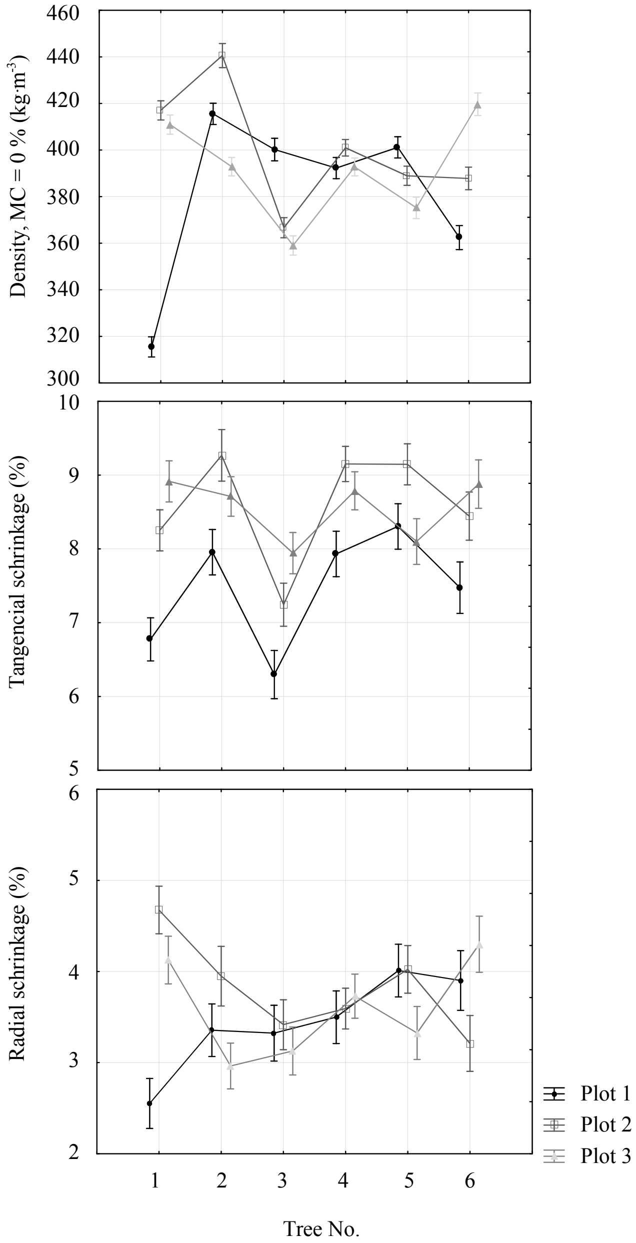

Fig. 2. Variability of wood density and shrinkage among trees.

On the contrary, Wagenführ (2000) reported again lower values for radial and tangential shrinkage (radial: 2.4 %, tangential: 6.3 %) in comparison with our study. Higher variability of shrinkage was observed among individual trees within the plots.

4 Conclusions

Our results indicated that white willow trees growing in the Czech lowlands produce wood of higher average density in relation with the literature, while the radial and tangential wood shrinkage were found to be in line with previous studies. We noticed significant differences among the plots. Nevertheless the variability of the examined properties was high among trees growing in the same plot.

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