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Physical Properties of Wood in Poplar Clones 'I-214' and 'S1-8'

Fizikalna svojstva drva klonova topole 'I-214' i 'S1-8'

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ABSTRACT • *Physical properties play an important role in predicting the quality of wood raw material. Variation in wood density and wood shrinkage of two different poplar clones cultivated on plantation "Drnje" near Koprivnica in Croatia was measured. One of poplar clones is* **'***I-214***'**, *whose wood properties have already been studied and often compared. Other poplar clone is 'S1-8', whose wood properties have been poorly researched, despite its good survival and growth rate. The results indicate that wood density of clone* **'***I-214***'** *is significantly higher in comparison to clone 'S1-8', but the difference, as far as practice is concerned, is negligible. In both clones, wood density increases and shrinkage decreases from pith to bark. Increased growth rate has a negative effect on wood density of researched clones.*

Key words: *Poplar clones, 'I-214', 'S1-8', wood density variation, wood shrinkage variation*

SAŽETAK • *Fizikalna svojstva drva važan su pokazatelj za predviđanje kvalitete drvne sirovine. U ovom su radu ispitane varijacije gustoće i utezanja drva dvaju klonova topole naraslih na plantaži Drnje u blizini Koprivnice u Hrvatskoj. Jedan od klonova topole je 'I-214', čija su svojstva drva već istraživana i često uzimana kao usporedna. Drugi je klon 'S 1-8', a svojstva njegova drva nedovoljno su istražena, usprkos njegovu dobrom preživljavanju i priličnoj brzini prirasta. Rezultati pokazuju da je gustoća drva klona 'I-214' signifikantno veća u usporedbi s klonom 'S1-8', ali je ta razlika za praksu zanemariva. Gustoća drva obaju klonova se povećava, a utezanje drva se od srčike prema kori smanjuje. Brzina prirasta negativno se odražava na gustoću drva istraživanih klonova.*

Ključne riječi: *klonovi topola, 'I-214', 'S1-8', varijacije gustoće drva, varijacije utezanja drva*

1 INTRODUCTION
1. UVOD

Trends in forestry are towards shorter rotations and more complete utilization of trees. Global poplar resources have been rapidly increasing in the last few decades, due to increasing demand for raw material. Rotations in poplar breeding are, depending on purpose, up to 15 years (DeBell *et al*., 2002). In relation to their rapid growth, poplar plantations can produce large volumes of wood in a short period of time. Considering the fact that future wood supplies may become more scarce, poplar clonal plantations present great domestic breeding potential in Croatia.

Poplar wood provides numerous product options, ranging from lumber to veneer, plywood and composites as wood-based products, as well as pulp and paper as fiber-based products. It is well known that different

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end uses require specific wood characteristics (Zhang *et al*., 1997). The selected clones must meet the needs of processing industry. Ongoing cultivar evaluation criteria are mainly growth rate, coppicing ability, adaptability and disease resistance. However, little attention has been paid to the wood quality of selected poplar clones. This is why additional emphasis needs to be placed on the utilization properties of the material, such as physical properties.

In general, wood density is considered to be the most important factor affecting wood quality (Zobel and van Buijtenen, 1989). Wood density is strongly related to other wood properties, such as mechanical strength (Panshin and de Zeeuw, 1980). Poplar wood is very versatile, with low density similar to that of softwoods, but with high strength values related to their limited density (Isebrands and Richardson, 2014). Wood density also responds well to genetic improvement (Zobel and Jett, 1995), such as in poplar breeding.

Additionally, wood dimensional stability is another significant physical property, mainly for the manufacture of solid wood products. Wood shrinkage is affected by a number of variables, density being one of them. According to Tsoumis (1991), greater shrinkage is generally associated with greater density. Until now, only a few studies on wood shrinkage in poplars have been carried out (Karki, 2001; Pliura *et al*., 2005; Kord *et al*., 2010).

For best utilization of wood, it is also important to know the effect of age on wood properties. Large portion of wood produced in poplar clones is in the juvenile core (Balatinecz *et al*., 2001). The juvenile wood properties generally change from pit outward.

The best known within-tree variability in wood is the change from the pith to the bark. The low density diffuse-porous woods, such as *Populus*, seem to have a somewhat higher density at the pith (Zobel and van Buijtenen, 1989).

Significant clonal variation in wood density of poplars has been reported by many authors (Yanchuk *et al*., 1984; Fang and Yang, 2003; Zhang *et al*., 2003; Kord and Samdaliri, 2011; Huda *et al*., 2014). Properties of poplar wood, showing significant interclonal variation, could indicate the possibility of identifying clones with superior wood properties.

Among registered cultivars in Croatian *Populus* culture, two poplar clones 'I-214' and 'S1-8', have been planted on the experimental site near the Drava river and previously investigated by means of wood anatomical properties (Šefc *et al*., 2009). On that site, clone 'S1-8' showed superior growth increment and better survival compared to clone 'I-214' (Pfeifer, 1994). The Italian clone, 'I-214', is a good example of an exceptional clone adapted to a large variety of sites and growing conditions (Ahuja and Libby, 1993). From the technological point of view, density of the wood produced is low compared to most other cultivated clones (Peszlen 1994). It shows density values of 300 kg/m^3 (Isebrands and Richardson, 2014). On the other hand, the results point to the intensive development of the Serbian clone, 'S1-8', in the juvenile phase of development (FAO 1998). Until now, physical properties of clone 'S1-8' have not been investigated.

The aim of this study is to determine physical properties of poplar clones 'I-214' and 'S1-8' from one site in Croatia, to investigate variations in wood density and shrinkage of the mentioned poplar clones and to investigate the relationship between the two properties.

2 MATERIAL AND METHODS
2. MATERIJAL I METODE

For the purpose of this study, three test trees of poplar clone 'I-214' and three of poplar clone 'S1-8' were selected according to the standard HRN ISO 3129:1999. Both poplar clones came from the same habitat. They were cultivated on plantation "Drnje" near Koprivnica in Croatia, located along the natural flow of the Drava River. The site is characterized by a continental climate and the soil is alluvial soil, more gravely and sandy. Both clones were planted in deep planting technique and with the density of 3.5 × 3.5 m.

Relevant parameters were collected and measured on the growth location of all test trees, such as: ground plan projection canopy, trees orientation toward the cardinal points, diameter at breast height, total tree height, height up to the first living branches and stump height (Table 1).

After cutting down, a test trunk, having the length of approximately 80 cm, was sawn from each test tree. Test trunk length started at breast height (1.3 m), downwards to root collar. Afterwards, these 80 cm long trunks were sawn into bark to bark cores of approximately 6 cm in thickness (Figure 1). Cores were then submitted to natural drying on dry and drafted stock. The samples were sawn in the radial direction from heart to bark and

Table 1 Tree characteristics of poplar clones 'I-214' and 'S 1-8'
Tablica 1. Svojstva stabala klonova topole 'I-214' i 'S 1-8'

Clone *Klon*	**Tree mark** *Oznaka stabla*	**Site** *Stanište*	**Total tree height** *Ukupna visina stabla* m	**Trunk height** *Visina trupčića* m	**Height up to first living branch** *Visina do prve žive grane* m	**Diameter at breast height** *Promjer na prsnoj visini* cm
'I-214'	18	Drnje (KP)	32.5	21	11.7	31
'I-214'	20	Drnje (KP)	30	18	10	31
'I-214'	21	Drnje (KP)	35	19	6.4	25
'S 1-8'	28	Drnje (KP)	37.5	17	8	34
'S 1-8'	29	Drnje (KP)	29.7	18	18	33
'S 1-8'	32	Drnje (KP)	33.3	23	6	26

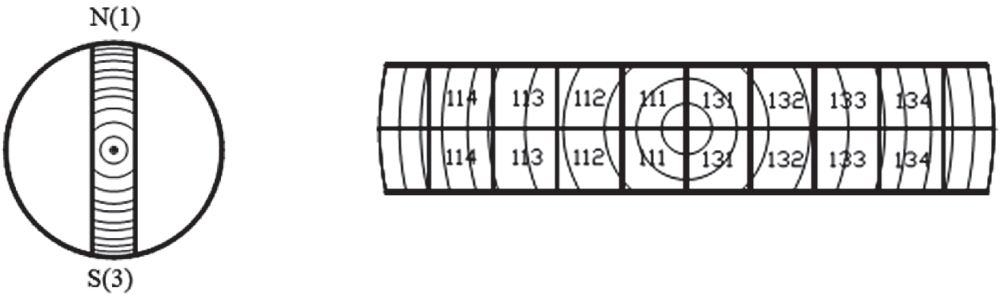

Figure 1 Bark to bark core (North – South) and samples of 20 mm × 20 mm × 25 mm from core
Slika 1. Srednjača (sjever – jug) i uzorci dimenzija 20 × 20 × 25 mm iz srednjače

labelled with markers that indicate from which tree they were sawn, to which side of the world they belong to and the ordinal number from pith to bark. After the cores had dried to a water content of about 12 %, rectangular samples of 20 mm × 20 mm × 25 mm were made from the highest part of the core, which was in the area of the breast height (1.3 m), (Figure 1).

In this study, the following physical properties were determined: density in absolutely dry condition and nominal density according to HRN ISO 3131:1999, radial and tangential shrinkage according to HRN ISO 4869:1999 and volumetric shrinkage according to HRN ISO 4858:1999.

Statistical analysis of the results and their comparison were carried out in specialised statistical programme Statistica 8. Statistical analysis showed the number of measured samples (n), minimum (min), average (aver) and maximum (max) value of certain measured properties as well as their standard deviation (STDEV) and coefficient of variation (CVAR).

3 RESULTS AND DISCUSSION
3. REZULTATI I DISKUSIJA

Physical properties of wood, especially wood density and dimensional stability, are important factors affecting wood quality. Average wood density in absolutely dry condition of clone ‘I-214’ is 388 kg/m^3 (Table 2). The value is somewhat higher than findings of other authors for the same clone (Peszlen, 1998; Balatinecz *et al.*, 2014). Average wood density in absolutely dry condition of clone ‘S1-8’ is 372 kg/m^3 (Table 2).

Statistical analysis showed the difference in average wood density between the two clones (Table 2). However, the difference in wood density between clones is only about 4 %, and for the purpose of wood processing and forestry practice this could be negligible.

The advantage of ‘S1-8’ is its better survival, better diameter growth rate and thicker bark compared to clone ‘I-214’ (Šefc *et al.*, 2009). Considering their low wood density, poplars have relatively high shrinkage values. According to some authors, this is mainly due to their chemical composition, e.g. relatively high polysaccharide content (Balatinecz *et al.*, 2014). Average shrinkage values between the two investigated clones are insignificant (Table 3). This is in accordance with Koubaa *et al.* (1998a), who reported that shrinkage values are in the same range for fast-growing hybrid poplars.

There are opposite findings about radial distribution of wood density for poplars. Einspahr *et al.* (1972) report that in *Populus tremuloides* wood, density was high near the pith, lower from three to five rings, and then increased towards the bark. Similar result was reported by Yanchuk *et al.* (1983). Scaramuzzi (1958) found uniform wood density from pith to bark in *Populus euroamericana* clones.

In this research, wood density in absolutely dry condition increased from pith to bark in both investigated clones (Figure 2). This is in accordance with the findings of Boyce and Kaiser (1961), Curró (1960),

Table 2 Statistical values of density in absolutely dry condition, nominal density, maximum radial, tangential and volume shrinkage of poplar clone ‘I-214’ and poplar clone ‘S 1-8’
Tablica 2. Prikaz statističkih vrijednosti gustoće u apsolutno suhom stanju, nominalne gustoće, maksimalnoga radijalnog, tangencijalnog i volumnog utezanja klona topole ’I-214’ i klona topole ‘S 1-8’

Poplar (Clone ‘I-214’) *Topola (klon ‘I-214’)*						Poplar (Clone ‘S1-8’) *Topola (klon ‘S1-8’)*				
ρ_o g/cm^3	ρ_y g/cm^3	$\beta_{r\,max}$ %	$\beta_{t\,max}$ %	$\beta_{v\,max}$ %		$\beta_{v\,max}$ %	$\beta_{t\,max}$ %	$\beta_{r\,max}$ %	ρ_y g/cm^3	ρ_o g/cm^3
28	28	28	28	28	*N*	29	29	29	29	29
0.360	0.311	3.9	7.5	13.0	*MIN*	11.3	7.2	2.7	0.300	0.346
0.388	0.336	5.1	9.7	15.6	*AVE*	15.1	9.6	4.6	0.323	0.372
0.449	0.392	8.2	12.4	19.0	*MAX*	17.9	12.1	7.7	0.362	0.414
0.022	0.022	1.16	1.12	1.63	*STDEV*	1.70	1.28	0.99	0.017	0.017
5.77	6.38	22.62	11.65	10.47	*CVAR*	11.26	13.32	21.30	5.09	4.52

Key/*Legenda*: ρ_o – density in absolutely dry condition / *gustoća u apsolutno suhom stanju*, ρ_y – nominal density / *nominalna gustoća*, $\beta_{r\,max}$ – total radial shrinkage / *totalno radijalno utezanje*, $\beta_{t\,max}$ – total tangential shrinkage / *totalno tangencijalno utezanje*, $\beta_{v\,max}$ – total volumetric shrinkage / *totalno volumno utezanje*, *N* – number of specimen / *broj uzoraka*, *MIN* – minimum value / *minimalna vrijednost*, *MAX* – maximum value / *maksimalna vrijednost*, *STDEV* – standard deviation/ *standardna devijacija*, *CVAR* – coefficient of variation / *koeficijent varijacije* (%)

Table 3 Pearson's correlation coefficients for the relationship between mean values of researched physical properties of poplar clone 'I-214' and poplar clone 'S1-8'
Tablica 3. Pearsonov koeficijent korelacije između srednjih vrijednosti određivanih fizikalnih svojstava klona topole 'I-214' i klona topole 'S1-8'

Poplar (Clone 'I-214') *Topola (klon 'I-214')* / **Poplar (Clone 'S 1-8')** *Topola (klon 'S 1-8')*	**Density in absolutely dry condition** *Gustoća u apsolutno suhom stanju*	**Nominal density** *Nominalna gustoća*	**Total radial shrinkage** *Totalno radijalno utezanje*	**Total tangential shrinkage** *Totalno tangencijalno utezanje*	**Total volumetric shrinkage** *Totalno volumno utezanje*
Density in absolutely dry condition / *gustoća u apsolutno suhom stanju*	p= **0.007**				
Nominal density / *nominalna gustoća*		p= **0.017**			
Total radial shrinkage / *totalno radijalno utezanje*			p= 0.131		
Total tangential shrinkage / *totalno tangencijalno utezanje*				p= 0.949	
Total volumetric shrinkage / *totalno volumno utezanje*					p= 0.478

Key / *Legenda*: Correlations are significant at $p < 0.05$ / *Korelacija je signifikantna pri p < 0,05*

Farmer and Wilcox (1968) and DeBell *et al.* (2002). Kord (2010) also reported an increasing trend in wood density, longitudinal, radial, tangential, and volumetric shrinkage, from the pith to bark in *Populus euramericana* trees. This can be explained by the fact that juvenile wood is known to be of lower density than mature wood (Dadswell, 1958; Zobel and Buijtenen, 1989). Similar patterns of wood density variation in the axial direction have also been reported in hybrids involving *P. alba*, *P. grandidentata*, and *P. tremuloides* (Johnson, 1942), in *P. trichocarpa* (Okkonen *et al*., 1972), and in *P. tremuloides* (Yanchuk *et al*., 1984).

There are conflicting findings on the correlation between wood density and ring width in poplars. Kennedy and Smith (1995) reported that there is an increase in wood density with faster growth. Density of wood is not related to ring width according to Göhre (1960). Mutibarić (1967) wrote about a slight negative correlation between ring width and wood density in *Euramerican poplar* hybrids in Yugoslavia.

In this research, negative correlation between wood density in absolutely dry condition and ring width was found in both investigated clones (Figure 3).

Dense wood results from fiber with thick walls and a low microfibril angle, which produces minimal longitudinal shrinkage, and increases radial and tangential shrinkage (Dadswell, 1958). Changes in wood shrinkage with cambium age are likely related to radial inter-tree variation in wood density, which often displays an inverse pattern of changes (Johnson, 1942; Okkonen *et al*., 1972; Yanchuk *et al*., 1984; Kord, 2010).

Pliura et al. (2005) found a positive correlation between wood density and both radial and tangential shrinkage. According to Koubaa and Smith (1959), there is a

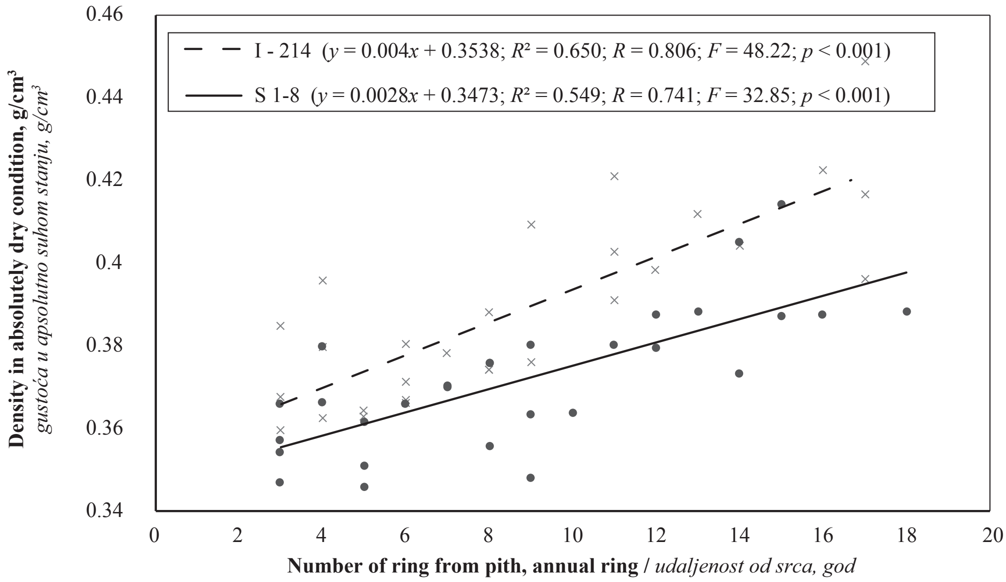

Figure 2 Radial distribution of wood density in absolutely dry condition of clone 'I-214' and 'S1-8'
Slika 2. Radijalna raspodjela gustoće u apsolutno suhom drvu klonova 'I-214' i 'S1-8'

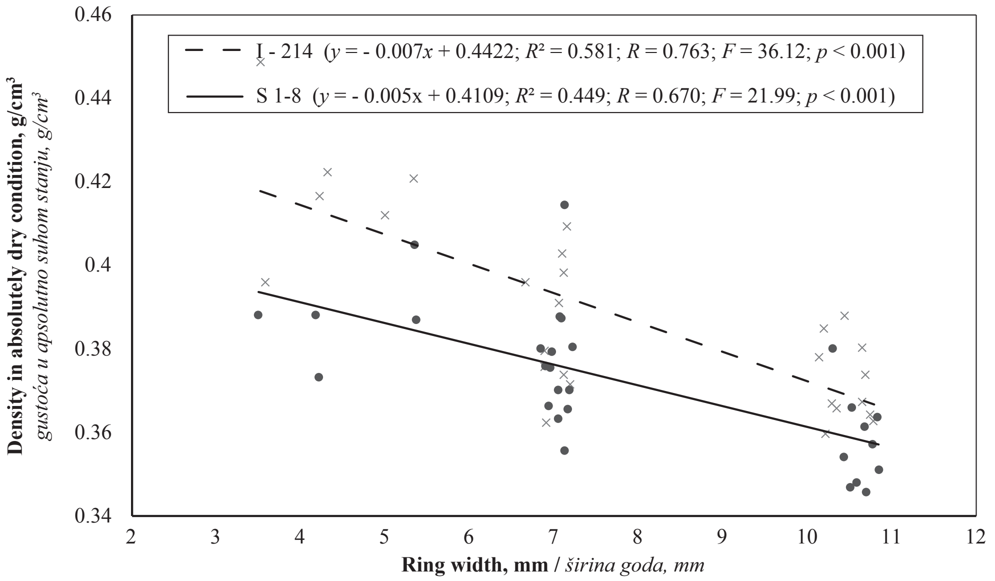

Figure 3 The ratio between wood density in absolutely dry condition and ring width of clone 'I-214' and 'S1-8'
Slika 3. Odnos gustoće apsolutno suhog drva i širine goda drva klonova 'I-214' i 'S1-8'

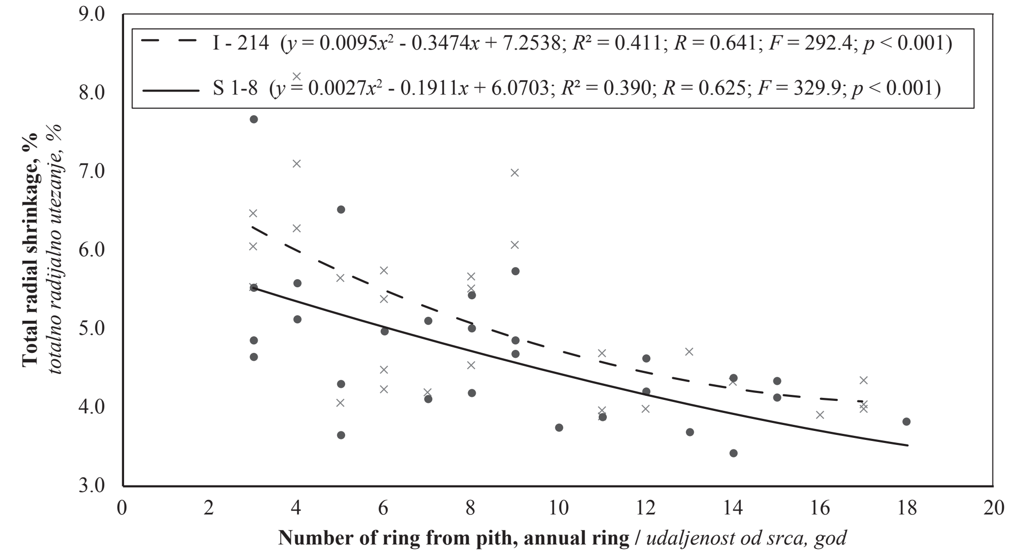

Figure 4 Radial distribution of total radial shrinkage of wood in clone 'I-214' and 'S1-8'
Slika 4. Radijalna raspodjela totalnoga radijalnog utezanja drva klonova 'I-214' i 'S1-8'

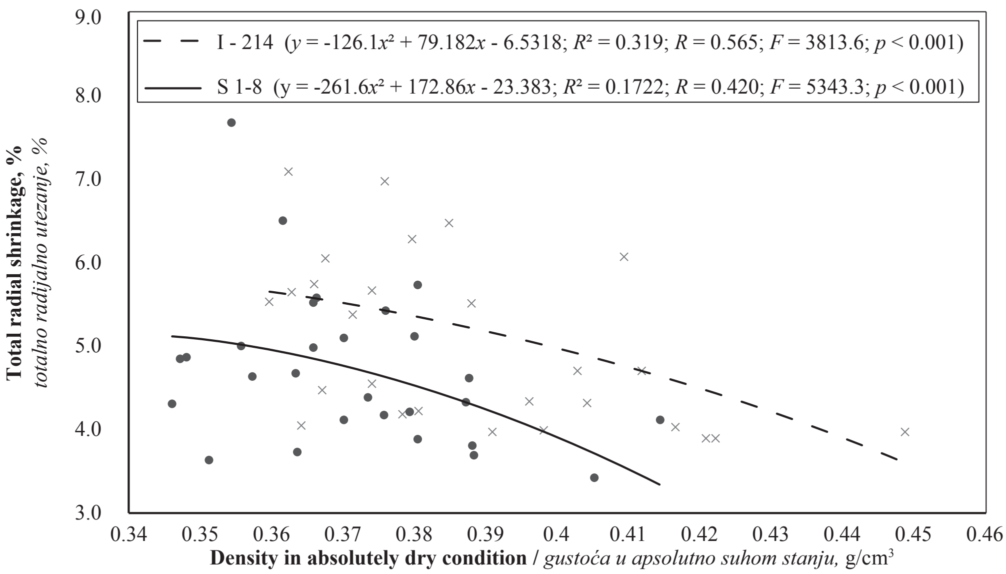

Figure 5 The ratio between total radial shrinkage of wood and wood density in absolutely dry condition of clone 'I-214' and 'S1-8'
Slika 5. Odnos totalnoga radijalnog utezanja drva i gustoće u apsolutno suhom drvu klonova 'I-214' i 'S1-8'

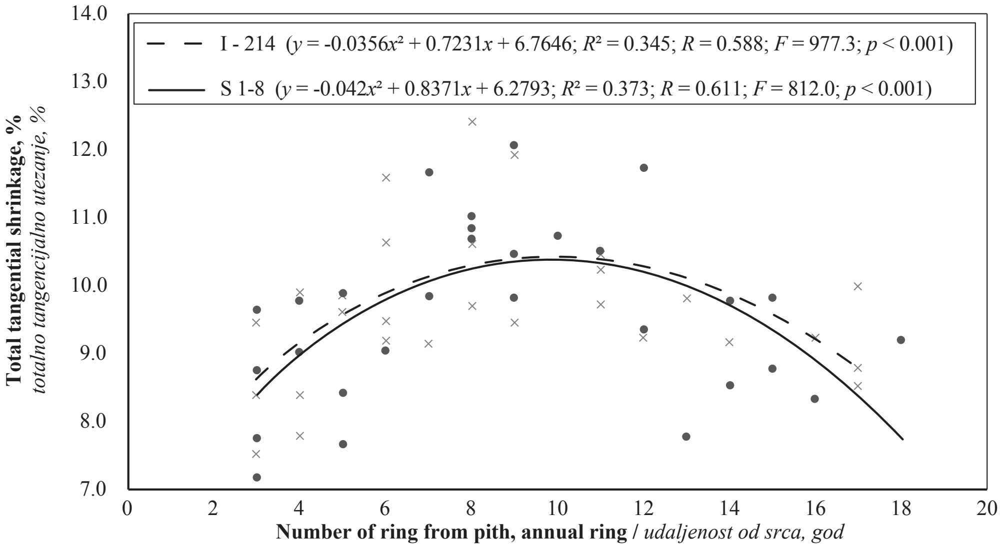

Figure 6 Radial distribution of total tangential shrinkage of wood in clone 'I-214' and 'S1-8'
Slika 6. Radijalna raspodjela totalnoga tangencijalnog utezanja drva klonova 'I-214' i 'S1-8'

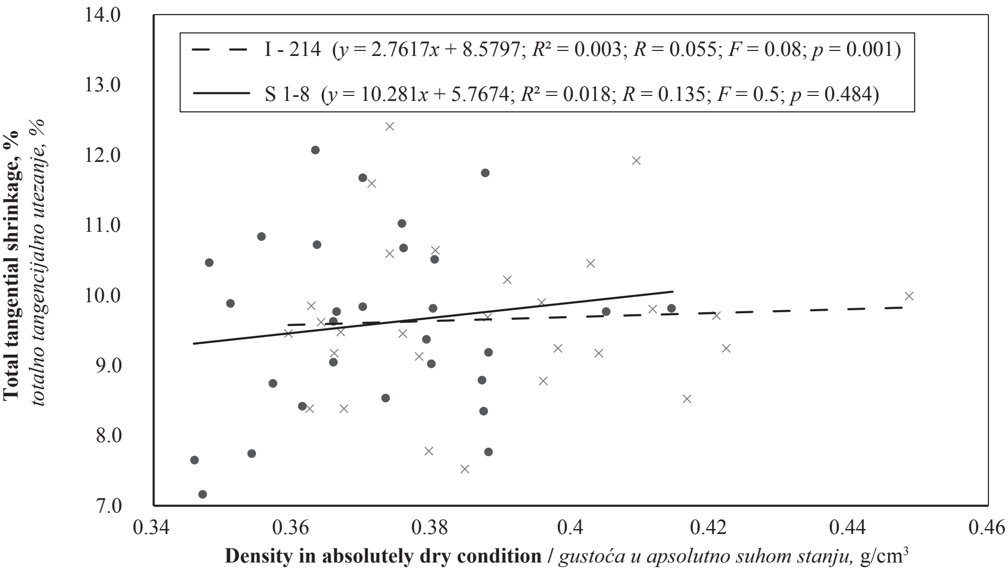

Figure 7 The ratio between total tangential shrinkage of wood and wood density in absolutely dry condition of clone 'I-214' and 'S1-8'
Slika 7. Odnos totalnoga tangencijalnog utezanja drva i gustoće u apsolutno suhom drvu klonova 'I-214' i 'S1-8'

significant positive correlation between basic wood density, and radial, tangential, and volumetric shrinkage in *Populus euramericana* hybrid clones. Kord *et al*. (2010) also reported a positive correlation between wood density, and radial, tangential, and volumetric shrinkage.

This research gave different results, and found a negative correlation between wood density in absolutely dry condition and total radial and volumetric shrinkage in both investigated clones (Figure 5 and 9). Due to a low correlation coefficient between total tangential shrinkage and density in absolutely dry condition (Figure 7) it is not possible to determine their relation. This could be explained by increasing of wood density from pith to bark and decreasing of wood density with growth rate.

There is a larger dissipation of measurements in total radial, tangential and volumetric shrinkage from pith to approximately the tenth annual ring (Figure 4, 6 and 8). From the tenth annual ring to bark, the correlation is negative with higher coefficient ratio. This might be explained by the above mentioned research on juvenile and mature wood of Dadswells (1958) and Zobel and Buijtenen (1989).

4 CONCLUSION
4. ZAKLJUČAK

There is a significant difference in wood density in absolutely dry condition and nominal density between poplar clones 'I-214' and 'S1-8' from Osijek. However, the difference in wood density between clones is only about 4 %, and for the purpose of wood processing and forestry practice this could be negligible. Total radial, tangential, and volumetric shrinkage showed no significant difference.

There was a general trend in the radial direction in both clones, in which wood density in absolutely dry condition increased from the pith to bark. On the contrary, total radial, tangential, and volumetric shrinkage

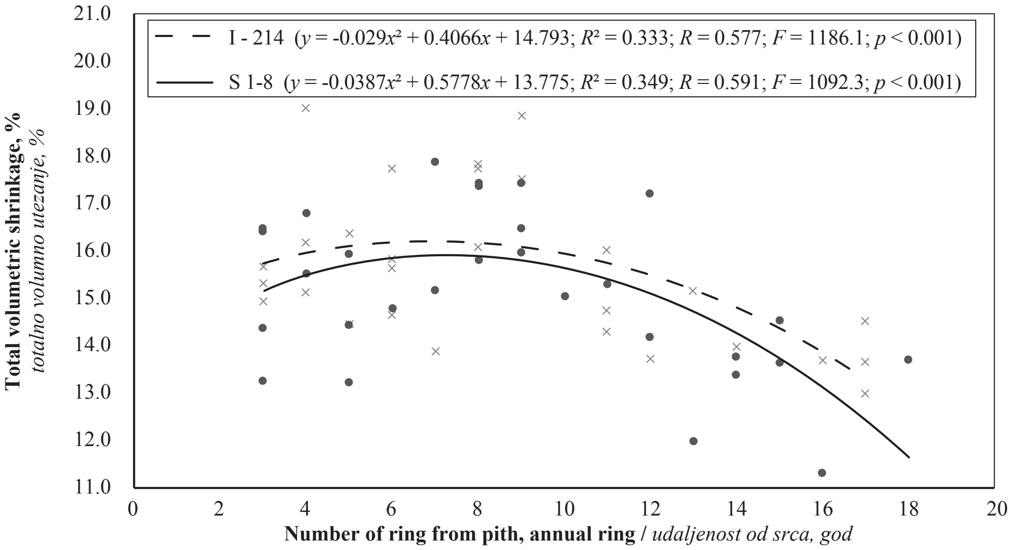

Figure 8 Radial distribution of total volumetric shrinkage of wood in clone 'I-214' and 'S1-8'
Slika 8. Radijalna distribucija totalnoga volumnog utezanja drva klonova 'I-214' i 'S1-8'

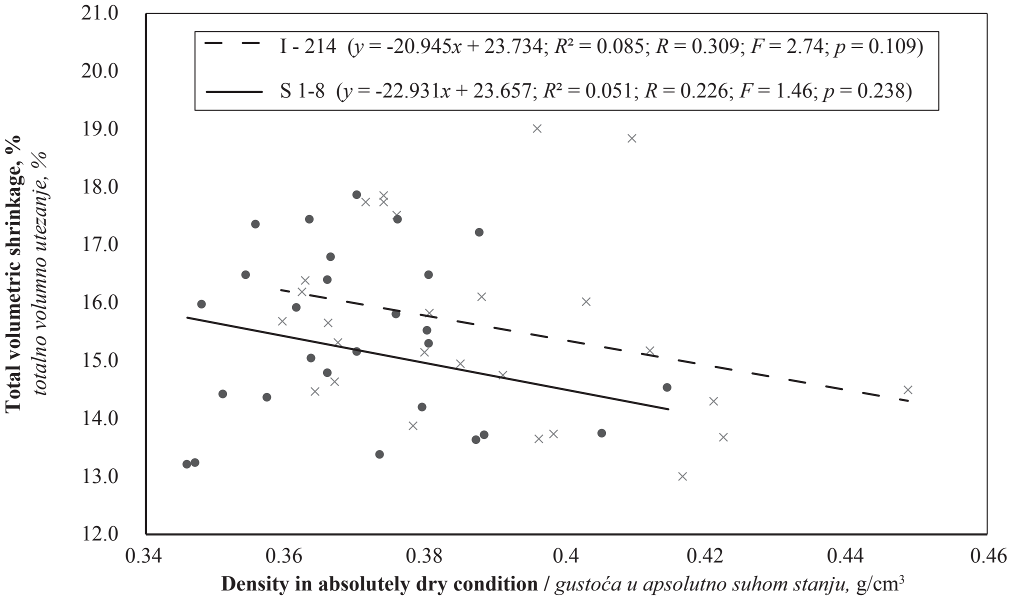

Figure 9 The ratio between total volumetric shrinkage of wood and wood density in absolutely dry condition of clone 'I-214' and 'S1-8'
Slika 9. Odnos totalnoga volumnog utezanja drva i gustoće u apsolutno suhom drvu klonova 'I-214' i 'S1-8'

showed a general decreasing trend in the radial direction from the pith to bark in both clones.

In general, there was a negative correlation between wood density in absolutely dry condition, and total radial, tangential, and volumetric shrinkage; although, tangential shrinkage was weakly correlated with wood density.

Forestry practice tends to provide high annual growth rate of clones and uniformity in wood density of material. The results of this research suggest the opposite. For better prediction of wood quality of these two clones, further investigation on mechanical properties should be carried out.

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