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Influence of site on sapwood and heartwood ratios of Turkish calabrian pine

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Abstract

In this study, the influence of site factor on the sapwood and heartwood ratios of Turkish calabrian pine (*Pinus brutia* Ten.) species was determined. The wood in this study was grown on four different sites in Turkey: Sucati-Kahramanmaras, Melli-Burdur, Yilanli-Mugla, and Kemalpasa-Izmir. The results indicated that the sapwood and heartwood ratios of the calabrian pine wood grown on these four sites averaged 93.81 percent and 6.13 percent, respectively. The highest heartwood ratio (8.33%) was determined for Sucati, followed by Yilanli, Melli, and Kemalpasa. Based on the results of the analysis of variance and the Scheffe test, it was found that differences in sapwood and heartwood ratios among the sites were quite significant ($p < 0.01$). These differences in sapwood and heartwood ratios might be attributed to ecological factors such as altitude, lime and organic material content of the soil, and soil type.

Sapwood and heartwood ratios in wood are considerably important parameters that characterize wood quality due to their own different physical and chemical properties. Specifically, in the species processed for timber and pulp production, the ratios of sapwood and heartwood play an important role. For example, the heartwood ratio of calabrian pine (*Pinus brutia* Ten.) species possesses much more resin sapwood portion. The resin results in various side effects such as quick filling at the continuous felt in pulp and paper industry, wearing out the saws in the sawing industry, etc. The sapwood portion prolongs the drying time of wood tremendously because of its high moisture content and shrinks/swells much more in comparison to heartwood.

In addition, heartwood affects the natural durability of wood directly because of its high content of extractives compared to sapwood. The natural durability of wood increases with increasing heartwood ratio. Yet, it is difficult to penetrate the wood preservatives into wood, especially, calabrian pine wood, in the case of existing high ratio of heartwood. If the sapwood and heartwood parts have the same moisture content and density as each other, their mechanical properties will not differ considerably.

Turkish calabrian pine covers the largest area (3,096,064 ha) among the conifers grown in Turkey (Bektas et al 2003), which corresponds to about 15.3 percent of the total forest area in Turkey. Calabrian pine is one of the fast-growing trees, the wood of which is an important raw material for various fields (such as packaging, ship making, furniture, construction, pulp and paper making, etc.) in forest products industries (Hamilton 1997). It is also worthwhile to note that the calabrian pine wood has the least heartwood portions compared to other pine species.

As a result, it is very important to investigate the sapwood and heartwood

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ratios of tree species. No information on the influence of sites on the sapwood and heartwood ratios of calabrian pine wood has been found in the literature so far. Therefore, the aim of this study was to determine the effects of sites on the sapwood and heartwood ratios of Turkish calabrian pine wood by using statistical methods.

Experimental methods

Preparation of the specimens

The calabrian pine logs were collected from four different sites: Sucati-K.Maras, Melli-Burdur, Yilanli-Mugla, and Kemalpasa-Izmir (Turkey), in different years, where forests are very productive. The characterization of the four sites is listed in **Table 1**.

On each site, the mean diameters at breast height (DBH) of the trees selected from four trial areas (20 by 20 m^2) were determined by following Turkish standard (TS 4176/1984). From each trial area, four trees (whose DBH values were representative of the mean diameter of the stand) were cut. The sapwood and heartwood ratios of the logs of each trial tree were measured on the parts of the stem cut at distances of 0.30 m, 1.30 m, 2.30 m, and 4.30 m starting from the base, and then every 2 m from the 4.30-m distance to the top.

Characterization of soil

The soils of the study sites were classified as Haploxerept (Gundogan 1998, Okatan et al. 1999). Two soil pits were excavated in each site plot until reaching bedrock. The soil samples were collected for laboratory analysis. The chemical and physical analyses of the soils were made by conventional methods (Black 1965). The results regarding the soil properties of the study sites are shown in **Table 1**.

Determination of heartwood ratio

It is easy to determine the heartwood portions of calabrian pine wood because the differences in color between sapwood and heartwood are obvious, i.e., the color of the heartwood changes from dark brown to red, and is distinguished due to the occurrence of pseudo-annual rings.

The heartwood ratio was determined by measuring the volumes of heartwood and the debarked stem. While the volume of logs at the base was measured by using the Face Means Equation of Smalian, the volume at the top sections was done by the typical formula of a cone. The heartwood ratio (*HWR*) was expressed by the following equation:

$$HWR\ (\%) = [V_h/V_t] \times 100 \quad [1]$$

where:

V_h = volume of heartwood (cm^3)

V_t = total volume of stem of the pine species (cm^3)

Determination of sapwood ratio

The ratio of sapwood (*SWR*) in calabrian pine wood was determined by subtracting heartwood the total volume of heartwood from the volume of the debarked stem and expressed as follows:

$$SWR\ (\%) = [(V_s - V_h)/V_t] \times 100 \quad [2]$$

where:

V_s = volume of sapwood (cm^3)

Furthermore, the effects of different sites on the sapwood and heartwood ratios were evaluated by using the analysis of variance (ANOVA) and Scheffe test.

Results and discussion

The results of the ANOVA and Scheffe test for the percent heartwood ratio of calabrian pine wood as a function of sites are shown in **Table 2**. The heartwood ratios are significantly affected by site studied (at the 0.01 level). The heartwood ratio was highest for the calabrian pine wood grown on the Sucati site (8.33%) followed by Melli, Yilanli, and Kemalpasa. The heartwood ratio determined for the Kemalpasa site differs significantly from those of the other sites studied, with the exception of the Yilanli site. This phenomenon might be explained by the fact that the Kemalpasa site had the lowest altitude (350 m), the highest lime content (55.64%), the lowest organic material content (1.54%), and the lowest pH value of 6.7, as confirmed by the results of the Scheffe test in **Table 1**.

It has been reported that calabrian pine showed its best growth in the altitude between 700 m to 900 m and with clay-loam-type soil containing sufficient amounts of calcium or lime (between 5% and 15%), and with organic matter higher than 1 percent (Zech and Cepel 1996, Bektas 1997). Specifically, it is known that a high amount of lime reduces the nutrition uptake of calabrian pine trees (Bektas 1997). Indeed, the physical, chemical, and mechanical properties of wood can essentially be

Table 1. — The results of the ANOVA and Scheffe test for the characterization of four different sites studied.[a]

Sites	pH	S	AT	MAR	MAT	Soil properties			
						D	ST	OM	CC
		(%)	(m)	(mm)	(°C)	(cm)			(%)
Sucati	7.3 A	45 A	800 A	708 A	16.5 A	60	SL	2.24 A	3.71 A
Melli	7.1 A	30 B	800 A	745 A	15.0 B	90	CL	2.84 A	11.94 A
Yilanli	7.1 A	23 B	700 A	1221 B	14.0 B	90	CL	2.43 A	15.11 A
K.Pasa	6.7 B	30 B	350 B	700 A	17.5 A	90	CL	1.54 B	56.64 B

[a] All site exposures were south. S = slope; AT = altitude; MAR = mean annual rainfall; D = depth; ST = soil type; OM = mean organic matter (OM<1%, insufficient; OM>1%, sufficient (Cepel 1996); CC = calcium carbonate content ($CaCO_3$) (CC<1% = no lime; CC 1% to 5% = low lime; CC 5% to 15% = mid-lime; CC>15% = high lime (Hizalan and Unal 1966). SL = sandy loam; CL = clay loam. The ANOVA significance level is 0.05. Values with the same capital letter within a column are not significantly different (Scheffe test).

Table 2. — The results of the ANOVA and Scheffe test for the percent heartwood ratio of calabrian pine wood as a function of sites.[a]

Sites	Avg. age	Avg. DBH	*n*	Mean	SD	SE	COV
	(yr.)						
Sucati	62	40	28	8.33 A	5.6921	1.06	30.17
Melli	64	43	42	6.77 A	4.7888	0.74	
Yilanli	67	43	49	5.25 AB	2.5689	0.38	
K.Pasa	61	42	40	4.16 B	2.5949	0.41	

[a] DBH = diameter at breast height; SD = standard deviation; SE = standard error; COV = coefficient of variation. The ANOVA significance level is 0.01. Values with the same capital letter within a column are not significantly different (Scheffe test).

Table 3. — The results of the ANOVA and Scheffe test for the percent sapwood ratio of calabrian pine wood as a function of sites.[a]

Sites	Avg. age (yr.)	Avg. DBH	*n*	Mean	SD	SE	COV
Kemalpasa	61	42	40	95.64 A	2.8754	0.45	5.42
Yilanli	67	43	49	94.75 AB	3.1308	0.48	
Melli	64	43	42	93.23 B	5.0536	0.78	
Sucati	62	40	28	91.60 B	8.5566	1.61	

[a] DBH = diameter at breast height; SD = standard deviation; SE = standard error; COV = coefficient of variation. The ANOVA significance level is 0.01. Values with the same capital letter within a column are not significantly different (Scheffe test).

varied by the environmental and soil conditions as well as silvicultural factors and tree age (Miranda et al. 2001). It is known that although heartwood volume is particularly related to the age of the tree, in this study it was found that there are other important factors that impact the heartwood ratio, such as climate and soil conditions.

The heartwood ratios (5.25% to 8.33%) of calabrian pine wood grown in sites studied here, except for that of Kemalpasa (4.16%), were determined to be smaller than that (4.9%) of the calabrian pine wood grown in Dutca-Mugla (Turkey), whose ecology is similar to that of the Kemalpasa site (Bozkurt et al. 1993).

The results of the ANOVA and the Scheffe test conducted for the percent sapwood ratio of calabrian pine wood as a function of sites are presented in **Table 3**. The ANOVA shows that differences in sapwood ratios among sites are found to be significant at the level of 0.01. The Kemalpasa site has the greatest sapwood ratio (95.64%) and the Sucatý site has the lowest sapwood ratio (91.60%). The sapwood ratio determined for Kemalpasa site is significantly different from those of the other sites, except for the Yilanli site. This fact might be explained by the same reasons just mentioned for heartwood ratio (**Tables 1** and **2**). As can be seen from **Tables 2** and **3**, the sapwood ratio appears to be significantly affected by the environmental and soil conditions.

Conclusions

This study determined the relationship between site factors and the sapwood and heartwood ratios of the wood of Turkish calabrian pine (*Pinus brutia* Ten.) grown on four different sites in Turkey: Sucati-K.Maras, Melli-Burdur, Yilanli-Mugla, and Kemalpasa-Izmir. The results of the ANOVA and the Scheffe test showed that differences in sapwood and heartwood ratios of the pine grown in different sites were clearly significant ($p < 0.01$). The sapwood and heartwood ratios of the calabrian pine wood on the four different sites averaged 93.81 percent and 6.13 percent, respectively. The highest heartwood ratio (8.33%) was determined for Sucati, followed by Yilanli, Melli, and Kemalpasa. The sapwood and heartwood ratios were significantly ($p < 0.01$) affected by ecological factors, especially lime and organic matter contents, altitude, and relative temperature.

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