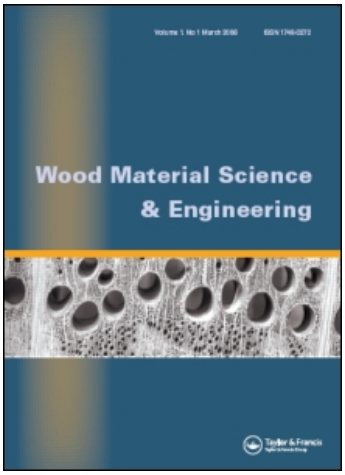

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George Mantanis[a]; Stergios Adamopoulos[b]; Ekaterina Rammou[a]
[a] Laboratory of Wood Technology, Department of Wood & Furniture Design and Technology, [b] Department of Forestry and Management of Natural Environment, Technological Education Institute of Larissa, Karditsa, Greece

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SHORT NOTE

Physical and mechanical properties of *Pinus leucodermis* wood

GEORGE MANTANIS[1], STERGIOS ADAMOPOULOS[2] & EKATERINA RAMMOU[1]

[1]*Laboratory of Wood Technology, Department of Wood & Furniture Design and Technology, and* [2]*Department of Forestry and Management of Natural Environment, Technological Education Institute of Larissa, GR-431 00, Karditsa, Greece*

Abstract
The present work reports on the main physical and mechanical properties of *Pinus leucodermis* mature wood, one of the least studied coniferous species in south-east Europe. *Pinus leucodermis* heartwood specimens were found to have average density values of 0.73 g cm^{-3} at equilibrium moisture content of 11.5% and average density of 0.64 g cm^{-3} under oven-dry conditions. The overall tangential shrinkage was 3.4% and the radial shrinkage was 1.9%. The modulus of rupture was on average 77 N mm^{-2}, while the static modulus of elasticity averaged 7087 N mm^{-2}. The hardness of *P. leucodermis* heartwood using the modified Janka test was 33.4 N mm^{-2} in the transverse direction and 48.0 N mm^{-2} in the longitudinal direction, while its compression strength parallel to grain was approximately 41.6 N mm^{-2}.

Keywords: *Bosnian pine, heartwood, Pinus leucodermis wood.*

Introduction

Pinus leucodermis, also known as Bosnian pine, is a forest species that occurs in the mountains of south-eastern Europe, in south-western Bulgaria, Bosnia, Albania, the former Yugoslav Republic of Macedonia, Serbia, northern Greece and locally in the south of Italy, growing at altitudes of 900–2500 m. It is a slow-growing species that usually grows up to a height of 38–40 m and a diameter of 150 cm (Farjon, 2005).

The species is mainly an ornamental and landscape tree rather than a timber crop. *Pinus leucodermis* wood is typically used in Greece and other areas in round form for building poles and fences and as raw material for making excellent wine barrels (Tsoumis, 1991). *Pinus leucodermis* wood has numerous resin canals (Figure 1) in the cross-section and is also characterized by a very distinctive resin odour. In recent years, there has been commercial interest in *P. leucodermis* wood for other technical uses (e.g. construction, window frames). However, information on the physical and mechanical properties of this timber, which is a prerequisite to enhance its uses, is very limited in the literature.

Materials and methods

Straight-grained mature heartwood of *P. leucodermis*, with an average number of 6–8 annual rings cm^{-2}, was collected from a high-altitude forest area of Pindos in north-west Greece. After a slow air-drying process of 6 months, small, clear wood specimens

Figure 1. Cross-section of *Pinus leucodermis* wood with numerous resin canals.

Correspondence: G. Mantanis, Laboratory of Wood Technology, Department of Wood & Furniture Design and Technology, Technological Education Institute of Larissa, GR-431 00, Karditsa, Greece. E-mail: mantanis@teilar.gr

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Table I. Information on testing of *Pinus leucodermis* wood.

Property	No. of specimens	Dimensions of specimens[a]	Standard
Density	40	40 × 20 × 20	DIN 52182
Shrinkage and swelling	30	10 × 20 × 20	DIN 52184
Static bending	40	360 × 20 × 20	DIN 52186
Axial compression	40	60 × 20 × 20	DIN 52185
Hardness (Janka)	20	50 × 50 × 50	ASTM D143-94

Note: [a]longitudinal × radial × tangential (mm × mm × mm).

were prepared from this material according to Table I. The specimens were then conditioned under normal conditions (20°C, 65 ± 3% relative humidity) for 8 weeks.

Wood density was determined according to DIN 52182 standards under two conditions: oven-dry and at 20°C and 65 ± 3% relative humidity. Shrinkage and swelling values (radial, tangential) were based on the measurement of the dimensions of the specimens under green and oven-dry conditions in accordance with the standard methodology (DIN 52184).

Static bending tests for the determination of modulus of elasticity (MOE) and modulus of rupture (MOR) were performed with a Zwick-Roell Z020 testing machine (Software testXpert V10.11) according to DIN 52186 standards (three-point bending). Axial compression strength and Janka hardness in the axial and transverse directions were determined according to DIN 52185 and ASTM D143-94 standards, respectively.

Results and discussion

The results obtained on the physical and mechanical properties of *P. leucodermis* wood are shown in Table II together with available literature values for *P. leucodermis* and the two main commercial pine species in the region, namely Scots pine (*Pinus sylvestris*) and Austrian pine (*Pinus nigra*). It should be noted that it is unknown whether the literature values given by Tsoumis (1991) refer to heartwood or sapwood. Consequently, they allow only a relative comparison with the values obtained in this study. Except for Tsoumis (1991), no other reference could be located providing information on properties of *P. leucodermis* wood.

Pinus leucodermis wood was found to possess quite different physical and mechanical properties from those reported for *P. leucodermis*, Scots pine and Austrian pine. Density values (oven-dry 0.64 g cm^{-3}, air-dry 0.73 g cm^{-3}) were higher, while shrinkage (radial 1.9%, tangential 3.4%) was much lower (almost half) than the densities of

Table II. Physical and mechanical properties of *Pinus leucodermis* wood and literature values.

		Literature values[b]		
Property	*P. leucodermis* wood[a]	*P. leucodermis*	*P. sylvestris*	*P. nigra*
Wood density (g cm^{-3})				
Oven-dry	0.64 ± 0.03	0.47	0.49	0.52
Air-dry	0.73 ± 0.04	0.53	0.53	0.55
Shrinkage (%)				
Radial	1.9 ± 0.4	4.1	4.0	4.1
Tangential	3.4 ± 0.6	6.0	7.7	7.7
Ratio T/R shrinkage	1.8 ± 0.2	1.5	1.9	1.9
Swelling (%)				
Radial	2.0 ± 0.5	–	–	–
Tangential	3.8 ± 0.7	–	–	–
MOE (N mm^{-2})	7,087 ± 1,275	–	11,765	11,765
MOR (N mm^{-2})	77 ± 6	69	98	103
Axial compression (N mm^{-2})	41.6 ± 4.2	40	54	39
Hardness (Janka) (N mm^{-2})				
Axial	48.0 ± 1.4	–	29	–
Transverse	33.4 ± 2.2	–	–	–

Note: [a]mean ± SD; [b]data from Tsoumis (1991).
MOE = modulus of elasticity; MOR = modulus of rupture.

0.47–0.55 g cm^{-3} and shrinkage values of 4.0–7.7% given by Tsoumis (1991). The large differences in density and shrinkage from the *P. leucodermis* literature values may be attributed to the origin of the material used in the study (heartwood) and its chemical composition (e.g. high content of extractives).

The average MOE was 7087 N mm^{-2}, which is very low compared with that of the other two pine species (11,765 N mm^{-2}). MOR was 77 N mm^{-2}, which is also lower. The compression strength parallel to grain of *P. leucodermis* wood averaged 41.6 N mm^{-2}. This value is comparable to the reported axial compression for *P. leucodermis* and Austrian pine, but lower than that of Scots pine. It was observed that almost all specimens exhibited an overall compression failure of the "shearing type" according to ASTM D 143-83 standard. Finally, the Janka hardness found to be 33.4 N mm^{-2} in the transverse direction and 48.0 N mm^{-2} in the longitudinal direction.

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