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COMPARATIVE WOOD ANATOMY OF *PINUS SYLVESTRIS* AND ITS VAR. *COMPACTA* IN THE WEST BLACK SEA REGION OF TURKEY

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SUMMARY

Pinus sylvestris L. subsp. *hamata* (Steven) Fomin var. *compacta* Tosun is quite different from the common form of *P. sylvestris* in its external morphology. The size of the needles, cones and seeds of the former are significantly smaller than those of the latter. Besides, this variety branches out beginning from the ground level, and has very dense branches and needles. The present study describes the anatomical properties of the wood of *P. sylvestris* var. *compacta* and compares them with typical *P. sylvestris*. The woods of these taxa have the same qualitative anatomical features, but most of the quantitative anatomical characteristics show significant differences: variety *compacta* has lower values than common *P. sylvestris* in tracheid length and diameter, ray height and bordered pit diameter.

Key words: *Pinus sylvestris* var. *compacta*, wood anatomy, Bolu Province, Turkey.

INTRODUCTION

The distribution of *Pinus sylvestris* L. (Scots pine) is wider than that of any other pine species in the world. Longitudinally, its range expands from Scotland to the Pacific Coast of Siberia; latitudinally, from Norway (70° 29' N) to Spain (37°) and from Arctic Siberia to Mongolia. It may also occur in the Mediterranean region (Mirov 1967). The distribution of *Pinus sylvestris* in Turkey expands from 28° 50' E (Orhaneli) in the West to 43° 05' E (Kagizman) in the East; and from 41° 48' N (Ayancik) in the North to 38° 34' N (Kayseri-Pinarbasi) in the South (Elicin 1971). Due to a great variety of environmental conditions along its wide global distribution, it has many subspecies, varieties and ecotypes (Mirov 1967; Elicin 1971; Yaltirik 1993; Ansin & Ozkan 1993). Elicin (1971) indicated that four different ecotypes exist in Turkey. Furthermore, Tosun (1988) defined a new variety of *P. sylvestris*, which is named *Pinus sylvetris* L. subsp. *hamata* (Steven) Fomin var. *compacta* Tosun, in Bolu province. With regard to its external morphology it is quite different from the typical form of *P. sylvestris*. The size of the needles, cones and seeds of this variety are significantly smaller than those of typical Scots pine. The seeds are lighter as well. Besides, it branches out beginning from the ground level, and it has an elliptic, long-elliptic or umbrella-shaped habit with very dense branches and needles. This compact variety of *P. sylvestris* occurs together with normal individuals of Scots pine in Cakmaklar, Tekke-Dortdivan and Gerede-Salur in Bolu province (Tosun 1988, 1996, 1999, 2003).

Variety *compacta* does not have special environmental requirements and occurs either in pure Scots pine stands or in mixed Scots pine stands with *Abies bornmuelleriana* Mattf. It does not have any exposure preference and ranges between 1200 and 1450 m in altitude (Tosun 1996). The crown closure of the stands with variety *compacta* in Cakmaklar–Bolu varies between 0.1 and 0.6.

The wood anatomical range and physical and mechanical properties of *P. sylvestris* have been studied by many researchers (*e.g.*, Greguss 1955; Jacquiot 1955; Kärkkäinen 1973; Laurow 1973; Laurila 1989; Wimmer 1990). Elicin (1971) reported on the wood anatomical variation of *P. sylvestris* from different provenances in Turkey.

The aim of the present study is to define the anatomical properties of the wood of *P. sylvestris* var. *compacta* and to compare them with those of typical *P. sylvestris*.

MATERIAL AND METHODS

The sample trees (three individuals for each variety) selected for wood anatomical examination are from the Cakmaklar–Bolu (altitude 1241 m) for *P. sylvestris* var. *compacta*, and from Kumluca–Bartin (altitude 1280 m) for the typical variety of *P. sylvestris*. The trunk diameters at breast height and trunk heights of the sample trees studied are shown in Table 1.

Both sample areas are in the West Black Sea Region of Turkey and have a similar sub-macroclimate type (West Black Sea Climate). However, the precipitation-effectiveness index (Im >55) in Bartin is greater than in Cakmaklar–Bolu (40 <Im <55) (Erinc 1996).

The wood specimens were extracted from the same side (west) at breast height of the trunks. For preparation of wood sections and macerations, standard procedures were applied (Yaltirik 1971). The following anatomical characteristics were investigated quantitatively for each sample tree: the tangential and radial lumen diameter of tracheids in earlywood and latewood, tracheid length, tracheid wall thickness, the number of tracheids per mm^2, bordered pit and pit aperture diameter in radial walls of earlywood tracheids, the number of axial resin canals per 10 mm^2, the tangential diameter of the axial resin canal complex, the diameter of radial resin canals, uniseriate ray height, fusiform ray height. Twenty-five measurements or counts were performed for the mean of each quantitative anatomical character except for the average number of tracheids

Table 1. Properties of the selected sample trees from Cakmaklar–Bolu and Kumluca–Bartin.

	Pinus sylvestris var. *compacta*			*Pinus sylvestris* typical form		
	Tree 1	Tree 2	Tree 3	Tree 1	Tree 2	Tree 3
Trunk height (m)	6.8	6.6	6.9	23	26	28
Trunk diameter at breast height (cm)	14	13.5	15	25	28	30
Estimated trunk age at breast height (years)*	65	60	67	70	80	86

* Estimates based on the site index yield table of *Pinus sylvestris* typical form (Kalipsiz 1988) and *P. sylvestris* var. *compacta* (Tosun 1996).

Table 2. Means and standard deviations of the quantitative anatomical features of *Pinus sylvestris* and *P. sylvestris* var. *compacta*.

	Pinus sylvestris typical form		*Pinus sylvestris* var. *compacta*		T-test
	M	SD	M	SD	Coefficient
TTDa	34.7	3.3	28.1	3.8	11.2 ***
RTDa	37.6	4.2	29.3	4.5	11.8 ***
TTDb	18.8	3.4	18.9	3.5	-0.1 ns
RTDb	8.2	3.4	7.0	1.9	2.6 **
TL	3367	550	2196	407	14.8 ***
TWTa	3.2	0.6	3.4	0.6	-2.4 *
TWTb	8.8	1.4	6.3	0.9	12.9 ***
NTmm^2	924	87	1144	92	-9.5 ***
NARC	4.7	1.6	10.2	3.6	-12.1 ***
ARCD	168.3	21.6	153.1	19.4	4.4 ***
RRCD	39.4	4.3	51.9	7.8	-12.1 ***
URHc	7.3	2.0	7.0	1.8	1.1 ns
URHd	190.1	58.2	181.9	49.6	0.9 ns
FRH	393.9	54.2	316.5	84.3	6.7 ***
BPD	23.5	1.5	19.8	1.2	10.4 ***
ADBP	5.9	0.5	5.0	0.5	6.3 ***

* = significant at the 0.05 level (two-tailed)
** = significant at the 0.01 level (two-tailed)
*** = significant at the 0.001 level (two-tailed)
ns = non-significant

TTDa: Tangential tracheid diameter in earlywood (μm) – **RTDa**: Radial tracheid diameter in earlywood (μm) – **TTDb**: Tangential tracheid diameter in latewood (μm) – **RTDb**: Radial tracheid diameter in latewood (μm) – **TL**: Tracheid length (μm) – **TWTa**: Tracheid wall thickness in earlywood (μm) – **TWTb**: Tracheid wall thickness in latewood (μm) – **NTmm^2**: Number of tracheids per mm^2 – **NARC**: Number of axial resin canals per 10 mm^2 – **ARCD**: Diameter of axial resin canal complex (μm) – **RRCD**: Radial resin canal diameter (μm) – **URHc**: Uniseriate ray height (number of cells) – **URHd**: Uniseriate ray height (μm) – **FRH**: Fusiform ray height (μm) – **BPD**: Bordered pit diameter (μm) – **ADBP**: Aperture diameter of bordered pit (μm) — M: Mean – SD: Standard deviation.

per mm^2, bordered pit and its aperture diameter which are all based on 10 observations each. To determine whether there are any significant differences between the wood of variety *compacta* and the common individuals of *P. sylvestris*, the quantitative anatomical properties were compared by the independent-samples T test in the SPSS 9.0 programme.

RESULTS AND DISCUSSION

The growth ring boundaries of *P. sylvestris* are distinct, and there is an abrupt transition from earlywood to latewood within the same growth ring. The bordered pits in radial tracheid walls in earlywood are uniseriate. The latewood tracheids are thick-walled. Ray tracheids are present and located at the upper and lower margins, but they are some-

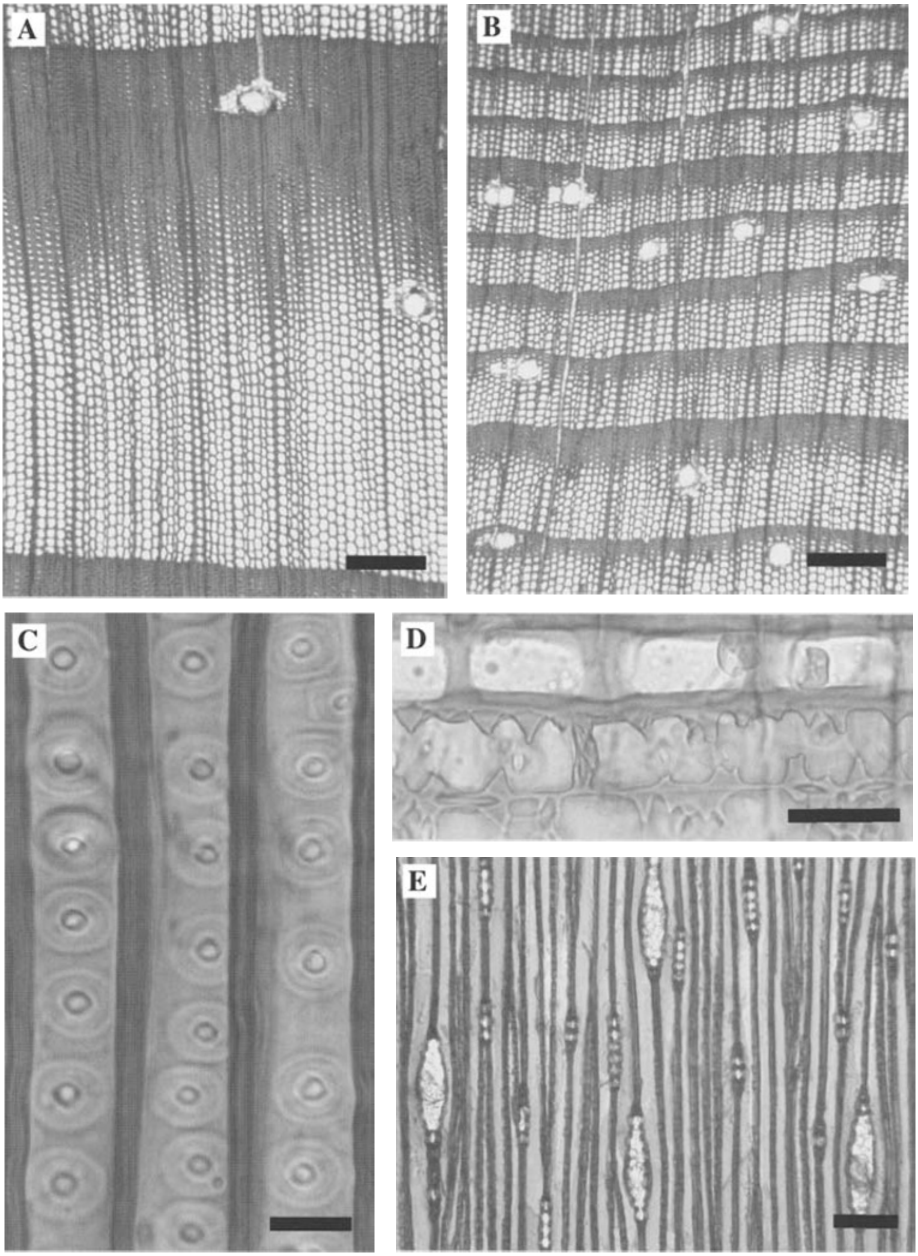

Figure 1. – A: Transverse section of the wood of typical *Pinus sylvestris*; scale bar = 300 µm. – B–E: *P. sylvestris* var. *compacta*. – B: TS; scale bar = 300 µm. – C: Bordered pits, RLS; scale bar = 25 µm. – D: Ray tracheids with dentate and cross-field pitting (window-like), RLS; scale bar = 30 µm. – E: Uniseriate and fusiform rays in TLS; scale bar = 200 µm.

times in the interior of the ray. Ray tracheid walls are prominently dentate. Both the end and horizontal walls of ray parenchyma cells are smooth (unpitted). The type of cross-field pitting is window-like. There is one pit per cross-field. Both axial and radial resin canals occur. Their epithelial cells are thin-walled.

The wood of *P. sylvestris* var. *compacta* has the same qualitative features as mentioned above for *P. sylvestris*. But, in terms of quantitative anatomical properties, there are statistically significant differences between the wood of both taxa (see Figure 1). Table 2 gives the quantitative wood anatomical features of *P. sylvestris* and variety *compacta*.

On the basis of trunk analysis for the site index yield table of typical *P. sylvestris* (Kalipsiz 1988), and for that of variety *compacta* (Tosun 1996) it can be stated that the mean growth ring width in *P. sylvestris* var. *compacta* is much narrower than that of typical *P. sylvestris*. Similarly, the present study showed that the mean width of the growth rings formed in the last ten years is 1.68 mm for *P. sylvestris* and 0.54 mm for variety *compacta*.

According to statistical analysis the following quantitative anatomical properties of variety *compacta* are significantly different from typical *P. sylvestris*: the tangential and radial diameters of earlywood tracheids are narrower in var. *compacta* than in normal trees. In latewood tracheids only the radial diameter differs between the two forms. Mean tracheid length is 3367 μm for typical *P. sylvestris* and 2196 μm for the variety *compacta*. According to the IAWA Committee (2004), it is in the medium size class for the former and in the short size class for the latter. The tracheid walls are thicker in the earlywood of var. *compacta*. Conversely, latewood tracheid walls of the typical form are thicker than in var. *compacta*. The number of tracheids per mm^2 and axial resin canals per 10 mm^2 in var. *compacta* is higher than in the common form. While the tangential diameter of axial resin canal complex in var. *compacta* is narrower than in typical *P. sylvestris*, the diameter of radial resin canals in var. *compacta* is wider. The fusiform ray height of var. *compacta* is shorter, and the bordered pits and the apertures are smaller than in typical *P. sylvestris*. As for the other quantitative anatomical features (tangential tracheid diameter in latewood and uniseriate ray height), there are no significant differences between the two forms examined.

Elicin (1971) provided quantitative wood anatomical data for the population of *P. sylvestris* in Seben-Bolu (the distance from Cakmaklar to Seben is 40 kilometres). His data are similar to those of typical *P. sylvestris* reported here, though for some features the values are intermediate between typical *P. sylvestris* and variety *compacta* (*e.g.*, tracheid length of 2658 μm).

In ecological wood anatomy many quantitative anatomical features have been shown to vary with climatic conditions (Elicin 1971; Baas *et al.* 1983; Carlquist 1988; Ozyalcin 2001). In the present study, the two Scots pine forms are, however, subject to similar climatic conditions.

The variety *compacta* individuals in Cakmaklar–Bolu have a much lower average stem diameter and tree height than the typical *P. sylvestris* stems of the same region (Table 1), in agreement with Tosun (1996), suggesting some type of dwarf growth. The effects of dwarf growth on wood structure of some conifers were studied by different researchers (Halbwachs & Kisser 1967; Baas *et al.* 1984; Li Zhengli & Zhang Xinying 1984; Wang Yufei & Li Zhengli 1989; Lim & Woong 1997). According to Baas *et al.* (1984), "conifers appear to show the greatest response" in terms of size reductions of their tracheids. Based on the comparative anatomical observations of wood structure of dwarf *P. parviflora* (Baas *et al.* 1984), *P. densiflora* and *P. thunbergii* (Baas *et al.* 1984; Li Zhengli & Zhang Xinying 1984; Lim & Woong 1997), *P. tabulaeformis* (Baas *et al.* 1984; Li Zhengli & Zhang Xinying 1984), *P. yunnanensis* var. *pygmaea* (Hüsüeh) Hüsüeh (Li Zhengli *et al.* 1994), tracheid length appeared much shorter and the tracheid diameter narrower in dwarfs than those of normal trees. Also, Laurila (1989) showed that small trees of *P. sylvestris* had shorter tracheids than those in normal sized trees. Moreover, the number of resin canals was greater in the wood of *P. yunnanensis* var. *pygmaea* than that of typical *P. yunnanensis* (Li Zhengli *et al.* 1994). In comparison with typical *P. sylvestris*, similar results for *P. sylvestris* var. *compacta* are evident. Wang Yufei and Li Zhengli (1989) indicated that the diameter of tracheid bordered pits and ray height in dwarf *Larix chinensis* was smaller. In the wood of the variety *compacta*, the bordered pits were also smaller and the fusiform ray height lower than in typical *P. sylvestris*. Baas *et al.* (1984) interpreted that the shorter and narrower tracheids in natural or artificial dwarfs, compared to their normal individuals, were comparable to the effects of extremely slow growth during tree senescence or prolongued physiological stress. Although the variety *compacta* cannot be classified as 'dwarfed', the fact that its tracheids were shorter and narrower may be due to relatively slow growth compared to normal Scots pine trees in the same stands.

The individuals derived from the seeds on the clonal seed orchard of variety *compacta* are also compact forms with slow growth (Tosun 1996). Since both the external morphological characteristics of *P. sylvestris* var. *compacta* and its quantitative wood anatomical properties were different from the common trees of *P. sylvestris*, variety *compacta* may be confirmed as a separate taxon as stated by Tosun (1988, 1999, 2003). Tosun (1988, 1996) interpreted that the compact variety of Scots pine was a mutant form of *P. sylvestris*. This hypothesis should be tested with molecular analyses.

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