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Research Article

Some of Wood Properties of Narrow Leaved Ash (*Fraxinus angustifolia* Vahl.) From Natural and Plantation Stands in Turkey

Kamile TIRAK HIZAL [a,*], Nurgün ERDİN [b]

[a] *Forestry and Forest Products Department, Vocational School of Forestry, Duzce University, Düzce, TÜRKİYE*
[b] *Forest Products Industry Engineering Department, Forestry Faculty, Istanbul University, İstanbul, TÜRKİYE(Retired)*
* *Corresponding author's e-mail address: kamiletirak@duzce.edu.tr*
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ABSTRACT
Ash wood is very important for forest products industry. Because of its fast growing property it was planting for severeal years. Wood quality may change with several factors which one of the important factor is site conditions. The aim of this study was to investigate the anatomical, physical properties and compression strength paralell to grain of natural and planted narrow leaved ash (*Fraxinus angustifolia* Vahl.) wood at different sites in Turkey. It was shown that there was a significant difference between natural and planted trees and between regions for all wood properties. Planted trees had higher density which had thicker double fiber cell wall, lower earlywood vessel frequency, higher and/or similar ray width, shorter earlywood vessels, lower multiseriate ray high number and length. The maximum oven-dry densities were 0.773 gr.cm^{-3} in Sinop and 0.719 gr.cm^{-3} in Adapazarı for planted trees. Higher shrinkage values were observed in denser planted trees. Planted trees exhibited higher compression strength parallel to grain (53.32 N.mm^{-2} in Adapazarı and 55.32 N.mm^{-2} in Sinop) than natural trees (51.02 N.mm^{-2} in Adapazarı and 50.05 N.mm^{-2} in Sinop). As a result; planted NLA wood showed better wood properties except shrinkage values.

Anahtar Kelimeler: *Anatomical properties, Physical properties, Fraxinus angustifolia, Dişbudak, Plantasyon*

Türkiye'de Doğal ve Plantasyon Meşcerelerinde Yetişen Dar Yapraklı Dişbudak (*Fraxinus angustifolia* Vahl.) Ağaçlarının Bazı Odun Özellikleri

ÖZET
Orman Ürünleri Endüstrisi için dişbudak odunu çok önemli bir yer tutmakta ve hızlı büyüme yeteneğinden dolayı yıllardır yetiştirilmektedir. Odun kalitesi çeşitli faktörlere bağlı olarak değişebilir ki bunlardan en önemlisi yetişme yeri şartlarıdır. Bu çalışmanın amacı Türkiye 'de farklı bölgelerde yetişen doğal ve plantasyonla yetişen dar yapraklı dişbudak (*Fraxinus angustifolia* Vahl.) odunlarının anatomik ve fiziksel özellikleri ile liflere paralel direncini belirlemektir. İncelenen tüm odun özellikleri için doğal ve plantasyonda yetişen ağaçlar arasında anlamlı farklılıklar gözlemlenmiştir. Plantasyonda yetişen ağaçların odunları daha kalın lif çeperi, düşük ilkbahar odunu trahe sıklığı, daha yüksek ve/veya eşit oranda öz ışını genişliği, daha kısa ilkbahar odunu traheleri, daha düşük multiseri öz ışını yüksekliği ve uzunluğuna sahiptir ve yoğunlukları fazladır. Plantasyonda yetişen ağaçlarda maksimum fırın kurusu yoğunluk (d_0) değeri Sinop bölgesinde 0.773 gr.cm^{-3} ve Adaparı bölgesinde 0.719 gr.cm^{-3}'dir. Daha yoğun plantasyon ağaçlarında daha yüksek daralma miktarı elde edilmiştir. Her iki bölgede de

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plantasyonda yetişen ağaçların (53.32 N.mm^{-2} in Adapazarı and 55.32 N.mm^{-2} in Sinop) liflere paralel basınç direnci doğal yetişenlerden (51.02 N.mm^{-2} in Adapazarı and 50.05 N.mm^{-2} in Sinop) daha yüksek çıkmıştır. Sonuç olarak; plantasyonla yetiştirilen dar yapraklı dişbudak odunları daralma miktarları hariç daha iyi odun özellikleri göstermiştir.

Keywords: *Anatomik özellikler, Fiziksel özellikler, Fraxinus angustifolia, Plantasyon, Dişbudak*

I. INTRODUCTION

Turkey was met with fast growing species in 1880's with *Pinus pinaster* and in 1939 with *Eucalyptus camuldensis* as foreign species [1]. Studies on fast growing species in Turkey were focused on native broadleaved species such as *Fraxinus* spp., *Alnus* spp., *Populus tremula*, *Ulmus* spp., etc. about two decades ago [2].

One of 24 genera in the Olive family, Oleaceae is the genus *Fraxinus* (ash) [3] and it includes 43 species distributed in temperate and subtropical areas of the northern hemisphere [4]. Narrow-leaved ash (NLA; *Fraxinus angustifolia* Vahl) is naturally grown species in southern Europe, the Balkans, the Caucasus, and Iran. NLA (*F. angustifolia*) and common ash (*F. excelsior*) are becoming important because of fast growing ability and valuable wood in European forestry. It is the most common ash species in the bottomland forests of the northern coastal regions of Turkey and its rotation age is between 40 and 50 years in plantations [2, 5]. Wood characteristics of NLA show similarities to common ash. It yields white, dense and high-quality wood and especially used in the veneer and furniture industries [5]. The mean annual increment can reach about 25 m^3 ha^{-1} and 15 m^3 ha^{-1} of stem wood over bark without any additional fertilizers or irrigation in plantations and natural stands, respectively; current annual increments can reach 33 m3 ha^{-1} of stem wood over bark at 15–20 years [6].

Hardwood has a complex tisssue which is composed of three main cell types: vessels (transport water), fibers (responsible for mechanical strength), and parenchyma (stores and transports nutrients) [7]. These tissues affect the quality of wood and found in different structural characteristics and relative proportions within wood. Wood quality is important for the end use of trees and the most effective parameter for wood is density. Density is closely correlated with many wood properties (physical, mechanical and technological) [8]. Wood density varies considerably for reasons including genetics [9], tree growth (ring number from the pith, ring width and silviculture) [10, 11] and environmental influences such as climate [12], elevation [13] and site fertility [14, 15]. Cell size and cell wall thickness determine the wood density therefore, cell variations in the structure of wood have significant impact on the quality and yield of pulp and paper products, and on the strength and utility of solid wood products [16]. For example for pulpwood fiber length is an important quality parameter. [17-19]. For many hardwood species wood density is largely affected by fibres, which are thick-walled cells composed of cellulose and lignin, that provide mechanical support [20, 21]. Other tissue types can also influence wood density. In xylem vessels, wider lümen area decreases wood density. Previous studies have shown increasing wood density correlates with decreasing xylem vessel lumen area over a range of species [22-24]. The shrinkage of wood is affected by cell width, wall thickness, frequency and vessel diameter [25] and the strength of the wood is related to fibres [26, 27].

Generally spacing effects on anatomical structure [28], spacing effects on mechanical properties [29], wettability and surface roughness of planted NLA ash wood were studied [30] but there is a little information on wood variability regarding its anatomical features and density which may have effect the processing and product performance. Therefore, knowing the wood properties of ash tree grown in plantation areas could be valuable in its utilization. The objective of this study was to determine and compare the anatomical, physical properties and compression strength parallel to grain of natural and planted NLA wood at different sites in Turkey.

II. MATERIALS and METHODS

NLA trees were sellected from two different sites in North of Turkey. In these plantation areas, trees were planted at 3x2 m spacing from unknown origin plantation stands and unmanaged stands. Sample trees were selected from the same diameter class, and avoiding extreme cases such as excessively knotty and crooked trees. A total of 12 trees were determined and numbered and measured at the breast height diameter before felling. Diameter at 1.3 m (DBH) was measured as the mean of two cross diameter. The trees and their location knowledge and details of the two sites are given in Table 1.

***Table 1.** Trees and site characteristics.*

Site	**Adapazarı**		**Sinop**	
	Natural	**Plantation**	**Natural**	**Plantation**
Tree age (*years*)	30-30-42	30	99-107-115	45
Region name/No	Çatalköprü/ 10	Süleymaniye /121	Başaran /59	Başaran /59
Cordination	40°47'52" / 30º32'42"	40°51'51" / 30º34'58"	42°00'22" / 34º55'39"	41 °59'01" / 35º55'11"
Altitude (*m*)	25	25	10	10
Precipitation ($mm\ yr^{-1}$)	783	783	874	874
Mean temperature (*°C*)	14.1	14.1	14	14
Soil	Clay loam	Clay loam	Sand	Sand
DBH (*cm*)	30-32	29-35	34-38	34-35
Tree height (*m*)	25-27	25-27	26-30	21-23

Each felled tree was cut from 0.3, 1.3 (DBH), 3.3, 5.3 m and upper of the stem destructively. For anatomical properties, 5 cm-thick discs were taken at 0.3, 1.3 and 3.3 m in height. Logs 50 cm in length were taken from at all heigths and were used for physical and mechanical tests (Figure 1).

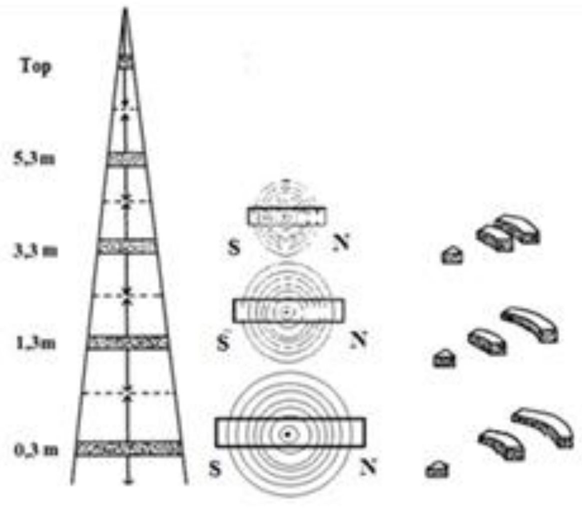

***Figure 1.** Schema of discs for wood anatomical studies.*

A. ANATOMICAL PROPERTIES

From each disc 5 cm wide strip were cut from North side to South side (Figure 2). Transverse surfaces of each strip were sanded. We used 3 strips for a tree and totally we had 36 strips.

Figure 2. *A strip was taken in disc. (North to South orientation)*

For anatomical characterization and eleminating the environmental factors, annual ring was selected for measuring from inner (first 5. annual ring), middle (1994 year) and near the bark (2009 year) in North and South side of strip at three height level (Figure 1). The 216 wood cubes (2x2x2 cm) were boiled in water for softening, and microscopic sections (transverse, radial and tangential) (approximately 10-15 µm thick) were cut with a sliding microtome Leica SM 2010 R, and then stained with safranin-0 (Merck) and prepared permanent slides. Wood macerations were carried out according to Jeffrey Method (%10 Nitric acid and %10 cromic acid) [31]. Determinig vessel length and fiber biometry only DBH strip was used.

In this study, the International Association of Wood Anatomists [32] list was used in descriptive wood anatomical studies and identification. For vessels, two measurements were made and analyze diameter (Tangential earlywood vessel diameter (µm)-TEVD, Tangential latewood vessel diameter (µm)-TLVD), and number of vessel per square milimeter (Earlywood vessel frequency (vessels mm^{-2})-EVF, Latewood vessel frequency (vessels mm^{-2})-LVF). For ray width (RW), the most predominant width was recorded not to bias the selection. Ray hight was evaluated according to ray number (uniseriate ray height-URHN, multiseriate ray height-MRHN) and length (uniseriate ray height (µm)-URHM, multiseriate ray height (µm)-MRHM), uniseriate and multiseriate seperately). Ray frequency (number of rays per milimeter-RN) was determined. From the macerated samples, vessels length (earlywood vesel length (µm)- EVL, latewood vessel lenght(µm)-LVL) and fiber diameter (fiber diameter (µm)-FD), length (fiber length (µm)-FL) and cell wall thickness (double fiber cell wall thickness (µm)-DFWT) were identified. Thirty one measurements for vessel, twenty five measurements for fiber length, width and wall thickness were made. Olympus BX 51 microscope connected to Olympus DP 71 camera was used to acquire images using the image analysis software ANALYSIS FIVE.

B. PHYSICAL PROPERTIES

Determinig physical properties, five different sampling heights (0.30, 1.30, 3.30, 5.30 m and top of stem) were used in the stem. Air-dry and oven-dry -density (Dm_{12}, Dm_0) [33], and shrinkage (tangantial, radial and volumetric)($\beta_{(t,r,v)}$) [34] were determined according to Turkish Standart [35] using wood specimens of 20x20x30 mm (along the grain). Fiber saturation point (FSP) was calculated by the following equation 1 [36]:

$$FSP = \beta_v / D_b \ (\%) \qquad (1)$$

where βv is the volumetric shrinkage (%) and D_b is the density value in volume (g/cm^3). Maximum moisture content (MMC) was calculated by the following equation 2:

$$M_{max} = FSP+(1.5-D_0)/(1.5x\ D_0)\ (\%) \qquad (2)$$

D_0 is the oven-dry density value (eq.2).

D_b is the density value in volume (wood basic density) (eq.3). The basic density was determined by the gravimetric method [36].

$$D_b = M_o/V_g \qquad (3)$$

where D_b is the basic density of wood (g/cm^3), V_g is the green volume of the specimen (cm^3), and M_0 is the dry-matter weight of specimen (g). Percentage of the cell wall and porosity were calculated by the following equations 4,5 [36].

$$V_c = D_o/D_c\ 100 \quad (4)$$

$$V_H = 100 - V_c \quad (5)$$

where V_c is percentage of the cell wall (%), D_o is oven-dry density (g/cm^3), D_c is oven-dry density of the cell wall (1.5 g/cm^3) and V_H is percentage of the porosity.

C. COMPRESSION STRENGTH PARALLEL TO GRAİN

Small test specimens were stored in an unheated room at uncontrolled condition for air drying. Following air-drying process, small and clear specimens were used to determine compression strength parallel to grain according to TS/2595 [37] After acclimatization, compression strength parallel to grain of the NLA wood were determined.

At the end of experiments, moisture contents (M) of specimens were measured according to TS 2471 [38] and the moisture content of specimen in which moisture content deviated from 12% determined. Then strength values were corrected (transformed to 12% moisture content) by using the following strength conversion equation 6:

$$\delta_{12} = \delta_m \times [1 + \alpha(M_2 - 12)] \quad (6)$$

where δ_{12} = strength at 12% moisture content (N/mm2), δ_m = strength at moisture content deviated from 12% (N/ mm^2), α = constant value showing relationship between strength and moisture content (a = 0.06), M_2 = moisture content during test (%).

D. STATİSTİCAL ANALYSIS

Statistical analysis were carried out using SPSS 23. Descriptive statistics were calculated for each parameter. Indepedent- Samples t test was used for evaluating differences between natural and planted trees and regions at 0.05 % significance.

III. RESULTS and DISCUSSION

A. ANATOMICAL PROPERTIES

An anatomical wood characterisation of NLA trees growing on natural and plantation stands for two different sites was studied. The mean and standart deviation of anatomic characteristics and differences between natural and planted NLA trees, and differences between regions were given in Table 2. The analysis of independent-sample t-test indicated that there was significant differences between natural and planted NLA wood about TEVD, TLVD, LVF, RN, UHRN, UHRM, MRHN, MRHM, RW and FL in Adapazarı region, TEVD, TLVD, EVF, LVF, RN, MRHN, MRHM, RW, EVL, LVL, FD and FWT in Sinop region. There was no significant difference between natural and planted NLA wood for EVF, EVL, LVL, FD, FWT in Adapazarı region and URHN, URHM, FL in Sinop region.

__Table 2.__ The mean values and statistical differences between natural and planted NLA trees in cell morphology.

Anatomical prop.	**Region**	**Natural Mean (Std)**	**Plantation Mean (Std)**	**P**
TEVD (*μm*)	Adapazarı	202.04 (97.44)[a]	171.68 (38.88)[1]	*
	Sinop	150.85 (42.72)[b]	167.58 (46.41)[2]	*
TLVD (*μm*)	Adapazarı	46.36 (14.70)[a]	47.91 (16.42)[1]	*
	Sinop	50.88 (14.46)[b]	39.02 (11.93)[2]	*
EVF (*vessels.mm⁻²*)	Adapazarı	11.89 (4.87)[a]	11.29 (3.54)[1]	ns
	Sinop	13.15 (4.20)[b]	11.66 (6.48)[1]	*
LVF (*vessels.mm⁻²*)	Adapazarı	17.01 (6.08)[a]	13.66 (3.89)[1]	*
	Sinop	14 (4.1)[b]	15.96 (4.88)[2]	*
RN (*ray.mm⁻¹*)	Adapazarı	8 (1.40)[a]	8.4 (1.37)[1]	*
	Sinop	7.9 (1.31)[a]	7.6 (1.04)[2]	*
URHN (*number*)	Adapazarı	7.27 (2.33)[a]	6.09 (1.914)[1]	*
	Sinop	8.21 (2.80)[b]	8.12 (4.20)[2]	ns
URHM (*μm*)	Adapazarı	123.57 (33.46)[a]	149.35 (41.16)[1]	*
	Sinop	163.63 (46.15)[b]	163.19 (76.95)[2]	ns
MRHN (*number*)	Adapazarı	13.52 (4.54)[a]	12.72 (4.09)[1]	*
	Sinop	14.86 (5.56)[b]	12.46 (4.39)[1]	*
MRHM (*μm*)	Adapazarı	262.75 (80.24)[a]	242.69 (72.22)[1]	*
	Sinop	289.76 (105.56)[b]	243.97 (81.76)[1]	*
RW (*μm*)	Adapazarı	38.84 (9.93)[a]	33.47 (7.76)[1]	*
	Sinop	33.50 (8.10)[b]	38.98 (9.10)[2]	*
EVL (*μm*)	Adapazarı	265.42 (27.56)[a]	263.60 (29.94)[1]	ns
	Sinop	296.50 (37.04)[b]	258.21 (35.85)[1]	*
LVL (*μm*)	Adapazarı	286.67 (27.73)[a]	290.90 (26.13)[1]	ns
	Sinop	326.78 (27.91)[b]	287.25 (31.60)[1]	*
FL (*μm*)	Adapazarı	1207.79 (140.25)[a]	1262.45(220.46)[1]	*
	Sinop	1147.40(203.82)[b]	1117.66(199.72)[2]	ns
FD (*μm*)	Adapazarı	23.62 (2.88)[a]	23.31 (2.53)[1]	ns
	Sinop	24.76 (3.17)[b]	24.01 (3.00)[2]	*
DFWT (*μm*)	Adapazarı	4.88 (0.72)[a]	4.94 (0.74)[1]	ns
	Sinop	4.60 (0.94)[b]	4.83 (1.02)[1]	*

*Letter indicates the significant difference between regions for natural grown NLA wood (P<0.05), Number indicates the significant difference between regions for plantation grown NLA wood (P<0.05), *indicates the significant differences betweeen natural and plantation grown NLA wood (P<0.05)*
TEVD- Tangential earlywood vessel diameter, TLVD – Tangential latewood vessel diameter, EVF- Earlywood vessel frequency, LVF- Latewood vessel frequency, RW- ray width, URHN- uniseriate ray height (number), MRHN- multiseriate ray height (number), URHM- uniseriate ray height, MRHM- multiseriate ray height, RN-number of rays per milimete, EVL- earlywood vesel length, LVL -latewood vessel lenght, FD- fiber diameter, FL- fiber length, DFWT- double fiber cell wall thickness

In Adapazarı TEVD for natural trees had higher values than planted NLA trees. Adversely, in Sinop higher values were seen in planted NLA trees. The heighest value of TLVD (47.91 µm) was determined in Adapazarı for planted NLA trees while minimum value (39.02 µm) was determined in Sinop for planted NLA trees. Güler et al. [28] reported that TEVD was 197.39 µm and TLVD was 61.12 µm for planted NLA trees with 3x2 spacing in Adapazarı and these results were higher than our results for planted NLA trees in Adapazarı and Sinop. For natural NLA trees, Bak [39] and Merev [40] found the TEVD values 55-333 µm and 227.71 µm, respectively. And for TLVD, Bak [39] and Merev [40] found 12-127 µm and 62.27 µm, respectively and all values were higher than in our study.

The maximum EVF (13.15 vessels.mm^2) was found in Sinop for natural trees while minimum value (11.29 vessels.mm^2) was found in Adapazarı for planted trees and the maximum LVF (17.01 vessels.mm^2) was found in Adapazarı for natural trees while minimum value (13.66 vessels.mm^2) was seen in Sinop for planted trees. There was significant difference between regions for natural and planted trees. Higher EVF was seen in Sinop for natural trees, and planted trees. In Adapazarı, natural trees had higher LVF and planted trees had lower LVF value. Bak [39] was found 6 and 10 vessels.mm^{-2} and Merev [40] was found 4.59 and 12.08 vessels.mm^{-2} in naturallly grown NLA, earlywood and latewood respectively. These values were lower than current study.

There was no significant difference between Adapazarı and Sinop for natural trees in ray number values. Ray number was higher in Adapazarı than Sinop for planted trees. Ray number was 8.83 ray.mm^{-1} [40] which was similar values for Adapazarı region both natural and plantation stands.

About URHN value, there was significant difference between regions for both natural and planted trees. In Sinop URHN was higher than in Adapazarı for both natural and planted trees. Planted trees had lower MRHN than natural trees for each regions. There was no significant difference between regions for planted trees whereas Sinop had higher MRHN value than Adapazarı. Merev [40] reported for natural NLA trees that MRHN was 13.60. This result was similar as current study.

There was no significant difference between natural and planted trees in Sinop for URHM values. For natural trees URHM was higher in Sinop (163.63 µm) than in Adapazarı (123.57 µm). There was significant difference between regions for planted trees. Bak [39] and Merev [40] reported that URHM was 42-212 µm and 95.89 µm for natural NLA trees. In current study all URHM values were higher than literature. MRHM was higher in natural trees (262.75 µm) than planted trees (242.69 µm) in Adapazarı and similar result was seen in Sinop (natural trees was 289.76 µm and planted trees was 243.97 µm). For natural trees MRHM was higher in Sinop (289.76 µm) than in Adapazarı (262.75 µm) whereas there was no significant difference between regions for planted trees. Güler et al. [28] were reported that MRHM was 299.73 µm for planted trees and this value was similar to natural trees in Sinop.

For natural and plantation trees there was significant difference between regions in RW values. According to this results, Adapazarı had higher RW than Sinop for natural trees while Sinop had higher RW than Adapazarı for planted trees. Merev [40] was found 39.07 µm for natural NLA trees and Güler et al. [28] was found 39.94 µm. All literature values were similar to natural trees in Adapazarı and planted trees in Sinop.

In current study, earlywood and latewood vessel lengths were evaluated seperately. In Sinop there was significant difference between natural and planted trees whereas there was no significant difference in Adapazarı for both EVL and LVL. For planted trees there was no significant difference between regions for planted trees. EVL and LVL values were higher in Sinop than in Adapazarı. In literature there was no seperation between EVL and LVL according to this reason Bak [39] was found 275 µm for natural trees and Güler et al. [28] was found 291.05 µm. It was seen that Bak [39] had similar results and Güler et al. [28] had higher values than current study.

According to regions FL values were higher in Adapazarı for natural (1207.79 µm) and planted trees (1262.45 µm) than in Sinop (FL was 1147.40 µm for natural trees and 1117.66 µm for planted trees. Lower value was found by Bak [39] (909 µm) and higher value was found by Güler et al. [28] (1292 µm).

While FD and FWT had no significant difference between natural and planted trees in Adapazarı, There was significant difference in Sinop. Bak [39] found 19 µm which was lower value than present study, Güler et al. [28] was found 24.56 µm which was similar to present study for FD. FWT was lower both (4 µm) [39] and (3.57 µm) [28].

B. PHYSICAL PROPERTIES

All physical properties andthe results of statictical analysis were given in Table 3. For both two regions (Adapazarı and Sinop), air and oven-dry density values were significant different between natural and planted trees. In Adapazarı and Sinop planted trees had higher air-dry density and oven-dry density than natural trees. There was significant difference between regions for air-dry and oven-dry densities. For natural trees, in Adapazarı (0.728 $gr.cm^{-3}$) air-dry density was higher than in Sinop (0.717 $gr.cm^{-3}$). In Sinop, air-dry density was higher than in Adapazarı for planted trees. Gürsu [41] reported that air-dry density was 0.682 $gr.cm^{-3}$ for natural NLA trees and Güler et al. [42] and Alioğulları [43] reported that air-dry density was 0.680-0.750 $gr.cm^{-3}$ and 0.680 $gr.cm^{-3}$ for planted NLA trees, respectively. Results of current study were higher than Güler et al. [42] and approximately similar to Alioğulları [43].

The variations in the wood density are due to several factors, such as genetics [9], tree growth (ring number from the pith, ring width, silviculture) [10, 11] and environmental influences (climate [12], elevation [13] and site fertility [14, 15]).

Variation in cell wall percentage is affect density and it is closely and possitively correlated with it and this is dependent on cell wall thickness, cell diameter and tissue proportions in turn [27, 44, 45]. Santini et al. [24] reported that for *Acacia marina* trees, high wood density was associated with low total vessel lumen areas and small sizes, thick-walled fibers, faster growth rates, larger tree sizes and in contrast, low density was associated with larger vessels with large lumen area, thin walled fibers, slower growth rates and small tree sizes. In current study, denser planted trees have thicker double fiber cell wall, lower earlywood frequency, higher and/or similar ray width, shorter earlywood vessels, lower multiseriate ray high number and length.

Table 3. *The mean values and statistical differences between natural and planted NLA trees in physical properties.*

Physical properties	**Region**	**Natural Mean (Std)**	**Plantation Mean (Std)**	**P**
Air-dry density	Adapazarı	0.73 (0.04)^a	0.75 (0.08)^1	*
(*g/cm^3*)	Sinop	0.72 (0.07)^b	0.81 (0.08)^2	*
Oven-dry density	Adapazarı	0.69 (0.05)^a	0.72 (0.07)^1	*
(*g/cm^3*)	Sinop	0.68 (0.07)^b	0.773 (0.07)^2	*
Shrinkage (%)	Adapazarı	10.44 (2.77)^a	10.96 (1.61)^1	*
β_t	Sinop	9.45 (1.63)^b	10.17 (1.65)^2	*
β_r	Adapazarı	5.55 (0.87)^a	5.60 (1.05)^1	ns
	Sinop	5.20 (1.12)^b	6.07 (1.04)^2	*
β_v	Adapazarı	16.40 (3.07)^a	17.00 (2.17)^1	*
	Sinop	15.08 (2.56)^b	16.70 (2.47)^1	*
FSP (%)	Adapazarı	28.43 (5.68)^a	28.95 (4.77)^1	ns
	Sinop	26.30 (4.63)^b	25.75 (3.89)^2	ns
MMC (%)	Adapazarı	98.92 (11.20)^a	102.61 (15.86)^1	*
	Sinop	108.34(16.24)^a	89.42(12.47)^2	*
Db (*g/cm^3*)	Adapazarı	0. 58 (0.03)^a	0.60 (0.05)^1	*
	Sinop	0.58 (0.05)^a	0.65 (0.05)^2	*
Vc (%)	Adapazarı	46.21 (3.13)^a	47.94 (4.32)^1	*
	Sinop	45.18 (4.48)^b	51.56 (4.69)^2	*
V_H (%)	Adapazarı	53.79 (3.13)^a	52.06 (4.32)^1	*
	Sinop	54.82 (4.48)^b	48.44 (4.69)^2	*

*Letter indicates the significant difference between regions for natural grown NLA wood (P<0.05), Number indicates the significant difference between regions for plantation grown NLA wood (P<0.05), * indicates the signiificant differences betweeen natural and plantation grown NLA wood (P<0.05)*
βt = Tangential shrinkage, βr = Radial shrinkage, βtv= Volumetric shrinkage, FSP= Fiber Saturation Point, MMC=Maximum Moisture Content, Db= Wood Basic Density, Vc = Percentage of the cell wall, V_H = Percentage of the porosity

Most studies have shown that ring porous hardwoods have frequent positive correlations between ring width and density [11, 46, 47] and ring width is attributed to the fact that earlywood zone is nearly constant from year to year and the wider rings therefore contain more dense latewood with fewer vessels

[27, 48]. In current study planted trees which has higher density have wider annual ring than natural trees for all regions [49]. At the time of formation of growth increment, the age of the cambium is also essential for wood propeties [27]. Differences on wood properties are partly the result of age effects (e.g. juvenile wood, mature wood). In that perspective, current results showed that planted trees were younger than natural trees and had the highest density in Sinop. Sinop region was in lower altitude than Adapazarı region and precipitation was higher than in Adapazarı. Result of these lower altitude and higher precipiation wood must show the lowest density but not. This may be related the soil structure. In Sinop, soil is sandy so water uptake from trees is lowest and the lowest water uptake caused highest density.

In plantation trees (in Adapazarı and Sinop), tangential, radial and volumetric shrinkages were significantly different from those of natural trees except radial srinkage in Adapazarı. All shrinkage values were significantly different between regions except volumetric shrinkage for planted trees. According to Güler et al. [42] tangential shrinkage was 7.68 % for planted trees and radial shrinkage was 5.04 % for planted NLA trees and this values were lower than current study. Moya and Munoz [50] reported that low density tend to have radial and tangential shrinking and this study was confirm this statement. Younger planted trees had higher shrinkage compared with natural trees in current study as reported in Keating and Bolza [51].They found that the younger plantation wood (<40 years) had higher shrinkage compared with older plantation trees in Fiji and Hawaii. Young trees have higher juvenile wood content. Juvenile wood has high shrinkage because of the cellulose molecules in the cell wall which are oriented at a significant angle away from long-the-grain direction [52].

FSP value was higher for natural trees (28.43 %) and planted trees (28.95 %) in Adapazarı than for natural trees (26.30 %) and planted trees (25.75 %) in Sinop. Similar result was observed by Güler et al. [42] (27.34 %).

MMC values had significant difference between natural and planted trees. According to this result, while planted trees (102.61 %) exhibited higher MMC than natural trees (98.92 %) in Adapazarı, natural trees (108.34 %) exhibited higher MMC than planted trees (89.42 %) in Sinop. There was no significant difference between regions for natural trees whereas there was significant difference between regions for planted trees. MMC was higher in Adapazarı than Sinop for planted trees. MMC was 128.26 % for *F. excelsior* [53] and 120.95 % for *F. angustifolia* [42]. These values were higher than currrent study.

Wood basic density (Db) had significant differences between natural and planted trees. Planted trees had higher basic density than natural trees for both regions. Between regions, there was no significant difference for natural trees whereas there was significant difference between regions for planted trees. Sinop region had higher basic density value (0.651 $gr.cm^{-3}$) than Adapazarı region (0.595 $gr.cm^{-3}$) for planted trees. According to current study, lower values were recorded 0.537 $gr.cm^{-3}$ by Güler et al. [42] for planted NLA trees.

There was significant difference between natural and planted NLA trees for both Vc and V_H. While Vc was higher in planted NLA trees for both regions, V_H was higher in natural trees. In Adapazarı, planted trees (47.94 %) had higher Vc value than natural trees (46.21 %) and in Sinop, planted trees (51.56 %) had higher Vc value than natural trees (45.18 %). Between regions, there was significant difference for both Vc and VH. For natural trees, Vc was lower in Sinop than in Adapazarı whereas for planted trees, Vc was lower in Adapazarı than in Sinop. These values were corrected the density values. Güler et al. [42] reported that Vc value was 42.28 % and this value was lower than current study.

C. COMPRESSION STRENGTH PARALLEL TO GRAIN

Compression strength parallel to grain was determined for natural and planted NLA trees for different regions (Table 4). According to the results, there was significant difference between natural and planted NLA trees for both Adapazarı and Sinop. Compression strength parallel to grain was 53.32 $N.mm^{-2}$ and 55.32 $N.mm^{-2}$ for planted trees in Adapazarı and in Sinop, respectively. There was no significant difference between Adapazarı and Sinop for natural NLA trees whereas there was significant difference between Adapazarı and Sinop for planted NLA trees. It was seen that Güler et al. [42] (58.64 $N.mm^{-2}$) and Alioğulları [43] (58.8 $N.mm^{-2}$) found higher strength values than present study. And compression strength parallel to grain was 52 $N.mm^{-2}$ for *F. excelsior* and 51.2 $N.mm^{-2}$ for *F. oxycarpa* [53]. Most of mechanical properties are closely correlated to density [54]. As in current study, it was shown that low density decreases the mechanical properties of NLA wood.

Table 4. *The mean values and statistical differences between natural and planted NLA trees in compression streng th parallel to grain.*

Property	Region	Natural Mean (Std)	Plantation Mean (Std)	P
Compression Strength Parallel to Grain (*N.mm^{-2}*)	Adapazarı	51.027 (5.817)^{a}	53.321 (8,437)^{1}	*
	Sinop	50.047 (8.327)^{a}	55.324 (8.906)^{2}	*

*Letter indicates the significant difference between regions for natural grown NLA wood (P<0.05), Number indicates the significant difference between regions for plantation grown NLA wood (P<0.05), *indicates the signiificant differences betweeen natural and plantation grown NLA wood (P<0.05)*

Finally, with this study, general wood properties of NLA have been examined and determined the differences between natural and planted trees.

IV. CONCLUSIONS

In this study, anatomical, physical and compression strength parallel to grain of natural and planted NLA trees which were grown in different regions were investigated.

There were significant differences between anatomical properties of natural and planted trees. EVF, URHN, MRHN, MRHM, EVL, FD values were higher in natural trees while URHM values were higher in planted trees. TEVD, LVF, RN, RW and FL values in Sinop was lower than in Adapazarı for natural trees and TEVD TLVD, RN, MRHN, EVL, LVL, FL values were lower in Sinop than in Adapazarı for planted trees. Fast-growing planted NLA trees had the lowest vessel frequency (EVF, LVF), URHN, MRHN, MRHM, EVL and FD. Anatomical properties were partially different, possibly owing to the expected variations between trees, age, region and sampling.

The significant difference in density was observed in natural and planted trees. Planted trees exhibited higher density than natural trees. Older natural trees in Sinop exhibited lower density than younger natural trees in Adapazarı while older planted trees in Sinop had higher density than younger planted trees in Adapazarı.

The statistical analyses evidenced significant differences between natural and planted trees for shrinkage property. Denser planted trees had higher shrinkage values than lighter natural trees. Shrinkage (tangential, radial and volumetric) was lower in Sinop than in Adapazarı for natural trees and planted trees except for radial shrinkage for planted NLA trees. There was no significant difference between natural and planted trees for FSP. And in Sinop FSP was lower than in Adapazarı for both natural and planted trees. Denser planted NLA trees had higher percentage of cell wall and lower percentage of porosity predictably.

Denser planted NLA trees exhibited higher compression strength parallel to grain. Planted trees had higher compression strength parallel to grain than natural NLA trees. Region effects on compression strength parallel to grain were seen on planted NLA trees.
Based on these findings, planted NLA wood which are denser than natural NLA wood indicates potantial suitability for handle tool and sport tools.

In conclusion, our data provide that all anatomic and physical properties correlate with each other and to better explain the relationship between these properties, ecological studies may be done in depth.

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