

Effects of Local Ecological Conditions on Some Anatomical Features of Black Alder (*Alnus glutinosa* Gaertn. subsp. *barbata* (C.A. Mey.) Yalt.) Wood.

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ABSTRACT

Forest trees can show different wood characteristics according to different site conditions. The changing wood properties are the quality of the wood material, and the quality determines the suitability of the wood material for a particular use place. Knowing the effect of local ecological conditions on wood properties in a growing environment can give an idea of which species can be grown in which site area. In this study, we investigated the variation of some anatomical properties of black alder wood which may be an alternative to other species in wood industry. For this purpose, 14 sample areas were taken from Arhavi-Hopa sub-region of Rize Kaçkar Mountains Site Region according to the sampling method selected from three different altitude zones (0-400 m, 401-800 m and 801-1200 m). Sample areas and sample trees have been selected among pure black alder stands at different stands that have similar aspects (north aspect). In the sample areas, one tree with dominant height was cut down and soil profiles were opened. Soil species were determined by taking samples of soil from the soil according to their depth grades. The available water capacity was calculated, soil reaction and organic matter amounts have been identified. On wood samples taken from cut trees; number of vessels, tangential diameter of vessel element, radial diameter of vessel element, vessel element length, ray length, ray width, number of rays in 1 mm, fiber length, fiber width, fiber lumen width) and fiber wall thickness were determined.
The changes of the anatomical characteristics of black alder wood according to the altitude zones were tested by analysis of variance.

Keywords: Ecological wood anatomy, Altitude, Moist environment, Soil properties.

1. INTRODUCTION

The creatures living in the forest ecosystem are directly or indirectly affected by their site area or the community. Plants, which are important components of the community, are also very sensitive to the conditions of the site conditions. During their growth, plants undergo the influence of different internal and external conditions, resulting in differences in structure and characteristics (Tessier et al. 1994; Roo-Zielinska & Solon 1997; Wodzicki 2001). In addition to the structural changes in a tree, differences in the wood properties can be seen in the two trees of the same species growing in the same stand, with the influence of environmental factors (Bozkurt & Erdin 2000). In order to understand the change in wood properties, various internal and external factors affecting the tree during growth should be analyzed very well. The change of one or more of these factors has an effect on the technological and anatomical characteristics of wood depending on the growth rate of the tree (Merev et al 2000).
The average temperature and precipitation amount among the ecological factors affect the annual ring width and radial growth of the tree. In addition, these factors cause changes in the annual ring structure because they are not constant during the life of the tree (Lara et al, 2001:Takahashi et al.2005: Cufar et

al, 2008: Gea-Izquierdo et al, 2012). Recent studies have also demonstrated the effects of temperature change on xylem phenology (Rossi et al. 2011).

Water availability is another important influencing factor linked to cambial activity and wood formation (Giovannelli et al. 2007; Camarero et al. 2010). In areas with high altitudes, severe environmental conditions such as low temperatures, strong winds, snowfall and short vegetation periods have been shown to reduce the radial growth of the tree (Coomes & Allen 2007; Gebauer et al. 2010). Again, depending on these conditions, the cell dimensions on the sides of the trees facing different directions are different from each other (Bozkurt & Erdin 2000).

Much research has been done to date to show the change of wood structure according to environmental and geographical factors. Ecological factors related to climate, such as water relations, photoperiod, physical and chemical properties of soil, in addition to physiographic characteristics of the site, significantly influence the morphology and anatomy of plants (Olsen et al. 2013; Cutter et al. 2004; Rigatto et al. 2004). The effects of altitude difference (Hosseini 2006; Barij et al. 2007; Kiaei & Samariha 2011; Kiaei 2011), temperature (Olano et al. 2012; Thomas et al. 2007) and water availability (Campbell et al. 2015) on forest plants have been discussed in many studies. Temperature can become an important limiting factor for tree growth at high latitudes or high altitudes, affecting anatomical properties (Vaganov et al. 2006). In a few studies, on tree-ring formation have tested the effects of avaliable water capacity on intraannual wood properties in natural arid or semiarid areas (de Luis et al. 2011), in manipulated natural environments (Belien et al. 2012), and under controlled conditions (Balducci et al. 2013).

A successive number of studies has focused on the fundamental relationship between different vessel elements and their function and importance for ecological strategy in temperate and tropical trees (Preston et al. 2006; Sperry et al. 2006; McCulloh et al. 2010). Other studies searched species main differences in vessel elements in relationship to moistness or drought (Choat et al. 2007; Martínez-Cabrera et al. 2009; Bosio et al. 2010). Additionally wood density has become ever important in studies on living strategy in trees from the tropics (Müller-Landau 2004).

A recent study it was investigated on the inter species variation of anatomical features within a tropical environments (Poorter et al. 2010). And also, the effects of soil properties such as physical and chemical have been discussed in many studies. Variations in wood anatomy or quality with tree growth are relationship of the soil characteristics(Rigatto et al. 2004; Malkocoglu 2012; Birtürk 2011). A low wood density may be acquired on sites with favourable soil properties for stand growth (particularly tree diameter) with a consequent low quality for structural uses (Cutter et al. 2004). And more, few studies declareted the effects of soil some properties on wood quality (Aguilar-Rodriguez et al. 2006).

Several investigations have been conducted in order to correlate anatomical wood traits to environmental characteristics. Some authors studied that several wood features respond to abiotic conditions such as: variations in diameter, length and frequency of vessels (Carlquist 2001; Luchi 2004; Bosio et al. 2010; Melo Júnior et al. 2011); length and width of fiber walls (Luchi 2004); presence of growth rings (Alves & Angyalossy 2000) while some authors biotic conditions such as: climate, climate change and site conditions (Eilman et al. 2013; Meena & Gupta 2014; Fichtler & Worbes 2012)

In Turkey the first study subjected to wood formation and different environments was conducted by Yaltırık (1971) on Acer L., and later Şanlı (1978) made a great study on Fagus orientalis Lipsky. In recent years ecological wood anatomy studies getting extended throughout Turkey and performed studies in species, genus or family levels (Gerçek et al. 1998; Kutbay et al. 1999; Merev & Yavuz 2000; Serdar 2003; Yaman & Sarıbaş 2004; Akkemik et al. 2007; Birtürk 2011; Erşen Bak 2006; Bozlar 2012; Malkocoglu 2012; Cihan & Akkemik 2013; Bozlar et al. 2014; Usta et al. 2014a; Usta et al. 2014b).

The anatomical characteristics of wood are thought to be the overall effect of altitude, aspect, land surface shape, land slope and soil characteristics and local climatic conditions in the local environmental factors in the changing environment according to the ecological conditions of the site. Trying to explain the possible changes in Wood's anatomical characteristics with just elevation factor can sometimes be misleading. In this study which is done within the scope of ecological wood anatomy, it was aimed to reveal the anatomical characteristics of black alder wood according to the growth environment factors and to suggest appropriate usage areas related to this species in the direction of the findings obtained. Alder is used in many fields including furniture, chipboard, packaging industry, plywood, coating and mould industry (Akyüz 1998).

2. MATERIAL AND METHODS

Description of the research area

The research area is located in the Rize Kaçkar Mountains site area of the Eastern Black Sea Region (Kantarcı 2005). This area is between 41 ° 18 ' 10 - 41 ° 31 ' 51 east longitudes and 41 ° 31 ' 51 - 41 ° 24 '

40 north latitudes (Figure 1). The research area has a significant impact on plant development in the immediate range of elevations and short altitudes, as it makes the aspect and slope differences more apparent due to its rugged structure. The research area, which also has a marine influence and is mostly affected by orographic precipitation, is the region with the highest precipitation in the country.

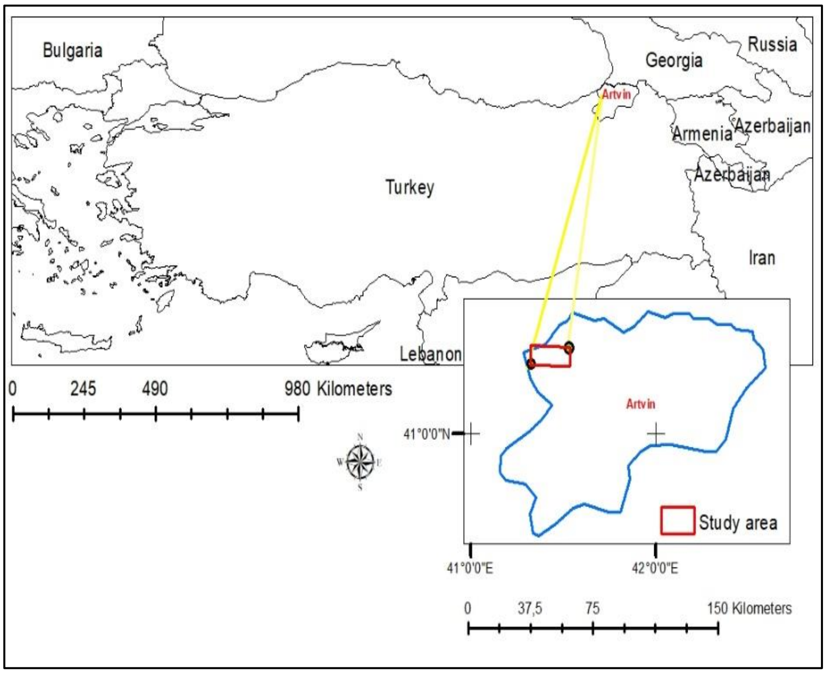

Figure1. Locations of the research field

Climate characteristics are the most important site factor in the species composition and distribution of plant communities. In order to determine the climatic type of the study area and evaluate its ecological results, a water balance was established using the meteorological data related to the research area (Thornthwaite 1948).

For this purpose, some climate data related to the altitude zones of the study area were obtained by interpolating the temperature and precipitation variables obtained from the nearest meteorological station (Hopa: 33 m) to the average of the altitude zones (200 m - 600 m - 1000 m) previously determined.

Table 1. Some climate features related to altitude zones

Climate properties	Altitude Zones		
	0-400 m	401-800 m	801-1200 m
Water economy	Very moist	Very moist	Very moist
Mean altitude (m)	200	600	1000
Annual toal precipitation (mm)	2334,8	2585,0	2853,2
Precipitation in vegetation period (mm)	1562,3	1331,1	1460,7
Mean annual tempeature (°C)	13,4	11,4	9,4
Actual evapo-transpiration (mm)	731,6	669,6	611.5
Water surplus (mm)	1603,2	1924,4	2241,6

Sample collection

The research area is divided into three altitude zones, from 0-400 m, 401-800 m and 801-1200 m. From these altitude zones, sample areas were determined at 14 points according to the selected sampling method. Care has been taken to ensure that the sample areas are in the normally covered alder stands. From the determined areas, a tree near the diameter of the stand centre tree was marked after the north direction, and wood samples were taken from the chest height. In addition, the local site factors (slope, aspect, land surface position, altitude) of each area are recorded and the soil profile is opened at each point. Disturbed soil samples were taken from the opened soil profiles, according to depths. Site characteristics for altitude zones are given in Tables 2 and 3.

Methods

The particle size of the soil samples (sand, silt and clay ratios) was determined by hydrometer method. For soil texture (Tommerup 1934), soil triangle was used. The field capacity and wilting point were determined by the pressure table method. The available water capacity is calculated by taking advantage of the difference between field capacity and wilting point. Soil reaction (pH) was determined by a wet-burning organic carbon Walkley-Black method using 1: 2.5 soilwater solution using glass electrode (Kantarcı 2005).

From the wood samples taken for anatomical measurements, cross sections were taken with the "Reichert" slide microtome device in the direction of the fibres. The Schultze method (Potassium Chlorate-Nitric Acid), which causes less damage to the tissue elements, has been used to release the Wood elements. On Wood preparations; number of vessels (NV), tangential diameter of vessel element (TDV), radial diameter of vessel element (RDV), vessel element length (VL), ray length (RL), ray width (RW), number of rays in 1 mm (NR), fiber length (FL), fiber width (FW), fiber lumen width (FLW) and fiber wall thickness (FWT) were measured on the wood elements liberated by maceration. Measurements and counts were made 25 times again. In the measurements and censuses, Carlquist 25 is based on the IAWA Committee 25-50 (Carlquist 1988; Committee on Nomenclature 1989). A correlation analysis was performed for the relationship between the anatomical characteristics of Black Alder wood and ecological factors. One-way analysis of variance (One-Way ANOVA) was used to determine the difference in altitude zones of these anatomical features (Kalıpsız 1981).

3. RESULTS AND DISCUSSION

Results Related to Local Site Environment Factors

In the study area where the physical properties of the soil were different according to the altitude zones, in the sample areas at the 1st altitude zone (AZ I), the sandy clay soils are dominant and the soil texture of the sample area at 390 m altitude is clayey. In the second altitude zone (AZ II) specimens, clayey clay soils are dominant and the soil texture heavy clay in the sample area at 560 m altitude and the soil texture at 600 m altitude is sandy clay. The soils of the sample areas at the third altitude zone (AZ III) are mostly clayey clay and heavy clay types and at 845 and 890 m altitudes, sandy-clay soils are dominant. From the lower altitude zones towards the upper altitude zones, it is understood that the average amount of clay in the soil increases, the amount of sand decreases, and a little thinner textured soil develops. Soils are very humid in terms of water economy and sample areas in the first altitude zone have medium acidity and sample areas in AZ II and III have severe acidity according to the average soil reaction values (Table 2).

Table 2. Soil texture and average soil properties for the altitude zones

Altitude Zones	Altitude (m)	Sand (%)	Silt (%)	Clay (%)	Soil texture*	AWC (%)	pH (1/2.5 soil/water)	OM (%)
I	300	80	6	14	Sandy loam	8,34	5,90	2,18
	365	75	14	11	Sandy loam	13,22	5,16	3,04
	390	54	20	26	Loamy clay	20,10	4,22	4,92
II	560	28	20	52	Heavy clay	17,24	4,69	1,51
	600	75	17	18	Sandy loam	22,24	4,69	7,05
	740	47	22	31	Loamy clay	19,0	3,91	4,39
	760	66	17	17	Loamy clay	22,10	4,30	6,52
III	840	54	16	30	Loamy clay	15,24	5,78	2,35
	845	66	14	20	Sandy clay loam	21,62	4,49	4,81
	890	64	15	21	Sandy clay loam	11,00	3,86	5,75
	930	49	17	34	Loamy clay	10,40	4,95	4,81
	960	35	20	45	Heavy clay	20,70	4,80	1,45
	980	34	24	42	Loamy clay	12,78	3,91	4,02
	1070	47	21	32	Loamy clay	20,18	4,82	3,52

AWC: Available water capacity, pH: Soil reaction, OM: Organic matter. *: Each sample area is given the texture of soil that is dominant.

Considering that the specific local climatic conditions of the research area will affect the wood properties of the trees together with the soil characteristics, the change of soil properties according to the altitude zones is important for the evaluations to be made. The change of soil properties was tested by analysis of variance. As a result of the analysis, other soil characteristics and slope, except organic matter, were different according to altitude zones (Table 3).

Table 3. Results of variance analysis on site characteristics

Soil characteristics	Altitude zones		Mean ± Std. Dev.	F ratio	Sig.level (*p*)
	I	(0-400 m)	70 ± 12 b		
Sand (%)	II	(401-800 m)	54 ± 19 a	14.79	0,001
	III	(801-1200 m)	50 ± 15 a		
	I	(0-400 m)	13 ± 6 a		
Silt (%)	II	(401-800 m)	19 ± 5 b	10.62	0,001
	III	(801-1200 m)	18 ± 6 b		
	I	(0-400 m)	17 ± 8.0 a		
Clay (%)	II	(401-800 m)	27 ± 17 b	11.62	0,001
	III	(801-1200 m)	32 ± 11 b		
	I	(0-400 m)	31 ± 13 a		
(Clay+Silt)	II	(401-800 m)	44 ± 19 b	14.48	0,001
	III	(801-1200 m)	50 ± 15 b		
	I	(0-400 m)	5.09 ± 0.8 b		
Soil reaction (pH)	II	(401-800 m)	4.56 ± 0.7 a	4.75	0,010
	III	(801-1200 m)	4.65 ± 0.8 a		
	I	(0-400 m)	14.00 ± 5.6 a		
Available Water Capacity (%)	II	(401-800 m)	20.12 ± 3.1 b	13.67	0,001
	III	(801-1200 m)	16.00 ± 5.9 a		
	I	(0-400 m)	3.38 ± 2.4 a		
Organic Matter (%)	II	(401-800 m)	4.87 ± 3.5 a	2.06	0,130
	III	(801-1200 m)	3.81 ± 3.0 a		
	I	(0-400 m)	40 ± 19 b		
Slope (%)	II	(401-800 m)	34 ± 11 a	72.30	0,001
	III	(801-1200 m)	50 ± 16 c		

Results related to anatomical features

One-way ANOVA was performed to determine the differences in the anatomical characteristics of Black Alder wood according to altitude zones. The mean values of some anatomical features of alder wood (NV, RDV, RL, RW, FL, FLW, FWT) differed according to altitude zones ($p<0.05$, $p<0.01$, $p<0.001$) (Table 4). Among the anatomical features showing significant differences, NV value varies in AZ I, II and III, 90, 93 and 88, respectively. Wood's RDV is reduced as the AZ I goes towards AZ III and ranges from 58.06 µm, 53.40 µm and 51.00 µm. In terms of NV, AZ I and AZ III are in the same group and AZ II is different. Looking at the change of TDV, it is seen that there is a decrease according to altitude zones (Table 5).

In the change of NV between the wood elements, the amount of water retained in the soil, the available water capacity (AWC) and the amount of precipitation are influential. In a majority of the studies performed, it was determined that NV in the unit area was an increase due to altitude increase (Noshiro et al. 1995; Serdar 2003; Lens et al. 2004; Erşen Bak 2006; Serdar & Gerçek 2007; Fisher et al. 2007; Yaman 2008; Yilmaz et al. 2008; Birtürk 2011; Bozlar 2012). Depending on the increase in altitude, in response to the drop in temperature, plants are increasing their numbers by reducing tracheal diameters to ensure safety in water transmission (Carlquist 1988; Erşen Bak 2006; Markesteijn et al. 2011; Scholz et al. 2014). Thus, the density of vessels also affects hydraulic conductivity and vulnerability to embolism (Martinez et al. 2012). However, it is still not right to generalize that the increase in the number of tracheas depends on the increase in altitude. Sometimes, besides the decreasing temperature due to the increase of the altitude, other factors may also occur which affect the water intake from the soil. It is also very important that the altitude change between the boundaries. In the study area, it is supported by this judgment that in the AZ II, the average temperature value of the vegetation period (16.4 ^{o}C) is not low enough to enhance water uptake. Also, at this altitude zone, it is noteworthy that the AWC is at its highest. According to many studies done, the increase of VL, TDV and RDV, the decrease of NV (February et al. 1995; Malan 1991; Searson et al. 2004) It was. It has been determined that NV increases, VL, RDV and TDV decrease (Wilkins et al. 1989), depending on the increase in the drought. In AZ III, NV and RDV in the unit area decrease. It is believed that such an outcome due to the increase of the altitude is due to the local climate conditions and the topographic and edifical features.

The place where the work is done is the highest precipitation area in my country. In a research area where a very moist climate type dominates, during the vegetation period, both the soil is saturated and the amount of precipitation is high. Humid air masses are present intensively in the research area, which is affected by the sea and is mainly fed by slope precipitation, especially in the AZ III, above the forest ecosystems where the sample areas are located, during the vegetation period. During the vegetation period, the soil water is saturated and the precipitation falling in the area is higher than the evapotranspiration (Table 1). In addition, the decrease in the amount of sand and the increase in the amount of clay in the sample areas in AZ III (Table 3) also make it difficult to remove the excess water in the soil. Despite the accumulation of excess water in the root zone and the covering of photosynthetic organs with moist air masses, the trees have reduced NV and RDV in the area in order to ensure safety in water transmission. In the study area, the AWC increased first, then decreased after the increase of the altitude, due to the amount of organic matter decreasing in the soil and the increasing amount of clay + silt. As the altitude increases, it is known that the AWC is decreasing (Yılmaz 2005). In general, the negative correlation between AWC and NV is frequently mentioned (Yılmaz et al. 2008; Birtürk 2011). In this study, a negative correlation was found between the AWC and NV in the unit area (Table 5).

In AZ III, NV decreased with the decrease of AWC. Even though the AWC amount is reduced compared to the AZ II, the NV has decreased because of the presence of sufficient water in the soil. This idea also supports the topographical and edaphic conditions of the research area. Yet, due to the dominance of coarse soils in the middle in AZ I, the free-flowing water and the evapotranspiration which will be realized more than the AZ II, the plants naturally increased trachea numbers for water intake safety. In addition to the survey (Zhang et al. 1998, Sarıbaş & Yaman 2009), studies on elevation and NV are not related to the increase in altitude in NV (Gerçek et al. 1998; Erşen Bak 2006) has. Another important issue that will explain the decrease in NV in AZ III is that the amount of precipitation falling at the altitude zones are different. The AZ II has an average 2200 mm of precipitation, but the AZ III has an average of 2663 mm of precipitation (Table 1). In the AZ III where the amount of precipitation is increased, the NV in the unit area is the least. With the increase of precipitation, it can be said that there is a decrease in NV. There is a negative correlation between the increase in the precision and NV (Moya & Fo 2007).

There is no difference in altitude zones in the VL between wood elements. VL is 886.1 µm in AZ I, 856.2 µm in AZ II, and 884.3 µm in AZ III. According to the altitude zones, the VL showed a decrease before and then an increase. There is a positive correlation between VL and the amount of water that wood can have (Topaloğlu 2013). As in this study, according to the altitude zones, a similar situation to the VL change is also true for Oriental beech taxa taken from northern slopes in Sinop Ayancık region. Topaloğlu (2013) found the THUs in the beech wood samples taken from four different altitude zones between 400-1200 m altitudes as 585,975 µm, 583,077 µm, 588,294 µm and 609,449 µm, respectively. That is, as the level increases, VL generally increase. Patterson and Tanowitz (1989) reported that VL is positively associated with the altitude in only one of the species studied. In the literature, besides the studies indicating that negative correlations between altitude, wood and VL (Noshiro et al. 1995; Gerçek et al. 1998; Yilmaz et al. 2008; Noshiro et al. 2010; Genç 2010), there are studies that did not find any correlations (Liu & Noshiro 2003; Lens et al. 2003; Pande et al. 2005). Again, there was no correlation between altitude and VL in this study (Table 5).

According to altitude zones, the anatomical characteristics of wood are different in RL and RW (Table 5). There were three different homogeneous groups in terms of RW in terms of two RLs. II. and the sample areas in AZ III are in the same homogeneous group in terms of RL, the sample areas in AZ I have different groups. RL decreases from AZ I (255 µm) to AZ II (223.5 µm), while AZ III increases (229.3 µm). In the transition from AZ II to AZ III, this increase in RL and RW may have been due to a gradual decrease in tracheal diameters between altitude zones. In general, as altitude zone increases, RL and RW decrease. As can be seen from Table 5, there is a negative correlation between altitude zones and RW Negative correlations between Altitude and RW are common (Noshiro & Suzuki 1995; Erşen Bak 2006; Birtürk 2011).

Table 4. Results of variance analysis on anatomical features

Anatomic properties	Altitude zones		Mean ± Std. Dev.	F ratio	Sig.level (*p*)
NV (1 mm^2)	I	(0-400 m)	90 ± 16 a	5.797	*0,003**
	II	(401-800 m)	93 ± 15 b		
	III	(801-1200 m)	88 ± 17 a		
NR (1 mm)	I	(0-400 m)	11±2 a	1.650	0,193
	II	(401-800 m)	11±2 a		
	III	(801-1200 m)	11±2 a		
RDV (µm)	I	(0-400 m)	49.4 ± 10.3 a	0.325	0,722
	II	(401-800 m)	51.2 ± 10.3 a		
	III	(801-1200 m)	51.2 ± 11.9 a		
TDV (µm)	I	(0-400 m)	58.02 ± 24.3 b	6.519	*0,002***
	II	(401-800 m)	54.18 ± 18.8 a		
	III	(801-1200 m)	51.00 ±19.3 a		
RL (µm)	I	(0-400 m)	255.0 ±102.9 b	4.495	*0,011**
	II	(401-800 m)	223.5 ± 99.0 a		
	III	(801-1200 m)	229.3 ±107.4 a		
RW (µm)	I	(0-400 m)	17.07 ± 2.19 c	49.026	*0,001***
	II	(401-800 m)	15.65 ± 1.96 a		
	III	(801-1200 m)	16.12 ± 2.50 b		
VL (µm)	I	(0-400 m)	886.1 ± 142 a	2.420	0,090
	II	(401-800 m)	856.2 ± 135. a		
	III	(801-1200 m)	884.3 ± 171. a		
FL (µm)	I	(0-400 m)	1248.9 ± 169.9 a	3.507	*0,030**
	II	(401-800 m)	1260.0 ± 160.8 a		
	III	(801-1200 m)	1294.3 ± 234.2 b		
FW (µm)	I	(0-400 m)	25.70 ± 4.15 a	0.696	0,499
	II	(401-800 m)	26.37 ± 4.24 a		
	III	(801-1200 m)	26.75 ± 4.16 a		
FLW (µm)	I	(0-400 m)	15.68 ± 4.13 a	6.496	*0,002**
	II	(401-800 m)	17.09 ± 4.09 b		
	III	(801-1200 m)	16.20 ± 3.71 a		
FWT (µm)	I	(0-400 m)	5.00 ± 1.40 b	16.935	*0,001***
	II	(401-800 m)	4.63 ± 1.13 a		
	III	(801-1200 m)	5.27 ± 1.25 c		

NV (1mm^2) : number of vessel; NR: number of rays; TDV: tangential diameter of vessel element; RDV: radial diameter of vessel elements; VL: vessel element length; RL: Ray length; RW: ray width; FL: fiber length; FW: fiber width, FLW: fiber lumen width; FWT: fiber wall thickness.

When the variation of the FL according to the altitude zones is examined, it is seen that as the altitude increases, FL also increases (1248.9 µm, 1260.0 µm, 1294.3 µm) and two different homogeneous groups emerged. Sample areas in AZ I and II were in the same homogeneous group with respect to FL, while sample areas in AZ III formed different groups. Correlation analysis showed a positive correlation between altitude and FL ($p<0.05$, $r=0.102$). Many studies have also reported negative correlations between FL and altitude (Erşen Bak 2006; Serdar & Gerçek 2007; Hemmasi et al. 2007; Kiaei 2011; Topaloğlu 2013). Studies that have not found a correlation between FL and altitude are also common (Liu & Noshiro 2003; Lens et al. 2003; Pande 2005; Aguilar-Rodriquez 2006; Hosseini 2006). In this study, contrary to the prevailing opinion in the literature, an association between FL and altitude are due to local ecological conditions. The precipitation, the duration of insolation, the average temperature and the number of overcast days during the vegetation period are not similar to the study area, in any of the above studies where negative correlations between altitude and FL were found. I mean, every research area has its own ecological conditions. In the study area, the mean precipitation during the vegetation period was 1331.1 mm and 1460.7 mm at the upper altitude zones, and the average temperature during the vegetation period was 16.4 ^{o}C and 14.4 ^{o}C.

Table 5. Results of correlation analysis

	Altitude (m)	NV	NR	TD	RDV	RL	RW	VL	FL	FW	FLW	FWT	pH	AWC
NV (1mm2)	-0,108**													
NR (1mm)	-0,102**	0,002												
TDV (µm)	0,091*	-0,065	-											
RDV (µm)	-0,133**	-0,053	-0,029	0,472*										
RL (µm)	-0,049	-0,056	-0,060	0,034	-0,055									
RW (µm)	-0,281**	-0,032	-0,071	-0,030	-0,038	0,396*								
VL (µm)	0,030	0,075*	0,123*	0,019	-0,013	0,060	0,046							
FL (µm)	0,102**	0,142**	0,086*	0,113*	-0,008	0,047	0,011	0,200**						
FW (µm)	0,049	-0,060	-0,029	0,072	0,076*	-0,029	0,016	0,035	0,106**					
FLW (µm)	0,038	-0,113**	0,002	0,121*	0,133**	-0,027	0,005	0,082*	0,164**	0,795*				
FWT (µm)	0,021	0,075*	-0,050	-0,069	-0,079*	-0,005	0,019	-0,067	-0,078*	0,392*	-0,246**			
pH	-0,302**	0,296**	0,279*	-0,027	0,090	0,225*	0,213*	0,361**	0,208*	-0,024	-0,088	0,094		
AWC (%)	0,128	-0,246**	-0,071	0,176*	0,082	-0,128	-0,178*	0,003	0,040	-0,034	0,131	-0,252**	-0,136	
Slope (%)	0,283**	0,426**	-0,035	-0,053	-0,215**	0,091*	-0,083*	0,188**	0,167**	-0,028	-0,162**	0,201**	0,251**	-0,567**

NV (1mm2) : number of vessel; NR: number of rays; TDV: tangential diameter of vessel element; RDV: radial diameter of vessel elements; VL: vessel element length; RL: Ray length; RW: ray width; FL: fiber length; FW: fiber width, FLW: fiber lumen width; FWT: fiber wall thickness; pH: soil reaction; AWC: avaible water capacity. ** p< 0.01, *p<0.

However, Hemmasi et al. (2007) and Kiaei (2011), the annual average total precipitation is 1300 mm and 1248.5 mm, and the average annual temperature is around 16 ºC. Yet, due to the increase in the amount of precipitation, it has been determined that the FL increases (Parra et al. 2013; Noshiro & Baas 2000). However, in the FL, there may not always be an increase due to the increase in the amount of precipitation. No matter how much the amount of Precipitation is, if the water entering the soil is not retained, so, if a humid environment is not established, the plants will not be able to benefit from the precipitation water sufficiently. Despite the high amount of precipitation, the FL has been significantly reduced in local ecological conditions where medium and coarse textured permeable soils exist (Usta et al 2014a).

When the variation of FW according to altitude zones were examined, values of 25.70 µm, 26.37 µm and 27.75 µm were found, respectively. It can be said that FW increases slightly as the altitude increases. However, this change did not make a difference between the altitude zones. With decreases in diameters of vessel, FW may be considered to have decreased. As elevation increases, there are studies that FW has decreased (Kiaei 2011; Erşen Bak 2006).

FLW is 15.68 µm in AZ I, 17.09 µm in AZ II and 16.20 µm in AZ III. The sample areas in AZ I and II were in the same homogeneous group for FLW, while the sample areas in AZ III formed different groups. Negative correlations between elevation and FLW have been reported (Erşen Bak 2006; Pourtahmasi 2011; Barij et al. 2007). In this study, there was no correlation between elevation and FLW, as in Moya and Fo (2008) and Topaloğlu (2013) studies.

FWT is 5 µm in AZ I, 4,63 µm in AZ II and 5,27 µm in AZ III. Three homogeneous groups were formed in terms of FWT. FLW and FWT are inversely proportional (Table 5). A similar relationship is also mentioned in several studies in the literature (Kiaei & Samariha 2011; Roque & Filho 2007; Topaloğlu 2013).

Correlation analysis revealed significant relationships between LLG and LCK ($p < 0.001$, $r = 0.795$ and $p < 0.001$, $r = 0.392$). As stated in the literature (Serdar 2003; Erşen Bak 2006; Birtürk 2011), as LG increases, LLG also increases. In addition, LCK increased with increasing LG, LCK decreased with increasing LLG (Kiaei & Samariha 2011).

4. CONCLUSIONS

Wooden quality is the criterion that determines the suitability of the wood material for a particular use area. Quality should be determined according to the places of use of wood. A feature sought for any place of use may not be preferred at other places of use. There are many factors that determine the suitability of a wood material for a place of use. Density, uniformity of annual rings, heartwood ratio and lengths of fibres are just a few of these factors. The proportions of the members of the wood structure change the mechanical and physical properties of the wood considerably, affecting the texture and structure of the wood. Increased trachea, parenchyma and thin-walled fibre content in the wood reduce wood density. Increasing the wall thickness increases the hardness of the wood. Generally, due to wall thickening, the mechanical and technological properties of wood also increase. Softwoods and light woods can be used in the furniture industry and in the coating industry. Wood's physical properties are closely related to cell structure and the rate of cell type participation in tissue. It is known that the most important among these physical properties is density.

The properties of wood material vary from tree to tree, depending on the type of wood and even different parts of the tree species. In this situation, internal and external factors are influential. Depending on internal and external factors, the woods of individuals of the same tree species in different sites may gain different characteristics. The subject of your research, Blak Alder wood, has a scattered array of macroscopically scattered traces. Density in scattered woods varies depending on the relationship between vessel and fiber wall ratios. Essentially, the change in cell wall thickness is an important factor in increasing density. Also, during the vegetation period, depending on the amount of precipitation falling into the stand, the annual rings may narrow and expand. This change in annual rings affects the intensity of wood. As a result of the annual ring narrowing, density increases in wood. In wood material, wood density is the most influential feature of resistance. In particular, it is known that species with low resistance or long fibres are preferred for papermaking. In the study area, it is seen that RDV and FL increased and two different homogeneous groups were formed due to the increase of a elevation. Towards the upper elevation levels, the increase in RDV indirectly reduced wood density and increased fiber length.

In the direction of these findings obtained from the Black Alder stands in the Artvin - Arhavi sub-region, woods from the upper altitudes (> 600 m) are thought to be more suitable for papermaking. Therefore, regardless of the purpose of use, wood production for different uses can be realized from the same kind of tree, under the influence of external factors. For example, significant adjustments can be made to certain wood properties by adjusting the distance between trees, artificially pruning or providing adequate nutrients and water.

In ecological wood anatomy studies where the effects of site conditions on the anatomical characteristics of the wood are revealed, it is sometimes misleading to make conclusions and assessments based only on altitude and latitude grades. It would be more appropriate to link the results and the evaluations to be made to altitude by taking into account the similarity, topographical and local climatic conditions.

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References

Aguilar-Rodriguez S., Terrazas T., Lopez-Mata L. (2006): Anatomical Wood Variation of Buddleja cordata (Buddlejaceae) Along its Natural Range in Mexico. *Trees*, 20, 253-261.

Akkemik Ü., Efe A., Kaya Z., Demir D. (2007): Wood anatomy endemic Rhamnus species in the Mediterranean region of Turkey. *IAWA Journal*, 28(3): 301-310

Akyüz M. (1998): Alder wood properties and usage properties, K.T.Ü. Forestry Faculty, Forest Property Problems Symposium, October, Trabzon, Proceedings Book. (In Turkish)

Alves E.S. & Angyalossy-Alfonso. (2002): Ecological trends in the wood anatomy of some Brazilian species. 2. Axial parenchyma, rays and fibres. *IAWA Journal* 23(4):391-418.

Balducci L., Deslauriers A., Giovannelli A., Rossi S., Rathgeber B.K.C. (2013): Effects of temperature and water deficit on cambial activity and woody ring features in Picea mariana saplings. *Tree Physiolgy*. 33: 1006-1017.

Barıj N., Stokes A., Bogaard T., Van Beek R. (2007): Does Growing on A Slope Affect Tree Xylem Structure and Water Relations?, *Tree Physiology*, 27, 757-764.

Belien E., Rossi S., Morin H., Deslauriers A. (2012): Xylogenesis in black spruce subjected to rain exclusion in the field. *Can. J. For. Res*. 42, 1306–1315.

Birtürk T. (2011): Wood anatomıcal characteristics of natıve maple tree (Acer l.) taxa of Black Sea regıon and the effetcs of different growth environments on these characteristics. PhD Thesis, Karadeniz Technical University, Graduate School of Natural and Applied Sciences. (In Turkish)

Bosio F., Soffiatti P., Torres Boeger M.R. (2010): Ecological wood anatomy of Miconia sellowiana (Melastomataceae) in three vegetation types of Paraná State, Brazil. *IAWA Journal*, 31: 179–190.

Bozkurt A., Y. & Erdin N. (2000): Wood Anatomy, Istanbul University, Publication No: 4263, Faculty Publication No: 466, Istanbul. (In Turksih)

Bozlar T. (2012): Wood anatomical characteristics of native beech (*Fagus orientalis* Lipsky) taxa of Sinop area and the effects of different growth environments on these characteristics. MSc Thesis, Karadeniz Technical University, Graduate School of Natural and Applied Sciences. (In Turkish)

Camarero J.J., Olano J.M., Parras A. (2010): Plastic bimodal xylogenesis in conifers from continental Mediterranean climates. *New Phytol*, 185:471–480.

Campbell G., Rabel. R.G., Da Cunha M. (2016): Ecological significance of wood anatomy of Alseis pickelii Pilg. & Schmale (Rubiaceae) in a Tropical Dry Forest. *Acta Botanica Brasilica*, 30: 124-130.

Carlquist S. (1988): Comparative Wood Anatomy, Springer-Verlag LTD, London, 436 p.

Carlquist S. (2001): Comparative wood anatomy. Systematic, ecological and evolutionary aspects of dicotyledon wood. Berlin, Germany. Springer-Verlag. 448 p.

Choat B., Sack L., Holbrook N.M. (2007): Diversity of hydraulic traits in nine Cordia species growing in tropical forests with contrasting precipitation. *New Phytol*. 175: 686–698.

Cihan C. & Akkemik Ü. (2013): Ecologıcal wood anatomy of some maquıs specıes naturally grow ın both medıterranean and black sea regıons of Turkey. *Eurasian Journal of Forest Science*, 1: 20-37

Committee on Nomenclature, 1989. IAWA List of Microscopic Features for Hardwood Identification, *IAWA Bull,* 10*:* 219-332.

Coomes, D.A. & Allen, R.B. (2007): Effects of size, competition and altitude on tree growth. *Journal of Ecology*, 95, 1084–1097.

Cufar K., Prislan P., De Luis M., Gricar J. (2008): Tree-ring variation, wood formation and phenology of Beech (Fagus sylvatica) from a representative site in Slovenia, SE Central Europe, *Trees*, 22, 749-758.

Cutter B.E., Coggeshall M.V., Phelps J.E., Stokke D.D. (2004): Impacts of forest management activities on selected hardwood wood quality attributes: a review. *Wood and Fiber Science*, 36: 84–97.

de Luis M., Novak K., Raventós J., Gricard J., Prislan P.,Cufar K. (2011): Climate factors promoting intra-annual density fluctuations in Aleppo pine (*Pinus halepensis*) from semiarid sites. *Dendrochronologia*, 29:163–169.

Eilmann B, de Vries S., den Ouden J., Mohren G., Sauren P., Sass-Klaassen U. (2013): Origin matters. Difference in drought tolerance and productivity of coastal Douglas-fir (*Pseudotsuga menziesii* (Mirb.)) provenances. *Forest Ecology and Management*, 302:133–143

Erşen Bak F. (2006): Ecological wood anatomy of a growing family of Oleaceae taxa Turkey, PhD Thesis, Karadeniz Technical University, Institute of Science and Technology, Trabzon. (In Turkish).

February E.C., Stock W.D., Bond W.J., Le Roux D.J. (1995): Relationships between water availability and selected vessel characteristics in Eucalyptus grandis and two hybrids. *IAWA Journal*, 16, V, 269-276.

Fichtler E. & Worbes M. (2012): Wood anatomical variables in tropical trees and their relation to site conditions and individual tree morphology. *IAWA Journal*, 33:119–140.

Fisher J.B., Goldstein G., Jones T.J., Cordell S. (2007): Wood vessel diameter is related to elevation and genotype in the Hawaiian tree metrosideros polymorpha (Myrtaceae), *American Journal of Botany*, 94 (5): 709-715.

Gea-Izquierdo G., Fonti P., Cherubini P., Martin-Benito D., Chaar H., Canellas I. (2012): Xylem hydraulic adjustment and growth response of Quercus canariensis Willd. to climatic variability, *Tree Physiology*, 32, 401-413.

Gebauer R., Volarik D., Funda T., Fundova I., Kohutka A., Klapetek V., Martinkova M., Anenkhonov O. A., Razuvaev A. (2010): Pinus pumila growth at different altitudes in the svyatoi nos peninsula (Russia), *Journal of Forest Science*, 56, 3, 101-111.

Genç R. (2010): Ecological wood anatomy of some woody angiospermae taxa in Camili, MSc Thesis, Karadeniz Technical University, Institute of Natural and Applied Sciences, Trabzon. (In Turkish)

Gerçek Z., Merev N., Ansin R., Ozkan Z. C., Terzioğlu S., Serdar B., Birtürk T. (1998): Leafy Kayacık hornbeam in Turkey (*Ostry carpinifolia* Scop.) in ecological wood anatomy. I.U. Forestry Faculty, *Pulley Oak and Flora of Turkey Symposium Proceedings*; 302-316, Istanbul. (In Turkish)

Giovannelli A, Deslauriers A, Fragnelli G, Scaletti L, Castro G, Rossi S, Crivellaro A. (2007): Evaluation of drought response of two poplar clones (Populus × canadensis Mönch ‘I-214’ and P. deltoides Marsch. ‘Dvina) through high resolution analysis of stem growth. *J Exp Bot* 58:2673–2683.

Hemmasi A.H, Soodmand R., Varshoie, A., Bazyar B. (2007): Study of height effect on ovendry specific gravity and biometrical ratios in ıranian beech tree wood from siahkal forest, *Journal of Agricultural Sciences*, 12 (4): 913-923.

Hosseini S.Z. (2006): The effect of altitude on juvenile wood formation and fiber length, a case study in ıranian beech wood (*Fagus orientalis* L.), *Journal of Agriculture Science and Technology*, 8 (3): 221-231.

Kalıpsız A. (1981): Statistical Methods, I.U. Faculty of Forestry, Publication No: 29-1, Istanbul. (In Turkish).

Kantarcı M.D. (2005): Forest Ecosytems Science. I.U. Publication No. 4594, Faculty of Forestry, Istanbul University Publisher, Istanbul. (In Turkish)

Kiaei M. & Samariha A. (2011): Fiber dimensions, physical and mechanical properties of five ımportant hardwood plants, *Indian Journal of Science and Technology*, 4 (11): 1460-1463.

Kiaei M. (2011): Basic density and fiber biometry properties of hornbeam wood in three different altitudes at age 12, Middle-East, *Journal of Scientific Research*, 8 (3): 663-668.

Kutbay H.G., Merev N., Ok T. (1999): Anatomical, phytosociological and ecological properties of pterocarya fraxinifolia (Poiret). *Turkish Journal of Agriculture and Forestry*, 23(5): 1189-1196.

Lara A., Aravena J.C., Villalba R., Wolodarsky-Franke A., Luckman B., Wilson R. (2001): Dendroclimatology of high-elevation nothofagus pumilio forests at their northern distribution limit in the central andes of Chile, Canadian, *Journal of Forest Research*, 31 (6): 925-936.

Lens F., Gasson P., Smets E., Jansen S. (2003): Comparative wood anatomy of Epacrids (Styphelioideae, Ericaceae s.l.), *Annals of Botany*, 91(6): 835-856.

Lens F., Luteyn J.L., Smets E., Jasen S. (2004): Ecological trends in the wood anatomy of vaccinioideae (Ericaceae s.l.). Flora 199: 309-319.

Liu J. & Noshiro S. (2003): Lack of latitudinal trends in wood anatomy of Dodonaea viscosa (Sapindaceae). *American Journal of Botany*, 90: 532-539.

Luchi A.E. (2004): Anatomia do lenho de Croton urucurana Baill. (Euphorbiaceae) de solos com diferentes níveis de umidade. *Revista Brasileira de Botânica* , 27(2):271-280.

Malan F.S. (1991): Variation, association and inheritance of juvenile wood properties of Eucalyptus grandis Hill ex Maiden with special reference to the effect of rate of growth. *South African Forestry Journal*, 157, 16-23.

Malkocoglu S. (2012): Effects to some anatomıcal features of black alder (*Alnus glutinosa subsp. barbata* (C.A. Mey.) Yalt.) wood of dıfferent sıte conditions. MSc Thesis. Karadeniz Technical University, Graduate School of Natural and Applied Sciences. (In Turkish).

Markesteijn L, Poorter L, Paz H, Sack L, Bongers F. (2011): Ecological differentiation in xylem cavitation resistance is associated with stem and leaf structural traits. *Plant, Cell and Environment*, 34: 137–148.

Martínez-Cabrera H.I., Jones C.S., Espino S., Schenk H.J. (2009): Wood anatomy and wood density in shrubs: Responses to varying aridity along transcontinental transects. *American Journal of Botany*, 96: 1388–1398.

Martinez-Vilalta J., Mencuccini M., Álvarez X., Camacho J., Loepfe L., Piñol J. (2012): Spatial distribution and packing of xylem conduits. *Botany*, 99: 1189-1196.

McCulloh K., Sperry J.S., Lachenbruch B., Meinzer F.C., Reich P.B., Voelker S. (2010): Moving water well: comparing hydraulic efficiency in twigs and trunks of conif-erous, ring-porous, and diffuse porous saplings from temperate and tropicalforests. *New Phytol*. 186, 439–450

Meena V.S. & Gupta S. (2014): Wood anatomy of albizia procera correlation between tropical and subtropical from different geographical zones of ındian subcontinent. *Int.J. Sci. Tech. R*es., 3(5): 1-18.

Melo Júnior J.C.F., Ceccantini G, Bona C. (2011): Anatomia ecológica do lenho de Copaifera langsdorffii Desf. (Leguminosae) distribuída em diferentes condições edáficas do cerrado sul-brasileiro. *Iheringia*, 66(2):189-200.

Merev N. & Yavuz H. (2000): Ecological wood anatomy Turkish Rhododendron L. (Ericaceae) intraspecific variation. *Turkish Journal of Botany*, 24: 227-237.

Moya R. & Tomazello Fo M. (2008): Variation in the wood anatomical structure of Gmelina arborea (Verbenaceae) trees at different ecological conditions in Costa Rica, *International Journal of Tropical Biology and Conservation*, 56 (2): 689-704.

Müller-Landau H.C. (2004): Inter-specific and inter-site variation in wood specific gravity of tropical trees. Biotropica 36: 20–32.

Noshiro S. & Suzuki M. (1995): Ecological wood anatomy of Nepalese Rhododendron (Ericaceae) 2. Intraspecific Variation, *Journal of Plant Research*, 108, 217-233

Noshiro S., Ikeda H., Joshi L. (2010): Distinct Altitudinal Trends in the Wood Structure of Rhododendron arboreum (Ericaceae) in Nepal, *IAWA Bulletin* n.s., 31 (4): 443-456.

Noshiro S., Suzuki M., Ohba H. (1995): Ecological wood anatomy of Nepalese Rhododendron (Ericaceae). 1. Interspecific Variation, *Journal of Plant Research*, 108, 1-9.

Noshiro S. & Baas P. (2000): Latitudinal trends in wood anatomy within species and genera: case in Cornus S.L. (Cornaceae). *American Journal of Botany*, 87: 1495-1506.

Olano J.M., Eugenio M., Garcìa-Cervigón A.I., Folch M., Rozas V. (2012): Quantitative tracheid anatomy reveals a complex environmental control of wood structure in continental Mediterranean climate. *Int. J. Plant Sci*., 173, 137–149.

Olsen J.T., Caudle K.L., Johnson L.C., Baer S.G., Maricle B.R. (2013): Environmental and genetic variation in leaf anatomy among populations of Andropogon gerardii (Poaceae) along a precipitation gradient. *American Journal of Botany*, 100, 1957-1968.

Pande P.K., Chauhan L., Singh M. (2005): Wood anatomical variations within the genus Castanopsis, *Journal of Tropical Forest Science*, 17 (3): 366-371.

Parra A.C., Pournavab R.F., Garcia V.B., Torres S.S., Ocanas F.G., Limon S.M. (2013): Differences of wood elements of *Prosopis laevigata* from two areas of Northeast Mexico. *American Journal of Plant Sciences*, 4, 56-60

Patterson R. & Tanowitz B.D. (1989): Evolutionary and geographic trends in adaptive wood anatomy in Eriastrum densifolium (Polemoniaceae), *American Journal of Botany*, 76 (5): 706-713.

Poorter L., McDonald I., Alarcón A., Fichtler E., Licona J.C., Peña-Claros M., Sterck F. J., Villegas Z., Sass-Klaassen U. (2010): The importance of wood traits and hydraulic conductance for the performance and life history strategies of 42 rainforest tree species. *New Phytol*., 185: 481–492.

Pourtahmasi K., Lotfiomran N., Brauning A., Parsapajouh D. (2011): Tree-ring width and vessel characteristics of oriental beech (*Fagus orientalis* L.) along an altitudinal gradient in the Caspian forests, Northern Iran, *IAWA Journal*, 32 (4): 461-473.

Preston K.A., Cornwell W.K., Denoyer J.L. (2006): Wood density and vessel traits as distinct correlates of ecological strategy in 51 California coast range angiosperms. *New Phytol*., 170: 807–818.

Rigatto P.A, Dedecek R.A., Monteiro de Matos J.L. (2004): Influencia dos atributos do solo sobre a qualidade da madeira de Pinus taeda para produção de celulose kraft. *Revista árvore*, 28: 267–273.

Roo-Zielinska E., & Solon J. (1997): Effect of geographical location on species composition, vegetation structure, diversity and phytoindicative characteristics in pine forests, *Environmental Pollution*, 98 (3): 347-360.

Roque R.M., & Filho M.T. (2007): Relationship between anatomical features and ıntra-ring wood density profiles in Gmelina arborea applying x-ray densitometry, *Cerne*, 13(4): 384-392.

Rossi S., Morin H., Deslauriers A., Plourde P.Y. (2011): Predicting xylem phenology in black spruce under climate warming. *Glob Change Biol*, 17:614–625.

Şanlı I. (1978): Anatomical studies on Oriental Beech (Fagıs orientalis) woods that occur in different regions in Turkey. Istanbul University Publication No: 2410, Faculty of Forestry Publication No: 256, Istanbul.

Sarıbaş M. & Yaman Ö. (2009): Xylological Investigations on Celtis australis L. Growing in Antalya-Kemer and Zonguldak-Devrek, *Journal of Bartın Forestry Faculty*, 11 (15): 1-15.

Scholz A., Stein A., Choat B., Jansen S. (2014): How drought and deciduousness shape xylem plasticity in three Costa Rican woody plant species. *IAWA Journal* 35: 337-355.

Searson M.J., Thomas D.S., Montagu K.D., Connroy J.P. (2004): Wood density and anatomy of water-limited eucalypts. *Tree Physiology*, 24, 1295-1302.

Serdar B. (2003): Ecological wood anatomy of Salicaceae family in Turkey. PhD Thesis, Karadeniz Technical University, Graduate School of Natural and Applied Sciences (In Turkish)

Serdar B. & Gerçek Z. (2007): Variations of wood anatomical Features of Poplar (*Populus* L.) Dependent on Non-Anatomical Factors, *D.U. Journal of Forestry*, 3 (1):76-89

Sperry J.S., Hacke U.G., Pittermann J. (2006): Size and function in conifer tracheids and angiosperm vessels. *American journal of Botany*, 93: 1490–1500.

Takahashi K., Tokumitsu Y., Yasue K. (2005): Climatic factors affecting the tree-ring width of Betula ermanii at the timberline on Mount Norikura, Central Japan, *Ecological Research*, 20, 445–451.

Tessier L., Nola P., Serre-Bachet F. (1994): Deciduous Quercus in the Mediterranean Region: tree ring/climate relationships, *New Phytologist*, 126, 2, 355-367.

Thomas D.S., Montagu K.D., Conroy J.P. (2007): Temperature effects on wood anatomy, wood density, photosynthesis and biomass partitioning of Eucalyptus grandis seedlings.*Tree physiology*, 27:251-260.

Thornthwaite C.W. (1948): An Approach Toward A Rational Classification of Climate, *Geographical Review*, 38 (1): 55-94.

Tommerup E.C. (1934): The Field Description of the Physical Properties of Soils, First Commission of Commission *I– Soil Physics of the International Society of Soil Science*, pp. 155–158. International Society of Soil Science, Versailles, France.

Topaloglu E. (2014): Effect of some envıronmental condıtıons on wood propertıes of Oriental Beech (*Fagus orientalis* Lipsky). PhD Thesis. Karadeniz Technical University, Graduate School of Natural and Applied Sciences, Trabzon, Turkey. (In Turkish).

Usta A., Yilmaz M., Malkocoglu S., Serdar B., Yilmaz S., Bozlar T. (2014a): The effects of environmental factors on wood anatomy of Black Alder (*Alnus glutinosa* (L.) *Gaertner Subsp*. Barbata (CA Meyer) Yalt). *Fresenius Environmental Bulletin*, 23: 1778-1784.

Usta A., Yilmaz M., Kahveci E., Yilmaz S., Ozturk H. (2014b): Effects of different site conditions on some properties of Black Alder (*Alnus glutinosa* (L.) Gaertner Subsp. Barbata (C.A. Meyer) Yalt). *Fresenius Environmental Bulletin*, 23:1840-1851.

Vaganov E.A. Hughes M.K., Shashkin A.V. (2006): Growth dynamics of conifer tree rings: Images of past and future environments . Springer, New York, New York, USA. pp 354.

Wilkins,A.P. & Papassotiriou S. (1989): Wood anatomical variation of Acacia meJauo xylon in relation to latitude. *IAWA Bull*. 10, 201-207.

Wodzicki T.J. (2001): *Natural Factors Affecting Wood Structure*, Wood Science and Technology, 35, 5-26.

Yaltırık F. (1971): Morphological and anatomical investigations on native Maple (Acer L.) Species, *I.U. Publication* No. 1661, O.F. Publication No: 179, Istanbul. (In Turkish).

Yaman B. & Sarıbaş M. (2004): Turkey's euxine area natural poplar (*Populus* L.) variation in trahan cells associated with upgrade of taxa size, *Süleyman Demirel University Faculty of Forestry Journal*, Series A, 1, 111-123.

Yaman B. (2008): Variation in quantitative vessel element features of Juglans regia wood in the Western Black Sea region of Turkey, *Agrociencia*, 42, 357-365.

Yılmaz M. (2005): Studies on some site factors affecting the growth (productivity) of the beech in pure oriental beech (*Fagus orientalis* Lipsky) ecosystems in East Black Sea region. PhD Thesis, Karadenzi Technical University Graduate School of Natural and Applied Sciences, Trabzon. (In Turkish).

Yılmaz M., Serdar B., Altun L., Usta A. (2008): Relationships between environmental variables and wood anatomy of *Quercus pontica* C. Koch (Fagaceae) *Fresenius Environmental Bulletin*, 17 (7b): 902-910.

Zhang S.Y., Deng L., Baas P. (1998): The ecological wood anatomy of the Lilacs (Syringa oblata var. giraldii) on Mount Taibei in Northwestern China, *IAWA Bulletin*, 9, 24-30.