

EVALUATION OF EARLYWOOD AND LATEWOOD OF CALABRIAN PINE (*Pinus brutia* Ten.) IN TERMS OF SITE INDEX

İbrahim BEKTAŞ

Prof. Dr. - Kahramanmaraş Sutcu Imam University
Faculty of Forestry, Department of Forest Industry Engineering
Address: Avsar Campus, Onikisubat, 46100, Kahramanmaraş, TURKEY
E-mail: ibtas63@yahoo.com

Abstract:

*In this paper, the effects of site index on the earlywood and latewood in the fibers (tracheids) biometry of Calabrian pine (*Pinus brutia* Ten.) and relationships between earlywood and latewood were researched. For this aim, test trees were collected from two similar Mediterranean regions in the south of Turkey. The analyses results showed that the existence of a significant effect of the site index on the earlywood and latewood in the fibers biometry except for the fibers lengths. In general, it is understood that the fibers biometry of latewood is the better than earlywood. Furthermore, the regression analysis was revealed that there is a weak relationship between earlywood and latewood in terms of the fibers biometry. In the end of evaluations, it was suggested that the topic on which more study needs to be done in future.*

Key words: Calabrian pine, earlywood, fibers biometry, latewood, site index.

INTRODUCTION

The term of site index is known as a criterion to determine the relative productivity of a district site or stand. Yeşil (1993) recorded that site index is defined as productivity of stand growth area and yield as well as production potential. Also, site index is defined as production power of products and services (Eler 2002). The site index method is the most widely accepted means for estimating site quality. However, proper application of this method of site evaluation requires suitable trees for the required height and age measurements (Carmean 1970).

A wood material is composed of early- and late woods. The earlywood is called as "springwood" and latewood is defined as "summerwood" as well.

As known that Earlywood is made of cells with large lumens and thin cell walls and appears light in color. Whereas late wood is made up of smaller cells with thicker cell walls and are the darker part of the growth ring (Örs and Keskin 2008, Bozkurt and Erdin 1997).

Kord and Samdaliri (2011) reported that an analysis of variance indicates that the site and clone had significant effect on fiber biometry. These results show strong relationships between tree dominance and site index and wood quality parameters as wood density and stem straightness reported by Leeuwen *et al.* (2011).

Pitts *et al.* (2001) and Pitts and Watson (2002) expressed the effects of tree age, biogeoclimatic zone and site index on wood density, fibers lengths and fibers coarseness in western SPF (white spruce, lodge pole pine, and subalpine fir) and eastern spruce-balsam fir mixtures.

The trends, from age and site quality, are very important concerning the management of the resource. Age and site index were found to impact significantly on many of the wood and pulp and paper characteristics measured (Kevin *et al.* 2000).

The specific gravity is another parameter influencing the pulp and paper quality and it is related to forestry practices, site index, growth conditions and wood species (Zobel 1984). Site quality was also found to have a significant effect on fiber structure development (Lindstrom 1997). Also, As (1992) studied the effects of site quality differences on some wood properties of maritime pine (*Pinus pinaster*) and reported that site indexes I to III significantly affected the air-dry densities of maritime pine wood grown in the Izmit region of Turkey.

The main purpose of this article is to determine the influence of site index on earlywood and latewood of Calabrian pine wood and research relationship between earlywood and latewood for fibers biometry.

Finally, it has been very little research on the subject so far and, so this reason consisted of the need of planning article. Therefore, it has expected important contributions to literature with this paper.

MATERIAL AND METHOD

Using test trees

The Calabrian pine (*Pinus brutia*) test trees were selected from test areas with the same properties as average (Table 1), since the effects of site index on fibers dimensions were essentially undertaken in the study. The logs were collected from the similar forests of the East and West Mediterranean regions in the southern part of Turkey. The selection of the test area and trees was determined by following methods

defined in (Bektaş *et al.* 2003). For each site index class, three trees were selected according to standard TS 4176 (TSE 1984).

Table 1

Some knowledge about the test areas and trees

Site index	Region (Mediterranean)	Mean tree age	Mean tree diameter (cm)	Mean altitude (m)	Exposure	Soil type
I	East and West	77	44	750	South	Clay-sandy loam
II	East and West	76	42	675	South	Clay-sandy loam
III	East and West	79	41	700	South	Clay-sandy loam

As seen in Table 1, other factors in order to demonstrate the effect of site index differences (region, altitude, exposure, age and soil type) was homogenized.

Determination of site index

The levels (I, II and III) of site indexes for the test trees were determined by using standard site index tables reported by Tsoumis (1969). As is known, tree quality decreases with increasing site index numbers.

Experimental methodology

The earlywood (EW) and latewood (LW) widths of fibers Lengths, fibers diameters, cell wall thicknesses and lumen diameters from anatomical properties were measured using microscope slides in the laboratory as follow.

The fibers diameters, lumen diameters and cell wall thicknesses of both early wood and late wood were measured in radial and tangential directions on the cross-sections of specimens. For measure fibers lengths of specimens (0.5mm thickness and 2cm long in parallel to grain), Jeffrey's method was applied. In this method, specimens were immersed into Jeffrey's solution until they were defibered and later, fibers lengths were measured with the microscope of Richard after they were washed with pure water (Bektaş *et al.* 2002).

To fibers length measurement, specimens (.05 (Thick.) by 2 (L) cm.) were first macerated by following conventional Jeffrey method. Then, the lengths of the macerated fibers were measured on Reichert's vizopan reflection equipment furnished with a monocular light microscope (Bektaş *et al.* 2002).

The cross sections of early and late wood parts of a specimen having a dimension of 1 (T)- by 1 (R)- by 2 (L) cm for the measurement of the cell wall thickness, were cut tangentially by a microtome (Reichert Model). The wood slides were prepared according to acetic acid-hydrogen peroxide method (Bozkurt and Erdin 1997). The measurements were done on the same equipment as used for the fibers length measurement.

On the other hand, Analysis of variance (ANOVA) and Duncan's mean separation test were used for statistical analysis of results.

Relationships between earlywood and latewood were determined using standard linear regression method (Kalipsiz 1988).

RESULTS AND DISCUSSION

By analyzing the data collected in the laboratory tests, obtained results are arranged as tables (Table 2 - Table 5) and graphics (Fig. 1-3).

The results of an analysis of variance and Duncan's mean separation test for the fibers diameters of earlywood and latewood are shown in Table 2.

Table 2

The results of earlywood and latewood widths of fibers Lengths as a function of site index

Site index		Number of samples	Mean (mm)	Standard deviation	Coefficient of variation	Probability
EW	I	60	4.31	1.291	29.95	Nonsignificant
	II	60	3.99	1.078	27.02	
	III	60	4.51	1.557	34.54	
	Total	180	4.27	1.345	31.50	-
LW	I	60	4.67	1.367	29.27	Nonsignificant
	II	60	4.25	1.402	32.99	
	III	60	4.13	1.296	31.38	
	Total	180	4.35	1.422	32.69	-
Mean	I	60	4.49	1.299	28.94	Nonsignificant
	II	60	4.12	1.378	33.51	
	III	60	4.32	1.558	36.07	
	Total	180	4.31	1.419	32.95	-

EW: Earlywood, LW: Latewood.

When Table 2 is examined, it can be seen easily that the relationships between site index and earlywood, latewood and average values of Calabrian pine are insignificant. That is, the difference of site index has not formed a significant effect on fibers lengths of both early wood and late wood values.

Also, it can be seen from the same table that latewood fibers are longer than earlywood even if difference is unimportant. This finding is confirmed by Bozkurt (1992). Again, referring to values in the Table 2, it can be said that in earlywood while the longest fibers lengths were measured in the I. site index, the shortest fibers length was determined in II. site index wood. This is show parallelism with Bozkurt and Erdin (1998)'s findings as well. However, unlike fibers lengths of earlywood, latewood fibers lengths showed a positive trend with site index numbers.

On the other hand, in the latewood, the longest fibers lengths were measured in I. site index and, the shortest fibers lengths were obtained from the II. site index. Indeed, this expected a result. Only, these assessments are specific to this species. It is obvious that different values may be obtained from other species.

Table 3

The site index analyses results of fibers diameters measurements

Site index		Number of samples	Mean (μm)	Standard deviation	Coefficient of variation	Probability
EW	I	60	35.0A	5.704	16.30	P<0.001
	II	60	37.0B	5.449	14.73	
	III	60	33.6A	5.385	16.03	
	Total	180	35.20	5.665	16.09	
LW	I	60	18.1A	2.594	14.37	P<0.01
	II	60	16.7B	2.619	15.68	
	III	60	17.7A	2.559	14.47	
	Total	180	17.58	2.638	15.10	
Mean	I	60	26.53	3.235	12.19	Nonsignificant
	II	60	29.87	3.444	12.82	
	III	60	26.63	3.267	12.27	
	Total	180	26.68	3.302	12.37	

EW: Earlywood, LW: Latewood.

The results of an ANOVA indicated in Table 3 that the site index had significant effect on Calabrian pine fibers diameters for earlywood ($p<0.001$) and latewood ($p<0.01$). So, cell wall thicknesses in both wood species' haven't composed also parallel trend with site index numbers. In this study, the values of earlywood, latewood and average widths were found between 33.6-37.0μm, 16.7-18.1μm and 26.53-29.87μm respectively as shown Table 3. In total, the fibers diameter of earlywood is thicker than latewood's diameter. It was corrected by Gellerstedt *et al.* (2009).

Means, standard deviations and coefficient of variations, ANOVA and Duncan test results of cell wall thicknesses by earlywood and latewood are demonstrated in Table 4.

Table 4

The values of fibers cell wall thickness according to site index

Site index		Number of samples	Mean (μm)	Standard deviation	Coefficient of variation	Probability
EW	I	60	5.62A	0.879	15.65	P<0.01
	II	60	5.92AB	0.775	13.08	
	III	60	6.10B	1.250	20.50	
	Total	180	5.88	1.003	17.06	
LW	I	60	7.01A	0.836	11.92	P<0.001
	II	60	7.51B	0.956	12.72	
	III	60	7.69B	1.241	16.15	
	Total	180	7.41	1.059	14.30	
Mean	I	60	6.32A	0.683	10.82	P<0.001
	II	60	6.72B	0.641	9.55	
	III	60	6.89B	1.028	14.91	
	Total	180	6.64	0.834	12.56	

EW: Earlywood, LW: Latewood.

All of the means in Table 4 of cell wall thickness increase slowly inversely proportional with site indexes. That is means, cell wall thicknesses of Calbrian pine indicate a decrease when increasing site index from I to III. from I to III. The analysis of variance demonstrate that site index has a significant effect on the cell wall thicknesses of earlywood and latewood at the confidence level of ($P < 0.01$) and ($P < 0.001$), respectively. It can be seen that latewood fibers are thicker wall than the earlywood fibers. Similar results were obtained by Huang *et al.* (2012). They recorded that the thick-walled LW fibers exhibit much more external fibrillation than the thin-walled EW.

The total the cell wall thickness values are 5.88, 7.41 and 6.64 μm for EW, LW and average, respectively. On the other side, Duncan's mean separation test reveals significant difference between site indexes I and III in earlywood, and site indexes I and II, and site indexes I and III in latewood. In a study indirectly related to this subject revealed by Kord and Samdaliri (2011) that site and clone had significant effect on wood density and fibers biometry.

Table 5

The test's results of earlywood and latewood for lumen diameters in term of site index

Site index		Number of samples	Mean (μm)	Standard deviation	Coefficient of variation	Probability
EW	I	60	29.26A	5.555	18.99	$P < 0.001$
	II	60	33.19B	4.900	14.77	
	III	60	30.61A	4.571	14.94	
	Total	180	31.02	5.258	16.95	-
LW	I	60	14.39A	2.900	20.15	$P < 0.01$
	II	60	13.38B	2.518	18.82	
	III	60	14.85A	2.652	17.86	
	Total	180	14.21	2.750	19.35	-
Mean	I	60	21.91A	2.731	12.47	* $P < 0.05$
	II	60	23.21AB	3.140	13.53	
	III	60	22.73B	2.670	11.75	
	Total	180	22.62	2.890	12.78	-

EW: Earlywood, LW: Latewood.

Table 5 shows that lumen diameters values of earlywood and latewood have not a proportional relation with site index numbers. But they have an important effect. Because the ANOVA test indicates that site index has a significant effect on lumen diameters of earlywood at the 999.9 percent confidence level and latewood at the 99.9 percent confidence level. Moreover, it is clear from the Duncan's mean separation test that significant differences exist in lumen diameters between site index I and II and site indexes II and III in the earlywood. This position is valid for latewood too. It has also been determined in As (1992) that there was a good relationship among the types of site indexes (I to III) for oven-dry densities of *Pinus pinaster* wood, the higher the site index number, the lower the density.

In the other studies relationship between site and wood density, significant site effects for wood density have been previously reported by Zhang *et al.* (2008).

On the other hands, it is an important issue to reveal the relationships between earlywood and latewood. Because some researchers studied what is the difference between early wood and late wood? And they determined a lot of differences among them. As known that Earlywood is made of cells with large lumens and thin cell walls and appears light in color. Whereas late wood is made up of smaller cells with thicker cell walls and are the darker part of the growth ring.

The results of previous statistics analyses depicted in Table 3-5 have been showed that there were a significant relation between site index and fibers diameters, cell, wall thicknesses and lumen diameters according to EW and LW.

So, they will be compared the means of earlywood and latewood of fibers diameters, wall thickness and lumen diameters by correlation analysis as calculating the coefficient of correlation (R) and the coefficient of correlation (R^2), and their results will be showed in graphics below.

Fig. 1 demonstrates the relationship between the values of earlywood and latewood of the fibers diameters. There is a fairly weak linear relationship ($R = 0.32$) and ($R^2 = 0.10$) between the earlywood and latewood of the fibers diameters in total. As is known, it is accepted that if values of R^2 consist of 0.50-0.30 and $R = 0.70$ -0.55, relation is weak, if $R^2 < 0.30$ and $R < 0.55$, relation is insignificant in regression and correlation analyses (Gürtan 1982).

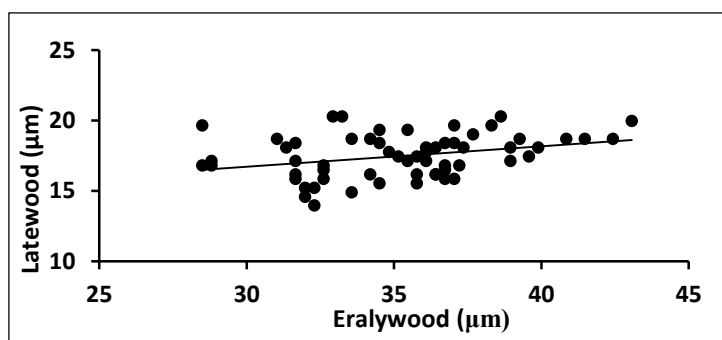


Fig. 1.

Relationship between earlywood and latewood of fibers diameters in Pinus brutia.

Fig. 2 shows the relationship between earlywood and latewood of fibers cell wall thicknesses. A similar relationship to the fibers diameters is also in question here. Relation between earlywood and latewood of fibers cell wall thicknesses is insignificant correlation because of ($R = 0.17$) and ($R^2 = 0.03$) for the total values.

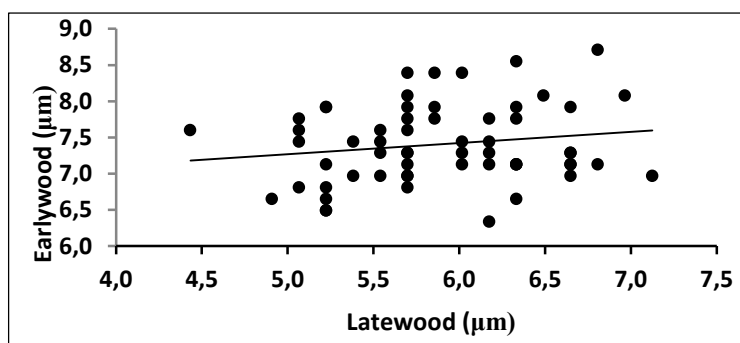


Fig. 2.

The graphic of relation between earlywood and latewood of fibers cell wall thicknesses.

Ultimately, Fig. 3 depicts the relationship between earlywood and latewood of fibers cell wall thicknesses determined with linear regression analysis. As can be seen from this figure, there is a negative relationship between earlywood and latewood because the signal of coefficient of determination ($b=-0,099$) is negative. At the sometime, degree of aforementioned relation is relatively weak because of $R^2 = 0.05$ and $R = 0.22$.

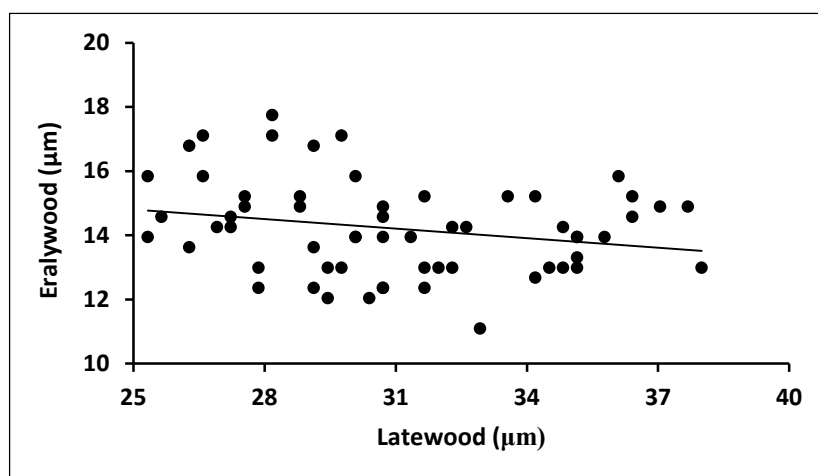


Fig. 3.

The relationship between earlywood and latewood of lumen diameters.

CONCLUSIONS

With this study has been aimed to find out influence of site index on the fibers lengths, fibers diameters, cell wall thicknesses and lumen diameter of Calabrian pine woods with regard to earlywood and latewood. Additionally, it was researched relationship between earlywood and latewood for fibers diameters, cell wall thicknesses and lumen diameters.

So, the following conclusions were obtained from this research:

An analysis of variance indicates that the site index and early- and late woods had nonsignificant effect on fibers lengths. But it is determined a significant relationship between site indexes and early- and late woods for fibers diameters, cell wall thicknesses and lumen diameters.

When the results were evaluated according to the earlywood and latewood, it is observed that in earlywood the fibers lengths are shorter, the fibers diameters are larger, the cell wall thickness is thinner and the lumens are wider than those of in latewood. The obtained data in comparison with site quality, only the cell wall thickness was increased when site index deteriorate. It has not been occurred any parallelism between fibers lengths, fibers diameters as well as lumen widths of earlywood and site quality.

Fibers properties in the latewood are slightly different from earlywood. Site index number increases, while the fibers lengths are decreased. Similarly, the largest fibers diameters were measured in I. site index class. Site index number increases in latewood; the cell wall thickness is also increased. The lumen width in latewood has no relevance with site index class.

Ultimately, the relationships between site index and wood properties has not researched enough so far. Therefore, there is need for more studies on this subject in the future.

REFERENCES

- As N (1992) The effect of different origins on the physical, mechanical properties of *Pinus Pinaster*. PhD Diss, The Science Institute of İstanbul University, Turkey.
- Bektaş İ, Alma MH, As N, Gündoğan R (2003) Relationship Between Site Index and Several Mechanical Properties of Turkish Calabrian Pine (*Pinus brutia* Ten.). FOREST PRODUCT JOURNAL 53(2):27–31.
- Bektaş İ, Göker Y, Alma MH (2002) Various Properties of the Woods of Radiata Pine, Exotically Grown in Turkey. Proc of IUFRO Meeting Management of Fast Growing Plantations, İzmit (Turkey), pp. 229–234.
- Bozkurt Y (1992) Wood Anatomy. Istanbul University Publications, İstanbul.
- Bozkurt Y, Erdin N (1998) Woody fibers and definition. JOURNAL OF FOREST FACULTY OF IU 39(4):1–16.
- Bozkurt Y, Erdin N (1997) Wood technology. Istanbul University Publications, İstanbul.
- Carmean WH (1970) Site quality for eastern hardwoods. USDA Forest Serv. Res. Pap. NE-144, Northeast. Forest Exp. Sta. Penn.
- Eler Ü (2002) The importance of site index. THE JOURNAL OF FORESTRY FACULTY OF SDU A(2):1–10.
- Gürtan K (1982) Statistical and research methods. Alaş Press, İstanbul.
- Huang F, Lanouette R, Law K (2012) Morphological changes of Jack pine latewood and earlywood fibers in thermomechanical pulping. BIORESEARCH 7(2):1697–1712.
- Kalıpsız A (1988) Statistical Methods. Doyuran Press, İstanbul.
- Kevin A, Turner MP, Male JR, Retief RJ (2000) The impact of site index and age on the wood, pulp and pulping properties of a Eucalyptus grandis clone (Tag 5). Proc of the IUFRO Conference “Forest Genetics for the next Millenium”, IUFRO Working Party, Durban (South Africa), pp.17–18.
- Kord B, Samdaliri M (2011) The Impact of Site Index on Wood Density and Fiber Biometry of Populus Deltoids Clones. WORLD APPLIED SCIENCES JOURNAL 12(5):716–719.
- Leeuwen V, Hilker T, Coops NC, Frazer G, Wulder MA, Newnham GJ, Culvenor DS (1997) Assessment of standing wood and fiber quality using ground and airborne laser scanning: A review. FOREST ECOLOGY AND MANAGEMENT 261:1467–1478.
- Lindstrom H (1997) Fiber length, tracheid diameter, and latewood percentage in Norway spruce: development from pith outwards. WOOD AND FRHER SCRMCE 29(1):21-34.
- Gellerstedt G (2009) Chemistry of Chemical Pulping. KTH- Royal Institute of Technology, Stockholm.

Örs Y, Keskin H (2008) Wood material technology. Gazi book house, Ankara.

Pitts S, Bicho P, Watson P (2001) Rapid prediction of fiber properties: Opportunities using forest site classification methods. Pulp and paper research institute (Research report PRR 1532), Montreal.

Pitts S, Watson P (2002) The application of stand level information to the prediction of fiber quality in eastern Canadian spruce and balsam fir. Pulp and paper research institute (Research report PRR 1594), Montreal.

TSE (1984) Selection of tree and wood specimens from stands for determining the physical and mechanical properties of wood. Turkish Standards Institute, TS No: 4176, Ankara.

Tsoumis G (1969) Wood as a Raw Material. Pergamon Press, New York.

Yeşil A (1993) Site quality researches on the natural Calabrian cluster pine. Proc of the International Symposium on *Pinus brutia*, Datça (Turkey), pp. 580-590.

Zhang SY, Yu Q, Chauret G, Koubaa A (2003) Selection for both growth and wood properties in hybrid poplar clones. FOREST SCIENCE JOURNAL 49(6):901-908.

Zobel B (1984) The changing quality of the world wood supply. WOOD SCI TECHNOL 18:1–17.