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THE EFFECTS OF THINNING INTENSITY ON THE GROWTH OF ORIENTAL BEECH (*Fagus orientalis* LIPSKY) PLANTATIONS IN TRABZON, NE TURKEY

UTJECAJ INTENZITETA PRORJEDA NA RAST AZIJSKE BUKVE (*Fagus orientalis* LIPSKY) U PLANTAŽAMA U TRABZONU NA SJEVEROISTOKU TURSKE

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ABSTRACT

In this study, the effects of first thinnings having different intensities in oriental beech (*Fagus orientalis* Lipsky) plantation areas were investigated in terms of diameter and height growth of trees. Sample plots were chosen from oriental beech plantation areas which are within the boundaries of Maçka–Yeşiltepe and Vakfıkebir districts of Trabzon province, Turkey. With removing of 0%, 10%, 25% and 40% of basal area in a hectare of stands which are in sapling stage, sample plots were established by applying thinnings which are in four different intensities (control, light, moderate, strong). After the thinning applications, basal areas were calculated by measuring diameters and heights of trees in established sample plots in order to reveal stand growth. The effects of thinnings were revealed related to some stand characteristics (average diameter, basal area, average height, relative diameter increment, etc.) and determined chosen trees. The effect of thinning intensity on average diameter, basal area, and volume values is statistically important in every two plantations. 2-year results showed that thinning increased the diameter increment significantly, and the increase in diameter increment was positively correlated with the thinning intensity in both experiments. Moreover, increments of diameter, height, basal area, and volume were higher in Maçka-Yeşiltepe experiment than in Vakfıkebir experiment. But, the values of moderate and strong thinning intensities applied in Vakfıkebir were close to each other. When all the results are evaluated, application of strong thinning intensity for Yeşiltepe sample plot, the moderate thinning intensity for Vakfıkebir sample plot is seen appropriate by us in terms of both stand development.

KEYWORDS: ORIENTAL beech, thinning intensity, growth, plantation, increments

INTRODUCTION
UVOD

Oriental beech (*Fagus orientalis* Lipsky) is the most important species of broad-leaved trees spreading in Turkey. Oriental beech is among the most important raw materials for the forest products industry besides making a significant contribution to the Turkish economy. Among leafy species, Oriental beech ranks first with respect to the spread area (1.9 million hectares) and tree wealth (Anonymous, 2012). Oriental beech has an annual average increment of 6.62 m^3

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per hectare in primary productivity so that it can reach 662 m^3 in hectare at the age of 100 (Carus, 1998). Beechwood has been classified as a moderate-intensity (0.66 g/ cm^3) wood. As a hardwood tree species, its wood is heavy, hard, strong and very resistant to shock. For this reason, it is suitable for steam-bending. The oriental beech tree is mainly used as firewood, but there are also other uses of it, such as particleboard, furniture, parquet, masts, traverse manufacturing, and paper. In general, Oriental beech has a similar appearance to European Beech (*Fagus sylvatica*) (Kandemir and Kaya, 2009). The determination of silvicultural treatments that need to be applied to obtain the highest quality and quantity of products in oriental beech forests and to benefit from plantation areas at the highest level is an important subject of forestry.

Strong thinning suitable for the biology of beech was performed while thinning treatments were applied. Strong thinning is frequently used in Central European Forestry. It is based on Schädelin (1942) principles. Firstly, positive selection is performed at a relatively early time in the development of stand where final crop trees are selected and competition is removed. Future trees are selected for the thinning of the stand and should be distributed as orderly as possible. Abetz (1975) developed various selective thinning methods in which the first thinning procedures are performed and final crop trees are selected for young plants. Busse (1935) then initiated the concept of group selection thinning developed by Kato (1973) in which an aggregation or a small tree group was addressed as an individual plant tree. Reininger (1993) developed a structural thinning that creates thinned stands.

Many studies focused on the effects of thinning on stand parameters and compared the thinned and untreated (control) stands (Bryndum, 1987; Hasenauer *et al.* 1996; Sharma *et al.* 2006; Spellmann and Nagel, 1996) or those with different thinning intensities (Guericke, 2002; Juodvalkis *et al.* 2005; Sanchez-Gonzalez *et al.* 2005; Utschig and Kusters, 2003). Similarly, the effects of different thinning regimes on stand value were also examined (Förster, 1993; Hasenauer *et al.* 1996; Kato and Mülder, 1998). Furthermore, the effects of different types of selective thinning, group selective thinning (Kato and Mülder, 1998), and early and late thinning results were studied (Henriksen and Bryndum, 1989; Klädtke, 2001). According to Schädelin (1942), Leibundgut (1982) and Schütz (1987), classical selective thinning is characterized by the repetition of the selection of future trees, and their number is reduced from the beginning of selection to the final thinning performed in the optimal phase. This means that the average distance between future trees increases in a period from the first thinning to the final thinning (Boncina *et al.* 2007).

Although the above-ground productivity of natural forests usually varies by the stand age, it tends to decrease after closure is provided (Ryan *et al.* 1996). For this reason, many ecologists and foresters have attempted to keep such changes under control in order to improve tree growth and wood quality (Macdonald *et al.* 2010). Among controlling methods, thinning treatment is considered as an important and effective way of managing forest growth and productivity (Roberts and Harrington, 2008). Thinning treatments, which are an integral part of intensive forestry activities, constantly improve the quality of stands by cleaning up slow-growing, damaged or unhealthy trees (Zeide, 2001). The productivity of stands treated by this method is improved, and then larger and higher quality trees are obtained (Nishizono, 2010). In broad-leaved stands, thinning can produce large-diameter trees, can improve the stem quality, can increase the variable volume and yield value and can shorten the management time (Hibbs *et al.* 1989; Mayor and Rodà, 1993; Cameron *et al.*, 1995; Nowak, 1996; Oliver and Larson, 1996; Miller, 1997; Medhurst *et al.* 2001; Juodvalkis *et al.* 2005; Rytter and Werner, 2007). In broad-leaved tree species, the purpose of thinning is usually to increase the quality of the final product (Savill *et al.* 1997). Stem size and quality are the decisive criteria for valuable timber production. Forestry practices and especially thinnings are important for high-quality wood production. It is well known that thinning has a significant influence on forest growth and productivity (Utschig *et al.* 2003; Spiecker, 1996; Boncina and Kadunc, 2007). To decrease the number of trees by performing thinnings in the stand may change the ecological conditions in the forest. One of the most important effects of thinning in the forest ecosystem is that the light-temperature-moisture change affects the litter decomposition, and thus, nutritional elements get into the forest soil and these nutritional elements make soils rich (Makineci, 2004). Although highly competitive trees are much more sensitive to the changes in water balance, the restriction of growth by water and the nutritional source is reduced by thinning (Pretzsch, 2005). Therefore, the aim of this study is to determine the effects of thinning intensity on the growth and increment of oriental beech in plantation areas established in different growing environments.

MATERIAL AND METHODS
MATERIJALI I METODE

Study Area – *Područje istraživanja*

Experimental plots were chosen from young oriental beech plantation areas which are within the boundaries of Vakfıkebir and Maçka districts of Trabzon province. The locations of experimental plots are presented in Figure 1.

Figure 1. Location of experimental plots
Slika 1. Položaj pokusnih ploha

Table 1. Some ecological conditions of plantations
Tablica 1. Neki ekološki uvjeti plantažnih područja

Ecological parameters Ekološki parametri	Plantations-Plantažne površine Vakfıkebir	 Maçka-Yeşiltepe
Altitude (m) Visina (m)	1340	1450
Slope (%) Nagib (%)	55	45
Aspect Položaj	NW	E
Age Dob	25	19
Seedling Age Starost sadnica	2+0	2+0
Planting spacing (m) Razmak sadnje	2x1	2x1
Annual average temperature (°C) Prosječna godišnja temperatura (°C)	7,4	7,0
Annual average precipitation (mm) Prosječna god. količina padalina (mm)	1197.8	1109.5
Annual water deficit (mm) Godišnji manjak vode (mm)	0.0	252.0
Annual excess water Godišnji višak vode	649.0	199.7

Some ecological parameters regarding the experimental plots are presented in Table 1. Furthermore, the sand ratios vary between 77.69 – 87.05% in Vakfıkebir and between 69.23 – 80.49 in Maçka-Yeşiltepe, and the drainage of the experimental plots is composed of well-drained soils. pH levels vary between 4.15 – 4.66 in Vakfıkebir and between 4.64 – 5.14 in Maçka-Yeşiltepe. The long-term data of close meteorological stations were used to determine the climatic characteristics of the regions where experimental plots were established. The data of Tonya meteorological station were used for Vakfıkebir sample plot while the data of Meryemana meteorological station were used for Yeşiltepe sample plot. Moreover, the Thornthwaite method was used to determine the climatic type of the experimental plots (Thorntwaite, 1948). The climatic type of Vakfıkebir sample plot was determined as the type which is very humid, at low temperature (Microthermal), with little or no water deficit, close to oceanic climate. The climatic type of Yeşiltepe sample plot was determined as the type which is semihumid, at medium temperature (Mesothermal), very strong and has water deficit in summer, close to continental climate (Yılmaz *et al.* 2016).

METHODS
METODE

Experimental plots were chosen from young, untreated oriental beech plantation areas with normal closure. The experimental plots were established according to randomized plots experimental design. With the removal of 0% (Control), 10% (Light), 25% (Moderate) and 40% (Strong) of basal area in a hectare of the experimental plots, sample plots were established by applying three thinning intensities with four replications. The plots are 900 m2 (30 m x 30 m) in size. The procedures determined for each plot were performed on the entire plot. The measurements were performed in an area of 400 m^2 (20 m x 20 m). 5 m-wide area surrounding this region was left as an isolation zone, and no measurement was performed in this area.

200-250 ha-1 (8-10 tree/measurement area) future trees suitable for managerial purposes with a regular development, a plump stem, and asymmetrical crown were identified in each experimental plot. The stems, the cramped stems, forked stems and whippers in the predominant layer that pressurize the future trees in the plots where thinning was applied and the dead or diseased individuals in the intermediate and lower layers were excluded from the plot according to thinning intensity. In these plots, the individuals living in the intermediate and lower layers were protected as much as possible. In the control plots, all of the trees were protected and no treatment was applied. For the thinning process, trees were selected and labeled outside the 2010 vegetation period. All of the trees that would remain in the measurement plot were labeled before thinning. The diameters and heights of all trees in the experimental plots were measured. Second measures were performed at the end of 2012 to determine the possible effects of the thinnings. The basal area volumes were calculated from the diameter values of trees measured at 1.30 m height. The value found was multiplied by hectare conversion coefficient and the amount of basal area in hectare was determined. The determination of the volume of experimental plots was performed in two stages. The trees removed by thinning treatment were cut, diameter measurements were performed with 0.30 m, 1.30 m and 2 m intervals in these trees, and the stem volumes were calculated by section method. In the calculation of volume, the stem was divided into three separate sections including stump, sections and end pieces, and the total stem volume was calculated by their addition. It was assumed that the stump was cylindrical and the end piece was conical. The "Huber" formula was used in the volume of the section. The volume values determined by using the measurements performed in the trees cut were associated with the diameters, and the tree volume table was created. The total volumes of experimental plots were determined by using the volume table to be created because the diameters of all trees were measured in the experimental plots. The stem volumes of trees were calculated for each experimental area using the diameter measurements of trees. Accordingly, the following formulas were developed for each experimental area (Yılmaz *et al.* 2016).

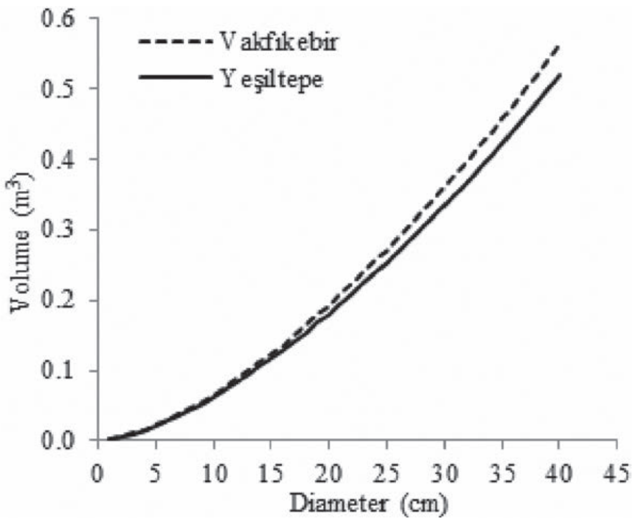

Figure 2. Single-entry tree volume chart
Slika 2. Jednostruki grafikon volumena stabla

Yeşiltepe Experimental area,
(R^2=0.956)

Vakfıkebir Experimental area,
(R^2=0.932)

In the equation, V represents the barked stem volume (m^3) and d represents the basal diameter (cm). According to this equation, in order to determine the stem volume of a tree, there is a need for the diameter values of that tree (Figure 2).

Analyses of variance (ANOVA) were performed to determine the effects of thinning intensity on growth and increments (%) in the plantations ($P < 0.05$). Data analyses were at the stand level. The normality distribution test was controlled for all variables before ANOVA. Because no indication of abnormality was found, there was no need to transform the variables before evaluation. Where significant differences occurred, treatment means were separated by Duncan's new multiple range test ($P < 0.05$).

RESULTS
REZULTATI

The values of pre-thinning average diameter (D), height (H), basal area (BA) and stem volume of plantations were compared according to thinning intensities (Table 2). Accordingly, statistically significant differences were found between all measurement parameters in both plantation areas ($p<0.05$). This means that experimental plots are not homogeneous. Comparisons were performed over the relative increments (%) to be able to better see the effect of thinnings on measurement parameters.

In both experimental plots, the highest RDI occurred in the plots where strong thinning was applied (Figure 4). In terms of RDI, in Vakfıkebir experimental plot, the control and li-

Table 2. Various stand characteristics of oriental beech plantations prior to thinning
Tablica 2. Različite strukturne značajke plantaža azijske bukve prije prorjede

Treatment Tretiranje	Stand density trees ha^{-1} Gustoća sastojine stabla ha^{-1}	Diameter cm Promjer cm	Height m Visina M	BA m^2ha^{-1} Temeljnica m^2ha^{-1}	Volume m^3ha^{-1} Volumen m^3ha^{-1}
Vakfıkebir Vakfıkebirski					
Control – Kontrolni	2325	11.25±3.65 b	10.38±2.30 b	20.79±6.42 b	163.73±44.4 c
Light – Slaba	3143	10.08±3.14 a	9.94±2.10 a	24.03±2.06 a	171.92±16.5 d
Moderate – Umjereni	3156	10.34±3.33 a	10.80±2.02 c	23.72±2.97 a	142.84±23.5 b
Strong – Jaka	2931	11.35±4.10 b	10.70±2.15 c	27.63±2.46 a	125.02±16.7 a
P-value – P-vrijednost		0.001	0.001	0.001	0.001
Yeşiltepe Yeşiltepski					
Control – Kontrolni	2745	8.47 ±2.45 b	8.90 ±3.65 a	12.30 ±2.72 b	104.45 ± 16.1 b
Light – Slaba	2896	8.28 ±2.41 b	9.11 ±2.75 a	14.76 ±1.93 d	111.42 ± 14.5 d
Moderate – Umjereni	2729	8.83 ±2.17 c	9.59 ±1.62 b	17.10 ±1.20 c	107.56 ± 12.7 c
Strong – Jaka	2417	7.82 ±2.26 a	9.11 ±4.49 a	15.27 ±2.61 a	86.68 ± 23.0 a
P-value – P-vrijednost		0.001	0.036	0.001	0.001

In all cases $P < 0.05$; standard deviation in parentheses. (BA: basal area)
U svim slučajevima $P < 0.05$; standardna devijacija u zagradama. (BP: temeljnica)

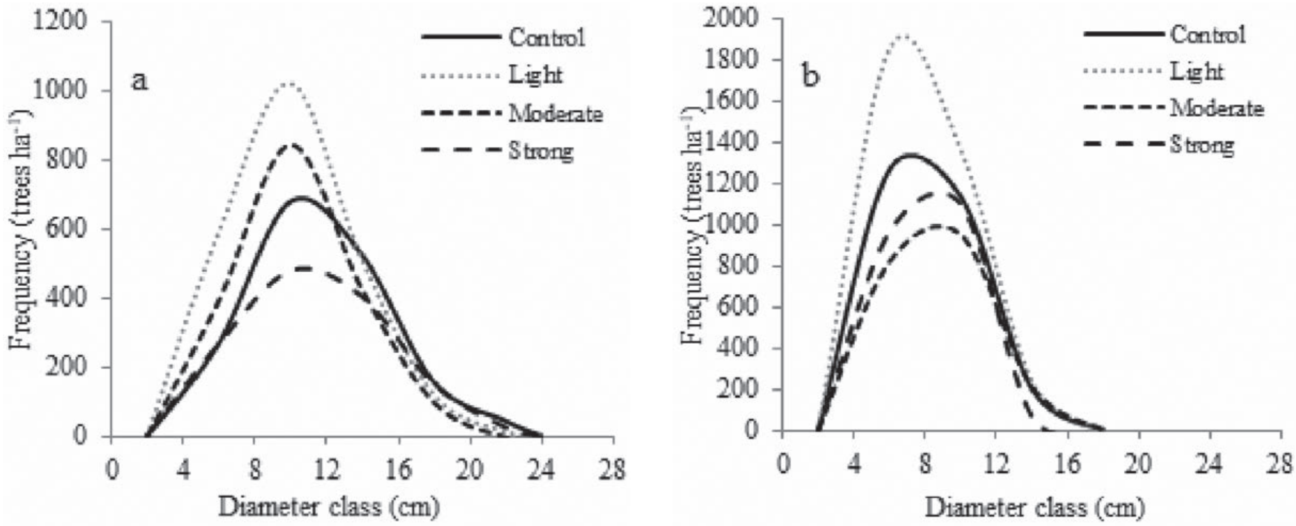

Figure 3. Distribution of trees in plantation areas to diameter classes
Slika 3. Distribucija broja stabala u plantažama s obzirom na debljinske razrede

ght thinnings and the moderate and strong thinnings were found statistically similar. In Yeşiltepe experiment, the light thinning was similar to control and moderate thinnings, and the strong thinning is statistically different from other thinnings (Table 2).

According to the results of the analysis of variance, significant differences were found between treatments in terms of average RBAI (%) in 2012 of Vakfıkebir experiment ($p<0.05$). In 2012, RBAI (%) was the highest in strong thinning and the lowest in the control treatment plot. Control was statistically similar to light and moderate thinnings while moderate and strong thinnings were statistically similar. As it can be seen in Table 2 and Figure 4, Yeşiltepe experiment has higher RBAI (%) in 2012. In Yeşiltepe experiment, a significant difference was found between treatments in terms of average RBAI (%) in 2012 ($p<0.05$). RBAI (%) was the highest in strong thinnings. Control, light and moderate thinnings are statistically similar (Table 2).

In Vakfıkebir experiment, significant differences were found between thinning intensities in terms of average RVI (%) in 2012 ($p<0.05$). It was determined that RVI (%) was the highest in strong thinning and the lowest in light thinning in 2012. Control treatment plots and light thinning are statistically similar while moderate thinning and strong

Table 3. Thinning effects on stand density, diameter, height, basal area, and volume after thinning and 2 years of growth
Tablica 3. Utjecaj prorjeđivanja na broj stabala, prsni promjer, visinu, temeljnicu i volumen nakon prorjeda i dvije godine rasta

Treatment Tretiranje	RD (cm) 2010	D (cm) 2012	BA 2012 (m^2ha^{-1})	V 2012 (m^3ha^{-1})	RDI (%)	RBAI (%)	RVI (%)	AHI* (m $year^{-1}$)
Vakfıkebir Vakfıkebirski								
Control – Kontrolni	14.05 ± 2.6 b	16.16 ± 3.4 b	47.66 a	193.84 c	11.65 a	24.93 ab	18.71 a	0.65 a
Light – Slaba	12.07 ± 2.8 a	13.84 ± 3.2 a	47.26 a	205.39 d	11.52 a	24.48 a	18.48 a	0.97 b
Moderate – Umjereni	12.34 ± 2.4 a	14.17 ± 2.8 a	49.74 b	172.94 b	12.77 b	27.34 bc	20.56 b	0.75 b
Strong – Jaka	13.79 ± 3.7 b	16.05 ± 4.1 b	59.27 c	152.60 a	13.17 b	28.88 c	21.22 b	0.85 b
P-value – P-vrijednost	0.003	0.002	0.003	0.001	0.002	0.004	0.006	0.015
Yeşiltepe Yeşiltepski								
Control – Kontrolni	9.01 ± 1.2 ab	9.97 ± 1.4 a	21.42 ab	124.10 b	12.31 a	27.02 a	19.61 a	0.89 a
Light – Slaba	8.72 ± 1.6 a	10.03 ± 1.9 a	22.87 b	132.79 d	12.50 ab	27.10 a	19.79 a	0.98 a
Moderate – Umjereni	9.60 ± 2.1 b	10.94 ± 2.2 a	25.64 c	130.38 c	13.92 b	30.47 a	22.15 a	0.83 a
Strong – Jaka	8.80 ± 1.7 a	10.45 ± 2.2 a	20.72 a	111.30 a	18.06 c	41.08 b	29.28 b	1.19 a
P-value – P-vrijednost	0.050	0.068	0.004	0.001	0.002	0.001	0.001	0.094

(RD: residual diameter, D: diameter, BA: basal area, V: volume, RDI: relative diameter increment, RBAI: relative basal area increment, RVI: relative volume increment, AHI: annual height increment).

(RD: rezidualni promjer, D: promjer, BA: temeljnica, V: volumen, RDI: prirast relativnog promjera, RBAI: prirast relativne temeljnice, RVI: prirast relativnog volumena, AHI: godišnji visinski prirast).

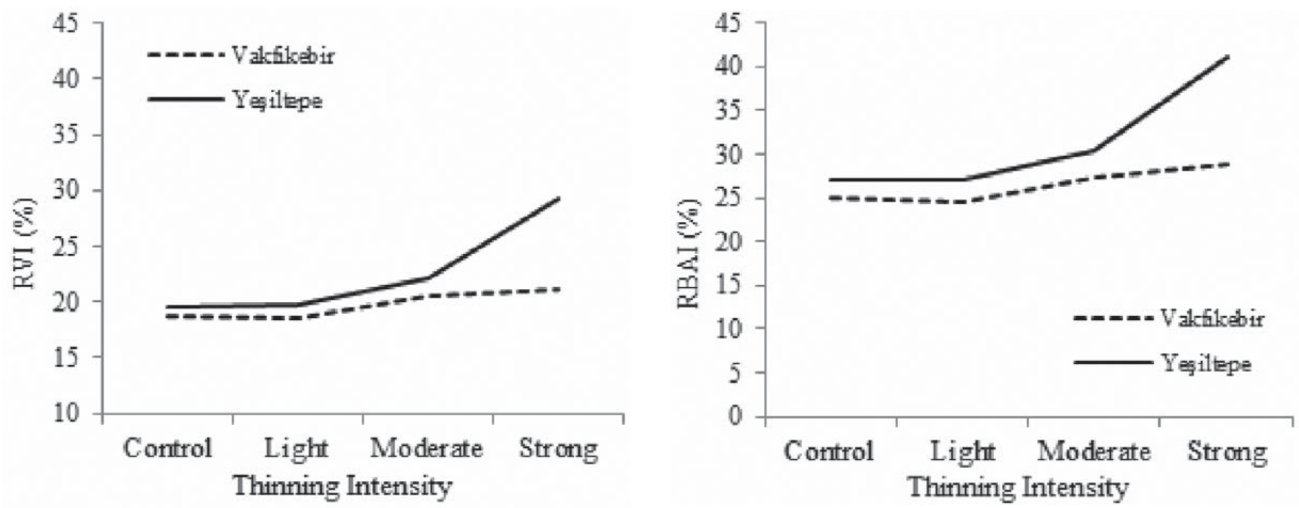

Figure 4. Relative volume increment and relative basal area increment of plantations
Slika 4. Prirast relativnog volumena i prirast relativne temeljnice u dvije plantaže

thinning are statistically similar (Table 2). In Yeşiltepe experiment, a significant difference was found between thinnings in terms of average RVI (%) in 2012 ($p<0.05$). RVI (%) was the highest in strong thinnings. Control, light and moderate thinnings are statistically similar (Table 2). In both experimental plots, the highest RVI (%) occurred in the plots where strong thinning was applied (Table 2, Figure 4).

The annual height increments in the plantation areas and the trees in the upper layer were evaluated statistically (Table 2). In Vakfıkebir experiment, according to 2-year height increments, the lowest height increment was determined in the control plot while the highest increment was determined in light thinning. Light, moderate and strong thinnings were found statistically similar. In Maçka-Yeşiltepe experiment, the lowest annual height increment is in moderate thinning and the highest increment is in strong thinning. The thinnings are statistically similar.

DISCUSSION
RASPRAVA

Oriental beech plantation areas gave an early response to thinning, and the highest diameter increments occurred in strong thinning in both plantation areas. However, the diameter increments in Maçka-Yeşiltepe plantation were found higher (Table 2). Similar to the findings of this study, it was indicated that diameter increments increased along with the increase in thinning intensity especially in younger leaved stands (Mayor and Rodà, 1993; Bréda *et al.* 1995; Hibbs *et al.* 1995; Rytter, 1995; Kerr, 1996; Medhurst *et al.* 2001; Clatterbuck, 2002; Meadows and Goelz, 2002; Juodvalkis *et al.* 2005; Makineci, 2005; Tufekcioglu *et al.* 2005; Rytter and Werner, 2007, Çiçek *et al.* 2013). The positive effects of thinning intensity on diameter increment can be attributed to the availability of more light, water, and nutrients for the thinned trees. The response given by the ecosystem to the thinning treatment was found to be associated with the increased diameter increment, water, and nitrogen use efficiency among the thinned trees, and the increased net photosynthesis ratio (Wang *et al.* 1995). It is possible to attribute the higher diameter increments in the Maçka-Yeşiltepe experiment in comparison with Vakfıkebir to lower stand age, or in other words, to the high growth potential. In the study supporting this study, Carus and Çiçek (2007) reported that the diameter increment in Oriental Beech decreased with the competition index among trees and the increasing plantation age. Thinning at the young stage enables individual trees to grow faster and develop more resistance to biotic and abiotic damages.

In our study, significant differences were determined between basal area and stem volume increments and thinnings in each plantation (Table 2). RBAI and RVIs were found higher in Yeşiltepe experiment (27.02 - 41.08%) compared to Vakfıkebir experiment (24.93 - 28.88%). The highest increments were found in strong thinning in both plantations. In the experiments, it was determined that RBAI and RVIs grew along with the increase in thinning intensity. However, in the old plantation Vakfıkebir experiment, RBAI and RVIs of moderate and strong thinnings gave close results and were statistically similar (Table 2). In the study carried out by Umut et al. (2000) on young Oriental Beech stands, moderate (20%) and strong thinning (40%) treatments were applied, and it was concluded that the treatments applied were effective in increasing the basal area but there was no significant relationship between the increase in treatment intensity and the increase in basal area. This result complies with the old plantation Vakfıkebir experiment. However, younger plantation Maçka-Yeşiltepe experiment does not comply. In Maçka-Yeşiltepe experiment, RBAI and RVIs increased with the increase in thinning intensity, and the other thinnings except for strong thinning were found statistically similar (Table 2). Since young plantations have higher growth potential compared to older plantations, they have a higher diameter, height, and basal area increments. Similar to the results of this study, it was seen that thinning increased the basal area growth in some leaved tree species (Cañellas *et al.* 2004; Pretzsch, 2005; Boncina *et al.* 2007), and in other studies, it decreased the basal area and volume increments (Simard *et al.* 2004; Çiçek *et al.* 2013). The importance of early silvicultural treatments on the future growth of young leaved stands (natural or plantation) has been emphasized in many studies (Schönau and Coetzee, 1989; Juodvalkis *et al.* 2005; Rytter and Werner, 2007; Matić *et al.* 2003). Schönau and Coetzee (1989) suggested that thinning should start early, recommended thinning at frequent intervals, and noted that the first thinning should be heavier than later ones. Early thinning can result in greater growth response, provided that the residual trees are vigorous (Oliver and Larson, 1996). The change in the basal area, volume and biomass increments in the reaction revealed by the stand against thinning can be explained by thinning intensity, thinning type, stand maintenance, stand age, growing environment and the differences between tree species (Çiçek *et al.* 2013). Our results support the known information about the effects of thinning on stand production.

We can say that the annual height increment in both plantations except for the control plot in Vakfıkebir experiment was not affected by the thinning intensity (Table 2). Similar results were obtained in various leaved tree species (Graham, 1998; Medhurst *et al.* 2001; Rytter and Werner, 2007). Except for very high and very low stand densities, stand density has significant effects on diameter growth, but it has no effect on height growth. In this study, the other thinnings except for the control plot in the older Vakfıkebir plantation were found statistically similar. The thinnings in the younger Maçka-Yeşiltepe plantation were found statistically similar. Along with the increase in the interval-distance of trees in fast-growing broad-leaved trees, the tree height may increase, decrease or remain unchanged (Alcorn *et al.* 2007; DeBell *et al.* 1996; Fang *et al.* 1999; Kerr, 2003; Pinkard and Neilsen 2003).

Variations in height growth with changes in available growing space could be attributed to ontogeny, to the range of tested spacing treatments, or to species. Height growth plays an important role in morphological acclimation to light competition (Lanner, 1985), with plants tending to allocate more photosynthate to height than diameter growth, which results in increasing stem slenderness (Benomar *et al.* 2012). On the other hand, height growth occurs early in the season when resources are not limited, and diameter growth occurs in summer when resources that restrict photosynthesis are limited (Wang *et al.* 1995).

Thus, stand density reduction by thinning increases soil water availability in summer, which primarily affects diameter increment. Bréda *et al.* (1995) found that thinning enhanced radial growth as a result of less severe water deficits in the thinned plot in late summer than in the control plot. Soil water measurements in our experimental plots showed that volumetric soil water contents were higher in thinned plots than in unthinned plots from July through September (Çiçek *et al.* 2010). Stone *et al.* (1999) also reported that thinning increased soil volumetric water content between May and August in the first year after thinning.

In this study, according to thinnings in the Maçka-Yeşiltepe experiment, the highest annual height increments occurred in strong thinning. However, the highest annual height increments in Vakfıkebir plantation were found in light thinning. Furthermore, the annual height increments in Maçka-Yeşiltepe plantation were found to be higher compared to the older Vakfıkebir plantation. This is thought to be related to the high growth potential of young stands as well as the aspects of plantations. Maçka-Yeşiltepe plantation is located in the eastern aspect while Vakfıkebir plantation is located in the south-western aspect. Mayer *et al.* (2002) reported that radiation interception at the canopy layer is higher on the SW facing slope, causing higher temperatures, higher evapotranspiration and, therefore, lower water availability.

CONCLUSION
ZAKLJUČAK

In this study, Oriental beech plantation areas gave an early response to thinning, and the highest diameter increments occurred in strong thinning in both plantation areas. However, the diameter increments in Maçka-Yeşiltepe plantation were found higher. Significant differences were determined between basal area and stem volume increments and thinnings in each plantation. Relative basal area and volume increments were found higher in Yeşiltepe experiment compared to Vakfıkebir experiment. The highest increments were found in strong thinning in both plantations. Our results support the known information about the effects of thinning on stand production.

Thinning during the young stage enables trees to grow faster and resist damaging agents. Thus, thinning practices should focus on young Oriental beech stands when the current annual increment is at its highest levels. Accordingly, future trees should be selected when the first thinnings are applied, and then attention should be concentrated on the crown development of future trees in order to maintain a desirable diameter increment and obtain enough stem diameter at the end of the rotation period.

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SAŽETAK

U ovom su istraživanju proučavani učinci prve prorjede različitih intenziteta u plantažnim područjima azijske bukve (*Fagus orientalis* Lipsky) vezano za povećanje promjera i visine stabala. Odabrane su primjerne plohe u plantažnim područjima azijske bukve unutar granica okruga Maçka–Yeşiltepe i Vakfıkebir u pokrajini Trabzon, Turska. Primjerne plohe utvrđene su prorjedom u četiri različita intenziteta (kontrolni, slaba, umjereni, jaka), uklanjanjem 0%, 10%, 25% i 40% temeljnice po hektaru sastojine u fazi mladika. Nakon prorjeđivanja, temeljnica je izračunata mjerenjem promjera i visine stabala u utvrđenim primjernim plohama kako bi se utvrdio rast sastojine. Utvrđeni su učinci prorjede povezani s određenim karakteristikama sastojine (prosječni promjer, temeljnica, prosječna visina, relativni debljinski prirast, itd.) i određenim odabranim stablima. Učinak intenziteta prorjede na prosječni promjer, vrijednost temeljnice i volumena pokazao se kao statistički važan u svakoj od dvije plantaže. Dvogodišnji rezultati pokazali su da je prorjeda značajno povećala debljinski prirast, a povećanje debljinskog prirasta je u pozitivnoj korelaciji s intenzitetom prorjede u oba eksperimenta. Štoviše, prirast promjera, visine, temeljnice i volumena bio je veći u eksperimentu u Maçka-Yeşiltepeu nego u eksperimentu u Vakfıkebiru. Međutim, vrijednosti umjerenog i jakog intenziteta prorjede u Vakfıkebiru bile su bliske. Nakon procjene svih rezultata, smatramo da je primjena jakog intenziteta prorjede u primjernoj plohi u Yeşiltepeu i umjerenog intenziteta prorjede u primjernoj plohi u Vakfıkebiru prikladna u smislu razvoja sastojine.

KLJUČNE RIJEČI: azijska bukva, intenzitet prorede, rast, plantaža, prirast