Effects of different thinning regimes on above ground biomass of young oriental beech (*Fagus orientalis* Lipsky) stands

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Abstract: The study was conducted to investigate the effects of different thinning regimes applied as moderate and heavy on above ground biomass of 25 years old oriental beech (*Fagus orientalis* L.) stand. A total of 9 trial plots, each consisted of 400 m^2 area, were established in Cankurtaran- Hopa region in 2008. In 3 trial plots, heavy thinning was applied (40% of basal area was removed). The other 3 trial plots were moderately thinned (20% of basal area was removed). Remaining 3 plots were allocated as control. The first measurements of tree diameters at basal area were made before the thinning application and the following years of 2008, 2009, 2010 and 2016. Biomass of trunk, branches, leaves and total biomass of trial plots were determined according to the developed biomass equations on dry weight basis. According to the results, biomass values decreased from heavy thinning through the control and biomass of moderate thinning plots located between. Although thinning practices decrease the number of individuals within plots, the increase rate of above ground biomass of the remaining trees found to be higher.
Keywords: *Fagus orientalis*, Oriental beech, Thinning, Above ground biomass

1. Introduction

Thinning is a cutting made in an immature crop or stands primarily to accelerate diameter increment but also, by suitable selection, to improve the average form of the remaining trees (Ford-Robertson, 1971). Thinning, a sustainable management in the forestry sector preserves the health of forests by planned active continual intervention after the sapling stage without permanently breaking stand closure among the trees through the natural regeneration stage (Genç, 2007). While the number of trees and stand closure decrease after thinning application in the stand, mean stand diameter increase. Basal area of the remaining stand decreases after thinning application, but in time basal area increment exceed the value of before thinning. At the same time, rotation age of the stand shorten with increased diameter at breast height and high grade timber might be produced (Kalıpsız, 1982).

Although, in some thinning applications the number of stem per ha are employed as thinning grades, in general, the values of mean diameter at breast height are mostly used. Thinning applications are namely used as light, moderate and heavy depending on the thinning intensity. In general, 10% of the total volume at basal area is removed from overstocked and fully stocked stands, it is called light thinning. If the total volume removal is changed between 10-20%, it is called moderate thinning and the total volume removal is more than 20%, it is called heavy thinning application (Odabaşı, 1985; Nyland, 1996; Smith et al., 1997; Avolio and Bernardini, 2007).

Intensity of thinning makes different gap sizes within the stand that regulates the degree of utilization of land, lateral branch elongation and survival, competition and health of individual tree diameter growth (Nyland, 1996; Smith et al., 1997). Thinning application made periodically as 5 or 10 year intervals which affects basal area of trees (Stefanjik and Stefanjik, 2001; Tüfekçioğlu, et al., 2004), tree heights (Medeiros et al., 2017), crown development (Makinen and Isomaki, 2004; Diaconu, et al., 2015) and enhancing value of the remaining trees' stem quality (Stefanjik, 2013; Kim, et al., 2016). Although some researchers argued that thinning implementations are not significantly affected the total biomass of the stands in the long term (Pesola et al., 2017), the others stated that total biomass of the stand are significantly affected by thinning (Nilsen and Strand, 2008; Verschuyl et al., 2011; Karlsson et al., 2015; Coletta et al., 2016).

This study was implemented to determine the effects of moderate and heavy thinning applications on above ground biomass of 25 years-old oriental beech (*F. orientalis* Lipsky) stand that the species is naturally distributed on the northern part of the Turkey and there is relict distribution areas on eastern Mediterranean region (Yilmaz et al., 2009) and high economic value in Turkish forest species (Talebi and Schütz, 2002; Ertekin et al., 2015).

2. Material and methods

2.1. Study area

The study was conducted on 25 year-old oriental beech plantation located on Hopa-Cankurtaran (41^0 40'N - 41^0 54'S) in Turkey. Plantation was made in 1984 using with 2-0 year-old oriental beech seedlings. Mean altitude of study area is 800 m.

According to interpolated long-term data of Hopa Meteorological observation station, research area receives a total of 2644.0 mm precipitation and the annual mean temperature of the study area is 10.4 ^{0}C, ranging from 3.1 ^{0}C to 18.7 ^{0}C in February and July, respectively (Anonymous, 2017). Soil of the study area is deep acidspodzol with sandy loam and loamy sand.

2.2. Experimental design

In 2008, a complete randomized design was applied to represent the sites and a total of 9 trial parcels were constructed (20x20m: 400 m^2 each). Of these, every 3 trial parcels allocated as heavy thinning, moderate thinning and control. The thinning applications were implemented as crown thinning in September of 2008. About 20% of the total basal area at breast height was removed for moderate thinning and 40% was removed for heavy thinning. No cutting was applied for the control parcels.

2.3. Field and laboratory analysis

In order to determine trunk, branch+leaves and total beech tree biomass, a total of 20 trees were felled from different diameter classes. In every tree, diameter at basal area, fresh weights of branches and leaves and trunk were determined in the field. At the same time, samples were taken in the field to determine oven dry weights. In the laboratory, to determine the oven dry weights of the trunk, branches+leaves and total weight, samples were dried 48 hours at 70 °C. Findings of diameter at basal area (cm), fresh (kg) and dry weights (kg) of trunk, branch+leaves and total biomass are given in Table 1.

Table 1. Average, minimum and maximum values of felled trees for biomass analysis

	Diameter	Fresh weight (kg)			Oven dry weight (kg)		
	($d_{1,30}$) (cm)	Trunk	Branch+leaves	Total	Trunk	Branch+leaves	Total
Average	15.0	89.9	17.87	107.85	49,71	12.70	62,4
Minimum	4.7	6.9	2.43	9.37	4.15	1.76	5.91
Maximum	25.8	231.1	36.86	267.92	121.32	25.84	147.16

2.4. Data analysis

Data was subjected to analysis of variance (ANOVA) with SAS statistical program. Means and differences between means were separated by least significant difference (LSD) analysis.

3. Result and discussion

Average above ground trunk dry biomass for the parcels were measured before the thinning applications that applied in the year of 2008 was 25.64, 25.45 and 25.13 ton/ha for control, moderately and heavily thinned parcels; respectively. The number of trees was 2600, 2417 and 2483 stems/ha for the control parcel, moderately thinned parcels and heavily thinned parcels, respectively. After thinning applications, average above ground dry biomass decreased to 20.98 and 15.68 ton/ha for moderately and heavily thinned parcels, respectively (Figure 1, Table 2).

When comparing the results of above ground trunk dry biomass in the year of 2008 and 2016, increment reached up to 172% in the control parcels, in another saying, dry trunk biomass changed from 25.64 ton/ha to 54.50 ton/ha. Biomass increment was higher for the moderately thinned parcels. Trunk dry biomass reached up to 207%, from 2008 through 2016, which equals to 34.44 ton/ha. The highest dry trunk biomass increment was measured in the heavily thinned parcels. Increment reached up to the 273% from the year of 2008 through 2016. Total trunk dry biomass increment was measured as 42.33 ton/ha between the first and the last measurements (Table 2). Dry matter biomass before and after thinning and according to the application years and types their importance levels were presented in Table 2. In 2008, 2009 and 2010 heavy thinned parcels had the lowest biomass and were statistically different from control and moderately thinned parcels. However, in 2016 the heavily thinned trees had the highest trunk dry biomass while control and moderately thinned trees were grouped together.

Table 2. Above Ground trunk dry biomass and number of trees by years and applications

Treatment	**2008**				**2009**		**2010**		**2016**	
	Before thinning		After thinning							
	N*(ha)	ton/ha	N(ha)	ton/ha	N(ha)	ton/ha	N(ha)	ton/ha	N(ha)	ton/ha
Control	2600	25.64	2600	25.64 [a]	2492	28.67 [a]	2442	31.64 [a]	2233	54.50 [b**]
Moderate Thinning	2417	25.42	1908	20.98 [b]	1908	23.67 [b]	1908	26.77 [b]	1783	55.42 [b]
Heavy Thinning	2483	25.13	1317	15.68 [c]	1317	18.12 [c]	1317	21.23 [c]	1317	58.01 [a]

N*: number of stems

**The values on the same line followed by the same letters are not significantly different at P<0.05.

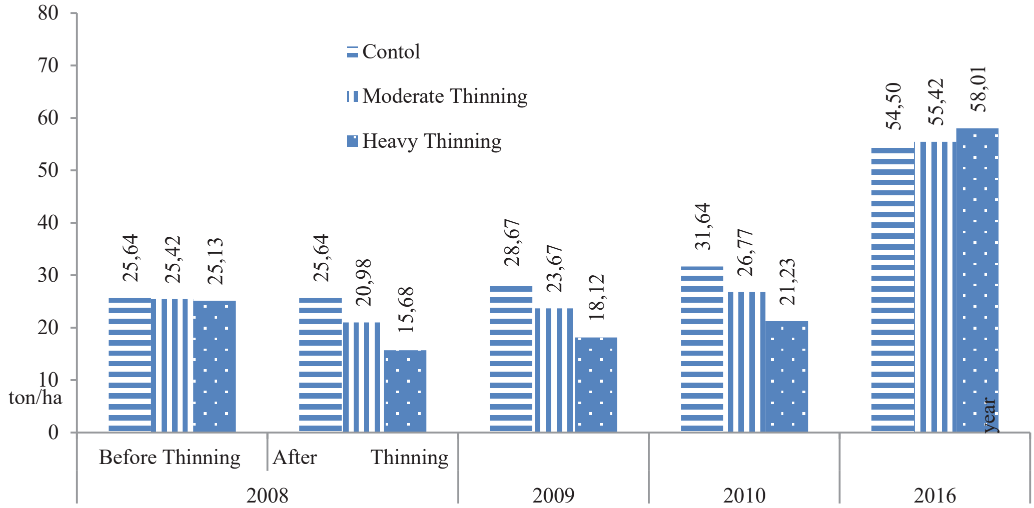

Figure 1. Changes in Trunk Dry Biomass by Years

After 8 years of thinning applications, branch+leaves total dry biomass increment was calculated as 7.45 ton/ha, which equals to 142% raise in the control parcels. Total branch+leaves dry biomass increment for the moderately thinned parcels was 8.44 ton/ha (% 161), reached from 11.23 ton/ha to 17.75 ton/ha from 2008 through 2016, respectively. Heavily thinned parcels showed statistically higher biomass increment comparing to the control and moderately thinned parcels in all years where thinning applications were made. Increment was calculated as 9.65 ton/ha which corresponds to 196% yield from first measurement through the last (Table 3). Dry matter biomass before and after thinning and according to the application years and types were presented in the Figure 2. Throughout the experiment control trees retained the highest branch+leaves biomass and the lowest were observed in the heavy thinned trees.

Table 3. Above Ground Branch+leaves Dry Biomass and Number of Trees by Years

Treatment	2008				2009		2010		2016	
	Before thinning		After thinning							
	N*(ha)	ton/ha	N(ha)	ton/ha	N(ha)	ton/ha	N(ha)	ton/ha	N(ha)	ton/ha
Control	2600	11.49	2600	11.49 [a]	2492	12.49 [a]	2442	13.34 [a]	2233	18.94 [a**]
Moderate Thinning	2417	11.23	1908	9.31 [b]	1908	10.13 [b]	1908	11.02 [b]	1783	17.75 [b]
Heavy Thinning	2483	11.11	1317	6.88 [c]	1317	7.56 [c]	1317	8.42 [c]	1317	16.53 [c]

N*: number of stems

**The values on the same line followed by the same letters are not significantly different at $P<0.05$.

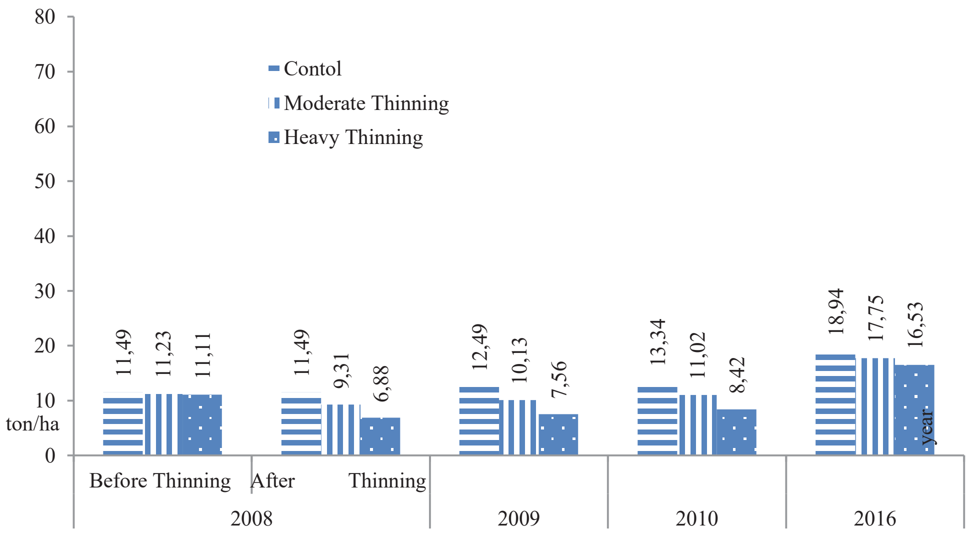

Figure 2. Effect of thinning application on branch and leaves dry biomass

Total dry biomass of trunk and branch+leaves yield was 36.35 ton/ha after 8 years of application on the control parcels which changed from 36.65 ton/ha in 2008 through 73.00 ton/ha in the year of 2016. Biomass yield increment was 164%. On the other hand, moderately thinned plots showed higher increments after 8 years as 197% comparing to the year of 2008. Total yield was calculated as 43.24 ton/ha. As trunk and branch+leaves dry weight biomass, the highest biomass accumulation was measured in the heavily thinned parcels. However, there was no statistically significant differences were detected between the applications and the control parcels. Increment was 35.93 ton/ha at the beginning of the experiment and was found as 74.28 ton/ha at the end of 2016. Biomass accumulation was calculated as 51.88 ton/ha which equals to 253% increase (Table 4). Dry matter total biomass of branch+leaves before and after thinning and according to the application years and types were presented in the Figure 3.

Table 4. Above ground total dry biomass and number of trees by years

Treatment	2008				2009		2010		2016	
	Before thinning		After thinning							
	N**(ha)	ton/ha	N(ha)	ton/ha	N(ha)	ton/ha	N(ha)	ton/ha	N(ha)	ton/ha
Control	2600	36.65	2600	36.65 ^{a}	2492	40.64 ^{a}	2442	44.51 ^{a}	2233	73.00 ^{a**}
Moderate Thinning	2417	36.20	1908	29.65 ^{b}	1908	33.12 ^{b}	1908	37.07 ^{b}	1783	72.89 ^{a}
Heavy Thinning	2483	35.93	1317	22.41 ^{c}	1317	25.41 ^{c}	1317	29.38 ^{c}	1317	74.28 ^{a}

N*: number of stems

**The values on the same line followed by the same letters are not significantly different at P<0.05.

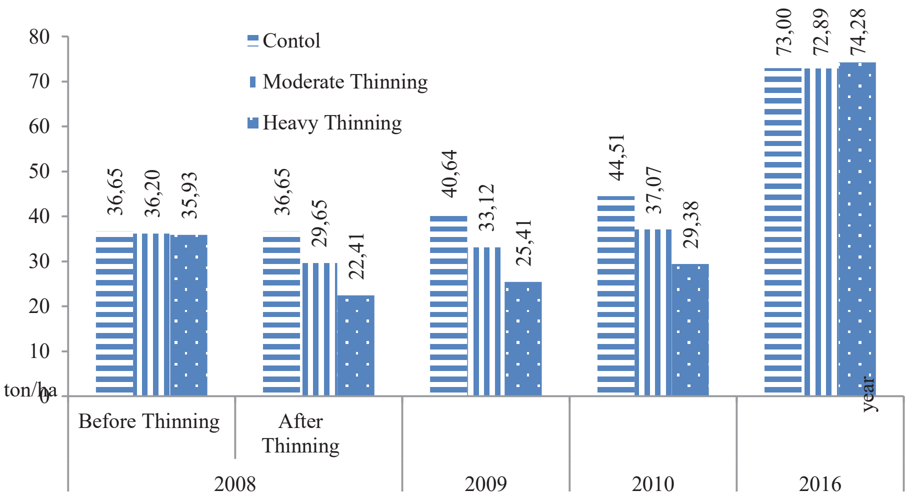

Figure 3. Total Dry Matter Biomass by Years

3.1. Regression equations

Dry matter biomass values of the tree parts were analyzed in MS Excel software program and the highest regression equations were determined. Trunk dry weight (TDW) is expressed as 99% with diameter at breast height of the trees. In other words, beech tree trunk dry weight biomass is dependent with 99% on diameter of the measured tree. Regression equation for the trunk dry weight is given below.

$$TDW= 0,2309 \times (d_{1,30})^2 - 0,9099 \times (d_{1,30})+ 0,7747 \quad (R^2 = 0,9918).$$

Regression analysis for branch+leaves dry weight (BLDW) biomass is expressed as 98% with diameter at breast height of the trees. That means, beech tree branches and leaves dry weight biomass are dependent with 98% on diameter of the measured tree. Regression equation for the BLDW is given below.

$$BLDW = 0,0151 \times (d_{1,30})^2 + 0,7905 \times (d_{1,30})- 3,2807 \quad (R^2 = 0,9897).$$

Total trunk and branch+leaves dry weight (TW) is expressed as 99% with diameter at breast height of the trees. Regression equation for the total dry weight is given below.

$$TW = 0,246 \times (d_{1,30})^2 - 0,1194 \times (d_{1,30}) - 2,506 \quad (R^2 = 0,9920).$$

Each forest stand has its own growth capacity, depending on the site index of the area. All of the living organisms, particularly forest trees species, are dependent on the availability of light in the stand and organic matter and water in the soil. Usage amounts and limitations of these resources restrict plant growth. As a result of these competitions, vigorous tree species survive and weak trees die. The current study revealed that in the control parcels where no thinning applications were applied, the average number of trees at the beginning of the study was counted as 2600 stems/ha and 8 years later in 2016 tree numbers was counted as 2233 stems/ha. This result showed that in the control parcels trees died due to increased competition for light, organic matter and water. Similar results were observed for moderately and heavily thinned stands where tree numbers after 8 years were counted as 1783 stems/ha and 1317 stems/ha, respectively.

On the other hand, trunk, branch+leaves and total dry matter biomass showed similar results with tree numbers. This might be expressed as the growing power of the site is gathered in the retained trees in the stand. In other words, biomass production capacity of the forest stand is not affected. The current study results are also supported by Pesola et al., (2017) that carbon accumulation therefore biomass production capacity of the site after thinning applications are not significantly affected. Similarly, Karlsson et al., (2015) stated that in young scots pine stands biomass accumulation is calculated 27% higher than the control parcels where the control parcel had 4000 stems/ha and thinned parcels had 2500 stems/ha. These studies also supported by Nilsen and Strand, (2008) that 10 years after thinning application in young *Picea abies* stands, above ground carbon accumulation, therefore, biomass production capacity of the site was 27% higher than the control sites.

In the current study, despite declining stem numbers in the remaining forest trees after thinning applications, the trees in the site produced higher biomass amounts comparing to the control parcels. This study were supported by Coletta et al., (2016) that 7 different thinning applications applied on Douglas stands yielded higher biomass accumulation than control sites. In addition, the highest biomass and carbon accumulation was observed on heavily thinned stands. Muñoz et al., (2008) stated that *Eucalyptus nitens* stands at the age of 6 year-old are very responsive to thinning applications in terms of biomass accumulation.

Although, increasing rate of thinning applications favor of higher biomass yield, heavy thinning applications to the stands might decrease stem quality due to increase in crown development and negative effect on natural branch pruning (Tonguç and Güner, 2017). Therefore thinning applications should have limitations in order to produce high quality timber and paper pulp. However, to get fully benefit from the biomass potential, it might be necessary to consider alternative management strategies such as increasing interest in biofuels and the generation of renewable energy, in addition to timber and pulp (Karlsson et al., 2015).

4. Conclusion

Moderate and heavily thinned stands yielded higher biomass than unthinned parcels. Diameters at breast height of the stems were also larger and diameter distributions were much uniform. Also, stem quality of the trees were much better in the thinned parcels. Furthermore, thinning and transportation costs, raw materials prices obtained from thinning, damage effects of different thinning regimes on the remaining stand should also be studied in greater details.

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