Thinning Effects on Production, Root Biomass and Soil Properties in a Young Oriental Beech Stand in Artvin, Turkey.

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Abstract

In this study, three thinning treatments were applied on a 0.54 ha, young oriental beech (*Fagus orientalis* Lipsky) stand (25-30 years old) in Karadag, Artvin in the fall of 1999. The treatments were: (1) no thinning, (2) light thinning, and (3) heavy thinning. Prior to thinning, the stand averaged 15000 trees ha^{-1} and 40.0 m^2 ha^{-1} of basal area, with an average mean diameter of 5 cm. Thinning reduced stand basal areas to about 31.1 and 24.9 m^2 ha^{-1} for the light and heavy thinning treatments, respectively. After 3-year, diameter increment was the highest in heavily thinned stand and the lowest in unthinned stand. The increment in stand basal area was about 10, 18 and 27 % in the unthinned, lightly thinned, and heavily thinned stands, respectively. Fine root biomass significantly decreased with thinning and thinning had no significant effects on soil pH and soil organic matter content.

Keywords: *Fagus orientalis*, thinning, growth, root biomass, soil properties

Doğu Kayını Ormanında Yapılan Aralamanın, Büyüme, Kök Biyokütlesi ve Toprak Özellikleri Üzerine Etkileri

Özet

Bu çalışmada, Karadağ - Artvin bölgesinde ve 0.54 ha büyüklüğündeki ve sırıklık çağındaki (25-30 yaş) doğal doğu kayını ormanında, üç farklı aralama işlemi (kontrol, mutedil aralama ve şiddetli aralama) Kasım 1999 tarihinde yapılmıştır. Aralamadan önce meşceredeki ağaç sayısı ortalama 15000 adet ha^{-1}, göğüs yüzeyi 40.0 m^2 ha^{-1} ve çap 5 cm olarak belirlenmiştir. Hafif ve şiddetli aralama sonucunda meşcere göğüs yüzeyleri yaklaşık olarak 31.1 ve 24.9 m^2 ha^{-1}' a düşürülmüştür. Üç yıl sonunda çap artımı şiddetli aralama yapılan parsellerde en yüksek olarak belirlenmiş ve göğüs yüzeyindeki artış şiddetli müdahale yapılan parsellerde %27, mutedil aralama da %18 ve kontrol de ise %10 olarak tespit edilmiştir. Kılcal kök kütlesi, şiddetli aralamaya maruz kalan parsellerde, kontrol ve mutedil aralama parsellerine oranla istatistik anlamda azalma göstermiştir. Toprak pH' sı ve organik madde içeriği aralama ve kontrol parselleri arasında anlamlı farklılık göstermemiştir.

Anahtar kelimeler: Doğu kayını, aralama, büyüme, kök biyokütlesi, toprak özellikleri

Introduction

Oriental beech (*Fagus orientalis* Lipsky) is one of the most abundant and wide spread tree species in the northern Turkey. It expands from the Bulgarian boundary in the west to Georgian boundary in the east and penetrates towards the inner and backward parts of both the Black Sea and Marmara geographical regions. In addition to this, oriental beech communities are also found on the north and northwest facing slopes of the Amanos Mountains in the Eastern Mediterranean geographical region of Turkey. Optimum growth conditions of the beech forests are found on the north-facing slopes of the Northern Anatolian orogenic belt in the Black Sea Region and the Istranca mountains in Thrace (Atalay, 1994; Aksoy and Mayer, 1998).

Thinning is an important silvicultural practice for improving tree growth by redistributing growth and increasing the growth rates of residual trees in forests. It also allows forest managers to select trees to which additional growth will be allocated. In general, the heavier the thinning, the greater the diameter growth response of individual trees is. However, very heavy thinning may reduce residual stand density to the point where stand-level basal area growth and volume growth are greatly diminished.

Recommendations for minimum residual stocking levels are necessary to maintain satisfactory stand-level growth.

Thinning as early as 20-25 years can increase the growth potential and value of hardwoods on good sites. Thinning regulates stand density and dramatically increases diameter growth of residual trees (Sonderman, 1984; Nyland, 1996). The other benefits of thinning are; increased usable growth, enhanced product quality, and creating healthy and stable forest structures. It enables sunlight to further penetrate into forest floor and therefore, stimulates decomposition of organic debris on the soil surface (Smith, 1997).

Changing canopy architecture shifts pattern of biomass partitioning among above- and belowground components (Cannel, 1985; Santantanio and Santantanio, 1987). Beets (1982) found important shifts in dry matter partitioning from branches and foliage to stems in a young plantations of *Pinus radiata* D. Don. Santantonio and Santantonio (1987) reported that heavy thinning (60% reduction in basal area) in a 12-year-old plantation of *Pinus radiata* D. Don. reduced the overall standing crop of live fine roots from 1.38 to 0.55 tons ha^{-1}. In the same study, the standing crop of live small roots declined from 1.03 to 0.54 tons ha^{-1}.

Fine and small roots represent an important biomass component of forest ecosystems. Production of fine roots can account for 8 (Keyes and Grier, 1981) to 67% (Grier et al., 1981) of net production. The broad range in these values indicates that important variation exists in the allocation of dry matter to fine and small roots. It could be possible through silvicultural practices to direct some of the production normally lost through fine root turnover to another tree component such as stem wood.

Influence of thinning on aboveground production of oriental beech is not well documented in Turkey. A study done by Umut et al. (2000) revealed that thinning was necessary in a 55-years-old oriental beech stand and that thinning increased stand growth more than control plots after nine-year. However, thinning impact on below ground biomass and soil properties haven't been studied in Turkey.

The objectives of this study were to determine the influence of heavy and light thinning on aboveground production, root biomass and some soil properties in 25-30 years old oriental beech stands located in Upper Arhavi, Artvin after a 3-year period.

Material and methods

The experiment was carried in a young stand of natural oriental beech (25-30 years old) located in the northeastern part of the province of Black Sea region (N, W), Karadag, Artvin, Turkey. This region is located in the north-facing slope, and characterized by a humid climate (about 2500 mm of annual precipitation) that is favorable to the development of beech stands.

The stand originated from advance regeneration that was released by a clear-cut conducted in 1975, and was left untreated until 2000. The study site was established in fully stocked, even-aged, undisturbed stands growing under uniform conditions with 100% of the overstory composition in beech and was entirely within around a 150 ha stand composed primarily of beech. Prior to thinning, the stand was dense and composed of small-diameter trees with short boles.

The study consisted of three replications of three thinning treatments applied in a randomized block design to the 9 treatment plots (each 30 x 20 m in size) in November 1999. The treatments were: (1) unthinned control, (2) light thinning to 9785 dominant and codominant trees per ha, and (3) heavy thinning to 6822 dominant and codominant trees per ha. High thinning was used to remove trees primarily from the upper crown classes as well as trees that were damaged, overmatured, diseased, and had poor bole quality or undesirable species.

The plots were measured immediately before and after thinning, and have been measured after 3 years in December 2002. Basal area calculations were made using diameter at breast height (dbh) for each tree. Tree heights were measured with a clinometer to the nearest dm on a sub-sample of trees, which were numbered. These sub-samples consisted of 20 trees per plot and were selected to represent all the diameter classes of the plots.

Soil coring technique was used to determine fine (0-2 mm), small (2-5 mm) and coarse (5-10 mm) root biomass (Joslin and Henderson, 1987). Five soil cores of 6.4 cm diameter were removed from each sampling plot from the surface 0-30 cm of soil. Cores that could not be sorted immediately were placed into a cold room (4 °C) until they could be. Roots were separated from the soil by soaking in water and then gently washing them over a series of sieves with mesh sizes of 2.0 and 0.5 mm. Roots were sorted into diameter classes of 0-2 mm, 2-5 mm and 5-10 mm. The roots from each size category were oven-dried at 70 °C for 24 h and weighed and ground. Mg, Ca, P, K and Na content of ground samples were determined using atomic absorption spectrophotometer. Two additional soil cores were taken from each plot to determine soil organic matter content, soil texture and soil pH. Soil samples were air-dried, ground and pass through 2 mm mesh-sized sieve.

The statistical significance of the differences between the different thinning treatments was analyzed using one-way analysis of variance. The means were separated according to Duncan's New Multiple Range Test at the 0.05 level of probability.

Results and discussion

Prior to thinning, the stand averaged 15000 stems ha^{-1} and 40.0 m^2 ha^{-1} of basal area, with an average total height 7 m, and a mean diameter of 5 cm. Light thinning reduced stand density to 9900 stems ha^{-1} and 31.15 m^2 ha^{-1} of basal area; heavy thinning reduced stand density to 6800 stems ha^{-1} and 24.91 m^2 ha^{-1} of basal area, immediately following thinning. Expressed as percentages, light thinning removed about 27% of trees, 19% of the basal area, whereas heavy thinning removed about 54% of the trees and 40% of the basal area. Both thinning treatments produced stand characteristics significantly different from the unthinned control (Table 1 and 2). There were significant differences in DBH and basal area among treatment plots three years after treatments ($P<0.05$). During the 3-year period following thinning, basal area increased to 36.91 and 31.75 m^2 ha^{-1} in the lightly and heavily thinned stands, respectively. During the same period, basal area in the unthinned stand increased from 39.46 to 43.45 m^2 ha^{-1}.

The rate of basal area growth over the 3-year period differed among treatments ($P<0.05$). The mean increment in stand basal area was about 10, 18, and 27 % in the unthinned, lightly thinned, and heavily thinned stands, respectively. Mean diameter growth was the highest in heavy thinning treatment (6.42 cm) and was the lowest in unthinned stand (5.81 cm). The mean height increment was the lowest in heavy thinned stand and didn't differ significantly among control and light thinning treatments. In the present study, a few trees died in unthinned and light thinned stands and no mortality occurred in heavy thinned stands. These changes in trees per ha were not significantly different among treatments ($P<0.05$).

Umut et al. (2000) found that light and heavy thinning greatly increased stand basal area and mean diameter growth over the 9-years-period following thinning in 55-years-old oriental beech stands. In the same study, the height increment was the lowest in the heavy thinned stands. In other studies with different species in USA: Meadows and Goelz (1999a) found that several thinning treatments in a 28-years-old *Quercus nigra* plantation did not significantly increase stand basal area growth after 7 years, while Meadows (2001) observed that light and heavy thinning treatments in a 28-years-old *Q. nigra* plantation significantly increased stand basal area compared to control after 5 years following thinning. In another study, the increases in stand basal area and diameter growth 3 years after application of four thinning treatments were the lowest in unthinned thirty-year-old *Quercus falcata-Liquidambar styraciflua* stand, and light thinning and heavy thinning treatments produced stand characteristics significantly different from the unthinned control (Meadows and Goelz, 1999b). Similarly, rates of increases in basal area growth of red maple were the greatest in the most heavily thinned stands during 5 years after thinning over a 14-years study (Londo et al., 1999). These stands also exhibited the highest gain in trees per acre. Actual growth per tree was minimal in the stands with intermediate levels of thinning. These findings are in agreement with our results in this study.

Fine root biomass was significantly higher in control compared to heavy thinning treatment ($P<0.05$) (Table 3). Heavy thinning caused in a 7% reduction in fine root biomass. Similar results observed by Santantanio and Santantanio (1987) in a *Pinus radiata* plantation in New Zealand, and they reported that thinning (60% reduction in basal area) reduced the overall standing crop of live fine roots from 1.38 ton ha^{-1} to 0.55 ton ha^{-1}. These results suggest that decreased competition among trees may shift some of the production into aboveground components rather than belowground production.

There was no significant difference between fine root biomass of control and light thinning treatment (Table 3). This could be due to the two reasons. First, the magnitude of the thinning might not be great enough to create a significant reduction in the fine root biomass of lightly thinned stand. Second, the three years time period after application of treatments might not be long enough to cause significant changes in fine root biomass between treatments. Small root biomass did not differ significantly among treatments. Mean small root biomass was slightly higher in control and light thinning treatments compared to heavy thinning treatments. Heavy and light thinning treatments had higher mean coarse root biomass than did control. This indicates that thinning may increase diameter and length of coarse roots.

Fine roots accounted for 69.8%, 70.0% and 76.8% of total root (0-10 mm) biomass for heavy, light and control sites, respectively. Higher percentage of fine root biomass in control site could be an indication of more fine root production due to intense competition compared to thinning treatments. Small root biomass was 14.6%, 16.1% and 15.4% of total root biomass for heavy thinning, light thinning and control, respectively. Coarse root biomass was 15.5%, 13.7% and 7.8% of total root biomass for heavy, light and control treatments, respectively.

Fine root biomass was significantly higher than small and coarse root biomass in all treatments. Small root biomass was higher than coarse root biomass but this was significant only in the control site. Overall mean of fine, small and coarse root biomass were 9137, 1941 and 1562 kg ha^{-1}, respectively.

Nutrient contents of roots varied with treatments (Table 4). Fine and small roots in heavy thinning sites had significantly higher phosphorus (P) content than the other sites had ($P<0.05$). Relatively low P content of roots and its significant change with treatments could be an indication that P is the most limiting nutrient element in the area due to high acidity of soils. Control sites had significantly higher fine root phosphorus content than light thinning sites had ($P<0.05$). Ca, Mg, K and Na content of fine and small roots didn't differ significantly among treatments. This might be due to high variation among plots. Overall mean nutrient contents of fine roots were lower than nutrient contents of small roots (Table 4). The reason of high nutrient content in small roots might be that oriental beech uses its small roots as some type of storage organ to supply nutrients into aboveground tissues when the availability of nutrients limited by the environmental conditions (cold weather, freezing in soil) in early spring.

Soil pH and organic matter content did not vary significantly among treatments (Table 5). Mean soil pH of all treatments were almost similar to each other. Soil organic matter content of control and light thinning plots were lower than that of the heavy thinning treatment plots. This could be the result of decomposition of dead roots left from cut trees due to thinning. Soil sand and silt content differed significantly between control and heavy thinning treatment, even though the magnitude of the differences were very small (close to 2%) (Table 2). The sand content of soils was relatively high. Higher rates of precipitation in the area could cause leaching of clay and silt particles from surface horizons to down into the soil profile.

Conclusions

Stand basal area growth and diameter increment were significantly higher in heavily and lightly thinned plots than unthinned plots. As a result of high stocking level, the unthinned stands were not favorable for the development of vigorous, high quality oriental beech trees. Heavy thinning gave the highest basal area growth and diameter increment. Thinning had no significant effect on height growth.

Fine root biomass significantly decreased with thinning while no significant thinning effects observed on small and coarse root biomass. Lower fine root biomass in the thinned stands may indicate that thinning shifts some of the below-ground production into above-ground production. Thinning had no significant effect on soil pH and soil organic matter content in three-year period while it increased phosphorus content of fine and small roots indicating better phosphorus supply to roots in heavily thinned stands.

Further research is needed to determine which time and what rate is best for these thinnings to apply. The duration of these effects and their influence on the pruning habits, growth patterns and height development of individual trees, and the effects of thinning on root biomass and soil properties in the long term need to be investigated.

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Table 1. Changes in the number of trees per ha, in diameter and height growth after thinning in a young oriental beech stand.

Treatment	Stems ha^{-1}			Mean diameter (cm)	Diameter growth (%)	Height growth (cm)
	Before thinning	After thinning	3-yr after thinning			
Unthinned	15245 a[1]	15245 a	15220 a	5.81 c	9.25 c	65 a
Light thinning	13423 a	9785 b	9775 b	6.23 b	17.05 b	68 a
Heavy thinning	14982 a	6822 c	6865 c	6.42 a	22.67 a	57 b

[1] Means in the column followed by the same letter are not significantly different at P=0.05.

Table 2. Changes in stand basal area ($m^2 ha^{-1}$), by treatment, following thinning in a young oriental beech stand.

Treatment	Before thinning	After thinning	3-yr after thinning	Basal area increment %
Unthinned	39.46 a[1]	39.46 c	43.45 c	10.11 a
Light thinning	38.25 a	31.15 b	36.91 b	18.49 b
Heavy thinning	41.36 a	24.91 a	31.85 a	27.45 c

[1] Means in the column followed by the same letter are not significantly different at P=0.05.

Table 3. Root biomass following thinning in a young oriental beech stand.

Root biomass (kg ha^{-1})	Heavy Thinning	Light Thinning	Unthinned
Fine root biomass	8938 b[1]	8888 b	9586 a
Small root biomass	1864 a	2033 a	1924 a
Coarse root biomass	1988 b	1731 b	967a
Total root biomass (0-10 mm)	12790 a	12652 a	12477a

[1] Means in the same row with the same letter are not significantly different at P=0.05.

Table 4. Nutrient contents of fine and small roots following thinning.

Treatments	Fine Roots (0-2 mm)				
	P ppm	Ca ppm	Mg ppm	K ppm	Na ppm
Unthinned	69.73b[1]	1391.76 a	792.70 a	1293.38 a	122.56 a
Light thinning	52.73a	1384.08 a	713.23 a	1100.32 a	153.56 a
Heavy thinning	81.18c	1451.06 a	827.93 a	1000.63 a	148.97 a
Mean	67.88	1408.97	777.95	1131.44	141.70
	Small Roots (2-5 mm)				
Unthinned	58.96b	1760.38 a	950.58 a	1840.43 a	179.94 a
Light thinning	38.89a	1692.30 a	856.82 a	1521.51 a	128.15 a
Heavy thinning	110.86c	1464.35 a	892.77 a	1398.81 a	115.17 a
Mean	69.57	1639.01	900.05	1586.91	141.09

[1] Means with the same letter in the same column are not significantly different in each root class category at P=0.05.

Table 5. Changes in some soil properties following thinning in a young oriental beech stand.

Soil Properties	Heavy Thinning	Light Thinning	Unthinned
Soil pH (1/2.5 H_2O)	5.63 a[1]	5.62 a	5.62 a
Soil organic Matter (%)	5.33 a	5.09 a	5.37 a
Sand (%)	90.23 b	92.52 a	92.87 a
Silt (%)	6.83 a	5.18 b	5.23 b
Clay (%)	2.93 a	2.30 a	1.76 a

[1] Means with the same letter are not significantly different at P=0.05.