http://dx.doi.org/10.22161/ijeab/2.1.32 ISSN: 2456-1878

Effects of Pruning on Diameter and Height Growth of *Pinus nigra* Arnold subsp. *pallasina* Plantations in Turkey

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***Abstract*—** *Pruning is a costly silvicultural operation and allows the production of high value timber. Effect of pruning on black pine and especially on Anatolian black pine (Pinus nigra Arnold subsp. pallasina) is not well known. The objective of the study was to evaluate pruning effects on diameter and height growth of Anatolian black pine. Pruned and the control treatments were carried out using 20 year old black pine plantation in Çorum providence of Turkey. Three pruning treatments were applied in 2004, 2009 and 2016 and diameter and height growths of trees were measured. Each pruning was done from the bottom to include one third of the crown. At the beginning of the study (first pruning) and after 5 years of the first pruning no difference was observed for DBH and height growth. However, diameter and height growth became important after 12 years of pruning between pruned and control stands. Results show that pruning could increase diameter growth and height of Anatolian black pine stands. To better understand, further detailed studies must be carried out investigating site effects, plant density and environmental variations.*

***Keywords*—Anatolian black pine, diameter growth, height growth, Pinus nigra, pruning.**

I. INTRODUCTION

Silvicultural treatments are applied from the beginning of the seedling emergence throughout the final harvesting in the forests. Pruning is an application for producing clear wood among the silvicultural managements for forest tree species (Forrester, 2013; Forrester et al. 2013). Clear wood is called as high quality knot-free timber and veneer logs (Pinkard and Beadle, 2010; Moreno-Fernández et al. 2014). In coniferous trees, diameter and the number of the knots present at the tree trunk are among the main factors decreasing the wood quality of timber (Víquez and Pérez, 2005; Erkan et al. 2016). Obtaining clear wood via pruning has the potential benefit to increase the net revenues (Neilsen and Pinkard, 2003). Pruning starts from the surface of the earth and is applied as a cut of living and non-living branches to a certain height of a tree. As the photosynthetic active leaf area is removed from the top crown by pruning, it may adversely affect the diameter increase depending on the tree species and the intensity of the pruning (Forrester, 2013; Långström and Hellqvist, 1991), but the diameter increase may not be adversely affected when the density of pruning light (Forrester, 2013; Uotila and Mustonen, 1994; Amateis and Burkhart, 2011). Moreover, some leaves on the lower branches may respire more than they photosynthesize. Thus they might be removed without negatively affecting diameter growth (Savill et al. 1997). The pruning of such sections of the crown may result in increase in the light usage efficiency and increases photosynthesis rates in the remaining upper section of the canopy (Forrester, 2013).

Pruning has generally limited and temporary effects on the height growth of trees as compared to the diameter increase (Amateis and Burkhart, 2011). However, there is no effect of pruning on the height increase for *Ficus microcarpa* or *F. virens* (Zhang et al. 2007), *Juniperus virginiana* (Schmidt and Wardle, 2002) and *P. pinaster* and *P. radiata* (Hevia et al, 2016). On the other hand, pruning affected height growth slightly for *P. sylvestris* (Långström and Hellqvist, 1991) and had no effect for *P. pinaster* and *P. radiata* (Hevia et al, 2016). Although pruning of forest trees requires high investment costs (Moreno-Fernández et al. 2014), the costs could be reduced to when applied only to selected trees in the forest (Neilsen and Pinkard, 2003). Moreover, pruning provides easiness for other silvicultural applications and making the stands more resistant to the forest fire (Savill et al. 1997).

In Turkey, State Forest Service (SFS) owns 99% of the forested areas of which 67% consisted of pure coniferous and mixed species with broadleaf trees and all the silvicultural treatments and management plans are prepared by SFS including thinning and pruning (URL 1). Having economic and ecological importance, pine species are widely utilized all over the world. Black pine (*P. nigra* Arnold) is broadly distributed in the Mediterranean region and is among the frequently used pine species in large plantations all over the region (Moreno-Fernández et al. 2014). Anatolian black pine (*P. nigra* Arnold subsp. *pallasina* (Lamb.) Holmboe) is one of the most important

tree species, mainly distributed in Western Anatolia and forms as pure or mixed stands (Tonguc et al. 2013). Anatolian Black pine has the third largest distribution area (4.2 million ha) after *P. brutia* and oak species in Turkey (URL 1) and largely used for reforestation and rehabilitation studies. It is also suitable for afforestation of high altitude lands with dry climatic conditions and steppes (Koski and Antola, 1993; Kaya and Temerit, 1994).

Pruning exercises are being implemented in Turkey (Erkan et al. 2016) and in other Mediterranean countries as a precaution against fire risk by reducing the flammable biomass on the ground and opening gap between the surface and tree crown (Bilgili, 2003; Bilgili et al. 2010; Ganteaume et al. 2011). Although black pine is largely planted, the effects of pruning on its diameter and height growth are not well documented (Moreno-Fernández et al. 2014). It is important that the pruning should be feasible before applying in large areas. Therefore, it is necessary to study whether or not pruning is feasible in specific tree species (Schmidt and Wardle, 2002). Although producing clear wood increases the value of the plantation, currently SFS conducts limited and low level pruning activities due to associated costs and the lack of accurate data about the effects of pruning on harvest quality.

The purpose of the present study was to determine the effects of pruning on diameter and height growth of Anatolian black pine plantations growing on dry climatic conditions located in Çorum city.

II. MATERIAL AND METHODS

2.1. Study sites

The study was carried out in Çorum providence of Turkey located on the north of the country (40º 35´ N- 34º 59´ S). The study area has continental dry climate characteristics. Soil of the plantation area is flat with loamy soils. Mean altitudes of the plantation areas are 925 and 920 m for pruning and control sites; respectively. The closest meteorological observation station is located in Çorum (806 m) and the annual mean temperature of the region is 10.8 °C, ranging from -0.3 °C to 21.3 °C in January and July, respectively (URL 2). Mean relative humidity is 68% where July and August are the driest months (58.8% and 60.5%, respectively) and 65 year (1950-2015) average precipitation is 432 mm (Table 1).

Table.1: Long term average meteorological conditions of the study area (1950-2015).

Parameter	Jan.	Feb.	Mar.	Apr.	May.	Jun.	July.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean temperature (°C)	-0,3	1	5	10,6	15	18,6	21,3	21,2	17,2	11,8	5,9	1,8
Relative humidity (%)	77,4	72,2	68,5	66,7	65,2	62,9	58,8	60,5	64,4	70,3	75,6	79,2
Mean precipitation(mm)	38,9	30,2	39,5	49,4	60,9	52,3	18,9	13,7	22,2	28,6	33,4	43,5

2.2. Experimental design and pruning regimes

Previously, Anatolian black pine trees were planted as 1 m x 2 m planting distance (Anonymous, 1976). The current planting distance is 1.5 x 3 m in Turkey (URL 3). The site was established in 1985. Following two years after planting, weed control and replacement of dead saplings were carried out. In 2004, when the stands were 20 years old, two plots were established for pruning and control. Prior to establishing the study sites, homogenous sites were searched and the chosen sites had uniform growth and ground vegetation covers. The first pruning application was set up on the same year. For every tree a unique number was given and then diameters at breast height (DBH) were measured and marked. A total of 100 trees with 5 replications were recorded. At the same time, 100 trees with 5 replications were also measured as the control. Each replication (row) consisted of 20 trees with surrounding unpruned trees around them for buffering in order to eliminate edge effect.

Second pruning application was carried out in 2009 and the third one in 2016. After each pruning applications, diameter growths of pruned trees and the trees in control were recorded. At the same time, for height growth measurements, a total of 10 trees from each replication were randomly chosen and numbered in pruned trees and in control. Height growths of trees were also recorded together with the diameter measurements. In each inventory, diameters of the trees were measured using a caliper at breast height of all trees (cm) and height growth of trees were measured using telescopic height measurement device (m).

For each pruning application, (2004, 2009 and 2016), one-third of the tree height of the crown area was removed including dead branches and live crown starting from ground level to upper canopy because pruning one-third of the crown reduces production very slightly (1%) at the end of rotation (Savill et al. 1997).

2.3. Data analysis

http://dx.doi.org/10.22161/ijeab/2.1.32 *ISSN: 2456-1878*

Data was subjected to one-way analysis of variance (ANOVA) with Minitab statistical program. Means were separated using Tukey's procedure.

III. RESULTS AND DISCUSSIONS

The first measurements and pruning were conducted in 2004 when trees were 20 years old. The ANOVA results revealed that DBH and height growth did not show any significant differences ($p< 0.05$) during the establishments of control (mean DBH 5.1 cm, mean height 4.9 m) and pruning parcels (mean DBH 5.6 cm, mean height 5.1 m) (Table 2).

At the age of 25 (5 years after pruning), mean DBH was measured as 6.6 cm and 5.6 cm for pruning parcels and control, respectively. Although there were small differences between them, the values for pruning and control parcels were not significant ($p< 0.05$). Average height growths of trees were measured as 5.3 m for both pruning and control parcels, hence there was not any statically significance ($p< 0.05$) between the pruning and control parcels for height growth. Pruning treatments did not effected either DBH or height growth of trees after 5 years (Fig. 1, Fig. 2).

The effects of pruning on DBH growth and height growth were found to be statically significant ($p<0.05$) when pine trees were 32 years old (12 years after the first pruning and 7 years after the second pruning). Mean DBH was 18.1 cm and 13.9 cm for pruned parcels and the control; respectively. The height growth of the parcels were also statistically significant between pruned and control trees. While average height was 7.5 m for control trees, average height was 9.6 m for pruned trees (Table 2, Fig 1, Fig. 2).

Table.2: ANOVA results showing DBH and height growth of Anatolian black pine after pruning treatment

	First Pruning			Second Pruning			Third Pruning		
	Age (year)	Mean height (m)	Mean diameter (cm)	Age (year)	Mean height (m)	Mean diameter (cm)	Age (year)	Mean height (m)	Mean diameter (cm)
Pruning	20	4.9 c*	5.7cd	25	5.3 c	6.6c	32	9.6a	18.1a
Control	20	5.1 c	5.1d	25	5.3 c	5.6cd	32	7.5b	13.9b

*Means followed by the same letters is not significantly different from one another. Mean separation within each column by Tukey's test at $p<0.05$.

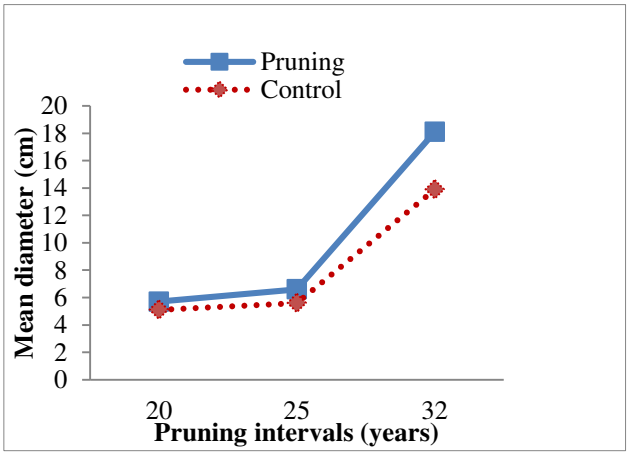

Fig.1: Mean diameter growth and pruning intervals

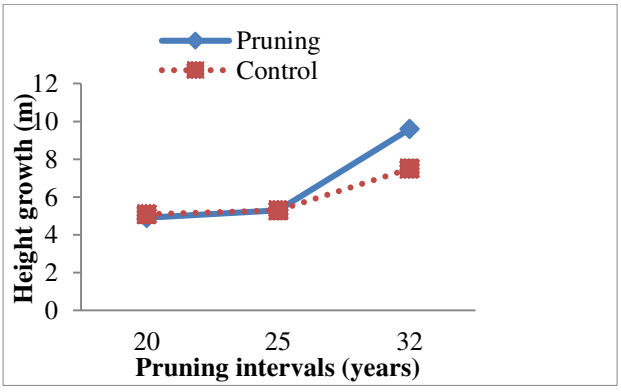

Fig.2: Height growth and pruning intervals

Tree species differ in their response to pruning time and pruning intensity. There are many reports regarding effects of pruning on different conifer and other tree species. While some researchers reported that pruning reduced diameter growth (Långström and Hellqvist, 1991; Uotila and Mustonen, 1994; Hevia et al, 2016) others did not report reduction in diameter growth (Pinkard and Beadle, 2010; Neilsen and Pinkard, 2003; Amateis and Burkhart, 2011). Effect on pruning on height growth is limited and usually is not as important as diameter growth (Amateis and Burkhart, 2011).

Studies dealing with the effects of pruning on black pine is scarce (Moreno-Fernández et al. 2014), and no published results exist for Anatolian black pine studying pruning effects of this subspecies. In the present paper, we report the effects of pruning on DBH growth and height increase for the Anatolian black pine 5 and 12 years after pruning. At the beginning of the study (20 year old plantation), mean height and mean diameter did not differ significantly between control and pruning treatment (Table 2). After 5 years, second pruning was performed mean height of the control and pruned trees were the same (5.3 m). Amateis and Burkhart (2011) reported that height growth is favored than DBH growth for young *P. taeda* to remain competitive in a stand. Our results indicated that pruning did not adversely affected Anatolian black pine's

competitive ability since they stand next to unpruned trees and had the same mean height. However; there was difference between pruned and control trees for mean diameter. Diameter increase was more pronounced for pruned trees, though not statistically significant. After 12 years of first pruning and 7 years of the second pruning, both height and diameter increase became statistically significant compared to control. After the second pruning the average height of the pine trees were 9.6 m compared to 7.5 m to control. Cannell and Dewar, (1994) argued that many tree species allocate more resources to apex than stem to keep dominance of crown position in the stand. Reducing lower branches further lowers the allocated resources to dead branches (Savill et al. 1997) and increase light intensity reaching to lower branches in a pruned stand (Takiya et al. 2010), thus increasing photosynthetic capacity to stimulate growth. DBH growth was also increased for pruned trees (18.1 cm) than control (13.9 cm). Similar results reported by Hevia et al, (2016) that DBH is positively affected by pruning application for *P. radiata* and *P. pinaster*. For black pine, pruning simultaneously applied with thinning had positive effects on DBH growth but only thinning with or without pruning did not produce statistically significant results for DBH growth, showing pruning is important for DBH growth for the black pine (Moreno-Fernández et al. 2014). Contrary to our results, there was not any statistically significant data for height increase with pruning for *P. nigra* subsp. *nigra* and *P. nigra* subsp. *salzmannii* (Moreno-Fernández et al. 2014). It is also noted that soil properties, mean rainfall and summer temperatures had significant effects on DBH growth for black pine (Moreno-Fernández et al. 2014). The present study conducted in an area where rainfall is 432 mm. Effects of pruning on DBH and height growth are more pronounced where soil properties and mean rainfall is lower (Moreno-Fernández et al. 2014; Hevia et al, 2016), which might explain why height growth was important in our study for black pine.

IV. CONCLUSION

The present study is the first report on pruning of Anatolian black pine. Pruning intensity along with stand intensity, their interaction with the environmental variations needs to be studied. Further work is necessary to fully understand pruning effects and to make appropriate recommendations suitable to Turkey's needs.

ACKNOWLEDGEMENTS

We would like to thank Orhan Çatalçam and Selim Umaysız of Çorum State Forestry Service for their help during the study.

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