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GROWTH PERFORMANCES IN PLANTING AND SEEDING AREAS OF TAURUS CEDAR (*CEDRUS LIBANI* A. RICH.)

SUMMARY

Planting and seeding are the main tools in successful forest establishment. It is well discussed based on global climate change and sustainable forestry recently. Seedling height, diameter at base, height increment of last growth period of planting areas established by two-year containerized seedlings and seeding areas established by sowing 13 kg pure seeds per ha were compared at sixth-year afforestation of Taurus Cedar (*Cedrus libani* A. Rich).

Averages of seedling height, diameter at base, height increment of last growth period were higher in planting than seeding. For instance, averages of seedling height were 150.4 cm in planting, and 81.6 cm in seeding. Beside, number of seedling was higher in planting (1767/ha) than seeding (1300/ha) at measurement period. Significant differences were found among sampled areas within planting and seeding areas, and between planting and seeding areas for the characteristics. Positive and significant ($p<0.05$) relations were found between the pairs of seedling height, diameter at base and height increment in both areas. Planting could be preferred to seeding in suitable sites in forestry practices.

Keywords: Afforestation, Forest establishment, Planting, Seedling, Sowing.

INTRODUCTION

According to inventory of United Nations Food and Agriculture Organization, there were 3.9 billion ha forest area in whole world, while an average of 4 million ha forest were disposed per year between 1990 and 2015 (FAO, 2015). Its wide distribution and global importance are getting highlights the protection of present forests and conversion of degraded areas. However, many environmental and biological factors such as climate, edaphic, geographic, afforestation method and species could be effective in the protection and conversion. Afforestation method and species can be intervened factors by forestry practices in these factors. These methods have

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advantages and disadvantages over each other. For instance, seeding can be performed for the species which has abundant and cheap seed.

In the study, afforestation methods are compared based on Taurus cedar (*Cedrus libani* A. Rich) which has limited studies. The species is classified as one of the economically important tree species for Turkish forestry and the "National Tree Breeding and Seed Production Programme" (Koski and Antola, 1993) because of its valuable wood properties such as light, soft, highly durable, special colour, smell and of being easily processed by hand and machine tools (Bozkurt *et al*., 1990), and large natural distribution, and high adaptation ability to different environmental conditions (i.e. potential tree species to resistance climate change). However, 48% (235229 ha) of forest of the species is unproductive (Anonymous, 2020) similar to general Turkish forest area. But together with its mixed stands, extremely degraded stands, and bare karstic lands occurred after degradation of Taurus cedar, range of this species covers an area of over 600 000 ha in Turkey (Saatcioglu, 1976; Boydak and Calikoglu, 2008). Forest establishment including afforestation, reforestation, artificial regeneration, rehabilitation and private plantation are the most important way in conversion of unproductive forest and potential area to productive (Bilir and Gulcu, 2015). Afforestation by planting and seeding is a fundamental tool for the establishment of new forests on barren landscapes and restoration of degraded forests ecosystems (Caliskan and Boydak, 2017). For instance, 85 899 ha reforestation was established by broadcast seeding method on bare karstic lands resulted from the destruction of Taurus cedar between 1984 and 2006 (Boydak and Calikoglu, 2008). About half a million seedling was produced for Turkish reforestation of the species in last decade (Anonymous, 2020). Beside, Taurus cedar have also planted in other countries for commercial forestry purposes such as in Italy (Fusaro, 1990), in Bulgaria (Tsanov *et al*., 1990), in Argentina (Ottone and Carloni, 1990). However, limited study was carried out to examine on the success of planting and seeding methods (e.g., Boydak and Ayhan, 1990; Boydak, 2003; Ayan *et al*., 2017; Ozel *et al*., 2018) in Taurus cedar. Besides, growth performances of the Taurus cedar in the planting and seeding areas have not been compared to select better reforestation method, yet. Therefore, in this study, growth performances in the planting and seeding sites were compared in order to contribute the present and future practices in forest establishment of the species.

MATERIAL AND METHODS

Planting and seeding sites were sampled from sixth-year afforestation established by seeds of seed stand (36°31'43" N latitude, 32°46'50" E longitude, 1750 m altitude) of the species at southern part of Turkey (Table 1, Figure 1). Data of seedling height (**H**), diameter at base (**D_o**) and height increment of last growth period (**HI**) was collected from three planting (**P**) and three seeding (**S**) areas which each of them was 300 m^2. The data was collected from sixth-year afforestation to minimize planting and seeding shock of first years. The planting areas were established by 3x1.5 m spacing and two-year containerized seedlings, while seeding areas were established by sowing 13 kg pure seeds/ha by routine governmental practices such as soil treatment, tending, dilution, re-seeding/planting in first three years.

Table 1. Geographic details of the planting and seeding areas

Method	Area	Latitude (N)	Longitude (E)	Altitude (m)	Aspect
Planting	**P1**	37°12′41″	31°59′10″	1865	West
	P2	37°14′40″	31°59′31″	1830	West
	P3	37°26′58″	31°46′42″	1210	West
Seeding	**S1**	37°13′30″	31°54′22″	1605	East
	S2	37°13′26″	31°56′34″	1720	West
	S3	37°14′38″	31°57′22″	1725	West

There could be many biological and other environmental factors on success performances of forest establishment. The sampled areas were selected from limited afforestation area of the species to minimize effect of these factors (i.e., similar soil characteristics, temperature, rainfall) based on the purpose of the comparison of afforestation methods in the study. Average slope and soil texture across the sampled areas was 15% and sandy loam at calcareous bedrock. Monthly climatic data of the area for last decade was given in Table 2 (URL, 2019).

Figure 1. Sampled areas from planting (left side) and seeding (right side)

Table 2. Monthly climatic data of the area for last decade

Characteristics	Months											
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Average temperature (°C)	-0.3	1.0	5.4	10.9	15.6	20.1	23.5	22.9	18.6	12.4	5.7	1.4
Average max. temperature (°C)	4.6	6.6	11.8	17.5	22.2	26.7	30.2	30.0	26.3	20.0	12.4	6.0
Average precipitation	33.7	23.8	26.3	38.6	41.3	20.9	7.4	5.2	11.3	32.8	37.1	41.0

The sampled area was classified by Erinc's Precipitation effectiveness index (Im) which was used widely in estimation of climate type (Erinc, 1965) as:

$$Im = P/Tom \quad (1)$$

Where, P was the annual total precipitation (mm) and Tom was the annual average maximum temperature (°C).

The sampled area was semi-arid according to Precipitation effectiveness index (Im=17.6).

The sampled areas of planting and seeding were compared for the growth characteristics by following model of multiple analyses of variance (MANOVA) using SPSS (SPSS, 2011).

$$Y_{ijk} = \mu + P_i + S_j + P(S)_{i(j)} + e_{ijk} \quad (2)$$

Where Y_{ijk} is the observation from the kth seedling of ith sampled area of jth method (planting or seeding), μ is overall mean, P_i is the effect of the ith sampled area, S_j is the effect of jth method, $P(S)_{i(j)}$ is the effect of interaction between method and sampled area, e_{ijk} is random error.

Sampled areas were grouped by Duncan's multiple range test (Duncan, 1955). Relation among the characteristics was estimated by Pearson' correlation at SPSS (SPSS, 2011).

RESULTS AND DISCUSSION

Characteristics

Planting showed higher growth performances than seeding for the seedling height, diameter at base and height increment of last growth period (Table 3). Averages of height, diameter at base, and height increment of last growth period were 150.4 cm, 38.6 cm and 35.5 cm in planting site, and 81.6 cm, 26.2 cm and 21.7 cm in seeding site, respectively. Averages of height were 43 cm at three years, 116 cm at six years, and 201 cm at nine years in a planting site originated from seed stand of the species (Bilir, 2004). Averages of height and root-collar diameter of three-year seedling were 20.8 cm and 4.1 mm in the species (Demirci and Bilir, 2001). Averages of height and diameter at base were found 498 cm, 724 cm and 313 cm, and 15.2 cm, 19.3 cm and 7.1 cm in three planting sites which were 12, 12 and 10 years in the species, respectively (Bilir *et al.*, 2018).

Annual height growths were 25.1 cm at planting and 13.6 cm in seedling areas in the present study while it was found 41.5 cm, 60.3 cm and 31.3 cm in three planting areas by Bilir *et al*. (2018), and 22.6 cm by Ozel *et al*. (2018). It showed that annual height growth was lower in seeding than planting in the present and early studies. However, there could be many environmental (e.g., preparing of site, spacing, climatic, edaphic) and biological (e.g., provenance, species) effects in success and growth performance of forest establishment (Yazici and Turan, 2016; Ayan *et al*., 2017; Yazici, 2018). Boydak (1996) reported that the species increased the growth performance fast after five or six years in natural stands of the species.

Table 3. Averages ($\bar{x}$) and standard deviation (SD) of the characteristics and Duncan's tes results for the sampled areas

Area	**N***	**Height (cm)**		**Diameter at base (mm)**		**Height increment (cm)**	
		$\bar{x}$	**SD**	$\bar{x}$	**SD**	$\bar{x}$	**SD**
P1	40	137.7^{b**}	42.4	37.7^{c}	6.8	31.5^{bc}	14.3
P2	51	133.6^{b}	40.7	36.0^{c}	6.1	34.0^{cd}	14.1
P3	68	170.6^{c}	50.7	41.2^{d}	7.4	38.9^{d}	15.2
Mean		150.4	48.6	38.6	7.2	35.5	14.9
S1	36	83.0^{a}	34.7	23.8^{a}	8.2	28.1^{bc}	15.6
S2	45	74.5^{a}	27.3	27.5^{b}	8.2	13.0^{a}	8.5
S3	36	88.9^{a}	31.8	26.8^{ab}	6.8	26.1^{b}	14.3
Mean		81.6	31.5	26.2	7.9	21.7	14.5
Overall		121.2	54.2	33.3	9.7	29.6	16.2

*; Number of individuals of sampled areas, **; Means with the same letter in the columns are not significantly different.

There were also large differences among sampled areas within planting and seeding and between planting and seeding areas for the characteristics. Averages of height varied between 74.5 cm (S2) and 170.6 cm (P3). Average of height increment of last growth period was three times higher in P3 (38.9 cm) than S2 (13 cm) (Table 3). The differences were also supported by the results of analysis of variance showing significant ($p \leq 0.05$) differences among sampled areas and between planting and seeding. Planting showed 84.3% higher height performance than seeding. It was 27.7% at planting areas (P2 and P3), and 19.3% at seeding areas (S2 and S3) for height (Table 3). Beside method x area interactions were found to be significant ($p \leq 0.05$) for the characteristics. Similar results were also reported among planting sites of the species (Bilir *et al*., 2018; Ozel *et al*., 2018). Planting areas had larger variation than seeding sites for H and HI based on standard deviation. And also, sampled areas were more homogenous for H than D and HI based on results of Duncan's multiple range test (Duncan, 1955) (Table 3). Beside, number of seedling was higher in planting (1767 seedlings/ha) than seeding (1300 seedlings/ha) at measurement period. Numbers of seedling were reported 6000 /ha on sunny slopes and 14000/ha on shady slopes at reforestation areas established by seeding of the species at the end of fifth vegetation period

(Boydak and Calikoglu, 2008). The results emphasized that importance of afforestation method, and local forestry practices.

Table 4. Correlation coefficients between the pairs of for seedling height (H), diameter at base (D) and height increment (HI) for the polled sampled areas

Methods	Traits	H	D_o
P		-	
S	**H**	-	
P&S		-	
P		**.869***	-
S	**D_o**	**.831***	-
P&S		**.897***	-
P		**.819***	**.663***
S	**HI**	**.739***	**.401***
P&S		**.814***	**.650***

*; correlation is significant at the 0.05 level.

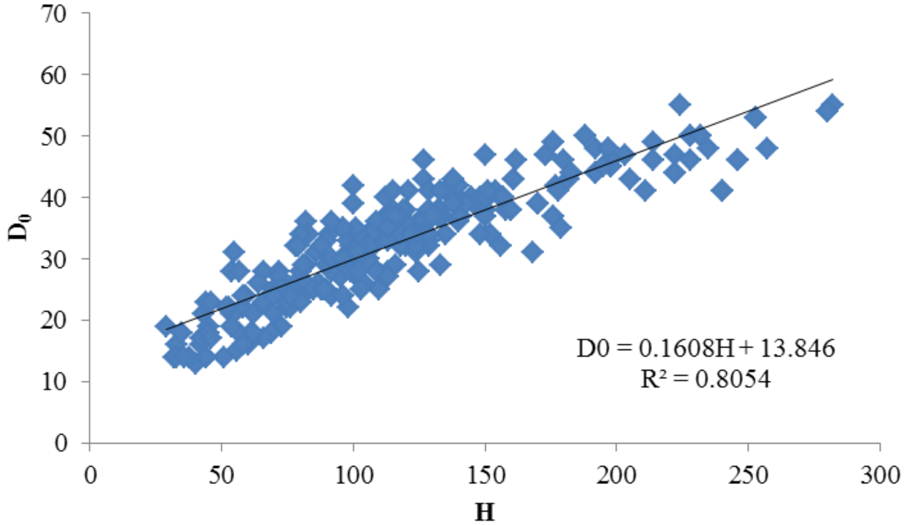

Figure 2. Relations between height (cm) and diameter at base (mm) for the areas of planting and seeding

Relations between the pairs of characteristics

Positive and significant (*$p<0.05$*) relations were found between the pairs of seedling height, diameter at base and height increment in all sampled areas (Table 4). Relation between height and diameter at base was also shown for the areas of planting and seeding in Figure 2. Similar relations between height and diameter were also reported by Bilir (1997 and 2004), Yazici (2018), Ozel *et al.* (2018), and Bilir *et al.* (2018) in the species.

CONCLUSIONS

Results of the study showed that planting could be preferred to establish fast stand to seeding. Differences of growth performances among sampled areas within areas emphasized importance of local forestry practices.

Significant relations between the pairs of characteristics could be used in future studies, and forestry practices such as forest tending and comprehensive determination of stand performance. Future performances of these areas or different study areas could be investigated for the more accurate conclusions.

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