

EFFECT OF SLOPE ON REPRODUCTION MORPHOLOGY AND QUALITY IN NATURAL REGENERATION OF BRUTIAN PINE

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Abstract

In this study, effect of slope on reproduction morphology (called also as seedling in this study) in natural regenerations of Brutian pine (*Pinus brutia*) to contribute natural regeneration and other forestry practices was examined based on seedling height and root-collar diameter by data collected from four years old natural seedlings sampled over slope ranges (S) at end of growth period of 2020.

Averages of seedling height were 97.7 cm for upper (S>40%), 96.7 cm for middle (30%<S<40%) and 106.3 cm for low (S<30%) slopes, while averages of root-collar diameter were 24.0 mm, 23.8 mm, and 24.6 mm, respectively. The results showed that lowest slope had higher growth performance than others. There were large differences within slope, and among slopes ($p<0.05$) according to results of analysis of variance for the characteristics. Relations between seedling height and root-collar ($r=0.67, 0.70, \text{ and } 0.76$) were positive ($p<0.05$) in each slope and pooled slopes ($r=0.81$). All seedlings of low slope were in first seedling quality class of Turkish Standard Institute, while it was 93.6% for upper slope and 96.6% for middle slope.

Key Words: Brutian pine, correlation, growth, variation.

1. Introduction

Forest is an ecosystem included many biotic and a-biotic elements, and their interactions. Forest tree species which cover human demand to wood and non-wood, and also other unmesurable forest products such as clean water and air, recreation and erosion control. In covering of this demand, natural regeneration is one of important forestry practices. For instance, 33438 ha forest area was regenerated according to latest Turkish forestry inventory (Anonymous, 2020). The practice has also a role for sustainable forestry based on balancing between supply and demand. However, advantages and disadvantages, and their future effect of natural regeneration and plantation practices, and their combination can not be estimated well because of climate change. It is known that there could be many environmental (i.e., edaphic and climatic factors, altitude, year) and biological (i.e., species, seed year, density of seed tree) factors effective on success of natural regeneration practices estimated by growth performance and numbers of reproductions/seedling, while they could be provenance, seed quality, type of seed source, quality and type of seedling for plantation practices. Determination of effectness has important role in natural regeneration practices of Brutian pine (*Pinus brutia* Ten.) because of its commercial wood production and largest distribution in Turkey by 5.74 million ha natural distributions of which 38.6% (2.16 million ha) to be unproductive (Anonymous, 2020), and also its resistance to arid area and different ecological conditions. The advantages is getting importance of the species for sustainable forestry. However, while many studies were carried out on seed source (Üçler et al., 2000; Dilaver et al., 2015; Bilir and Çetinkaya, 2018), seedling quality and morphology (Yılmaz and Bilir, 2016; Özel et al., 2018; Bilir, 2019), there were limited studies on growth performance (e.g., Şırlak, 1987; Çifçioğlu, 1998; Çatal et al., 2017; Çetinkaya, 2019; Yazıcı, 2021), and effect of environmental factors (Çifçioğlu, 1998; Yazıcı, 2021) in natural regeneration. In these studies effect of slope in natural regeneration of Brutian pine has not been studied, yet.

In the present study, effect of slope on growth performance in natural regeneration of Brutian pine was estimated for comparison by cultural seedling to contribute silvicultural and other forestry practices of the species.

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2. Material and Methods

Studied populations were sampled from natural regeneration which was 4 years old at southern part of Turkey of Brutian pine (Figure 1) based on slope (**S**) ranges classified as upper (**S**>40%), middle (30%<**S**<40%) and low (**S**<30%) in the study (Table 1).

Table 1. Location of studied populations.

Slope	Latitude (N)	Longitude (E)	Altitude (m)
Upper (S >40%)	37°41'36"	30°50'28"	1064
Middle (30%< S <40%)	37°41'37"	30°50'29"	1051
Low (S <30%)	37°41'36"	30°50'28"	1047



Figure 1. Sampled areas (upper, middle and low from left) in the study.

Regeneration areas were sampled randomly as 100 m² (10x10 m) for each slope class given above from 4 years old natural regeneration area at same location of Brutian pine at end of growth period of 2020. Height of reproduction called also seedling in this study (**SH**) and root-collar diameter (**RCD**) of each natural reproduction were measured. The following linear model of variance analysis was performed for comparison of the growth characteristics according to slope groups:

$$Y_{ij} = \mu + C_i + e_{ij} \quad (1)$$

where Y_{ij} is the observation from the j^{th} reproduction of the i^{th} slope group, μ is general mean, P_i is the random effect of the i^{th} slope group, and e_{ij} is random error.

Homogenous groups of slope classes were estimated by Duncan's test (Duncan, 1955) for the SH and RCD. Correlation between SH and RCD was estimated by Pearson's correlation using SPSS statistical package program in each and pooled aspects.

The seedlings were classified according to quality classes of Turkish Standard Institute (TSI) (Anonymous, 1988, Table 2).

Table 2. Seedling classes for four years seedling of TSI.

Quality classes	SH (cm)	RCD (mm)	SH+RCD
First class	70≤SH	2≤RCD	70≤SH + 2≤RCD
Second class	70> SH ≥60	-	70>SH ≥60 + 2≤RCD
Cull	60>SH	2>RCD	60>SH + 2>RCD

3. Results and Discussion

3.1. Growth characteristics

Averages of SH and RCD were 97.7 cm, 96.7 cm and 106.3 cm, and 24.0 mm, 23.8 mm, and 24.6 mm for upper, middle and low slopes, respectively (Table 3, Figure 2). Annual seedling height and root-collar diameter were 24.4 cm, 24.2 cm, 26.6 cm, and 6.0 mm, 6 mm, and 6.2 mm, respectively. They were 8.9 cm and 1.7 mm in advanced regenerations of seven stands of the species (Çetinkaya, 2019). Averages of aspectual seedling height were ranged from 10.1 cm to 14.4 cm, and root-collar diameter varied between 11.2 mm and 11.3 mm (Yazıcı, 2021). Averages of seedling heights were higher than averages of early studies, while root-collar diameter was changed. The results showed importance of local condition and practices. Averages of seedling height and root-collar diameter were 18.4 cm and 4.9 mm in one year bare-root seedlings, and 14.8 cm and 4.6 mm in one year containerized seedlings, respectively (Yılmaz and Bilir, 2016). They were 8.2 cm and 4.0 mm for 1+0 year bareroot seedlings; while they were 16.5 cm and 5.8 mm 1+1 years containerized seedlings (Bilir, 2019). It could be said that growth performance of natural reproduction was higher than cultural seedling. However, there could be many environmental effect on growth performance of seedlings such as nursery practices, nursery conditions, growing media and year. Mother tree of natural regeneration was more adaptive for the area. It emphasized importance of local seed source.

As given in Table 3, large differences among individuals within slope for the characteristics were also found. For instance, individual seedling height and root-collar diameter were between 70 cm and 200 cm, and 23.0 mm and 27.9 mm, respectively in low slope (Table 3). Low slope showed also highest variation for both SH and RCD (Table 3). Large differences were also reported within stand (Çetinkaya, 2019) and within aspect (Yazıcı, 2021) natural reproductions in Brutian pine.

Table 3. Averages, ranges, and standard deviation of the characteristics for the slopes.

Slope	Characteristics							
	Average	SH (cm)			RCD (mm)			
		Min.	Max.	St. Dev.	Average	Min.	Max.	St. Dev.
Upper (47)*	97.7 ^{a**}	63.00	154.00	19.8	24.0 ^a	23.1	25.9	.73
Middle (58)	96.8 ^a	55.0	150.0	22.1	23.8 ^a	22.3	26.3	.81
Low (57)	123.1 ^b	70.00	200.00	27.4	24.6 ^b	23.0	27.9	.97
Total	106.3	55.0	200.00	26.5	24.2	22.3	27.9	.91

*; Number of seedlings measured per sampled area in the parenthesis; **; the same letters show similar groups.

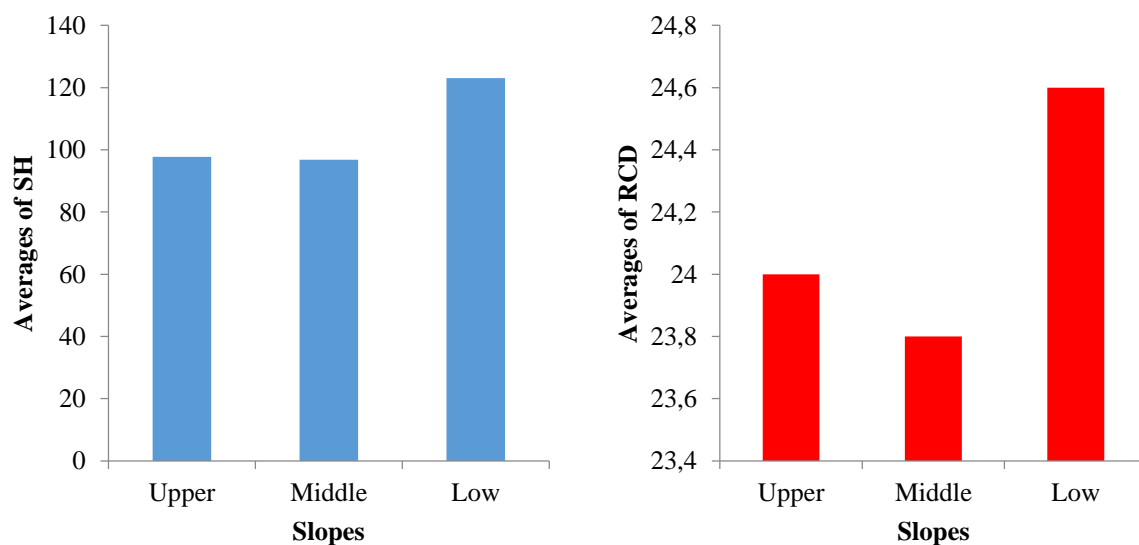


Figure 2. Averages of SH and RCD in the slopes.

Large differences among slopes and within slope were well accordance with by results of variance analysis (Table 4). Variance analysis results showed statistically significant ($p<0.05$) differences among aspects for the characteristics (Table 4). Similar results were also reported among stands (Çetinkaya, 2019), and among aspects (Yazıcı, 2021). They were also reported for seed source (Üçler et al., 2000; Dilaver et al., 2015; Bilir and Çetinkaya, 2018), and for seedling type (Yilmazer and Bilir, 2016; Özel et al., 2018; Bilir, 2019) in cultural seedlings of the species. Low slope was different from upper and middle slopes by Duncan's multiple range test (Tables 3 and 4).

Table 4. Results analysis of variance for the characteristics.

Characters	Source of variation	Sum of squares	Degrees of freedom	Mean of squares	F value	P
SH	Between groups	24679.27	2	12339.636	22.313	.000
	Within group	87929.29	159	553.014		
	Total	112608.56	161			
RCD	Between groups	21.561	2	10.780	15.115	.000
	Within group	113.400	159	.713		
	Total	134.961	161			

There could be many environmental and biological factors could be effective in growth performances of reproductions, and cultural seedlings. Yazıcı (2021) found that aspect was an important environmental factor on seedling height in natural regeneration of the species. Çifçioglu (1998) reported that altitude, aspect, and location on the slope were effective at different levels on the generation success and height growth and, also differences according to the years in Brutian pine. Effect of seed sources and seedling types were also reported in the species (Bilir and Çetinkaya, 2018; Yilmazer and Bilir, 2016; Özel et al., 2018; Bilir, 2019).

3.2. Seedling quality

The natural juvenility called also seedlings in the present study were classified according to quality classes of TSI given in Table 2 (Anonymous, 1988), although the classification was prepared for grown seedlings at the nursery practices.

All seedlings of low slope were in first quality, while it was 93.6% for upper slope and 96.6% for middle slope for SH according to seedling quality classes of Turkish Standard Institute (Table 5). All seedlings of slope groups were in first quality for RCD according to the quality classes (Table 5).

Table 5. Distribution (%) of seedlings to quality classes for the slopes.

Slopes	SH			RCD
	First class	Second class	Cull	First class
Upper	93.6	6.4	-	100.0
Middle	96.6	1.7	1.7	100.0
Low	100.0	-	-	100.0
Total	96.9	2.5	0.6	100.0

Percentages of cull seedlings were 67.6% for SH and 37% for RCD in one year old natural juvenility of Brutian (Çetinkaya, 2019). It could be said that quality of natural juvenility could be change for many environmental (i.e., edaphic and climatic) and biological (i.e., age, density) factors. New studies were suggested to estimate effect of different ecological factors such as temperature, rainfall, altitude, and their interactions by Çetinkaya (2019). However, cultural seedlings had higher quality seedlings than natural reproductions (Dilaver et al., 2015; Bilir and Çetinkaya, 2018; Yilmazer and Bilir, 2016; Özel et al., 2018; Bilir, 2019).

3.3. Correlation

Significant ($p<0.05$) and positive correlations were estimated and between SH and RCD for upper ($r=0.67$), middle ($r=0.70$), low ($r=0.86$), and polled ($r=0.81$) slopes (Figure 3). Positive and significant correlations between SH and RCD were also reported in natural regeneration (Çetinkaya, 2019; Yazıcı, 2021) of the species.

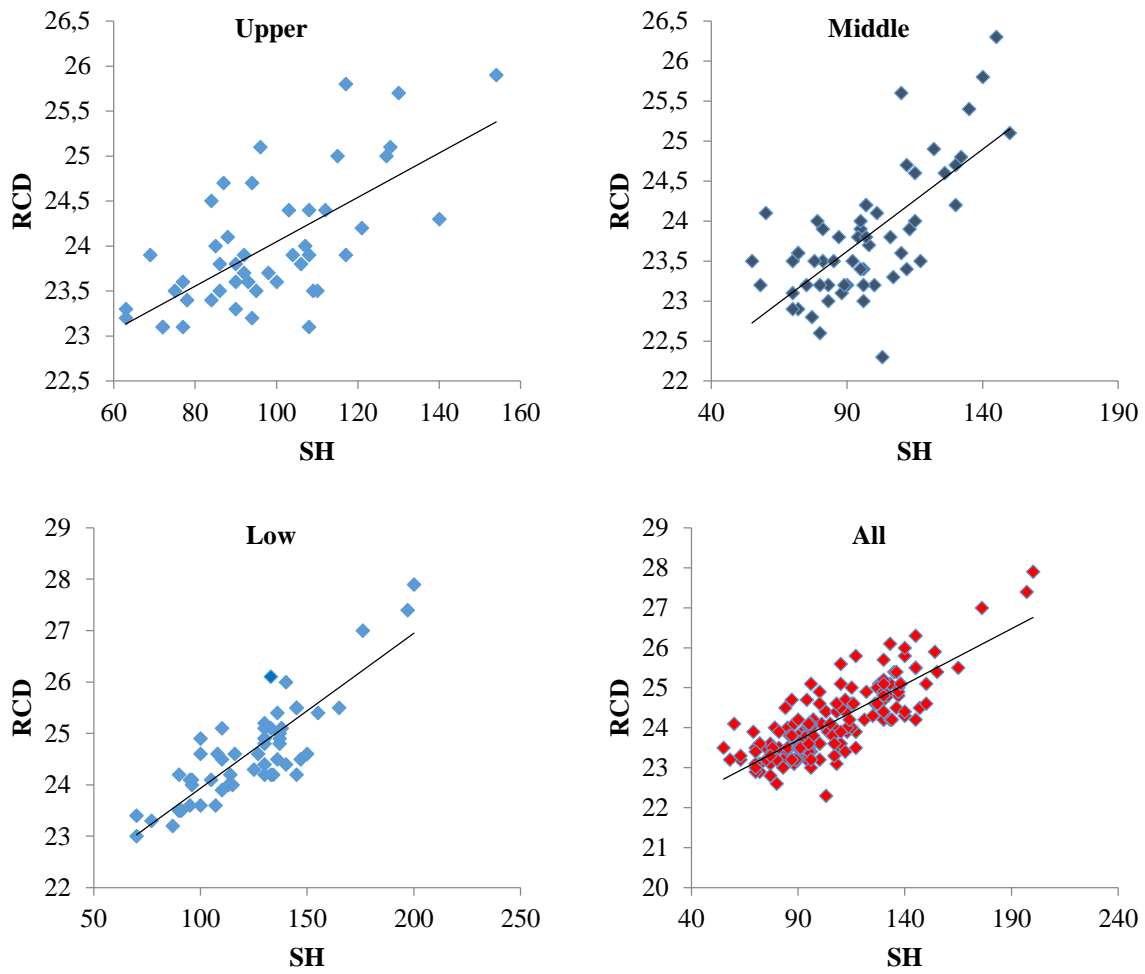


Figure 3. Relations between SH and RCD in the slopes.

Positive and significant relations between seedling height and root-collar diameter were reported in cultural seedlings of brutian pine (Dilaver et al., 2015; Çerçioğlu and Bilir, 2016; Yılmazzer and Bilir, 2016; Bilir and Çetinkaya, 2018). It could be used for natural regeneration and nursery practices in the species.

4. Conclusions

Variation in the characteristics based on slope showed importance of selection of local natural regeneration method. Significant differences among slopes the characteristics could be used for different purposes in silvicultural practices such as selection of seed collection areas. Correlation between the characteristics could be used in thinning out practices at juvenile age in the species.

This study was carried out to estimate effect of slope on growth performance in limited areas of the species. New studies should be organized for different ecological factors such as climatic and edaphic characteristics and their interactions suggested as different studies. Results of the study should be compared by results of artificial regeneration practices based on new studies.

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