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Growth performance of seed sources in a progeny trial of *Pinus brutia* Ten.

Alper Ahmet Ozbey[1] and Nebi Bilir[2]✉

[1]South-Western Anatolia Forest Research Institute, Antalya, Turkey
[2]Faculty of Forestry, Isparta University of Applied Sciences, Isparta, Turkey

✉ nebibilir@isparta.edu.tr

Abstract

Progeny trial is a field trial established for different forestry purposes such as selection and establishment of seed sources. Tree height and diameter at breast height were examined in a 23-year-old progeny trial. The trial was established by seedlings of five seed orchard populations and five seed stand populations, which were mother/base populations of the orchards in Turkish red pine (*Pinus brutia* Ten.), to compare the seed sources for the traits in this study.

Trees of seed orchard populations showed higher growth performances in comparison with the trees of seed stand populations for the traits. Most of the seed stand populations had higher tree height than their seed orchard populations opposite to the diameter at breast height. While the seed sources were similar ($p>0.05$), populations showed significant differences ($p<0.05$) for both traits according to the results of analyses of variance.

Tree height was more homogenous than the diameter at the breast height based on Duncan's multiple range tests and coefficients of variations. A positive and significant correlation ($p<0.05$) was found between the traits in both seed stand populations and seed orchard populations.

Keywords

Breeding; Height; Diameter; Gain; Variation

Contents

1 Introduction

Seed stands selected phenotypic from natural stands or plantations, and seed orchards established with clones or seedlings of plus trees selected from natural stands are important seed sources in forestry (Bilir et al. 2004). A seed orchard is a plantation of assumed superior genotypes established for the production of tree seeds, while a seed stand consists of selected trees with desirable characters (Kang and Bilir 2021). In Turkish forestry, seed orchards generally originated from seed

stands. New seed orchards are established vegetative with grafts selected based on progeny trials according to the "National Tree Breeding and Seed Production Programme of Turkey" in Turkish red pine (*Pinus brutia* Ten.)(Koski and Antola 1993) because of its valuable wood product and the largest natural distribution by 5.2 million ha which is 26% of the total forest area of Turkey (Anonymous 2020). Besides, the species has high adaptation ability to different edaphic and climatic conditions such as annual rainfall varies between 400 mm and 2000 mm in its natural distribution (Atalay et al. 1998). The establishment of seed orchards and progeny trials is one of the main stages of the tree breeding programmes.

However, while seed orchard seedlings and seed stand seedlings were compared morphologically (e.g., Dilaver et al. 2015; Cercioglu and Bilir 2016; Cetinkaya and Bilir 2020), they have not been compared for a long growth period, yet. In this study, a 23-year-old progeny trial established by seed orchard seedlings and seed stand seedlings of Turkish red pine were compared based on tree height and diameter at breast height to contribute selection and establishment of seed sources in the species.

2 Materials and methods

Seed orchards have been established with clones or seedlings collected from plus trees selected phenotypic from seed stands in Turkey. One-year containerized seedlings of progeny trial were grown 27 seed trees selected phenotypic from each of five seed stand populations (S1-S5), and their five seed orchards populations (O1-O5) (Table 1) consist of 31 (O1), 25 (O2), 25 (O3), 28 (O4) and 20 (O5) clones sampled from the stands. The seedlings were planted by 3x2 m spacing by four replicates at the experiment site from the southern part of Turkey (36°57'30'' N latitude and 30°36'39'' E longitude, 292 m altitude) in 1997 (Figure 1). Tree height and diameter at breast height were measured by 6 trees from each family at each replicate at the end of the 23rd year in 2020.

Table 1. Details of the seed sources.

Seed stands				Seed orchards			
No	**Latitude (N)**	**Longitude (E)**	**Altitude (m)**	**No**	**Latitude (N)**	**Longitude (E)**	**Altitude (m)**
S1	36°45'00''	31°57'55''	650	**O1 (S1)***	37°00'40''	30°50'19''	100
S2	36°35'30''	30°28'00''	320	**O2 (S2)**	36°58'00''	30°40'42''	257
S3	36°44'34''	29°28'36''	600	**O3 (S3)**	36°40'04''	29°10'39''	240
S4	37°06'20''	29°07'30''	800	**O4 (S4)**	37°01'13''	30°43'35''	275
S5	37°04'30''	29°32'40''	1100	**O5 (S5)**	36°58'11''	30°32' 42''	260

* Mother populations of the seed orchard in parentheses.

The seed stand and seed orchard populations were compared by the following model of multiple analyses of variance (MANOVA), while seed sources were compared by linear model of ANOVA at SAS (2004):

$$Y_{i\,j_k} = \mu + F_i + B(F)_{j(i)} + e_{ijk}$$

Where Y_{ijk} is the observation from the kth tree of the jth population in the ith replicate, μ is the overall mean, B(F)$_{j(i)}$ is the effect of the jth population in the ith replicate, and e_{ijk} is random error.

$$Y_{ij} = \mu + P_j + e_{ij}$$

Where Y_{ij} is the observation from the k^{th} tree of the j^{th} seed source, μ is the overall mean, p_j is the random effect of the j^{th} seed source, and e_{ij} is the random error.

Figure 1. Trial area by seed stand (left side) and seed orchards (right side) seedlings.

Populations were grouped by Duncan's multiple range test (Duncan 1955) for the traits based on the result of analyses of variance. Phenotypic correlations (r_p) between tree height and diameter at breast height for the seed sources were estimated by Rohlf and Sokal (1995).

$$r_P = \frac{\sum xy}{\sqrt{\sum x^2 \sum y^2}}$$

Where $\sum xy$ is the sum of the factors of the traits x and y, $\sum x^2$ and $\sum y^2$ are phenotypic variances of the traits x and y.

3 Results and discussion

Seed orchard populations showed higher growth performances (14.15 m for height and 17.73 cm for diameter at breast height) than the seed stand populations (14.07 m for height and 17.02 cm for diameter at breast height) for the traits (Table 2). The differences were 8 cm for height and 0.71 cm for diameter. Genetic gains were estimated 3.16% for height and 7.66% for diameter in the progeny trial of *Pinus brutia* (Ozbey 2022). It was 9% higher for volume in seed orchard populations than seed stand populations at 14th years of progeny trial of the species (Calikoglu et al. 2011). The results also varied for height and diameter at different ages in progeny trials (i.e.,

Isik and Isik 1999; Ortel et al. 2010) and provenance trials (i.e., Calikoglu et al. 2020) of *Pinus brutia*. They emphasized importance of ages for accurate estimations.

The differences between seed sources were not significant (*p>0.05*) for both traits based on the results of analyses of variance opposite to morphological seedling characteristics of the species (e.g., Dilaver et al. 2015; Cercioglu and Bilir 2016; Cetinkaya and Bilir 2020). However, it could be too early for an accurate discussion because of the long rotation age of Turkish red pine which is 60 years (Eler 1992).

While seed stand populations had higher tree height than their seed orchard populations, except of O5 (13.66 m) and its mother population S5 (13.15 m), seed orchard populations showed higher diameter at breast height than their mother/base seed stand populations, except of O2 (17.55 cm) and its mother population S2 (18.18 cm) (Table 2 and Figure 2). The results of analyses of variance showed significant differences (*p<0.05*) among the populations for both traits. It was also reported among 46 populations for the traits in the provenance trial of the species (Ozbey 2022). The results emphasized the importance of seed sources for better growth performance. However, there could be many genetic (Kang and Bilir 2021) and environmental (Yazici and Turan 2016) factors that could be effective on the performances.

Table 2. Averages and coefficients of variations for the traits in the populations.

Seed	Traits			
Sources	Tree height (m)		Diameter at breast height (cm)	
	Average*	CV_p %**	Average	CV_p %
S1	14.81^{c}	8.95	18.56^{cd}	21.89
S2	14.21^{bc}	9.03	18.18^{bcd}	23.60
S3	14.17^{bc}	13.17	17.05^{bc}	23.82
S4	14.04^{bc}	11.98	16.81^{bc}	22.72
S5	13.15^{a}	11.46	14.61^{a}	23.98
Total	14.07	11.41	17.02	22.65
O1	14.79^{c}	11.51	19.29^{d}	16.09
O2	14.06^{bc}	13.21	17.55^{bcd}	22.52
O3	13.99^{bc}	12.72	17.53^{bcd}	21.09
O4	13.99^{bc}	12.36	17.17^{bc}	24.18
O5	13.66^{ab}	12.96	16.44^{b}	22.77
Total	14.15	12.76	17.73	23.69
General	14.14	12.71	17.69	23.67

Tree height was more homogenous than the diameter at breast height by Duncan's multiple range tests. Coefficients of variations (CV_p %) were higher in diameter at breast height than height (Table 2). The results showed the importance of diameter at breast height as a selection trait for breeding purposes. Similar results were also reported by Ortel et al. (2010) and Calikoglu et al. (2020) in different ages of progeny and provenance trials in *Pinus brutia*.

A positive and significant correlation (*p<0.05*) was found between the traits in both seed stand populations (*r=0.778*) and seed orchard populations (*r=0.758*). It was also reported for genetic and phenotypic relations in the provenance trial (Ozbey

2022) and in the progeny trial (Isik et al. 1999) of Turkish red pine. The relation could be used for selection purposes such as optimum selection age and future studies.

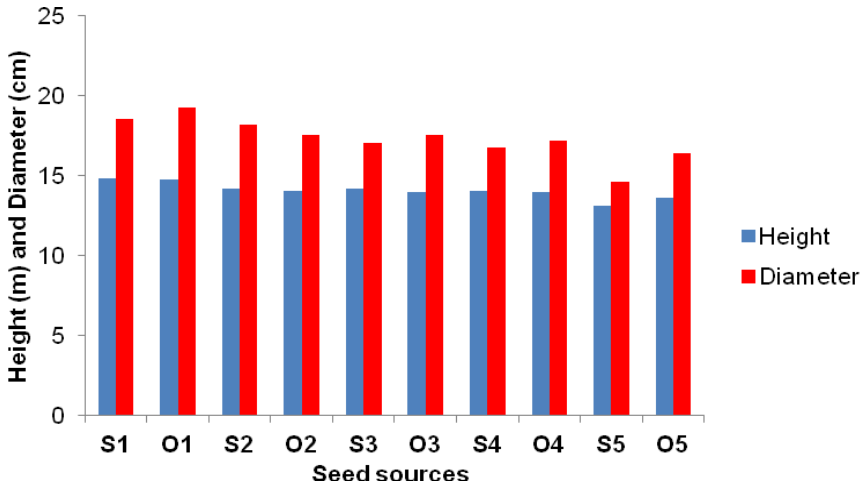

Figure 2. Averages of traits in the populations.

4 Conclusions

Future estimations should be continued based on 60 years rotation age of the species. The study was conducted in a progeny trial of the species, and other progeny trials of the species should be compared with the results of the present study. The present study was focused on quantity traits, but quality traits should be also added together with other quantity traits to the future studies.

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