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VARIATION IN GROWTH AMONG PROVENANCES OF *PINUS BRUTIA* IN A 32-YEAR-OLD EXPERIMENT FROM SOUTHERN TURKEY

SUMMARY

The provenance trial established by seedlings of 46 seed sources of Turkish red pine (*Pinus brutia* Ten.) was investigated based on 32-year-old tree height and diameter at breast height in this study.

Averages of tree height, and diameter at breast height were 9.32 m, 17.9 cm, respectively, while there were large differences among provenances and within provenance for the characters. Tree height varied between 7.04 m and 10.62 m, and diameter at breast height ranged from 14.48 cm to 21.46 cm in the provenances.

Results of analysis of variance showed significant ($p \leq 0.05$) differences among provenances for the characters. Block, and block x provenance interaction were also significant ($p \leq 0.05$) for the characters. Provenances were more homogenous for diameter at breast height than tree height based on results of Duncan's multiple range tests. There was positive and significant (r=0.74, $p < 0.05$) relations between height and diameter at breast height.

The results showed importance of the provenance and local forestry practices in the species.

Keywords: Adaptation, Afforestation, Origin, *Pinus brutia*, Variance

INTRODUCTION

Turkish red pine (*Pinus brutia* Ten.) is classified as one of the most economically important tree species for Turkish forestry and the "National Tree Breeding and Seed Production Programme" (Koski and Antola, 1993) because of its commercial wood product and the largest natural distribution by 5.2 million ha which of %26 of total forest area of Turkey (Anonymous, 2020). The species has high adaptation ability to different environmental conditions (Ortel *et al*., 2010) such as annual rainfall varies between 400 mm and 2000 mm (Atalay *et al*., 1998). It is getting importance of the species and its provenances based on climate change. Provenance or also called origin can be defined shortly the place

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that vegetative or generative material collected. Provenance trial is one of the main stages of tree breeding programmes to estimate variations, seed transfer regions (e.g., White *et al*., 2007) and adaptation ability, and to establishment and selection of seed sources for future plantations, and for other purposes such as resistance to biotic and a-biotic damages (e.g., Hattamer and König, 1975; Falkenhagen, 1991), and also to determine better seed source to afforestation area to obtain higher quality and quantity forest products. For instance, it was estimated that, by selecting suitable provenances, 30% to 50% gain could be realized in the species (Isik *et al*., 2002). Reflection of provenances of a species can vary to the ability and damages according to different environmental conditions.

For the purposes, national provenance trials were established by 50 provenances in Turkish red pine in 1987 (Cengiz *et al*., 1999). However, performances of provenances can change because of many biological and environmental factors such as edaphic, climatic, species, especially provenance and years (e.g., Cengiz *et al*., 1999; Ortel *et al*., 2010; Calikoglu *et al*., 2011; Calikoglu *et al*., 2020), and also their interactions.

Future studies are suggested based on different growth performances reported in provenances of the species in early studies by Ortel *et al*. (2010), Isik *et al*. (2002), and Calikoglu *et al*. (2020).

It is suggested that provenance trial should be surveyed by rotation age which is 60 years in the species (Eler, 1992) or by half of rotation age which is 30^{th} years (Isik *et al*., 2002) for accurate estimations. Rotation age is also related to selection age (Ozbey *et al*., 2020) as known. They emphasize importance of new studies on future years of provenance trials. While, 10^{th} and 20^{th} years of the trial were examined by Isik *et al*. (2002) and Ortel *et al*. (2010), 32^{nd} year result has not been investigated in the trial, yet.

The present study is including new results by 32^{nd} year collected data.

In this study, growth performances of provenances, and their variations were compared in a 32-year-old trial of Turkish red pine to estimate whether significant differences among provenances for height and diameter or not to contribute present and future practices in the species.

MATERIAL AND METHODS

The provenance trial was established by one-year containerized seedlings grown 30 seed trees selected phenotypic from each 46 seed sources (mostly seed stands, P2-P50) (Table 1).

The seedlings were planted by 3x1.5 m spacing by three replicates also called block at experiment site from southern part of Turkey (37°02'02" N latitude, 30°10'49" E longitude, 1045 m altitude) in 1998 (Figure 1). Tree height (**H**), and diameter at breast height ($\mathbf{D_{1.30}}$) were measured at end of growth period of 2020.

Table 1. Geographic details of the provenances

No	Latitude (N)	Longitude (E)	Altitude (m)	No	Latitude (N)	Longitude (E)	Altitude (m)
P2	35°17'	33°24'	500	**P25**	39°12'	28°08'	400
P3	35°18'	33°32	320	**P26**	39°36'	26°34'	550
P4	37°05'	34°33'	1000	**P28**	39°50'	25°55'	400
P5	36°11'	32°45'	600	**P29**	39°24'	28°22'	350
P6	36°05'	32°41'	650	**P30**	39°58'	28°40'	450
P7	36°14'	33°15'	650	**P31**	40°00'	28°55'	600
P8	37°07'	34°31'	800	**P32**	37°04'	30°32'	1100
P9	36°55'	34°26'	750	**P33**	37°30'	30°51'	650
P10	36°13'	33°43'	100	**P34**	37°21'	30°54'	400
P11	36°45'	34°10'	1150	**P35**	36°21'	35°57'	385
P12	36°57'	34°24'	1150	**P36**	37°46'	36°42'	800
P13	36°17'	32°48'	1000	**P37**	35°54'	36°01'	480
P14	37°24'	30°37'	800	**P38**	37°00'	28°19'	60
P15	37°30'	30°41'	800	**P39**	37°06'	28°32'	750
P16	36°59'	30°33'	275	**P40**	37°17'	28°34	750
P17	36°45'	31°58'	650	**P41**	38°50'	28°04'	350
P18	36°42'	32°10'	1000	**P42**	39°42'	28°37'	600
P19	36°24'	29°30	720	**P43**	40°11'	30°49'	600
P20	36°24'	29°32	830	**P44**	41°39'	35°27'	100
P21	37°17'	30°58'	750	**P45**	40°38'	36°43'	250
P22	36°36'	31°57'	350	**P46**	41°05'	32°41'	450
P23	36°26'	30°15'	250	**P47**	37°29'	42°00'	700
P24	36°35'	30°28'	350	**P50**	35°18'	33°03'	200

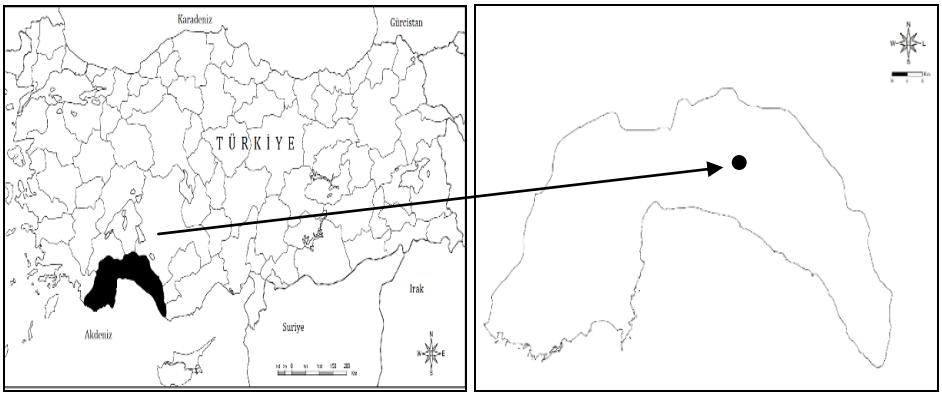

Figure 1. Location of the experiment site

The provenances were compared by following model of multiple analyses of variance (MANOVA) using SAS (2004). Provenances were grouped by Duncan's multiple range test (Duncan, 1955) based on results of analyses of variance.

$$Y_{ijk} = \mu + P_i + S_j + P(S)_{i(j)} + e_{ijk} \qquad (1)$$

Where Y_{ijk} is the observation from the k^{th} tree of i^{th} block/replicate of j^{th} provenance, μ is overall mean, P_i is the effect of the i^{th} block, S_j is the effect of j^{th} provenance (j= 1, 2….46), $P(S)_{i(j)}$ is the effect of interaction between block and provenance, e_{ijk} is random error.

Phenotypic Pearson' correlation (r_p) between tree height and diameter at breast height were estimated by Rohlf and Sokal (1995):

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

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

RESULTS AND DISCUSSION

Averages of tree height (**H**), and diameter at breast height ($\mathbf{D_{1.30}}$) were 9.32 m, 17.9 cm, respectively, while there were large differences among provenances and within provenance for the characters (Table 2).

Average of tree height was 61 cm at 5^{th} year (Cengiz *et al*., 1999), while averages of tree height and diameter at breast height were 2.38 m and 2.3 cm at at provenance trial of the species at 10^{th} year (Isik *et al*., 2002), respectively. They were 6.3 m and 11.9 cm at 20^{th} year (Ortel *et al*., 2010).

The results showed that growth increments were lower in early years. It emphasized importance of years for accurate estimations in provenance trials. Tree height and diameter at breast height were ranged from 7.04 m (P47) to 10.62 m (P33) for H, and between 14.48 (P47) cm and 21.46 cm (P6) for $D_{1.30}$ (Table 2).

Large differences among provenances were also reported in early studies in the species (Cengiz *et al*., 1999; Isik *et al*., 2002; Ortel *et al*., 2010; Calikoglu *et al*., 2011; Calikoglu *et al*., 2020).

Marginal provenances (P45, P46 and P47) of the species showed lower growth performances than other provenances in the site (Table 2). The result was well accordance with early result in provenance trial of the species (Isik *et al*., 2002).

However, many environmental and biological factors together with provenance could be effective on growth performance such as climatic, edaphic or site (e.g., Isik *et al*., 2002; Yazici and Turan, 2016; Calikoglu *et al*., 2020), species (e.g., Yazici, 2018). It showed importance of local seed sources.

Table 2. Averages and results of Duncan's multiple range test for height (**H**) and diameter at breast height ($\mathbf{D_{1.30}}$) of the provenances

	H			**$D_{1.30}$**	
Provenance no	Number of individuals	Average (m)*	Provenance no	Number of individuals	Average (cm)
P33	24	10.62^{a}	P6	22	21.46^{a}
P7	24	10.34^{ab}	P35	23	20.75^{ab}
P6	22	10.32^{ab}	P10	20	20.19^{abc}
P15	22	10.29^{ab}	P16	21	20.14^{abc}
P10	20	10.23^{abc}	P9	23	20.01^{abcd}
P5	23	10.21^{abc}	P11	22	20.00^{abcd}
P11	22	10.11^{abcd}	P39	19	19.92^{abcd}
P9	23	10.02^{abcde}	P33	24	19.73^{abcd}
P40	23	9.97^{abcdef}	P7	24	19.61^{abcde}
P39	19	9.95^{abcdefg}	P15	22	19.52^{abcde}
P24	22	9.94^{abcdefg}	P37	19	18.81^{abcdef}
P3	24	9.88^{abcdefg}	P8	21	18.72^{abcdefg}
P35	23	9.85^{abcdefg}	P40	23	18.63^{abcdefg}
P19	20	9.73^{abcdefgh}	P5	23	18.47^{abcdefgh}
P16	21	9.65^{abcdefgh}	P29	22	18.45^{abcdefgh}
P2	21	9.65^{abcdefgh}	P42	23	18.42^{abcdefgh}
P29	22	9.64^{abcdefgh}	P24	22	18.28^{abcdefgh}
P18	22	9.60^{abcdefgh}	P23	18	18.27^{abcdefgh}
P38	17	9.56^{abcdefgh}	P3	24	18.10^{abcdefgh}
P21	23	9.54^{abcdefgh}	P21	23	18.10^{abcdefgh}
P8	21	9.50^{abcdefgh}	P38	17	18.10^{abcdefgh}
P44	24	9.50^{abcdefgh}	P19	20	18.04^{abcdefghi}
P37	19	9.42^{abcdefgh}	P36	24	17.71^{bcdefghi}
P13	24	9.34^{abcdefgh}	P12	21	17.69^{bcdefghi}
P30	23	9.29^{abcdefghi}	P34	24	17.65^{bcdefghi}
P14	21	9.25^{abcdefghi}	P26	18	17.61^{bcdefghi}
P25	22	9.23^{abcdefghi}	P22	23	17.54^{bcdefghi}
P17	23	9.19^{bcdefghi}	P4	23	17.50^{bcdefghi}
P23	18	9.18^{bcdefghi}	P13	24	17.38^{bcdefghi}
P42	23	9.18^{bcdefghi}	P18	22	17.33^{bcdefghi}
P22	23	9.09^{bcdefghi}	P14	21	17.26^{bcdefghi}
P34	24	8.97^{bcdefghi}	P28	21	17.19^{bcdefghi}
P20	21	8.83^{cdefghi}	P32	24	17.18^{bcdefghi}
P41	20	8.80^{defghij}	P20	21	17.11^{cdefghi}
P50	23	8.78^{defghij}	P25	22	17.06^{cdefghi}
P36	24	8.73^{defghij}	P41	21	16.90^{cdefghi}
P4	23	8.70^{defghij}	P17	23	16.79^{cdefghi}
P12	21	8.66^{efghij}	P44	24	16.79^{cdefghi}
P32	24	8.63^{efghij}	P50	23	16.47^{defghi}
P43	21	8.58^{fghij}	P31	21	16.39^{defghi}
P31	21	8.54^{ghij}	P2	21	16.21^{efghi}
P26	18	8.54^{ghij}	P30	23	16.17^{efghi}
P28	21	8.38^{hij}	P43	21	15.91^{fghi}
P46	20	7.91^{ijk}	P45	21	15.38^{ghi}
P45	21	7.47^{jk}	P46	20	15.04^{hi}
P47	17	7.04^{k}	P47	17	14.48^{i}
General	**997**	**9.32**		**997**	**38.5**

*; Same letters show similar groups.

Order of provenances changed for the characters (Table 2). For instance, provenances 33 (10.62 m), 7 (10.34 m), 6 (10.32 m), 15 (10.29 m),and 10 (10.23 m) showed highest performance for height as the first five provenances, while they were 6 (21.46 cm), 35 (20.75 cm), 10 (20.19 cm), 16 (20.14 cm) and 9 (20.01 cm) for diameter at breast height (Table 2, Figure 2). They also changed in provenance trials of the species at different ages (Isik *et al*., 1987; Gurses, 1993; Cengiz *et al*., 1999; Isik *et al*., 2002; Ortel *et al*., 2010). Coefficient of variation of diameter at breast height (23.11%) was higher than that of height (17.45%) in total provenances. However, provenances were more homogenous for diameter at breast height than tree height based on number of homogenous groups of results of Duncan's multiple range test (Table 2).

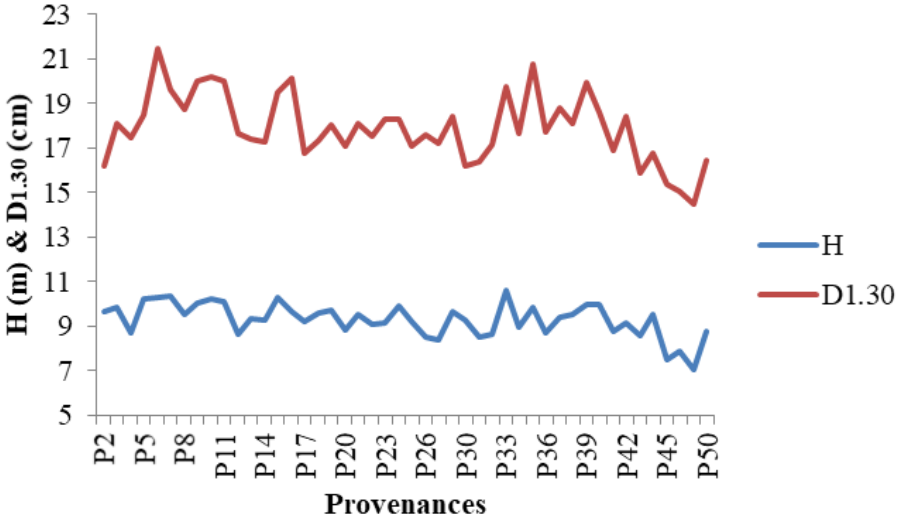

Figure 2. Averages of the provenances for the characters

The differences among provenances (Table 2) were also well accordance with results of analysis of variance. Results of ANOVA showed significant ($p \leq 0.05$) differences among provenances for the characters (Table 3). It was also reported early results of the provenance trial (Cengiz *et al*., 1999; Isik *et al*., 2002; Ortel *et al*., 2010; Calikoglu *et al*., 2020). The results of ANOVA also showed that block and block x provenance interaction were also significant ($p \leq 0.05$) effective on the characters (Table 3). It could be related to numbers of provenance and planted seedlings from each provenance. The interaction could change for the years (Cengiz *et al*., 1999; Isik *et al*., 2002; Ortel *et al*., 2010; Calikoglu *et al*., 2020). It was also found that the results could vary by type of statistical models used in estimations in provenance trials (Magnussen, 1993; Hamann *et al*., 2002; Joyce *et al*., 2002; Dutkowski *et al*., 2006; Funda *et al*., 2007; Ye and Jayawickrama, 2008; Calikoglu and Ozbey, 2017; Ozbey, 2022).

Environmental variance had higher in the variance component for the both characteristics (66.25% for H and 84.42% for $D_{1.30}$) (Table 4). The results (Tables 3 and 4) showed that importance of the provenance and local forestry practices. Similar result was also found by Isik *et al*. (2002). It was clear that it could be getting importance by climate change as also emphasized by Calikoglu *et al.* (2020). It could be said that mass selection among provenances and individual selection within provenance would play important roles in forestry practices based on higher variation.

Table 3. Results of analysis of variance

Characters	Source of variation	Degrees of freedom	Sum of squares	Averages of squares	F value	P value
H	Block (B)	2	2146532	1073266	31.5	<.0001
	Provenance (P)	45	5120382	113786	3.32	<.0001
	BxP	90	3095261	34392	1.88	<.0001
	Error	859	15737175	18320.34		
$D_{1.30}$	Block (B)	2	33551	16775	7.47	<.001
	Provenance (P)	45	217429	4831.76	2.14	<.001
	BxP	90	203577	2261.96	1.54	<.002
	Error	859	1260753.07	1465.99		

Table 4. Variance components of the characters

Characters	σ_B^2	σ_P^2	σ_{BxP}^2	σ_e^2
H	3137 (11.34%)	3927.1 (14.19%)	2269.1 (8.20%)	18324 (66.25%)
$D_{1.30}$	39.20 (2.25%)	123.43 (7.09%)	108.31 (6.22%)	1468.5 (84.42%)

σ^2_B is the variances among blocks, **σ^2_P** is the is the variances among provenances, **σ^2_{BxP}** is the variances of interaction between block and provenance, **σ^2_e** is the environmental variances.

Positive and significant ($r=0.74$, $p<0.05$) relations were found between the pairs of height and diameter at breast height. It was also reported by Cengiz *et al*. (1999), Isik *et al*. (2002), Ortel *et al.* (2010), Calikoglu *et al.* (2020), and Ozbey (2022) in early results of provenance trials of the species. The result could be used for forestry practices of the species such as selection and tending.

CONCLUSIONS

Variation for growth among provenances and with provenance emphasized importance of local seed sources and individual selection within provenance instead of mass selection. P6 and P10 provenances had higher growth performances for both characteristics. They could be used in forest establishment of the trial site.

Tree height and diameter at breast height were examined in present study. Quality characters such as stem form should be also added to future studies to obtain higher quality wood product in the trial.

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