Bilir, N., Özel, H.B., Öztürk, Y.O., Ertaş, T.B. (2023): Growth variations in clonal seed orchards of Anatolian black pine. Agriculture and Forestry, 69 (3): 97-104.doi:10.17707/AgricultForest.69.3.07

DOI: 10.17707/AgricultForest.69.3.07

Nebi BİLİR*[1],
Ahmet Alper BABALIK[1], Halil Barış ÖZEL[2],
Yasin Oğuzhan ÖZTÜRK[3], Tuğçe Baloğlu ERTAŞ[3]

CLONAL VARIATIONS IN GROWTH CHARACTERISTICS OF ANATOLIAN BLACK PINE SEED ORCHARDS

SUMMARY

Seed orchard is an important cultivated seed source to produce genetically seed crop for forestry practices. Growth characteristics have important roles in management of seed orchards and seed harvesting. Growth variations among seed orchards, and among clones within orchard were investigated in three seed orchards of Anatolian black pine [*Pinus nigra* Arnold subsp. *pallasiana* (Lamb.) Holmboe] based on tree height, diameter at base, diameter at breast height, and crown diameter measured at end of growth period of 2022. The seed orchards were established consist of 30, 30 and 34 clones selected phenotypically from natural stands in 1994 (SO1), 1991 (SO2) and 1985 (SO3), respectively.

Averages of tree height (9.30 m), diameter at base (31.91 cm), diameter at breast height (27.13 cm), and crown diameter (7.09 m) were the highest in SO3, while they were the lowest as 5.78 m, 24.50 cm, 20.26 cm, 5.00 m, respectively in SO2. However, clones and ramet within clone in seed orchards showed large differences for the characteristics. For instance, clonal averages of crown diameter ranged from 3.55 m to 6.46 m in SO2. SO1 had the highest annual increments for the characteristics except of tree height of SO3. Results of analysis of variance indicated significant ($p \leq 0.05$) differences among the orchards, and among clones within orchard except of tree heights of SO1 and SO2 for the characteristics. Tree height was more homogeneous than the other characteristics according to the Duncan's multiple range test.

Positive and significant ($p \leq 0.05$) relations were found between the pairs of tree height, diameter at base, diameter at breast height, and crown diameter in each seed orchard both phenotypic and genotypic. Results of the study could be used in establishment and management of seed orchards.

Keywords: Breeding, Correlation, Diameter, Height, Ramet, Variance

[1]Nebi Bilir (correspondingauthor: nebibilir@isparta.edu.tr), Ahmet Alper Babalik, Faculty of Forestry, Isparta University of Applied Sciences, Isparta, TÜRKIYE,

[2]Halil Barış Özel**,** Forestry Faculty of Bartın University, Bartın, TÜRKIYE,

[3]Yasin Oğuzhan Öztürk, Tuğçe Baloğlu Ertaş, The Institute of Graduate Education, Isparta University of Applied Sciences, Isparta, TÜRKIYE

Notes: The authors declare that they have no conflicts of interest. Authorship Form signed online.
Recieved:09/04/2023 *Accepted:21/07/2023*

INTRODUCTION

According to the latest forestry inventory, Turkey has 23.1 million ha forest area of which 9.6 million ha is unproductive. Anatolian black pine [*Pinus nigra* Arnold. subsp. *pallasiana* (Lamb.) Holmboe] is an important tree species in Turkish forestry and forestry practices by 4.2 million ha natural distribution including which of 31.9% is unproductive (OGM, 2022). The species is also one of the main species of "National Tree Breeding and Seed Production Programme" (Koski and Antola, 1993). It has 73 selected seed stands at 9375.7 ha, and 57 established seed orchards at 475.8 ha (ORTOHUM, 2022). The seed sources play important roles to produce improved seeds and conversion of unproductive forest to productive forest in the species. Seed orchard is a plantation of assumed superior genotypes established to produce tree seeds. Typically, it is clones or seedlings from selected trees, isolated to reduce pollination from outside sources, even ground and wide spacing to facilitate cone harvest, and managed for early, easily accessible, and abundant seed production (Kang and Bilir, 2021). Seed orchard can be also defined shortly as one of the cultivated seed sources. Orchard managers and owners focus on growth and reproductive characteristics in the cultivation practices such as spacing, pruning, tree density. For instance, significant relations are reported between growth and reproductive characteristics in different forest tree species (e.g., Bhumibhamon, 1978; Nikkanen and Velling, 1987; Dutkuner *et al*., 2008; Bilir *et al*., 2008 and 2017; Kang and Bilir, 2021). Growth characteristics balanced by different forestry practices are important factors in management practices, and in harvesting of cheap seed crop. Estimation of variations of growth characteristics is one of the main stages for decision on present and future management practices in seed orchards.

Variations among clones within seed orchard, and among orchards were estimated for tree height, diameter at base, diameter at breast height, and crown diameter, together with correlations among the characteristics in three seed orchards of Anatolian black pine to contribute seed orchard management practices of the species in this study.

MATERIAL AND METHODS

The study was carried out in three Anatolian black pine clonal seed orchards established at 8m x 8 m spacing by 30, 30 and 34 clones selected phenotypically from natural seed stands in 1994, 1991 and 1985, respectively (Table 1, Figures 1 and 2).

Table 1. Some details of the orhards

Orchard	Latitude (N)	Longitude (E)	Number of clones	Number of seedlings	Area (ha)	Establishment year
SO1	37°57′58″	30°34′25″	30	2800	17.6	1994
SO2	38°04′19″	30°05′46″	30	2000	13.8	1991
SO3	37°09′28″	29°40′19″	34	1248	9.4	1985

Figure 1. Studied seed orchard, SO3

Figure 2. Location of the seed orchards

Five ramets of each clone were sampled in the orchards. Tree height (**TH**), diameter at base (**D_0**), diameter at breast height (**$d_{1.30}$**), and crown diameter (**CD**) of the sampled ramets were measured at end of growth period of 2022.

Collected data was performed by following model of analysis of variance (ANOVA) to compare seed orchards, and clones within orchard for the growth characteristics at SAS (SAS, 2004).

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

Where Y_{ijk} is the observation from the k^{th} ramet of the j^{th} clone in the i^{th} orchard, μ is overall mean, $B(F)_{j(i)}$ is effect of the j^{th} clone in the i^{th} orchard, and e_{ijk} is random error.

Seed orchards and clones within orchard were grouped by Duncan's multiple range test (Duncan, 1955) for the characteristics based on results of analysis of variance.

Phenotypic correlations (r_p) between the pairs of the tree height, diameter at base, diameter at breast height and crown diameter were estimated in each orchard as (Falconer, 1989):

$$r_p = \frac{COV_{f(x,y)}}{\sqrt{\sigma^2_{f(x)}}\sqrt{\sigma^2_{f(y)}}}$$

Where $COV_{f(x,y)}$ is the phenotypic covariance between characteristics x and y, $\sigma^2_{f(x)}$ and $\sigma^2_{f(y)}$ are the phenotypic variances for characteristics x and y, respectively.

Genetic correlations (r_g) between the pairs of the characteristics were estimated as (Falconer, 1989):

$$r_g = \frac{COV_{f(x,y)}}{\sqrt{\sigma^2_{f(x)}\sigma^2_{f(y)}}}$$

Where $COV_{f(x,y)}$ is the genetic covariance between characteristics x and y, $\sigma^2_{f(x)}$ and $\sigma^2_{f(y)}$ are the additive genetic variances of characteristics x and y, respectively.

RESULTS AND DISCUSSION

Growth variations

Averages, clonal ranges, and coefficient of variations were given for the characteristics and orchards in Table 2. The oldest seed orchard (SO3) had the highest growth performance for the characteristics, while they were the lowest in the youngest seed orchard (SO2). However, SO1 showed the highest annual increments for the characteristics except of tree height of SO3 (Table 2). This may be affected by many factors (Eriksson *et al*., 1973). Kang (2001) reported that young seed orchards were more variable than that of older. Age was an important factor in growth and reproductive performances in seed orchards of Scots pine (Bilir *et al*., 2006).

Table 2. Averages ($\bar{x}$), clonal ranges and coefficient of variation (CV%) for the characteristics and orchards.

		SO1			**SO2**			**SO3**	
	$\bar{x}$*	**Range**	**CV**	**$\bar{x}$**	**range**	**CV**	**$\bar{x}$**	**range**	**CV**
TH (m)	6.45^b	5.38-8.05	1.35	5.78^a	4.89-6.63	1.40	9.30^c	7.26-10.93	0.97
D_0 (cm)	25.63^b	22.14-30.18	1.41	24.50^a	16.32-29.48	1.59	31.91^c	23.64-39.56	1.11
$d_{1.30}$ (cm)	22.42^b	19.32-27.26	1.52	20.26^a	13.88-25.38	1.68	27.13^c	21.04-34.74	1.16
CD (m)	5.91^b	4.24-7.76	1.71	5.00^a	3.55-6.46	1.94	7.09^c	5.26-8.79	1.27

**; Same letters are not significantly different among orchards.*

There were high differences among clones within orchard for the characteristics. For example, the differences were about 50% (5.38 m, 8.05 m) in SO1, 36% in SO2 and 51% in SO3 for tree height which had the lowest coefficient variations in all the orchards. There could many biotic and a-biotic factors impact on the performances and variation such as age, orchard location and genetic structures of clones (Eriksson *et al*., 1973; Bilir *et al*., 2006; Kang and Bilir, 2021). Clones were more heterogenous for crown diameter based on coefficient variations (Table 2, Figure 3). The seed orchards were established at 8m x 8 m spacing, larger than a common plantation. The variation could change in the future by competition among ramets. The results were well accordance with coefficient of variations of the characteristics in mother populations of the seed orchards. Coefficients of variations were the lowest for tree height and the highest for crown diameter in mother populations (Bilir *et al.*, 2023). However, variations among mother trees of base populations (Bilir *et al*., 2023) were higher than among clones of seed orchard populations. It could be because of management practices in the orchards. The growth variations among clones were also reported in seed orchards of different forest tree species (i.e., Varol *et al.*, 2017; Dutkuner *et al*., 2008; Bilir *et al.*, 2006), and among individuals in plantations (i.e., Kartal and Bilir, 2022) and in a seed orchard (Ertekin, 2006) of Anatolian black pine. The variation could be balanced by different management practices such as pruning. The results indicated importance of individual selection than mass selection in establishment of seed orchards. Ramets within clone showed also large differences for the characteristics. For instance, individual ramet growths were ranged from 3.92 m to 8.43 m for tree height, varied between 20.70 cm and 31.10 cm for diameter at base in first clone of SO2. They could be related to where the cuttings taken in mother tree. However, many a-biotic and biotic factors could effect on variations of growth performances (e.g., Bilir *et al*., 2018; Yazici, 2018; Yazici and Turan, 2016).

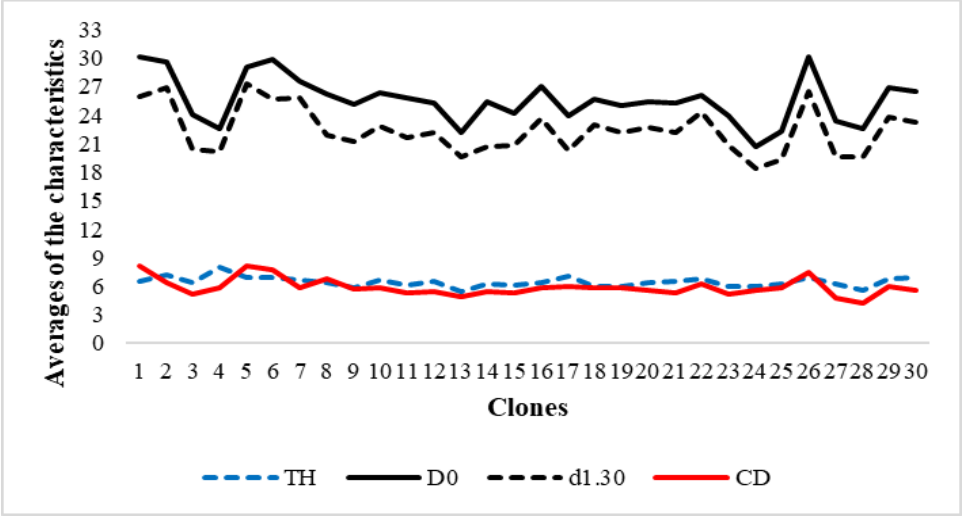

Figure 3. Clonal averages of SO1 for the characteristics

There were significant ($p \leq 0.05$) differences among clones within orchard except of tree heights of SO1 and SO2, and among the seed orchards for the characteristics based on results of analysis of variance. Tree height was more homogeneous than the other characteristics according to the Duncan's multiple range tests and coefficient of variations in each orchard (Table 2). The differences indicated different management practices for each orchard in growth characteristics. The variation could be used for different purposes such as selection of superior clone/ramet in seed orchards emphasized by Imren *et al.* (2021) or balanced by different management practices.

Correlations

Results of correlation analysis indicated positive and significant ($p \leq 0.05$), phenotypic and genotypic relations among the pairs of the characteristics in the orchards (Table 3). Similar trends were also reported in seed orchards of different forest tree species (e.g., Bhumibhamon, 1978; Dutkuner *et al*., 2008; Bilir *et al.*, 2006 and 2008). The relations emphasized that less characteristics could be used in management of orchards, and in future studies.

Table 3. Phenotypic correlations (below diagonal) and genetic correlations (above diagonal) among the characteristics for the orchards

	r_g/ r_p	TH	D_0	$d_{1.30}$	CD
SO1			.429*	.468**	.468**
SO2	**TH**	-	.722**	.727**	.740**
SO3			.712**	.684**	.609**
SO1		.395**		.952**	.771**
SO2	**D_0**	.700**	-	.947**	.764**
SO3		.575**		.914**	.740**
SO1		.395**	.928**	-	.759**
SO2	**$d_{1.30}$**	.740**	.922**		.799**
SO3		.627**	.868**		.690**
SO1		.352**	.681**	.727**	
SO2	**CD**	.726**	.756**	.785**	-
SO3		.470**	.612**	.633**	

**; Correlation is significant at the 0.05 level, **; Correlation is significant at the 0.01 level.*

The phenotypic and genotypic relations (Table 3) showed easy character could be used in selection of mother trees for establishment and management practices of seed orchards by estimation of heritability for the characteristics.

CONCLUSIONS

Variation among ramets within clone emphasized importance of place where the cuttings taken from mother tree. It could be important in establishment stage of seed orchard. Variation could be a guide for selection of superior clone or ramets for second generation establishment of seed orchards for managers. Management strategies should be planned for each seed orchard. Significant phenotypic and genotypic relations among the pairs of the characteristics could be used in establishment and management practices of seed orchards. Future studies

should be carried out by long-term data and different characteristics such as stem straight to produce better quality wood product.

ACKNOWLEDGEMENTS

Authors thank to local forestry managers for their help during data collection. This study was supported by the Scientific and Technological Research Council of Turkey (TUBITAK, Project No:221O178). Authors also thank to TUBITAK for the financial support.

REFERENCES

Bhumibhamon, S. (1978). Studies on Scots pine seed orchards in Finland with special emphasis on the genetic composition of the seed. Communicationes Instituti Forestalis Fenniae, 94:1-118.

Bilir, N., Babalik, AA., Ozel, H.B., Ozturk, Y.O., T. Baloglu, Ertas. (2023). Growth variation in seed stands of Anatolian black pine. IV-International Anatolian Congress on Multidisipary Scientific Research, 17 of February, 2023, Kars, Turkey (in press).

Bilir, N., Catal, Y., Tekocak, S., Cercioglu, M. (2017). Fertility variation in endemic populations of Ehrami black pine (*Pinus nigra* Arnold. subsp. *pallasiana* var. *pyramidata*). Journal of Forestry Research, 28(4):683-686.

Bilir, N., Prescher, F., Ayan, S., Lindgren, D. (2006). Growth characters and number of strobili in clonal seed orchards of *Pinus sylvestris*. Euphytica, 152:293-301.

Bilir, N., Prescher, F., Lindgren, D., Kroon, J. (2008). Variation in seed related characters in clonal seed orchards of *Pinus sylvestris*. New Forests, 36:187-199.

Bilir, N., Yazici, N., Ozel, H.B. (2018). Examination of Taurus cedar (*Cedrus libani*) afforestation in Isparta province of Turkey. International Conference Reforestation Challenges, June 20-22, 2018, Belgrade, Serbia, Book of Abstracts, 33.

Duncan, D.B. (1955). Multiple range and multiple F-test. Biometrics, 11:1-5.

Dutkuner, I., Ulusan, M., Bilir, N. (2008). Influence of growth on reproductive traits and its effect on fertility and gene diversity in a clonal seed orchard of Scots pine *Pinus Sylvestris* L. Journal of Environmental Biology, 29:349-352.

Eriksson, G., Lindgren, D., Jonsson, A. (1973). Flowering in a clone trial of *Picea abies* Karst. Studia Forestalia Sueccica, 110:4-45.

Ertekin, M. (2006). Clonal variations in flowering, cone production and seed characteristics of black pine (*Pinus nigra* Arnold. subsp. *pallasiana* (Lamb.) Holmboe) seed orchard originated from Yenice-Bakraz. Ph.D. Thesis, Zonguldak Karaelmas University Graduate School of Natural and Applied Sciences Department of Forest Engineering.

Falconer, D.S. (1989). Introduction to quantitative genetics, Longman Scientific Technical, Longman Group U.K. Limited.

Imren E., Kurt R., Yücedağ C., Bilir, N., Özel H.B., Çetin M., Şevik H. (2021). Selection of superior clones by the multi-dimensional decision-making techniques in Scots pine seed orchard. Journal of Forests, 8:13-22.

Kang, K.S. (2001). Genetic gain and gene diversity of seed orchard crops. Ph.D Thesis. Swedish University of Agricultural Science, Umeå, Sweden. Acta Universitatis Agriculturae Sueciae, Silvestria 187, pp.75.

Kang, KS., Bilir, N. (2021). Seed orchards (Establishment, Management and Genetics). OGEMVAK Press, Ankara.

Kartal R., Bilir, N. (2022). Evaluation of Ehrami black pine plantations in Isparta district: 30th year results. Bartin University International Journal of Natural and Applied Sciences, 5:10-17.

Koski, V., Antola, J. (1993). National Tree Breeding and Seed Production Programme for Turkey 1994-2003. The Research Directorate of Forest Tree Seeds and Tree Breeding, Ankara.

Nikkanen, T., Velling, P. (1987). Correlations between flowering and some vegetative characteristics of grafts of *Pinus sylvestris*. Forest Ecology and Management, 19:35-40.

OGM. (2022). Forest inventory of Turkey. General Directorate of Forestry of Turkey, Ankara.

ORTOHUM. (2022). website of The Research Directorate of Forest Tree Seeds and Tree Breeding publishers, Ankara, Turkey.

SAS. (2004): Statistical Analysis System, SAS Institute, Inc. Cary., N.C., USA.

Varol, T., Özel, HB., Bilir, N. (2017). Drought effects on reproductive and growth characteristics in seed orchards. Pakistan Journal of Botany, 49:1225-1229.

Yazici, N. (2018). Effect of species and environmental factors on growth performances in afforesration of *Cedrus libani* and *Pinus brutia*. Fresenius Environmental Bulletin, 27:6913-6917.

Yazici, N., Turan, A. (2016). Effect of forestry afforestation on some soil properties: A case study from Turkey. Fresenius Environmental Bulletin, 25:2509-2513.