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Differences between provenances in terms of some morphological characteristics in the scotch pine (*Pinus sylvestris* L.) provenance trial of the Lakes region

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Abstract: This study was carried out to evaluate some morphological features of a scotch pine (*Pinus sylvestris* L.) provenance trial, which was established twenty years ago with thirty provenances in Isparta-Aydoğmuş and Burdur-Kemer, located in the Mediterranean climate zone. Within the scope of the research, measurements and observations were made on some morphological characteristics (tree diameter, branch thickness, number of branches, branch angle) in the most successful ten provenances, according to the results of scientific studies carried out from the day the experiment was established until today. When a common evaluation is made in terms of all studied characters, Çatacık, Mesudiye, Şenkaya, Sarıkamış, and Gölköy provenances can be recommended as an alternative seed source for the trial areas and their surroundings.
Keywords: Lakes region, Provenance trial, Scotch pine, Mediterranean, Turkey

Göller yöresi sarıçam (*Pinus sylvestris* L.) orijin denemesinde bazı morfolojik özellikler bakımından orijinler arası farklılıklar

Özet: Bu çalışma, Akdeniz iklim kuşağında yer alan Isparta-Aydoğmuş ve Burdur-Kemer'de 2000 yılında 30 orijinle kurulmuş olan sarıçam (*Pinus sylvestris* L.) orijin denemesinin bazı morfolojik özellikler bakımından değerlendirilmesi amacıyla gerçekleştirilmiştir. Araştırma kapsamında, denemenin kurulduğu günden bugüne kadar gerçekleştirilen bilimsel çalışmaların sonuçlarına göre diğerlerine kıyasla daha başarılı oldukları belirlenen 10 orijinde bazı morfolojik özellikler (ağaç çapı, dal kalınlığı, dal sayısı, dal açısı) ölçülmüştür. Ölçülen tüm karakterler bakımından ortak bir değerlendirme yapıldığında Çatacık, Mesudiye, Şenkaya, Sarıkamış ve Gölköy orijinleri deneme alanları ve çevresi için alternatif tohum kaynağı olarak önerilebilir.
Anahtar kelimeler: Göller yöresi, Orijin denemesi, Sarıçam, Akdeniz, Türkiye

1. Introduction

Scotch pine (*Pinus sylvestris* L.) is an ecologically and economically valuable tree species. Ecologically, it is the only tree species which distribution ranges throughout all Northern Europe. It is found in ecosystems that provide habitats for many plant and insect species, such as mountain forests in the Mediterranean, taiga forests in Siberia, and Caledonian forests in Scotland. With the protection of Scotch pine forests, at least 64 habitats within the scope of Natura 2000 will be protected. In economic terms, this species is widespread in all European Union countries and constitutes approximately 20% of the commercial forest areas of these countries. It has an essential share in the timber production of the Nordic countries. Due to all this ecological and economic importance, Scotch pine has been one of the most researched tree species (Matías and Jump, 2012).

Climate change and increasing temperatures due to global warming are observed almost everywhere globally. In the Reports which are published so far on Climate Change, published by the International Climate Change Panel (IPCC), climate change has been demonstrated with factual findings. According to the reports, if climate change continues at its current pace, the future structure, distribution, and genetic diversity of forest ecosystems will be affected. A warmer climate will cause grazing land to increase and forests to shift northward. The boreal forest belt will shrink, and some species will disappear at higher altitudes. The range of many southern or low-altitude populations will shrink, and populations may be extinct. In addition, it will not be possible to make natural or artificial regeneration by using local seed resources, so perhaps only the provenances brought from outside to these areas will be able to continue their lives (Morgenstern, 1996). For these reasons, to be successful in afforestation studies under the new environmental conditions created by climate change, it may be necessary to choose more drought and climate change-resistant provenances as a substitute for local seed sources. The selection of provenances resistant to drought and other different climatic conditions will be possible through provenance trials and some physiological and morphological studies performed in these trials. Observation of provenance trials in the long term will be an excellent resource for researchers to see the effects of climate change on forests. It will provide researchers with

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an idea about how forests can be managed in the future (Schmidtling, 1993).

Provenance trials, which have been used for more than 200 years in studies examining the adaptation of plants to the growing environment, contribute to our learning of the genetic adaptation of plant species to different climatic and environmental conditions or their phenotypic plasticity (Matyas, 1996). Through these trials, the most appropriate seed resources for a region are determined, the transfer zones of resources with high adaptability are persistent, and information is obtained for the breeding areas of the species with afforestation studies to be carried out. In addition, effects of global warming due to climate change and pollution in the atmosphere on species can be determined by provenance trials (Işık et al., 2002).

Scotch pine spreads over an extensive area of 12 000 km in the east-west direction and 4300 km in the north-south direction. Scotch pine is the most widely distributed conifer species in the world, and it establishes pure and mixed forests in a significant part of the northern hemisphere, starting from the north of Spain, Scotland, Russia, Mongolia, Turkey, and the Caucasus in the south (Boratynski, 1991). While it is located in coastal areas in Northern Europe, it reaches an altitude of 2700 m in Turkey and grows in extensive and different environments up to the northern forest border (Yaltırık, 1988; Eckenwalder, 2009; Farjon, 2010).

The climates in the areas where Scotch pine is located vary in terms of temperature and precipitation because the species is extremely plastic and can grow in a variety of conditions. It can grow in continental climates where the temperature can drop below -10°C in winter and rise above 30°C in summer, as well as in humid temperate regions where the average annual temperature is 2-8°C, and average precipitation is more than 500 mm. It can even grow in subpolar climates, particularly where the temperature drops to -60°C. (Atalay and Efe, 2012). A seventeen-year-old Scotch pine clone study revealed that the needle leaves could endure temperatures as low as -70°C to as high as -80°C (Nilsson and Walfridsson, 1995). Extreme temperatures in our nation's terrestrial regions, where yellow pine grows, typically vary between -40°C and 40°C (Atalay and Efe, 2012). Although the annual precipitation in the regions where Scotch pine is found varies from 400 to 600 mm, and the species is drought tolerant, it has been shown that northern Anatolia, where the annual precipitation surpasses 600 mm, is where the species is most widely distributed (Atalay and Efe, 2012).

Despite having a vast natural distribution area, particularly in the northern hemisphere and in our country, Scotch pine does not naturally occur in Isparta or the area around it. Scotch pine, on the other hand, falls under the heading of "plastic species" or "species with great plasticity." Therefore, it is well known that such species with great plasticity adapt to a variety of settings in addition to their existing habitat and even grow and develop just like in that environment (Ürgenç, 1982). The biological success of the Scotch pine saplings incorporated in the Anatolian black pine stood as a group and cluster mixing and planted around Gölcük Crater Lake in Isparta 25 years ago as part of origin trials is support for the aforementioned viewpoint (Gezer et al., 2002). Given this information, the significance of Scotch pine both economically and ecologically, its high plasticity, the rapid shift in the species' geographic range brought on by climate change, the emergence of climate anomalies brought on by climate change, particularly the rise in temperatures and the strain on species not tolerant of drought, and in order to contribute to the study, In the current study, ten (10) origins that outperformed the others based on measurements and observations taken at various ages over the trial's 20-year duration were compared in terms of some morphological characteristics.

2. Material and methods

2.1. Material

The research material is the Scotch provenance experiment established in Aydoğmuş (Isparta) and Kemer (Burdur) in 2000 (Figure 1). The altitude of the Aydoğmuş trial area is 1103 m, and its aspect is southwest. Kermes Oak (*Quercus coccifera* L.) quarries are scattered in and around the experimental area. The soil structure is clayey. Erinç's "Precipitation Efficiency Index" (Im= P/Tom) formula was used to determine the precipitation, climate class, and vegetation type of the experimental area (Erinç, 1965). As a result of the calculations, it has been determined that the precipitation climate class of Aydoğmuş is semi-arid, and the vegetation type has steppe characteristics. The altitude of the Kemer trial area is 1180 m, and the aspect of the area is southwest. It was established in degraded forest area of Anatolian black pine (*Pinus nigra* Arn. subsp. *pallasiana* (Lamb.) Holmboe). Like the Aydoğmuş trial area, the soil of this area is clayey. Again, according to Erinç (1965), it has been determined that the climate class of Kemer is semi-arid, and the vegetation has steppe characteristics. In 2000, Gezer et al. established trials with 30 saplings of Scotch pine provenances, 27 of which were from Turkey and three from foreign seed sources (France and Greece). "Triple Replicated Random Plots Trial Design" was used as a design in the trials. The place and order of the provenances in the replications were determined following the coincidence rules, and 30 saplings represented each provenance in the replications. A total of 2700 saplings (30 provenance*3 replication*30 saplings) were planted in two trial areas.

Saplings planted in Aydoğmuş and Kemer experimental areas have been evaluated many times in different periods, and scientific results have been published (Gezer et al., 2002; Gülcü and Bilir, 2015; Gülcü and Bilir, 2017). In all of these scientific evaluations, the provenances were compared with some essential morphological and genetic features. Suggestions were made about the provenances predicted to be suitable for the region and similar growing environments in line with the results achieved. In this context, provenances 3, 5, 12, 18, 21, 22, 23, 27, 29, and 34 emerged as the top ten provenances in terms of the characters studied (Gezer et al., 2002; Gülcü and Bilir, 2015; Gülcü and Bilir, 2017). Therefore, only these provenances were considered in our study (Table 1).

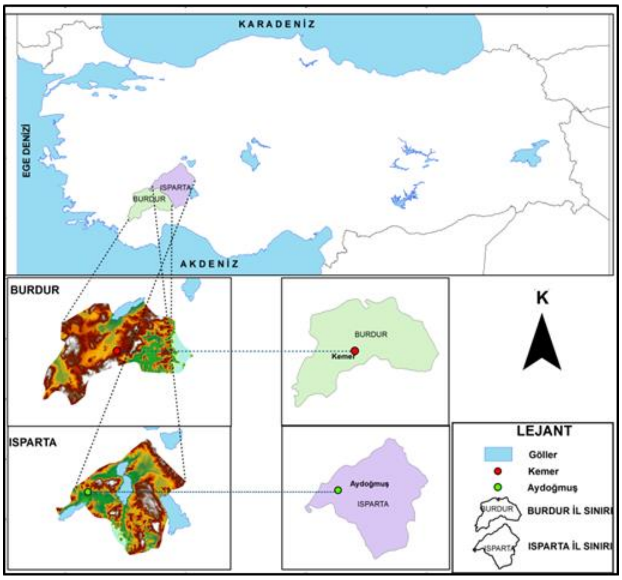

Figure 1. Location of study areas

Table 1. Some information about the provenances that are the subject of the study

Provenance number	Provenance name	Latitude (N)	Altitude (m)
3	Senkaya- Aydere	40°38′	2050
5	V.Köprü-Ovacık-Kunduz	41°10′	1200
12**	Akdağmadeni-Aktaş	39°41′	910
18	Koyulhisar-Ortakent	40°23′	1950
21	Çatacık-Değirmendere	39°58′	1550
22	Vezirköprü-Gölköy	41°10′	1300
23	Mesudiye-Arpaalan	40°22′	1650
27	Sarıkamış-Merkez	40°18′	2350
29	Akyazı-Dokurcun	40°37′	1450
34**	Erzurum-Merkez	39°54′	1570

** Seed orchard

2.2. Method

In both trial areas, measurements were carried out on fifteen individuals, five from each provenance in each repetition. Tree diameter, branch thickness, number of branches, and branch angle measurements were made in this context. The diameter of the individuals was measured from 1.30 m above the ground with the help of a caliper. Branch thicknesses of each individual were measured using a caliper by determining the two thickest branches from the branches in the 3rd and 4th node on the central axis of the trunk (Işık, 1998). Then, by taking the average of these two branch thicknesses, the average branch thickness of that individual was determined. Branch angles were also determined with the help of an electronic caliper by determining the thickest branches at the 3rd and 4th nodes on the central axis of the trunk, at a distance of 7 cm from the junction of the branches with the trunk. Then, the average of the angles of these two branches was taken, and the average branch angle of that individual was determined. For the number of branches, branches thicker than 2 cm were counted (Işık, 1998).

2.3. Statistical analyses

To evaluate the obtained data, variance and Pearson correlation analyses were performed with SPSS. One-way analysis of variance was performed to determine whether there were statistical differences between the provenances in terms of the measured characters for each trial area and to reveal homogeneous groups between the provenances with the Tukey test if there is a difference. To display both the trial areas and the trial area x provenance interaction, multiple variance analyses were performed for each studied character. Correlation analysis was also conducted to determine the relationship between the studied characters.

3. Results

In this study, the lowest average tree diameter was measured at the Erzurum provenance in the Aydoğmuş trial area, while the highest average tree diameter was measured at the Gölköy provenance (Table 2). In the Kemer trial area, the lowest mean diameter was measured at the provenance of Sarıkamış, while the highest diameter was measured at the provenance of Akyazı. Except for Şenkaya and Kunduz provenances, provenances had larger diameters in Kemer compared to Aydoğmuş (Figure 2). While the average diameter was 9.44 cm in the Aydoğmuş trial area, the average diameter was 10.26 cm in Kemer. According to the analysis of variance results, while there was no statistically significant difference between provenances in terms of this character in Aydoğmuş, it was determined that there was a significant difference ($p \leq 0.01$) in Kemer. According to the multiple variance analysis results in which the experimental areas, provenances, and provenance*area interaction were evaluated together, only the difference between the trial areas was found to be statistically significant in terms of tree diameter. Differences between provenances and differences arising from provenance*area interaction were statistically insignificant (Table 3).

While the differences observed between the provenances in terms of branch thickness in Aydoğmuş were statistically significant, the differences between the provenances were insignificant in Kemer (Table 2). In the Aydoğmuş trial area, the highest average branch thickness was measured in Akdağmadeni, followed by the provenances Mesudiye, Gölköy, and Çatacık. The lowest average branch thickness was determined in Sarıkamış provenance. In Kemer, the highest branch thickness was measured at Mesudiye and Koyulhisar, and the lowest branch thickness was measured at the provenance of Şenkaya. It has been determined that the provenances in Aydoğmuş have thicker branches than the provenances in Kemer (Figure 2). According to the analysis of multiple variances, it was revealed that there were significant differences between the experimental areas and the provenances in terms of branch thickness. At the same time, the area*provenance interaction was statistically insignificant (Table 3). When the trial areas were compared, it was determined that the average branch thickness was 1.88 cm in Aydoğmuş and 1.40 cm in Kemer.

It was determined that the difference between the provenances in terms of the number of branches in both Aydoğmuş and Kemer trial areas was statistically significant (Table 2). In the Aydoğmuş trial area, the highest average number of branches was determined at the Gölköy provenance. The least average number of branches was determined in Akyazı and Mesudiye provenances. In the Kemer trial area, the highest average number of branches was determined in the Akyazı provenance, and the lowest average number of branches in the Erzurum provenance. It was observed that the provenances of Kunduz, Gölköy, and

Erzurum had more branches in the Aydoğmuş experimental area, while the other provenances in Kemer had more branches (Figure 2). When the experimental sites were compared, it was determined that the average number of branches in the Aydoğmuş experimental area was 7.70, and the average number of branches in Kemer was 10.91. According to the multiple variance analysis results in which the provenance, area, and provenance*area interaction were evaluated together, it was determined that the difference arising from the area, provenance, and area*provenance interaction in terms of branch number character was statistically significant (Table 3).

There was no statistically significant difference between the provenances in terms of branch angles in both trial areas (Table 2). In the Aydoğmuş trial area, the highest average branch angle was observed at the Şenkaya provenance. Çatacık and Mesudiye provenances, respectively, followed by Şenkaya provenance. The lowest mean branch angle was determined at the provenance of Koyulhisar. In Kemer, the highest average branch angle was observed at the provenance of Sarıkamış, and the lowest average branch angle value was observed at the provenance of Çatacık. Except for the Sarıkamış provenance, the provenances in Aydoğmuş were found to have higher branch angles than the provenances in Kemer (Figure 2). When the experimental areas were compared in terms of this character, the average branch angle was found to be 60.08° in Aydoğmuş trial area and 50.80° in Kemer. According to the analysis of multiple variances, the difference arising from the interaction of provenance, area, and provenance*area was statistically significant for this character (Table 3).

Correlation analysis was carried out to reveal the relationships between the measured morphological characters (Table 4). Accordingly, a positive correlation was found between tree diameter and the number of branches ($p \leq 0.05$). A similar relationship was found between branch thickness and branch angle ($p \leq 0.05$).

Table 2. Means of diameter at breast height (DBH), branch tickness (Bt), branch number (Bn) and branch angle (Ba) of provenances in the study areas.

Provance name	Aydoğmuş												Kemer											
	DBH (cm)			Bt (cm)			Bn (n)			Ba (°)			DBH (cm)			Bt (cm)			Bn (n)			Ba (°)		
	M	Std	HG	M	Std	HG	M	Std	HG	M	Std	HG	M	Std	HG	M	Std	HG	M	Std	HG	M	Std	HG
Akdağmadeni	10.01	2.54	a	2.19	0.68	a	7.00	2.51	bc	56.69	19.81	a	10.61	3.04	abc	1.37	0.57	a	9.53	3.96	cd	46.06	15.93	a
Akyazı	9.97	2.01	a	1.74	0.27	ab	4.73	2.88	c	59.79	15.50	a	12.09	2.60	a	1.52	0.51	a	20.93	9.60	a	59.62	12.10	a
Çatacık	9.63	2.21	a	2.04	0.57	ab	5.53	1.92	c	65.66	8.28	a	11.75	2.07	ab	1.39	0.22	a	7.27	3.47	cd	42.84	18.10	a
Erzurum	8.21	1.91	a	1.76	0.42	ab	6.60	4.93	bc	56.15	17.81	a	9.25	2.32	bc	1.31	0.24	a	5.53	2.77	d	48.40	18.02	a
Gölköy	10.28	1.98	a	2.07	0.44	ab	16.80	5.49	a	63.13	10.04	a	11.39	2.51	abc	1.46	0.27	a	12.67	5.25	bc	49.16	12.67	a
Koyulhisar	10.08	2.03	a	1.98	0.55	ab	7.40	3.44	bc	49.45	23.67	a	10.20	1.76	abc	1.56	0.41	a	16.27	6.18	ab	48.46	17.73	a
Kunduz	9.34	2.16	a	1.79	0.58	ab	10.47	4.12	b	59.43	11.79	a	8.93	2.92	bc	1.33	0.30	a	5.73	3.01	d	50.69	16.42	a
Mesudiye	8.67	1.76	a	2.13	0.63	ab	5.53	2.33	c	65.49	11.30	a	10.69	2.51	abc	1.56	0.33	a	8.93	4.77	cd	50.58	12.95	a
Sarıkamış	8.73	1.62	a	1.49	0.41	b	6.27	4.42	bc	57.76	18.76	a	8.65	1.38	c	1.34	0.24	a	9.67	4.62	cd	61.21	14.13	a
Şenkaya	9.43	2.27	a	1.62	0.73	ab	6.67	2.74	bc	67.25	13.76	a	9.08	1.66	bc	1.22	0.18	a	12.60	4.88	bc	50.93	17.35	a
Overall Mean	9.44			2.77			7.70			60.08			10.26			1.40			10.91			50.80		
F	1.60			2.77			13.45			1.79			3.97			1.62			13.01			1.93		
P	0.12^{ns}			0.01**			0.00**			0.075^{ns}			0.00**			0.12^{ns}			0.00**			0.052^{ns}		

(M: Mean, Std:Standard deviation, HG:Homogeneous groups)

Table 3. Results of multiple variance analysis

	Source of variation	Sum of squares	Degrees of freedom	Mean Square	F Value	Level of significance (P)
Tree diameter	Provenance	39.282	9	4.365	0.839	0.581^{ns}
	Area	51.419	1	51.419	9.885	0.002**
	Provenance*Area	68.412	9	7.601	1.461	0.162^{ns}
Branch thickness	Provenance	4.768	9	0.530	2.518	0.009**
	Area	17.065	1	17.065	81.122	0.000**
	Provenance*Area	2.688	9	0.299	1.420	0.179^{ns}
Branch number	Provenance	2124.161	9	236.018	11.480	0.000**
	Area	774.413	1	774.413	37.669	0.000**
	Provenance*Area	2596.320	9	288.480	14.032	0.000**
Branch angle	Provenance	4374.740	9	486.082	1.963	0.044*
	Area	6462.593	1	6462.593	26.094	0.000**
	Provenance*Area	4537.694	9	504.188	2.036	0.036*

*p<0.05, **p<0.001, ns: non significance

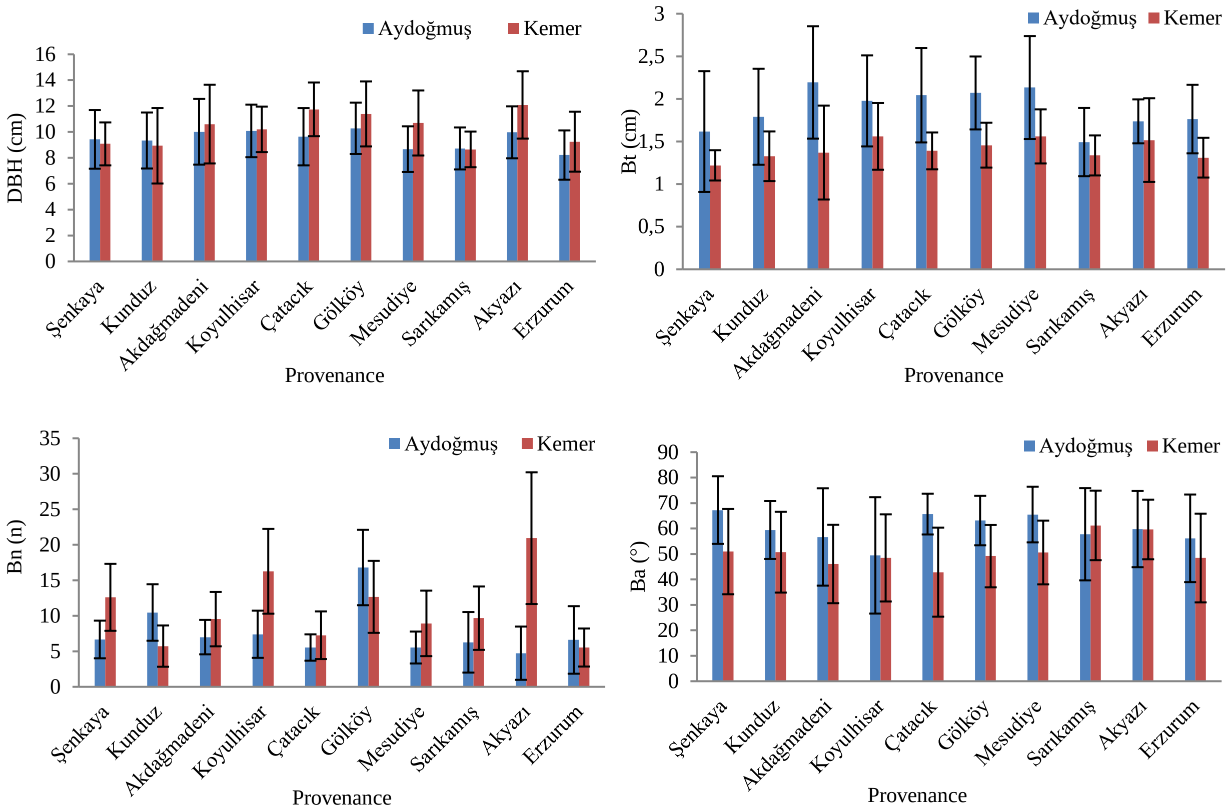

Figure 2. Mean values of diameter at breast height (DBH), branch thickness (Bt),branch number (Bn), and branch angle (Ba) of the different provenances at Aydoğmuş and Kemer

Table 4. Correlation analysis results of morphological characters

	DBH	Ba	Bn	Bt
DBH	1			
Ba	-.376	1		
Bn	.527*	-.050	1	
Bt	-.092	.548*	-.134	1

DBH: Diameter diameter at breast height, Bt: branch tickness, Bn: branch number, Ba: branch angle,*p<0.05

4. Discussion and conclusion

Out of the investigated provenances in this study, Gölköy, Koyulhisar, and Akdağmadeni from the Aydoğmuş experimental area stand out in terms of tree diameter, while Akyazı, Çatacık, and Gölköy provenances from the Kemer trial area stand out as the provenances with the highest average diameter values. When the trial areas are compared regardless of provenance, the provenances have developed 8.77% more diameter in Kemer than in Aydoğmuş. It is thought that this situation may have resulted from the fact that sapling deaths were higher in the Kemer trial area compared to Aydoğmuş and, accordingly, the individuals found a freer and broader growth area and the opportunity to receive more light for themselves. In the areas with similar growing environment characteristics to the trial areas and their surroundings, the origins that can grow 10 cm or more in diameter in both trial areas can be recommended as a seed source in foreign species afforestation to be made with Scotch pine. Because, in some studies carried out on Scotch pine and Red pine seedlings, it was determined that diameter and height development of seedlings decreased as water stress increased (Kandemir, 2002; Pichler and Oberhuber, 2007; Sudachkova et al., 2009; Kulaç, 2010; Semerci et. al. 2017; Akça and Yazıcı, 1999).

When the experimental areas were examined, it was determined that the provenances in Aydoğmuş formed 34.29% thicker branches than those in Kemer, contrary to the diameter and number of branches. In a scientific study, it was determined that branch growth decreased under drought stress (Bhusal et. Al, 2020). Therefore, it can be said that the individuals in the Aydoğmuş trial area are exposed to less drought stress than the individuals in Kemer. Tree diameters and branch thickness were estimated to be higher in the same areas under normal conditions. However, these two features were high in different areas. According to the data of the General Directorate of Meteorology, Kemer receives relatively less precipitation than Aydoğmuş. For this reason, the branch thickness of the individuals in Kemer was less than Aydoğmuş. However, on the contrary, the diameters of Scotch pine individuals in Kemer were higher. The reason for this can be explained by the fact that they increase in diameter due to the large gaps between the individuals due to the high number of individual deaths due to drying. In a study conducted in these areas in 2015, it was determined that individuals in Aydoğmuş have relatively thicker branches in terms of branch thickness, and this is similar to our study (Gülcü and Bilir, 2015).

The high number of branches indicates that the growth is healthy. To examine the growth and development of the origins, branch number measurements were carried out. In terms of the number of branches belonging to the provenances, the best three provenances were determined as Gölköy, Kunduz, and Koyulhisar provenances in Aydoğmuş, and Akyazı, Koyulhisar and Gölköy provenances in Kemer. In the provenances in Kemer, 41.69% more branch formation was observed than in the provenances in Aydoğmuş. It is stated that similar results were obtained in previous years (Gülcü and Bilir, 2015). A study on Turkish pine determined that there was no difference between red pine individuals in terms of the number of branches (Işık, 1998). Another study on Turkish pine determined that the seedlings from the seed stand were more branched than the seedlings from the seed orchard in terms of the number of branches (Çelik, 2009).

When the provenances are compared in terms of branch angle, the first three provenances with higher branch angles were determined as Şenkaya, Çatacık, and Mesudiye provenances in Aydoğmuş, and Sarıkamış, Akyazı, and Şenkaya provenances in Kemer. When the experimental areas were compared in terms of this character, the average branch angle was found to be 60.08° in Aydoğmuş trial area and 50.80° in Kemer. In the measurements made in 2015, it is stated that the individuals in Kemer are more orthogonal (Gülcü and Bilir, 2015). This may be because individuals in Kemer initially exhibited an upward branching propensity due to their density, but over time, as a result of increased individual mortality, they exhibited a tendency to branch horizontally as a result of an increase in the distance between individuals in Kemer. Akdağmadeni and Erzurum origins, which came from the seed garden, formed tighter angles than the other origins, according to the analysis of the origins according to the seed source. In a study carried out in Turkish pine, similar results were obtained, and it was stated that the individuals in the seed orchards were relatively narrow angled compared to the individuals in the seed stands in terms of branch angles (Çelik, 2009). It has been stated that the probability of permanent or falling knots in trees, which is an undesirable feature in terms of trunk quality, is estimated by the branch angle, and branches with narrow or wide angles form more misshapen and oversized knots than those with right angles (Raymond and Cotterill, 1990). In addition, branch angle is an essential factor in heavy snowfalls and stem and branch breakage, and it would be appropriate to prefer provenances with low branch angles in such areas.

When the measured characters were evaluated together, it was determined that the provenance of Mesudiye in the Aydoğmuş trial area stood out the most compared to the others. The provenance of Mesudiye was followed by Çatacık, Şenkaya, Gölköy, Akyazı, Sarıkamış, Kunduz, Akdağmadeni, Koyulhisar and Erzurum provenances, respectively. In Kemer, on the other hand, it has been determined that Çatacık provenance stands out in terms of measured characters. Çatacık provenance is followed by Sarıkamış, Gölköy, Akyazı, Mesudiye, Kunduz, Koyulhisar, Erzurum, Akdağmadeni and Şenkaya provenances, respectively. It is noteworthy that the Çatacık provenance is among the top three prominent provenances in both trial areas.

In conclusion, based on the investigated characters, provenances that can be suggested as seed sources are Çatacık, Mesudiye, and Şenkaya for the Aydoğmuş trial area and Çatacık, Sarıkamış, and Gölköy for the Kemer trial area. Further, the trials/provenaces investigated in this study should be re-evaluated in terms of the same features again in the future, to be shared with the forestry science world and practitioners.

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References

Akça, H., Yazıcı, I., 1999. İzmir Yöresinde Yetiştirilen Kızılçam (*Pinus brutia* Ten.) Fidanlarında Değişik Sulama Miktarlarında Oluşan Fizyolojik Değişiklikler. Aegean Forestry Research Institute Publications, Technical Bulletin Series No: 13, İzmir, Aegean Forestry Research Institute.

Atalay, İ., Efe, R., 2012. Sarıçam (*Pinus sylvestris* var. *sylvestris*) Ormanlarının Ekolojisi ve Tohum Nakli Açısından Bölgelere Ayrılması. Ministry of Forestry and Water Affairs-Forest Trees and Seeds Research Institute Publications, 5, Ankara.

Bhusal, N., Lee, M., Han, A. R., Han, A., Kim, H. S., 2020. Responses to drought stress in *Prunus sargentii* and *Larix kaempferi* seedlings using morphological and physiological parameters. Forest Ecology and Management, 465: 118099.

Boratynskı, A., 1991. Range of natural distribution. In: Giertych, M., Matyas, C., eds. Genetics of Scots pine. Developments in plant genetics and breeding, 19–30.

Çelik, S., 2009. Bazı tohum meşcereleri ve bahçeleri tohumlarıyla kurulan kızılçam (*Pinus Brutia* Ten.) ağaçlandırmasın da genetik çeşitliliğin yapılanması. Master Thesis, Süleyman Demirel University, Graduate School of Natural and Applied Sciences, Isparta.

Eckenwalder, J.E., 2009. Conifers of the World. The complete referens. Portland, London: Timber Press.

Erinç, S., 1965. Yağış Müessiriyeti Üzerine Bir Deneme ve Yeni Bir İndis. Istanbul University, geography institute publications, (41), İstanbul.

Farjon, A., 2010. A Handbook of the World's Conifers (2, 1). Brill academic publishers, USA.

Gezer, A., Gülcü, S., Bilir, N., 2002. Isparta Göller Yöresi Sarıçam (*Pinus Silvestris* L.) orijin denemeleri (İlk aşama sonuçları). Turkish Journal of Forestry, 1: 1-18.

Gülcü, S., Bilir, N., 2015. Provenance variations of Scots pine (*Pinus sylvestris* L.) in the Southern part of Turkey. Pakistan Journal of Botany, 47(5): 1883-1893.

Gülcü, S., Bilir, N., 2017. Growth and survival variation among Scots pine (*Pinus sylvestris* L.) provenances. International journal of genomics, 2017,1-7.

Işık, F., 1998. Kızılçamda (*Pinus brutia* Ten.) Genetik Çeşitlilik, Kalıtım Derecesi ve Genetik Kazancın Belirlenmesi. Batı Akdeniz Ormancılık Araştırma Enstitüsü Yayınları, Technical Bulletin No:7, Antalya

Işık, F., Keskin, S., Cengiz, Y., Genç, A., Doğan, B., Tosun, S., Özpay, Z., Uğurlu, S., Örtel, E, Dağdaş, S., Karatay, H., Yoldağ, İ., 2002. Kızılçam Orijin Denemelerinin 10 yıllık Sonuçları (Orijin-Çevre Etkilemeşimi ve Tohum Transferi üzerine Etkisi), Technical Bulletin No: 14, T.C. Ministry of Environment and Forestry, Western Mediterranean Forestry Research Directorate, Antalya.

Kandemir, G.E., 2002. Genetics and physiology of cold and drought resistance in Turkish Red pine (*Pinus brutia* Ten.) populations from Southern Turkey. Ph D. Thesis ODTU Institute of Science, Ankara

Kulaç, Ş., 2010. Kuraklık stresine maruz bırakılan Sarıçam (*Pinus sylvestris* L.) fidanlarındabazı morfolojik fizyolojik ve biyokimyasal değişimlerin Araştırılması. Doctoral Thesis, Karadeniz Technical University, Institute of Science and Technology, Trabzon.

Matías, L., Jump, A.S., 2012. Interactions between growth, demography and biotic interactions in determining species range limits in a warming world: the case of *Pinus sylvestris*. Forest Ecology and Management, 282: 10-22.

Matyas, C., 1996. Climatic adaptation of trees: Rediscovering provenance tests. Euphytica, 92(1-2), 45-54.

Morgenstern, K.E., 1996. Geographic Variation in Forest Trees: Genetic Basis and Application of Knowledge in Silviculture, UBC Press, 209, Canada.

Nilsson , J.E., Walfridsson, E.A., 1995. Phenological variation among plus-tree clones of *Pinus sylvestris* (L.) clones in northern Sweden. Silvae Genetica,. 44: 20- 28.

Pichler, P., Oberhuber, W., 2007. Radial growth response of coniferous forest trees in an inner Alpine environment to heat-wave in 2003. Forest Ecology and Management, 242(2-3): 688-699.

Raymond, C.A., Cotterill, P.P., 1990. Methods of assessing crown form of *Pinus radiata*. Silvae Genetica, 39(2): 67-71.

Schmidtling, R.C., 1993. Use of Provennace tests to predict response to climate chance: lobbly pine and Norway sruce. Tree Physiology, 14: 805-817.

Semerci, A., Semerci, H., Çalişkan, B., Çiçek, N., Ekmekçi, Y., Mencuccini, M., 2017. Morphological and physiological responses to drought stress of European provenances of Scots pine. European journal of forest research, 136(1): 91-104.

Sudachkova, N.E., Milyutina, I.L., Romanova, L.I., 2009. Adaptive responses of Scots pine to the impact of adverse abiotic factors on the rhizosphere. Russian Journal of Ecology, 40 (6): 387-392.

Ürgenç, S., 1982. Orman Ağaçları Islahı. Istanbul University, Faculty of forestry publications, İstanbul.

Yaltırık, F., 1988. Dendroloji Ders Kitabı. Istanbul University, Faculty of forestry publications, İstanbul.