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Selection and Pomological Characterization of Superior Native Almonds (*Amygdalus communis* L.) in Siirt, Turkey

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Abstract

Turkey has a large number of seedling almond trees, which originate from seeds and show great variability, especially in terms of fruit characteristics. This valuable germplasm that has survived until today has the potential to both register new varieties directly and use them as parents in almond hybridization studies. The study was conducted to select promising almond (*Prunus amygdalus* L.) genotypes propagated by seeds in Siirt province, Turkey. The whole native population consisting of seedling almond trees growing under unirrigated conditions were screened based on late flowering, superior nut traits and tree productivity. 18 promising genotypes were selected from a natural population of approximately 34.200 seedling almond trees. Promising genotypes had a range of 5.14 g and 8.17 g for nut weight, 1.03 g and 1.46 g for kernel weight, 16.3% and 22.6% for kernel ratio, 3.12 mm and 4.65 mm for shell thickness, 0% and 20% for double kernel percentage. They had hard shelled nuts and sweet kernels. Eight genotypes had light-colored kernels. Two genotypes (56-AY-19 and 56-AY-97) produced very large-sized nuts. The results revealed the potential of promising genotypes to contribute as material to breeding studies and become new local cultivar candidates.

Keywords: *Almond; Prunus amygdalus* L.; Superior genotype; Selecting; Siirt

Abbreviations: By including the abbreviations of Table 4 and Table 5, the number of these 4 abbreviations has been increased:

A: August; F: February; C: Closed; KS: Kernel size; M: March; ML: Medium large; NWE: Nut weight (g); SH: Shell hardness; SS: Suture of shell; SW: Slightly wrinkled; Vh: Very hard; VL: Very large; W: Wrinkled.

Introduction

Cultivated almond (*Prunus dulcis* [Mill.] D.A. Webb, syn. *Prunus amygdalus* (L.) Batsch) is widely distributed from Asia to North America [1]. Almond is one of the popular nuts whose production and consumption is increasing today. It has been reported that the remarkable increase in almond production in California is also associated with the development of consumer awareness due to its benefits on human nutrition and health [2]. Almond fruit is included in nutritional diets with its fatty acids, proteins, dietary fiber, complex carbohydrates, vitamin E, polyphenols and many minerals [3,4]. Almond is beneficial for various diseases such as heart, cancer, joint, rheumatism and skin diseases, and that it increases the level of HDL (high density lipoproteins) in the blood and reduces the level of LDL (low density lipoproteins) with the fatty acids and phytosterols it contains [5,6].

In Anatolia, almond is cultivated in almost every region except the Eastern Black Sea coastal regions and plateaus, but its culture is more common in the Aegean, Mediterranean, Marmara and Southeastern regions. It was emphasized that Southeastern Anatolia has the potential to become an important almond cultivation center in the future as a result of the expansion of irrigation facilities [7]. Almond production in various countries is based mostly on selected seedling populations consisting of different genotypes. These genotypes, adapted to local production areas, are the result of natural selection. The culture of continuous seed propagation, which has been practiced in different areas of Anatolia since ancient times, has led to the emergence of large-scale seedling almond populations [8,9]. Unfortunately, these populations, which constitute local almond genetic resources, are gradually decreasing and even in danger of extinction in some places. Seedling almond populations with wide genetic diversity may contain valuable individuals or chance seedlings with high resistance to various biotic and abiotic stress conditions. Many commercial almond cultivars, which have an important place in world almond production, have been released as chance seedlings [10,11].

Genetic diversity in almonds is of great importance in terms of determining gene pools, developing conservation strategies and identifying genetic resources [12,13]. Genetic diversity of native almond populations is a need for a successful breeding program and provides many opportunities for breeding efforts and introduction of promising genotypes [14].

Collecting, evaluating and identifying promising genotypes from local populations is one of the basic methods in almond breeding programs [14,15]. Selecting valuable individuals from seedling tree populations in different areas can contribute to the progress of breeding. Related studies contribute to the discovery of superior genotypes within seedling almond populations and the conservation of genetic resources [15-17]. Morphological characterization of germplasm collections is the reference for plant breeders [18]. The aim of this research is to examine almond genotypes propagated by seeds in Tillo and Kurtalan districts of Siirt province located in southeastern Anatolia region and to determine the nut and tree traits of most promising genotypes for future breeding studies.

Materials and Methods

Research area

Siirt province (41° 57' east longitude and 37° 55' north latitude) is in the southeast of Turkey and in the southwest of the Lake Van basin (Figure 1). Most of the province is surrounded by mountains. Its altitude is 895 m. In the province, summers are hot and dry, and winters are cold. Monthly mean temperature varies between 2.7 °C (January) and 30.7 °C (July). Its annual total rainfall is 718 mm. It receives the lowest rainfall in July (2.7 mm) and the highest rainfall in March (113.3 mm) (Figure 2). Tillo and Kurtalan are two of the districts of Siirt province. They exhibit climate traits like Siirt.

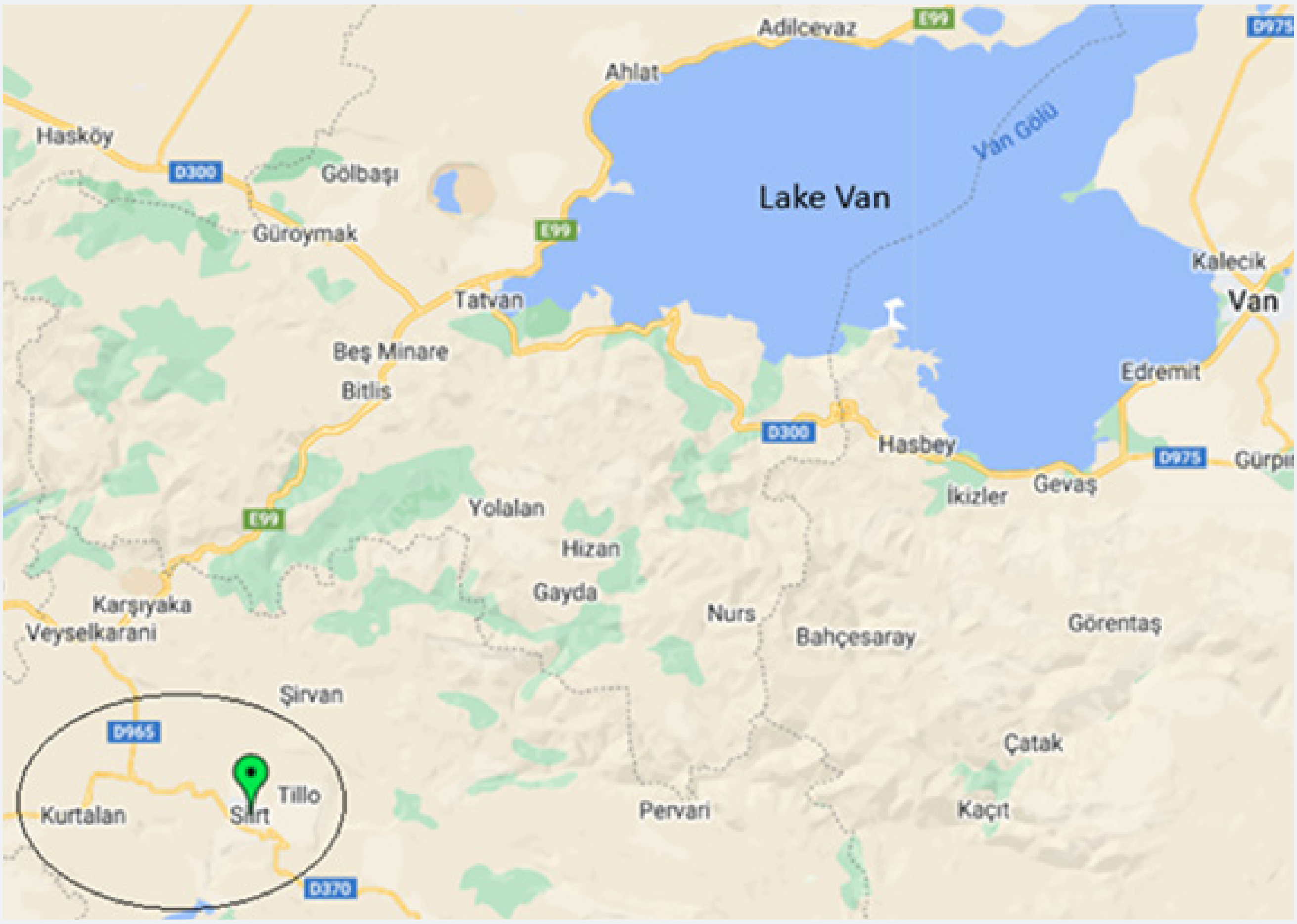

Figure 1: Research area (Siirt) located in the southwest of the Lake Van basin and in the southeast of Turkey.

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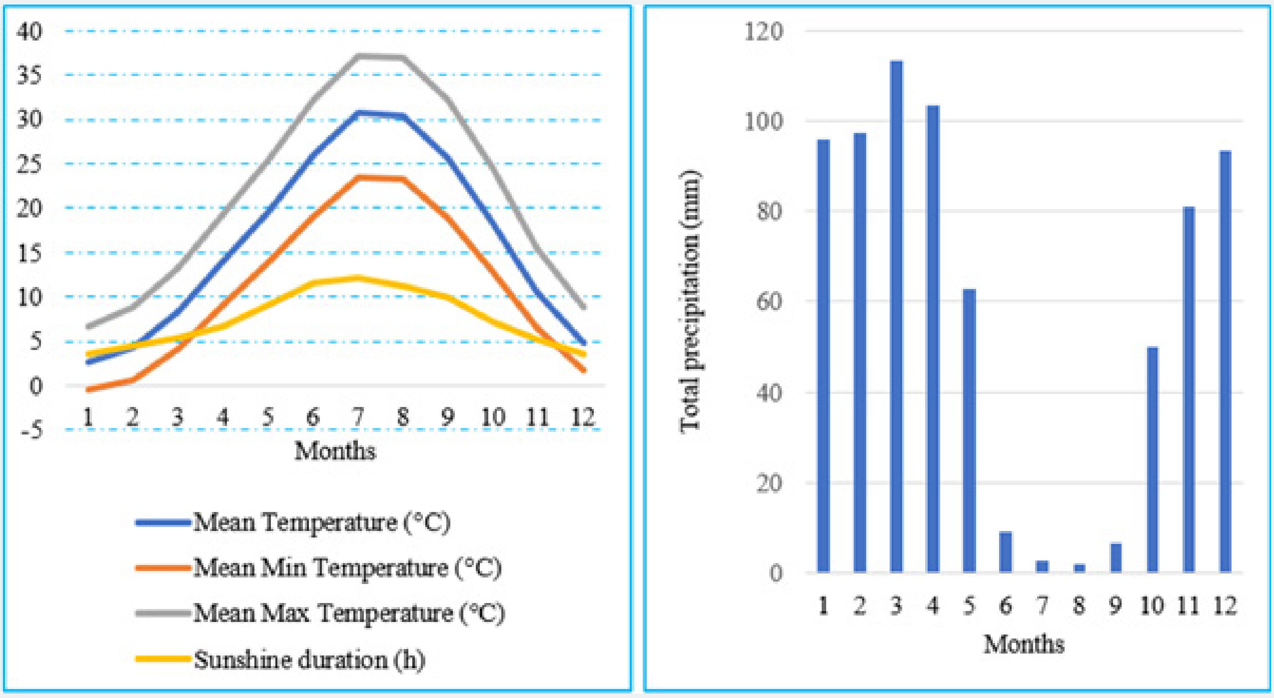

Figure 2: Long-term (1939-2022) temperature and precipitation data for Siirt province [19].

Plant Materials

This research was conducted for three years (2010-2012) in seedling almond populations in Tillo and Kurtalan districts of Siirt province (Southeastern Anatolia). In the first year, 34.200 seedling almond trees growing under unirrigated conditions in Tillo and Kurtalan districts were screened based on late flowering, superior nut traits and tree productivity. In seedling population, 103 genotypes were examined and their detailed nut and tree traits were recorded. Among them, those with kernel weight higher than 0.85 g were choosen and thus the number of genotypes was reduced to 57 in 2011. These genotypes were evaluated based on the Weighted Ranking Method [15-17,20,21], and 18 genotypes were selected as promising. In addition, the range and distribution of some nut and kernel traits and phenological data were evaluated in the almond genotypes examined in the first year (2010) and the second year (2011).

Tree traits

Trunk circumference at 60 cm height from the ground (cm), tree height (m), tree shape, yield and altitute were described. Weeks of the bud breaking, first flowering, full flowering, end of flowering, and harvest dates were recorded for all genotypes.

Nut and kernel traits

Nut traits examined were nut thickness, nut width, nut length, shell thickness, nut weight, nut size, shell hardness, nut shape, shell porosity, suture of shell and ease of hulling. Kernel traits were kernel thickness, kernel width, kernel length, kernel weight, kernel ratio, the number of kernel per ounces, kernel size, double kernel ratio, sound of kernel, kernel taste, kernel shriveling, kernel pubescence and kernel color. Nut weight (fruit in shell) and kernel weight (g) were determined using a digital scale sensitive to 0.01 g. Dimensions (mm) and shell thickness (mm) of the nuts were measured with a digital caliper. Nut and kernel traits were determined on randomly choosen 30 nuts for each genotype [17,20-22].

Results and Discussion

Phenological observation data. Phenological observation data were recorded on a weekly basis for two years (2011-2012) for both the 57 genotypes evaluated in the second year and the 18 promising genotypes and are presented in Table 1 and Table 2.

The first flowering occurred in the last week of February and the first and second weeks of March in the second year, and in the first and second weeks of March in the third year (Table 1). The genotypes were in full bloom in the first three weeks of March in the second year, and in the second and third weeks of March in the third year. Harvest times were 20-28 August in the first year and 24-27 August in the second year. Phenological observation data indicated genetic diversity in terms of flowering behavior.

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Table 1: Phenological data of 57 genotypes examined in the second (2011) and third year (2012).

Phenological observations	Second year		Third year	
	Month/week	Number of genotype	Month/week	Number of genotype
Bud breaking	February/IV	27	-	-
	March/I	23	March/I	36
	March/II	7	March/II	21
First flowering	February/IV	15	-	-
	March/I	20	March/I	30
	March/II	22	March/II	27
Full flowering	March/I	27	-	-
	March/II	9	March/II	27
	March/III	21	March/III	30
End of flowering	March/II	27	March/III	15
	March/III	30	March/IV	42
Harvest time	20-24 August	36	24-25 August	37
	25-28 August	21	26-27 August	20

The numbers I, II, III and IV indicate the week of the relevant month.

Table 2: Phenological observation data for promising almond genotypes.

Genotype	Altitute (m)	Bud breaking		First flowering		Full flowering		End of flowering		Harvest	
		2011	2012	2011	2012	2011	2012	2011	2012	2010	2011
56-KR-02	964	M I	M I	M I	M II	M II	M III	M III	M IV	28 A	27 A
56-AY-19	1179	M I	M II	M I	M II	M III	M III	M III	M IV	24 A	25 A
56-AY-22	1196	M I	M II	M II	M II	M III	M III	M III	M IV	24 A	25 A
56-AY-23	1188	M I	M II	M II	M II	M III	M III	M III	M IV	24 A	25 A
56-AY-30	1207	M II	M II	M II	M II	M III	M III	M III	M IV	23 A	25 A
56-AY-34	1193	M II	M II	M II	M II	M III	M III	M III	M IV	23 A	25 A
56-AY-36	1185	M I	M II	M II	M II	M III	M III	M III	M IV	23 A	25 A
56-KR-39	985	F IV	M I	F IV	M I	M I	M II	M II	M III	25 A	25 A
56-AY-52	1215	M II	M II	M II	M II	M III	M III	M III	M IV	23 A	24 A
56-AY-68	1225	F IV	M I	F IV	M I	M I	M II	M II	M III	21 A	23 A
56-AY-69	1164	M II	M II	M II	M II	M III	M III	M III	M IV	21 A	24 A
56-KR-74	930	M I	M I	M I	M II	M II	M III	M III	M IV	26 A	27 A
56-KR-75	933	M II	M II	M II	M II	M III	M III	M III	M IV	26 A	27 A
56-KR-78	995	M I	M II	M II	M II	M III	M III	M III	M IV	26 A	27 A
56-KR-83	980	F IV	M I	F IV	M I	M I	M II	M II	M III	26 A	27 A
56-KR-86	977	F IV	M I	M I	M I	M I	M II	M II	M IV	27 A	26 A
56-KR-87	975	M II	M II	M II	M II	M III	M III	M III	M IV	27 A	26 A
56-KR-97	987	M I	M II	M II	M II	M III	M III	M III	M IV	28 A	26 A

The numbers I, II, III and IV indicate the week of the relevant month. F: February, M: March, A: August.

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In almonds, heritability of flowering time is high [23]. Early flowering limits almond cultivation in areas where late spring frosts occur. The flowering dates may vary from year to year depending on winter conditions [16]. Therefore, the development of late-flowering almond cultivars is among the main objectives of most breeding programs [10,24]. It is extremely important to select high quality almonds that are not affected by late spring frosts in almond growing ecologies. In this research, promising genotypes that bloom fully in the third week of March in the first and second years offer value.

The growing altitudes of 18 promising genotypes varied from 930 to 1225 (Table 2). In the promising genotypes, bud breaking and first flowering occurred between the last week of February in 2011 and the second week of March, and between the first and second week of March in 2012. Full flowering was in the first week of March for 4 genotypes, in the second for 2 genotypes and in the third week of March for 12 genotypes in 2011. In 2012, the week of full flowering did not change in 12 genotypes, while it occurred 1 week later in 6 genotypes compared to the previous year. Thus, full flowering was the third week of March in the first and second year for most promising genotypes. For the majority of promising genotypes, end of flowering was the third week of March (14 genotypes) in the first year and the fourth week of March (16 genotypes) in the second year. Phenological observation data indicated genetic diversity in terms of flowering behavior. Studies of almond germplasm from different areas also show year-to-year differences in flowering dates and harvest times [15,25,26].

Differences in flowering behavior in almonds may result from ecological conditions such as location, climate, temperature and altitude, as well as the genetic structure of the almond trees [11,27]. In related studies conducted in various ecologies in Anatolia, flowering season differences of many promising almond genotypes have attracted attention. Regional flowering seasons of promising genotypes, depending on the year, have been reported as early-mid April and early May in Kemaliye district of Erzincan Province [21], early March to early April in Kahramanmaras [28], late April in the Van Lake Basin [29], mid-March to mid-late April in Elazığ [16], mid-March to mid-April in Pertek district (Tunceli) [22], late March to mid-late April in Isparta [17], early March in Derik district (Mardin) [30], mid-February to early March in Yenipazar, Bozdoğan and Karacasu districts of Aydın province [15], mid-February to late March in Araban and Yavuzeli districts of Gaziantep [31] and mid-December to mid-January in Datca peninsula of Mugla [32].

In promising genotypes, harvest times varied between 21 August and 28 August in the first year and between 23 August and 27 August in the second year. Harvest seasons of almond genetic resources may exhibit variations [26]. Relevant research reveals that harvest seasons vary depending on regions, years and climatic conditions, as well as genotypic characteristics. Regional or local harvest seasons for promising almond germplasm have been reported as mid-August in the Van Lake Basin [29], early to late September in Pertek (Tunceli) district [22], early to mid-March in Çınar (Diyarbakır) district [33], late July to early September in Yenipazar, Bozdogan and Karacasu districts of Aydın [15], mid-September to early October in Yesilyurt district of Malatya [34] and early July to early August in Datca peninsula of Mugla [32].

Nut and Kernel Traits

Table 3 shows the range and distribution of some nut and kernel traits in almond genotypes examined in the first and second year of the study. The 103 genotypes examined in the first year had a range of 1.80-7.80 g for nut weight, 0.46-1.45 g for kernel weight, 13-31% for kernel ratio, 1.90-4.70 mm for shell thickness, 0-32.5% for double kernel ratio and 32.5-100% for sound of kernel. The 57 genotypes investigated in the second year exhibited a range of 2.23-8.64 g for nut weight, 0.60-1.55 g for kernel weight, 14-26% for kernel ratio, 2.61-4.65 mm for shell thickness, 0-50% for double kernel ratio and 60-100% for sound of kernel. Data indicate genetic variation regarding nut and kernel characteristics of the genotypes. Almond germplasm can show a wide variation in nut characteristics [14,16,26,35].

Table 3: Range and distribution of some nut and kernel traits in 103 almond genotypes examined in the first year and 57 almond genotypes in the second year.

Traits	First year			Second year		
	Range	Number	%	Range	Number	%
Nut weight (g)	1.80-3.00	19	18.4	2.23-4.85	18	31.5
	3.01-5.00	56	54.3	5.01-5.96	18	31.5
	5.01-7.00	26	25.2	6.06-6.95	11	19.2
	7.01-7.80	2	1.19	7.06-8.64	10	17.5
Kernel weight (g)	0.46-0.55	4	3.8	0.6-0.73	3	5.2
	0.56-0.65	16	15.5	0.80-0.85	6	10.4
	0.66-0.75	17	16.5	0.88-0.89	4	7
	0.76-0.85	14	13.5	0.91-0.97	10	17.5
	0.86-0.95	17	16.5	1.00-1.09	7	12.2
	0.96-1.05	17	16.5	1.10-1.19	14	24.4
	1.06-1.15	5	4.8	1.20-1.28	6	10.4
	1.16-1.25	7	6.7	1.34-1.38	3	5.2
	1.26-1.45	6	5.8	1.45-1.55	4	7

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Kernel ratio (%)	13.01-15.0	9	8.7	14-15	7	12.2
	15.01-17.0	16	15.5	16-17	7	12.2
	17.01-19.0	21	20.4	18-19	19	33.3
	19.01-21.0	18	17.4	20-21	17	29.8
	21.01-23.0	16	15.5	22-23	3	5.2
	23.01-25.0	12	11.6	24-25	3	5.2
	25.01-31.0	11	10.6	26	1	1.7
Shell thickness (mm)	1.90-2.70	11	10.6	2.61-2.97	5	8.7
	2.71-3.50	54	52.4	3.08-3.47	11	19.2
	3.51-3.90	23	22.3	3.50-3.98	22	38.5
	3.91-4.70	15	14.5	4.00-4.65	19	33.3
Double kernel (%)	0	84	81.5	0	42	73.6
	2.51-7.5	8	7.7	5	8	14
	7.51-12.5	3	2.9	15-Oct	2	3.5
	12.51-17.5	3	2.9	20	2	3.5
	17.51-22.5	2	1.9	30	1	1.7
	22.51-32.5	3	0.9	50	1	1.7
Sound of kernel (%)	32.50-37.5	1	0.9	60	1	1.7
	62.50-82.5	11	10.6	80	1	1.7
	82.51-92.5	11	10.6	90	2	3.5
	92.51-97.5	6	5.8	95	4	7
	97.51-100	74	71.8	100	49	86

Table 4 exhibits the nut traits of 18 promising genotypes. They had a range of 15.3-18.3 mm for nut thickness, 23.1-32.2 mm for nut width, 32.5-41.7 for nut length and 3.12-4.65 mm for shell thickness. All genotypes had nut weight over 5 g. Nut weight ranged from 5.14 g to 8.17 g. Two genotypes (56-AY-19 and 56-AY-97) produced very large-sized nuts. The number of large-sized genotypes was 11. The five genotypes had medium large-sized nuts. Promising genotypes had hard-shelled nuts. The six genotypes were heart shaped. Nut shape was ellipse in five genotypes, long oval in five genotypes, long narrow in one genotype and round one genotype. The nuts of six genotypes had less pored shells. Shell porosity was intermediate pored for 9 genotypes and densely pored for three genotypes. All genotypes produced nuts with closed suture of shell. Hulling was easy for 11 genotypes, and ease of hulling of the remaining 7 genotypes was medium (Table 4). In related research, many promising almond genotypes have been identified in terms of nut traits such as nut shape, shell porosity, suture of shell and easy hulling [31,32,34,36-39].

Preferences regarding shell hardness in almonds may vary from country to country. Many Californian and Spanish almond cultivars have hard-shelled nuts [11]. Hard-shelled almond varieties are more preferred in Mediterranean countries [40]. The reasons why hard-shelled almonds are preferred in the Mediterranean region are that they adapt more easily to non-irrigated conditions, are more resistant to attacks by birds, rodents and insects, can be stored for a long time and thus maintain their commercial value throughout the season [41].

Kernel traits of promising genotypes were presented in Table 5. They had a range of 5.7-7.7 mm for kernel thickness, 13.5-17.4 mm for kernel width and 22.1-27.6 mm for kernel length. Kernel size of two genotypes (56-AY-19 and 56-KR-75) was very large. Number of kernels per ounce varied between 19.4 and 27.5. Kernel ratio was between 15.8% and 22.6% and was generally low due to the hard-shell structure of the genotypes, but kernel size was large size for 12 genotypes and medium large for 4 genotypes. Kernel weight varied from 1.03 g to 1.46. Five genotypes (56-AY-19, 56-AY-74, 56-AY-75, 56-AY-86 and 56-AY-97) had kernel weight higher than 1.3 g. Our promising genotypes were comparable in terms of kernel weight and size to many promising selected local almond genotypes with kernel weight over 1 g, very large and large kernel size, reported by various researchers [16, 22, 31, 32, 39,42-44]. It is desired that commercial almond cultivars have kernel weight over 1 g [10,11]. Many almond varieties or genotypes have been reported to produce fruits weighing more than 1.0 g in the USA, Spain, Italy and France [45].

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Table 4: Nut traits of promising almond genotypes.

Genotpe	Nut thickness (mm)	Nut width (mm)	Nut length (mm)	Shell thickness (mm)	NWE (g)	Nut size	SH	Nut shape	Shell porosity	SS	Ease of hulling
56-KR-02	16.5	24	40.7	3.56	5.95	Large	Vh	Long oval	Less pored	C	Easy
56-AY-19	17.6	32.2	40.6	3.83	8.17	VL	Vh	Ellipse	Densely pored	C	Easy
56-AY-22	15.8	23.1	38.4	3.12	5.28	ML	Vh	Long narrow	Intermediate	C	Easy
56-AY-23	16	26.7	38.7	4.32	7.26	Large	Vh	Long oval	Intermediate	C	Medium
56-AY-30	16	25	35.4	3.89	6,34	Large	Vh	Heart	Less pored	C	Medium
56-AY-34	16.2	26	35.3	4.06	6.71	Large	Vh	Heart	Less pored	C	Medium
56-AY-36	15.8	24.6	36.1	4.24	6.67	Large	Vh	Long oval	Less pored	C	Easy
56-KR-39	15.6	23.9	33.5	3.46	5.62	ML	Vh	Ellipse	Less pored	C	Medium
56-AY-52	15.3	27.8	34.5	3.5	5.14	ML	Vh	Heart	Intermediate	C	Medium
56-AY-68	16.6	27	36.7	4.51	6.13	Large	Vh	Ellipse	Less pored	C	Medium
56-AY-69	16.3	26.2	35.6	4.04	6.1	Large	Vh	Long oval	Intermediate	C	Easy
56-KR-74	16.7	25.5	37.5	3.96	7.06	Large	Vh	Heart	Densely pored	C	Medium
56-KR-75	17.3	25	35.3	4.02	6.99	Large	Vh	Ellipse	Intermediate	C	Easy
56-KR-78	15.4	23.5	37.1	3.92	5.96	Large	Vh	Long oval	Intermediate	C	Easy
56-KR-83	16.2	23.7	32.5	3.87	5.65	ML	Vh	Ellipse	Intermediate	C	Easy
56-KR-86	18.3	26.5	41.7	4.65	6.79	Large	Vh	Heart	Intermediate	C	Easy
56-KR-87	17.4	23.6	35.2	3.87	5.37	ML	Vh	Heart	Densely pored	C	Easy
56-KR-97	17.9	28.1	37.1	4.35	7.4	VL	Vh	Round	Intermediate	C	Easy

C: Closed; ML: Medium large; NWE: Nut weight (g); SH: Shell hardness; SS: Suture of shell; Vh: Very hard; VL: Very large.

Table 5: Kernel traits of promising almond genotypes.

Genotype	Kernel thickness (mm)	Kernel width (mm)	Kernel length (mm)	Kernel weight (g)	KS	Kernel ratio (%)	Number of kernels per ounce	Double kernel (%)	Sound of kernel (%)	Kernel taste	Kernel color	Kernel shriveling	Kernel pubescence
56-KR-02	6.7	13.9	26.9	1.19	Large	20	23.8	0	95	Sweet	Light	Smooth	Low
56-AY-19	6.3	17.4	27.4	1.46	VL	17.9	19.4	5	90	Sweet	Medium	SW	Low
56-AY-22	6.3	13.9	26.3	1.13	ML	21.4	25.1	5	100	Sweet	Medium	Smooth	Low
56-AY-23	5.7	15	25.3	1.15	Large	15.8	24.7	0	100	Sweet	Dark	SW	Low
56-AY-30	6.5	14.3	23.1	1.05	ML	16.6	27	0	100	Sweet	Light	SW	Low

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56-AY-34	6.7	14.3	22.6	1.15	Large	17.1	24.7	0	100	Sweet	Light	SW	High
56-AY-36	5.9	13.6	25.3	1.09	ML	16.3	26	0	100	Sweet	Medium	Smooth	Low
56-KR-39	6.9	14.7	24.8	1.27	Large	22.6	22.3	0	90	Sweet	Medium	SW	Low
56-AY-52	6.6	14.3	24.2	1.03	ML	20	27.5	10	100	Sweet	Medium	SW	Low
56-AY-68	6.7	16.2	25.2	1.19	Large	19.4	23.8	20	100	Sweet	Medium	SW	Medium
56-AY-69	7	15.9	24.9	1.23	Large	20.2	23	0	100	Sweet	Light	SW	Low
25-KR-74	7.5	14.9	26.3	1.38	Large	19.5	20.5	0	100	Sweet	Medium	SW	Low
56-KR-75	7.4	14.6	25.4	1.43	VL	20.5	19.8	0	100	Sweet	Light	Smooth	High
56-KR-78	6.5	13.5	27.1	1.14	Large	19.1	24.9	0	100	Sweet	Light	Smooth	High
56-KR-83	7.7	14.5	22.1	1.16	Large	20.5	24.4	0	100	Sweet	Medium	Smooth	Low
56-KR-86	6.6	15.7	27.6	1.34	Large	19.7	21.2	0	80	Sweet	Light	W	Low
56-KR-87	6.8	14.1	24	1.14	Large	21.2	24.9	0	100	Sweet	Light	Smooth	Low
56-KR-97	6.9	16.7	26.4	1.39	Large	18.8	20.4	0	100	Sweet	Medium	Smooth	Low

KS: Kernel size; ML: Medium large; VL: Very large; SW: Slightly wrinkled; W: Wrinkled.

Table 6: Tree traits of promising almond genotypes.

Genotype	Tree height (m)	Trunk circumference (cm)	Tree habit	Nut yield
56-KR-02	4.5	54	Spreading	Medium
56-AY-19	7	100	Spreading	High
56-AY-22	7.5	200	Spreading	High
56-AY-23	6	80	Spreading	High
56-AY-30	9	140	Spreading	High
56-AY-34	8	110	Spreading	High
56-AY-36	8	90	Spreading to upright	High
56-KR-39	7.5	90	Spreading to upright	Medium
56-AY-52	8	118	Spreading	High
56-AY-68	8	155	Spreading to upright	Medium
56-AY-69	7	136	Very spreading	High
56-KR-74	8	58	Upright	Medium
56-KR-75	5	67	Spreading	High
56-KR-78	6	70	Spreading	Medium
56-KR-83	4.5	65	Upright	Medium
56-KR-86	5.5	120	Very spreading	Medium
56-KR-87	4.5	54	Spreading to upright	High
56-KR-97	5	52	Spreading to upright	Medium

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On the other hand, double kernel, sound of kernel, kernel color, kernel taste, kernel shriveling and kernel pubescence are also the characteristics emphasized in almond breeding efforts [10,40]. Although double kernel is an undesirable trait, its percentage varies between varieties depending on climatic conditions. The majority of genotypes did not produce double kernels. Double kernel ratio of 4 genotypes was between 5% and 20%. Climatic conditions during both ovule development and fertilization periods can affect the double kernel ratio [46]. Especially low temperatures before and during flowering cause double kernel ratio to increase [47]. Sound of kernel of 14 genotypes was 100%. Light-colored sweet kernel formation is the desired trait [10]. Eight genotypes had light-colored kernels. All promising genotypes produced sweet kernels. Kernel shriveling was smooth for 8 genotypes, slightly wrinkled for 9 genotypes and wrinkled for one genotype. Kernel pubescence was low for the majority of genotypes. In related studies, many researchers have identified various promising genotypes with similar characteristics in terms of double kernel, sound of kernel, kernel color, kernel taste, kernel shriveling and kernel pubescence [22,31,32,43, 48] Figure 3 shows some promising genotypes.

Figure 3: Nut images of some promising almond genotypes.

Tree traits of promising genotypes

Tree heights of the genotypes varied 4.5 m to 9 m (Table 6). Their trunk circumferences were between 52 cm and 200 cm. Half of the genotypes had a spreading tree habit. Tree growth habit was spreading, spreading to upright, upright and very spreading. Many researchers described similar tree habits for almond genotypes [15,18,26,29]. In addition, tree yield was high in 10 genotypes and medium in 8 genotypes. Productivity in almonds is genotype and year dependent linked to the climatic conditions and to the physiological status of the trees [49].

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Conclusion

The findings of the study revealed a wide variability in nut and kernel characteristics of the seed-originated almond genotypes investigated. The data determined in this research were obtained from almond genotypes grown in unirrigated and neglected conditions. It can also be expected that promising genotypes would exhibit better results under controlled conditions. All of promising genotypes producing sweet kernels weighing over 1 gram attracted attention with their many nut and kernel characteristics. The results revealed the potential of promising genotypes to contribute as material to breeding studies and become new local cultivar candidates.

Conflict of Interest

Celapkulu C and Balta F declare that they have no competing interests.

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