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Pomological Attributes and Chemical Composition of Cultivars and Wild Genotypes of Pistachios (*Pistacia vera* L.) in Iran

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A R T I C L E I N F O

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A B S T R A C T

The study was conducted to evaluate the pomological attributes and chemical composition of 35 pistachio (*Pistacia vera L.*) genotypes, including fifteen wild-types and twenty of the important cultivar pistachios from Iran. The results revealed that cultivar pistachios in terms of important characters such as the split nuts (78.57%), blank nuts (6.96%), 100-nuts weight (118.86 g), and size (20.84 mm) were superior to wild cultivars. Higher percentages of the split nuts were observed for 'Akbari' genotype (92.81%), and the lowest rate of blank nuts was observed in 'Fandoghi 48' (2.84%). Pistachio kernel is rich in nutrients which is almost the same in wild and cultivar genotypes. The mean N, P, K, Mg, Ca, Na, Fe, Zn and Mn values of the pistachio kernels studied were 3.39%, 0.52%, 0.88%, 0.14%, 0.27%, 0.08%, 33.20 μg g^{-1}, 22.40 μg g^{-1} and 7.38 μgg^{-1}, respectively. The ranges of protein and oil content were 13.70-23.63% and 45.81-55.49%, respectively. According to the results, there was a considerable difference in physical and pomological properties among wild and cultivar pistachio nuts, while there was less difference in oil content and nutrition quality between them.

Introduction

Pistachio (*Pistacia vera* L.), which is also expressed as 'Green Gold' is one of the most important agricultural crops in Iran. According to taxonomic classification, the genus *Pistacia* is a member of Anacardiaceae and consists of 13 or more species (Bompard, 2009). *Pistacia* was believed to have evolved 80 million years ago in Central Asia (AL-Saghir, 2010). The natural habitat of the wild *P. vera* is unique to Central Asia, near the borders of Turkmenistan, Afghanistan, and Northeast of Iran (Khanazarov *et al.*, 2009). Between known species of pistachios, three important wild *Pistacia* species, including *P. vera* L., *P. atlantica* and *P. khinjuk* grow Iran (Mozaffarian, 2005). Forests wild-type *P. vera* extended to Northeast of Iran with a total area of about 75000 hectares (Behboodi, 2005). Of the genus *Pistacia*, only *P. vera* is cultivated commercially, and the rest of the species are used mainly as rootstocks for pistachios (Ford-Lloyd, 2012). Pistachio was introduced into the Mediterranean region by the Romans at the beginning of the Christian era (Crane, 1978).

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Pistachio is cultivated for nut production and has a unique feature that distinguishes it from other nuts because of its natural shell splitting before the harvest. This unique feature allows pistachio nuts to be marketed extensively in-shell for fresh consumption because their kernels can be easily separated without mechanical cracking (Kashaninejad and Tabil, 2011). Varieties and drying conditions influence the physical quality characteristics of nuts and kernels, including their dimensions and weight, the percentage of split nuts, blank nuts percentage, and a ratio of kernel/nut (Aliakbarkhani *et al.*, 2015; Rezaei *et al.*, 2019; Tsantili *et al.*, 2010). Nuts are rich sources of multiple nutrients and interest in nut consumption and human health outcomes are on the increase. Pistachio is one of the nuts that is commonly consumed in diets; and therefore, it is necessary to know its chemical composition and nutritional value (De Souza *et al.*, 2017). Research shows that cultivar, weather conditions and cultural practices on the orchard affect nut nutritional properties (Rabadán *et al.*, 2019; Zhu *et al.*, 2015). Pistachio cultivars show differences in the protein content, oil content and minerals (Atatashafrooz *et al.*, 2015; Bellomo *et al.*, 2009; Rabadán *et al.*, 2017).

Iran is the largest pistachio producer and one of the leading centers of diversity that has many unique wild genotypes and cultivars of pistachio (Khadivi *et al.*, 2018). Due to the high diversity of pistachio genotypes in Iran, identification of the characteristics of the genotypes and their comparison seem necessary. The study aimed to investigate the pomological attributes and chemical composition of cultivar and wild pistachios (*Pistacia vera* L.) of Iran and to identify superior genotypes for different traits.

Materials and Methods

Study area and Experimental materials

Thirty-five genotypes of *P. vera* consisting of twenty cultivar and fifteen wild genotypes were used in the present investigation (Table 1). Pistachios were harvested during the commercial harvest period when the fruit reached a physiological maturity stage. Twenty different cultivar genotypes of pistachio were collected at the experimental orchard in the Buien-Zahra of Qazvin, Iran (50°08’E and 35°96’N). The wild pistachio genotypes used in this study were collected from pistachio habitat of Maraveh-Tappeh area, Golestan Province, Iran in the geographical coordinates of the region 55°14’E to 56°23’E longitude and 37°54’N to 38°15’N.

Table 1. List of pistachio accessions.

Accession	Type	Accession	Type
Genotype 1	Wild genotype	Ahmad Agaei	Cultivar
Genotype 2	Wild genotype	Shahpasand 32	Cultivar
Genotype 3	Wild genotype	Pakzadi	Cultivar
Genotype 4	Wild genotype	Kaleghochi	Cultivar
Genotype 5	Wild genotype	Italiaei riz	Cultivar
Genotype 6	Wild genotype	Italiaei Dorosht	Cultivar
Genotype 7	Wild genotype	Badami kaj	Cultivar
Genotype 8	Wild genotype	Razavi	Cultivar
Genotype 9	Wild genotype	Momtaz	Cultivar
Genotype 10	Wild genotype	Qatruyeh	Cultivar
Genotype 11	Wild genotype	Nazari	Cultivar
Genotype 12	Wild genotype	Abbasali	Cultivar

Table 1. Continued.

Genotype 13	Wild genotype	Mohseni	Cultivar
Genotype 14	Wild genotype	Rezaei	Cultivar
Genotype 15	Wild genotype	Kerman	Cultivar
Akbari	Cultivar	Badami Nishkalaghi	Cultivar
Fandoghi 48	Cultivar	Ghazvini	Cultivar
Sefidkhorasan	Cultivar		

Number of nuts per cluster and nut attributes

Harvest operations were carried out, when fruits have a reddish hull that signals the physiological maturity stage. After the harvest, the nuts from each cluster were separated and the total number of nuts per cluster was recorded. In order to determine the percentage of split and blank nuts, after drying the nuts, a sample of 100 nuts was randomly selected in each replication and then the number of split and blank nuts in them was determined, which was then expressed as a percentage. Then, in 100 g nuts, shell and kernel were separated and weighted and the ratio of the kernel to shell weight was recorded as kernel percentage.

Determination of physical properties of pistachio nuts

As shown in Fig. 1, length, width and thickness of nut have been defined as the distance from the calyx end to the stem (L), the maximum diameter (W), and the distance from the highest point to the lowest point (T), of pistachio nut when placed on a horizontal plate, respectively (Kashaninejad and Tabil, 2011).

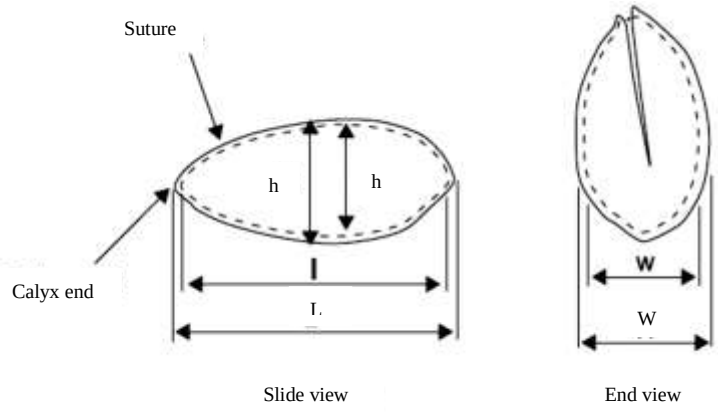

Fig. 1. Characteristic dimensions of pistachio. The dotted lines represent the kernel inside the nut.

Chemical analyses

To determine nutrient elements, kernel samples were dried in an oven at the temperature of 72°C for 120 h until reaching constant weight. The dried samples were ground, then ashed at 550°C for 4 h. Ashes were dissolved in 2N HCl and brought to a volume of 50 mL with distilled water and this extract was used to measure nutrients (Estefan *et al.*, 2013). Phosphorus content was analyzed using a spectrophotometer model PG Instrument +80, (Leicester, UK). Potassium and Sodium were determined by flame photometry using a Jenway PFP7 flame photometer (Jenway, UK). Concentration of calcium, magnesium, iron, zinc and manganese was achieved by atomic absorption spectrophotometry (Varian AA220, Australia). Protein concentration of the ground nut powder was estimated by multiplying the total nitrogen content, which was obtained through the Kjeldahl method (FOSS, 2003), by a conversion factor of 5.30 for pistachio (Greenfield and Southgate, 2003).

Oil content was determined by Soxhlet method (AOAC, 1990), 3 g dried ground kernels were weighted. The extraction procedure was performed using a Soxtec System HT 1043 Extraction Unit (Tecator, Hoganas, Sweden) and pure acetone was used as the solvent. The extraction process was set at 140 °C for 3 h. Extracted samples were weighted, and the percentage of oil content was determined as the difference in weight of dried samples before and after extraction (Sheibani and Ghaziaskar, 2008).

Statistical analysis

This experiment was conducted according to a completely randomized design with four replicates. The data obtained from the experiment were analyzed in SAS 9.1 software. The mean values were compared using Duncan's multiple range test at 5% level ($p \leq 0.05$).

Results

Genotype showed a significant effect on the number of nuts per cluster, split nuts, blank nuts, 100-nut weight and kernel percentage. Among the genotypes studied, 'genotype 12' recorded the highest number of nuts per cluster (28.33). Higher percentages of the split nuts were observed in 'Akbari' (92.81%) and 'Nazari' (92.49%), followed by 'Sefid khorasan', 'Abbasali' and 'Ahmad Agaei' with corresponding values of 91.81, 91.25 and 87.85%, respectively. The lowest rate of blank nuts was observed in 'Fandoghi 48' (2.84%), followed by 'Badami kaj' and 'Sefid khorasan' with corresponding values of 3.03 and 3.58%, respectively. The highest 100-nut weight value (142.7 g) was related to 'Akbari' while the lowest value (47.46) was for 'genotype 9'. 'Sefid khorasan' showed the highest ratio of kernel/nut weight (55.73%) of the genotypes in this study, it was followed by 'Pakzadi' and 'Badami kaj' with corresponding values 54.33 and 53.88% (Table 2).

Table 2. Pomological attributes, proteins and oil content of 35 cultivars and wild pistachio genotypes (*Pistacia vera* L.).

Genotype	No. of nuts per cluster	Split nut (%)	Blank nut (%)	100-nuts weight (g)	Kernel (%)	Proteins (%)	Oil (%)
Genotype 1	18.33±2.40[a]	22.17±1.20	21.21±1.18	57.74±0.99	52.22±2.03	16.69±0.48	50.34±1.04
Genotype 2	23.00±1.52	14.87±1.89	24.39±1.83	55.50±1.37	51.14±3.62	14.20±0.35	52.84±0.96
Genotype 3	21.00±1.00	20.33±1.22	22.11±1.76	59.51±2.08	51.97±1.65	14.99±0.37	51.07±1.77
Genotype 4	19.33±1.45	18.14±1.41	21.95±1.19	55.67±2.15	52.69±1.49	16.23±0.73	48.75±1.78
Genotype 5	19.00±1.00	19.21±0.61	23.48±2.10	51.36±0.89	50.20±1.39	17.17±0.41	51.31±1.70
Genotype 6	17.66±1.45	22.09±1.83	20.70±0.76	57.55±1.79	53.18±2.07	16.28±0.95	45.81±1.99
Genotype 7	25.66±1.45	13.78±2.14	26.01±1.02	48.24±1.60	53.42±1.58	17.22±0.43	46.22±1.74
Genotype 8	22.66±1.45	11.86±0.72	29.63±1.14	50.90±0.77	49.88±2.71	15.45±1.03	47.86±0.97
Genotype 9	22.66±1.33	16.49±1.84	29.19±2.31	47.46±1.69	49.45±1.17	14.52±0.35	47.05±1.84
Genotype 10	25.00±1.52	17.48±1.52	29.00±2.40	54.35±1.37	53.39±2.68	15.97±0.20	48.14±1.75
Genotype 11	20.00±1.15	16.45±0.32	24.21±1.05	46.06±0.88	54.18±0.75	13.70±0.29	48.38±1.35
Genotype 12	28.33±0.88	13.34±0.69	29.60±3.20	59.41±1.90	50.12±3.04	15.74±0.79	50.95±2.30
Genotype 13	25.00±2.08	20.20±0.17	24.96±0.81	48.50±1.18	49.12±0.70	14.75±0.45	50.73±2.48
Genotype 14	22.33±0.88	14.08±1.65	26.17±2.18	55.97±1.42	50.84±1.90	14.73±0.73	52.76±1.54
Genotype 15	20.33±1.45	13.90±0.70	28.74±5.09	54.43±1.12	50.45±1.09	15.59±0.62	51.54±1.91
Akbari	10.33±0.33	92.81±1.49	5.36±1.42	142.7±1.13	53.41±1.23	23.63±0.30	52.56±0.89
Ahmad Agaei	14.00±0.57	87.85±3.61	5.72±0.92	119.3±2.53	50.84±2.77	19.61±0.34	53.20±1.07
Kaleghochi	9.66±0.33	66.66±3.30	10.68±2.04	131.7±4.94	48.44±0.82	22.71±0.62	55.49±0.89

Table 2. Continued

Fandoghi 48	10.00±0.57	85.98±5.15	2.84±0.13	140.6±2.83	53.56±1.30	18.44±0.79	51.57±1.79
Momtaz	14.66±1.20	77.78±3.93	9.57±0.85	119.2±6.51	52.76±2.12	23.58±0.47	53.89±0.92
Ghazvini	21.33±1.45	78.23±1.69	4.10±0.25	94.72±5.59	48.50±2.54	18.81±0.27	52.85±1.12
Sefid khorasan	27.00±1.52	91.81±1.51	3.58±0.76	94.40±4.54	55.73±1.17	20.40±0.25	51.40±0.96
Pakzadi	10.66±0.66	85.15±2.18	9.30±1.24	123.90±4.6	54.33±1.82	19.87±0.61	52.16±1.03
Shahpasand 32	21.33±1.45	90.82±2.02	4.39±1.31	108.80±3.13	51.32±1.16	21.69±0.27	48.93±0.89
Abbasali	23.66±1.45	91.25±1.69	5.25±1.38	103.53±3.19	47.77±2.08	19.43±0.22	51.11±1.69
Razavi	12.66±1.33	77.95±2.43	6.73±0.82	117.66±5.55	53.35±0.64	19.85±0.31	50.77±1.09
Badami kaj	12.66±1.20	79.83±2.63	3.03±0.92	129.32±5.40	53.88±0.63	20.79±0.59	49.51±0.44
Qatruyeh	12.33±0.88	80.21±1.62	5.38±1.18	111.58±4.51	51.86±2.02	18.10±0.39	50.60±1.62
Nazari	14.66±0.33	92.49±1.80	4.63±1.13	130.32±6.16	52.64±3.68	20.84±0.28	53.59±1.54
Badami Nishkalaghi	14.66±0.66	44.37±1.50	11.05±1.77	124.22±3.12	52.26±1.88	19.78±0.30	49.86±1.37
Mohseni	19.66±1.20	75.75±2.57	5.10±1.06	140.32±5.19	50.96±2.94	19.04±0.39	50.31±1.51
Rezaei	13.66±1.20	78.61±3.49	10.61±1.56	137.09±1.74	47.75±0.85	20.51±0.18	50.49±0.95
Kerman	13.00±1.52	84.20±1.19	6.73±0.40	133.59±5.70	50.15±2.84	21.14±0.45	52.75±1.26
Italiaei Dorosht	19.66±1.45	22.60±1.14	18.58±0.82	80.48±3.41	48.31±1.01	19.25±0.75	51.94±1.42
Italiaei riz	20.66±0.88	87.03±2.24	6.51±0.75	93.58±1.62	53.82±1.95	21.81±0.43	52.98±0.95
Mean	18.56	52.16	14.87	90.85	51.54	18.01	50.69

[a] Data are means of three experimental replicates ± standard error.

Table 3 shows the size distribution of the pistachio nuts and kernel. The results indicated that the mean length, width, and thickness for nuts and kernels of cultivar pistachio were 20.86, 13.18, 12.17, 18.20, 10.08 and 8.97 mm, respectively, whereas these values for wild pistachios were 14.36, 8.21, 7.39, 11.72, 6.43 and 5.67 mm, respectively (Table 3).

Table 3. Nut and kernel characteristic of pistachio cultivars/wild genotypes.

Genotype	Nuts			Kernels		
	Length (mm)	Width (mm)	Thickness (mm)	Length (mm)	Width (mm)	Thickness (mm)
Genotype 1	15.49±1.70 [a]	9.22±0.82	8.41±0.89	12.78±1.49	7.06±1.00	6.46±1.16
Genotype 2	15.10±1.85	9.33±1.60	7.67±1.44	12.07±1.75	7.20±1.34	6.53±1.31
Genotype 3	15.78±0.83	8.49±0.75	7.17±0.98	13.00±1.04	7.30±0.46	5.27±0.91
Genotype 4	14.64±1.10	8.64±0.49	8.05±0.64	12.82±0.97	7.47±0.41	6.18±0.71
Genotype 5	14.79±1.37	8.73±0.88	7.88±0.87	12.83±1.51	6.83±0.68	6.05±0.92
Genotype 6	15.62±1.75	9.31±0.82	8.52±0.90	13.00±1.58	7.48±0.70	6.86±0.89
Genotype 7	13.83±0.78	7.34±0.87	6.66±0.89	10.80±0.91	5.09±0.87	5.10±0.71
Genotype 8	13.45±0.54	7.74±0.47	6.84±0.48	10.35±0.67	5.40±0.22	5.10±0.38
Genotype 9	13.11±0.96	7.66±0.54	6.95±0.66	10.27±0.82	5.66±0.91	5.36±0.78
Genotype 10	13.51±0.94	8.65±0.55	7.96±0.53	10.90±0.94	6.93±1.04	6.19±0.45
Genotype 11	13.29±0.30	7.19±0.30	6.44±0.28	10.81±0.41	5.62±0.58	4.50±0.16
Genotype 12	14.98±1.42	8.59±0.51	7.70±0.60	11.99±1.63	6.67±0.90	5.86±0.60
Genotype 13	14.15±0.95	7.81±0.38	6.98±0.41	11.84±0.72	6.02±0.54	5.13±0.36
Genotype 14	13.79±0.98	7.65±0.69	6.65±0.63	11.15±1.04	5.90±0.99	5.07±0.52
Genotype 15	13.93±0.39	7.80±0.37	7.03±0.20	11.21±0.16	5.92±0.23	5.40±0.10

Table 3. Continued.

Akbari	24.47±0.56	14.33±0.23	12.69±0.61	21.32±0.17	10.91±0.46	10.27±0.80
Ahmad Agaei	21.18±0.25	13.64±0.14	12.14±0.18	18.25±0.20	10.08±0.10	8.91±0.30
Kaleghochi	20.71±0.56	14.09±0.11	13.14±0.55	18.05±0.61	10.48±0.38	8.71±0.69
Fandoghi 48	23.02±0.69	15.13±0.10	13.35±0.33	20.14±0.39	10.69±0.71	9.37±0.24
Momtaz	21.37±0.26	13.37±0.31	11.82±0.56	18.46±0.23	10.45±0.06	9.18±0.40
Ghazvini	21.80±0.85	11.75±0.16	9.90±0.15	18.85±0.32	10.23±0.61	8.98±0.16
Sefid khorasan	21.25±0.39	11.56±0.22	10.67±0.56	18.32±0.51	9.56±0.36	8.41±0.53
Pakzadi	19.87±0.30	13.11±0.90	12.71±0.29	17.53±0.43	10.27±0.35	9.37±0.52
Shahpasand 32	20.01±0.72	11.51±0.34	9.86±0.38	17.52±0.47	8.57±0.61	7.53±0.09
Abbasali	20.89±0.22	13.34±0.36	11.57±0.32	18.65±0.07	10.13±0.20	8.38±0.38
Razavi	20.94±0.11	16.12±0.24	14.40±0.43	19.06±0.05	10.84±0.44	10.20±0.66
Badami kaj	19.85±0.85	13.96±0.45	12.68±0.50	17.18±0.47	9.85±0.25	9.78±0.48
Qatruyeh	20.27±0.38	12.62±0.21	12.03±0.24	17.55±0.14	9.81±0.37	8.16±0.25
Nazari	22.42±0.36	14.25±0.10	12.14±0.09	20.01±0.25	10.64±0.82	8.70±0.12
Badami Nishkalaghi	19.19±0.21	12.45±0.66	12.42±0.23	16.21±0.23	9.32±0.19	9.49±0.27
Mohseni	19.54±0.10	12.89±0.35	13.33±0.44	17.46±0.16	10.18±0.73	10.08±0.54
Rezaei	20.84±0.51	13.04±0.40	14.29±0.52	18.63±0.64	11.09±0.14	9.76±0.53
Kerman	21.01±0.20	13.10±0.70	12.35±0.34	17.51±0.69	10.15±0.40	8.07±0.24
Italiaei Dorosht	20.43±0.53	10.60±0.20	11.27±0.14	17.07±0.20	9.17±0.28	7.97±0.14
Italiaei riz	18.22±0.15	12.83±0.26	10.69±0.27	16.23±0.03	9.27±0.39	8.04±0.17
Mean	14.36	8.28	7.39	11.72	6.43	5.67

[a] Data are means of three experimental replicates ± standard error.

Table 4 shows the mineral element contents of the pistachio genotypes kernel. The minimum and maximum contents of macro elements, namely, N, P, K, Mg, Ca and Na ranged from 2.56 to 4.46%, 0.39 to 0.66%, 0.64 to 1.16%, 0.12 to 0.17%, 0.23 to 0.34% and 0.073 to 0.099% with an average of 3.39, 0.52, 0.88, 0.14, 0.27 and 0.08%, respectively. Also, the Fe, Zn and Mn contents of *P. vera* kernels were found between 19.98 to 47.90 μg g^{-1}, 18.64 to 26.84% μg g^{-1} and 4.87 to 9.12 μg g^{-1} with an average of 33.20, 22.40 and 7.38 μg g^{-1}, respectively (Table 4). 'Akbari' had the highest N and K content and 'Momtaz' had the highest Ca, Fe and Mn content. Also, 'Fandoghi 48', 'Ghazvini' and 'Pakzadi' genotypes had the highest Mg, Na and Zn content, respectively (Table 4).

Table 4. Mean values for the main nutritional components in 35 pistachio cultivars and wild genotypes.

Genotype	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Na (%)	Fe (μg g^{-1})	Mn (μg g^{-1})	Zn (μg g^{-1})
Genotype 1	3.15±0.09[a]	0.54±0.01	0.90±0.07	0.26±0.01	0.15±0.01	0.073±0.00	36.53±1.35	8.11±0.29	21.88±1.21
Genotype 2	2.68±0.06	0.46±0.01	0.82±0.02	0.25±0.02	0.14±0.01	0.074±0.00	28.69±1.33	7.07±0.70	21.04±1.02
Genotype 3	2.83±0.06	0.56±0.01	0.92±0.08	0.27±0.00	0.16±0.00	0.080±0.00	39.08±1.29	6.17±0.75	22.48±1.62
Genotype 4	3.06±0.13	0.39±0.02	1.01±0.05	0.27±0.02	0.15±0.00	0.076±0.00	26.65±3.17	6.04±1.02	18.64±0.44
Genotype 5	3.24±0.07	0.45±0.01	0.79±0.02	0.32±0.00	0.12±0.00	0.082±0.00	30.96±2.29	6.78±1.23	19.48±0.75
Genotype 6	3.07±0.18	0.55±0.01	0.94±0.04	0.27±0.02	0.15±0.00	0.074±0.00	38.95±0.63	6.79±1.14	21.44±0.99
Genotype 7	3.25±0.08	0.57±0.00	0.85±0.03	0.24±0.00	0.12±0.01	0.077±0.00	27.15±1.61	6.94±0.27	22.20±1.73
Genotype 8	2.91±0.19	0.48±0.01	0.81±0.15	0.23±0.01	0.13±0.00	0.083±0.00	30.75±1.99	6.36±1.08	20.65±0.63
Genotype 9	2.74±0.06	0.39±0.01	0.84±0.02	0.25±0.02	0.13±0.00	0.078±0.00	19.98±0.60	6.70±0.52	22.81±1.08

Table 4. Continued.

Genotype 10	3.01±0.03	0.50±0.02	0.78±0.02	0.26±0.01	0.15±0.00	0.084±0.00	37.32±0.86	8.40±0.37	20.08±1.21
Genotype 11	2.58±0.05	0.50±0.01	0.91±0.05	0.25±0.01	0.12±0.00	0.089±0.00	26.47±1.78	6.02±1.31	19.04±0.82
Genotype 12	2.97±0.15	0.50±0.02	0.74±0.01	0.29±0.01	0.14±0.00	0.088±0.00	31.84±1.57	7.51±0.75	21.34±0.98
Genotype 13	2.78±0.08	0.58±0.01	0.87±0.11	0.28±0.00	0.16±0.00	0.089±0.00	27.86±0.60	7.68±1.05	20.58±0.62
Genotype 14	2.78±0.13	0.40±0.01	0.79±0.01	0.30±0.01	0.15±0.00	0.078±0.00	38.04±2.43	4.87±0.36	22.45±1.59
Genotype 15	2.94±0.11	0.48±0.02	0.88±0.00	0.24±0.00	0.12±0.00	0.084±0.00	25.68±0.31	8.04±0.73	21.70±1.67
Akbari	4.46±0.05	0.60±0.03	1.16±0.01	0.26±0.02	0.15±0.01	0.082±0.00	26.41±2.91	8.91±0.38	25.43±1.15
Ahmad Agaei	3.70±0.06	0.61±0.01	0.76±0.02	0.33±0.01	0.15±0.00	0.083±0.00	40.35±2.90	8.29±0.69	21.71±0.34
Kaleghochi	4.28±0.11	0.64±0.01	1.02±0.04	0.33±0.00	0.14±0.01	0.093±0.00	46.94±1.68	8.44±0.12	22.43±0.65
Fandoghi 48	3.48±0.14	0.54±0.02	0.96±0.01	0.27±0.00	0.17±0.00	0.080±0.00	38.82±2.19	8.01±1.42	24.14±0.40
Momtaz	4.45±0.08	0.56±0.01	0.82±0.02	0.34±0.01	0.15±0.01	0.084±0.00	47.90±1.72	9.12±0.30	23.78±0.43
Ghazvini	3.55±0.05	0.52±0.02	0.82±0.02	0.29±0.01	0.16±0.01	0.099±0.00	41.90±0.92	8.04±0.73	23.93±0.63
Sefid khorasan	3.85±0.04	0.59±0.03	0.64±0.02	0.31±0.01	0.12±0.00	0.097±0.00	33.71±4.96	7.48±1.48	23.04±1.01
Pakzadi	3.75±0.11	0.54±0.02	1.01±0.06	0.26±0.01	0.15±0.00	0.091±0.00	25.78±1.54	6.97±0.90	26.84±1.14
Shahpasand 32	4.09±0.05	0.53±0.01	1.07±0.05	0.24±0.02	0.16±0.00	0.094±0.00	28.05±0.86	7.62±0.89	24.13±1.61
Abbasali	3.66±0.04	0.46±0.00	0.95±0.01	0.25±0.01	0.17±0.00	0.082±0.00	29.18±1.32	6.95±0.72	24.12±0.74
Razavi	3.74±0.06	0.54±0.02	0.93±0.02	0.27±0.00	0.14±0.00	0.086±0.00	35.41±1.63	7.94±0.39	21.04±1.15
Badami kaj	3.92±0.11	0.66±0.02	0.72±0.01	0.25±0.00	0.15±0.01	0.094±0.00	40.68±1.61	8.48±0.66	23.05±1.00
Qatruyeh	3.41±0.07	0.57±0.05	1.00±0.04	0.29±0.01	0.14±0.00	0.085±0.00	33.82±1.59	7.94±1.22	24.17±1.54
Nazari	3.93±0.05	0.63±0.01	1.14±0.00	0.31±0.01	0.17±0.00	0.089±0.00	45.17±1.29	7.06±1.20	22.20±0.63
Badami Nishkalaghi	3.73±0.05	0.57±0.00	0.88±0.03	0.29±0.02	0.12±0.01	0.087±0.00	27.62±1.64	7.33±1.10	21.59±0.74
Mohseni	3.59±0.07	0.44±0.01	0.75±0.00	0.23±0.01	0.14±0.00	0.077±0.00	33.32±1.63	7.60±1.03	25.16±0.96
Rezaei	3.87±0.03	0.55±0.02	0.83±0.01	0.27±0.01	0.16±0.00	0.088±0.00	32.69±1.32	6.14±0.50	23.71±1.59
Kerman	3.99±0.08	0.64±0.01	0.94±0.01	0.25±0.00	0.15±0.01	0.094±0.00	34.09±2.12	8.67±0.25	25.80±1.16
Italiaei Dorosht	3.63±0.14	0.52±0.02	0.88±0.01	0.26±0.01	0.14±0.01	0.091±0.00	31.98±1.35	7.64±0.39	23.37±1.87
Italiaei riz	4.11±0.08	0.55±0.01	0.83±0.01	0.25±0.00	0.15±0.01	0.088±0.00	34.32±1.79	7.74±0.72	22.59±1.80
Mean	3.39	0.52	0.88	0.27	0.14	0.08	33.20	7.38	22.40

[a] Data are means of three experimental replicates ± standard error.

Genotype had a significant effect on the percentage of protein and oil content. The protein content of genotypes varied from 'Akbari' (23.63%) to 'genotype 11' (13.70%) with an average of 18.01% (Table 2). Protein content varied significantly among all pistachio genotypes in this study. The mean protein content of cultivar and wild pistachios was 20.46 and 15.55%, respectively (Table 2). Among the wild genotypes, 'genotype 5' (17.17%) had the highest protein content.

Oil content varied significantly among different genotypes studied. The values of the oil content of genotypes ranges were between 45.81 and 55.49%, with a mean value of 50.69% for all genotypes 'Kaleghochi' (55.49%) and 'Ahmad Agaei' (53.53%) showed the highest oil content between genotypes studied (Table 2). The mean oil content of the cultivar and wild pistachios was 51.80 and 49.58%, respectively (Table 2).

Discussion

The data showed that the cultivar pistachio genotypes are 1.5 times larger compared to the wild genotypes. A comparison of wild and cultivar *P. vera* in respect to some physical and pomological characteristics showed that wild genotypes are typically much smaller than the cultivar genotypes, are non-split and are

characterized with a high level of blank nuts. These results indicate the advantage of cultivar genotypes compared to wild genotypes in physical and pomological properties. Differences between physical and pomological properties of genotypes studied here might be affected by genetic, nutritional and hormonal factors, location, and pollen source. Moreover, climatic conditions, exposure to environmental stresses, lack of disease and pest avoidance strategies and poor pollination of wild genotypes play an essential role in these differences. A more substantial effect of the genotype in the physical and pomological characteristics of pistachio had been previously stated (Aliakbarkhani *et al*., 2015; Boualem *et al.*, 2015; Galedar *et al.*, 2010; Rezaei et al., 2019). Aliakbarkhani *et al.* (2015), in a similar study with different cultivars comparing phenotypic variation of Iranian pistachios varieties, recorded the number of nuts per cluster of 11-28, blank nut 0-5.67%, split nut 73-93%, weight of 100 dried pistachios 72-122 g, fruit length 1.1-2.43 mm, fruit width 1.1-1.83 mm, fruit thickness 0.63-1.5 mm, length of the pistachio kernel 1.13-1.97 mm, width of the pistachio kernel 0.6-1.23 mm, thickness of the pistachio kernel 0.63-1.1 mm for Iranian pistachio nuts. Boualem *et al.* (2015) reported that the highest values of nut length, nut width, and nut thickness were 17.31, 7.70 and 6.63 mm, respectively.

Relevant contents of mineral elements were found on pistachio genotypes are in agreement with previous studies (Aliakbarkhani *et al*., 2015; Harmankaya *et al.*, 2014; Rabadán *et al.*, 2018). Harmankaya *et al.* (2014) reported that K, P, Ca, Mg, Fe, Zn and Mn contents of *P. vera* kernels were found between 6.33 to 8.06 mg/kg, 3.63 to 5.22 mg/kg, 1.61 to 3.22 mg/kg, 1.71 to 2.40 mg/kg, 47.26 to 38.44 mg/kg, 24.59 to 15.79 mg/kg and 9.57 to 4.84 mg/kg, respectively. From the nutritional point of view, pistachio kernel is rich in mineral elements, and the amount of these elements was almost the same in the wild and cultivar genotypes. These data suggest an influence of wild pistachio trees on mineral nutrients uptake and transport in environmental stress conditions and further studies can be performed to use them as rootstock for commercial cultivars according to the nutritional efficiency of these wild genotypes. Cultivar and wild pistachios, due to the high value of mineral elements, could play an important role in the diet of inhabitants in different parts of the world. Harmankaya *et al.* (2014) stated that pistachios are a good source of minerals, especially K and P. 'Ohadi' and 'Halebi' varieties had the highest K and P content. Bullo *et al.* (2015) reported pistachios also contain significant Mg, Ca, Mn and Zn. Due to their mineral profile, pistachios could play a beneficial role in human health.

There are also differences in oil content and protein content of pistachio kernels from different genotypes (Abdoshahi *et al.*, 2011; Rabadán *et al*., 2018; Tsantili *et al*., 2010). Abdoshahi *et al*. (2011) reported the protein content in five Iranian pistachio cultivars varied from 16.2% to 20.7%. Atatashafrooz *et al*. (2015) determined the protein content in different cultivars of pistachio, and the highest and lowest percentage of protein was determined in 'Fandoghi48' (21.39%) and 'Badami' (18.21%), respectively. Kashaninejad and Tabil (2011) reported that the protein content of two pistachio cultivars Ohadi and Kerman was 20.8 and 20.6%, respectively. Our results were in line with the values obtained in earlier research on protein content. The difference between the amounts of kernels protein contents of pistachio cultivars might arise due to differences in factors like the genotype, locations, and environmental conditions.

The variations in oil content observed in samples obtained from the cultivar pistachios were far less compared to the oil produced from wild pistachios. Oil content values determined in the pistachios kernel confirms the results reported for other pistachio cultivars (Catalán *et al.*, 2017; Ghrab *et al.*, 2010; Rabadán et al., 2019), as well as other nut crops such as almonds (Kodad *et al.*, 2014; Kodad and Socias i Company,

2008). Ghrab *et al.* (2010) reported a mean oil content that ranged between 56 and 78% for the local germplasm in pistachio ecotypes in Tunisia and the range of 53-56% reported for the kernels of two pistachio cultivars in Turkey (Kola *et al.*, 2018). According to the obtained results under study (Mahmoodabadi *et al.*, 2012), the amount of oil in cultivars was 54.93% to 55.4%. These results are in agreement with the present study.

Conclusions

These results confirm that physical and pomological properties and the composition of the pistachio kernel are affected by genotypes. There is considerable variation in size and other pomological characteristics among wild and cultivar pistachio nuts, while there was less difference in nutrition quality between them. These findings could be considered for the selection of superior genotypes and breeding new varieties.

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