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Adaptability study of commercial pistachio cultivars in seven regions of Khorasan-Razavi province, Iran

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ABSTRACT

Purpose: Pistachio is one of the strategic products of Iran. To maintain the position of this strategic product in the global market and to increase its production, potential areas in other parts of the country should be identified and orchards with suitable cultivars should be developed. To this end and to determine the adaptability of five pistachio cultivars with different climatic conditions of Khorasan-Razavi province, a trial was conducted. **Research method:** Cultivars including: Akbari, Fandoghi, Badami-Sefid, Ahmadaghaei and Kalleghoochi were investigated in seven selected orchards in Neyshabour, Bajestan, Torbat-e-Jam, Khoshab, Gonabad, Bardaskan and Mahvalaat cities in a RCBD during 2019-2021. **Findings:** Despite damages caused by storms, the Badami-Sefid cultivar had the highest yield in Bajestan. At Feyzabad the most product was Ahmadaghaei with 18 kg per tree, followed by Badami-Sefid and Akbari, followed by Kalleghoochi and Fandoghi with 9 kg/tree. But in other areas such as Gonabad, where strong winds blow normally, Ahmadaghaei, with strong cluster connected to the tree branch, and hence wind cannot cause much damage to the crop, seems suitable for cultivation, as well as Akbari. In case of the Akbari cultivar, its chilling requirement should be considered. **Research limitations:** More varieties of pistachios were not found in the orchards. **Originality/Value:** The results showed that Badami-Sefid cultivar due to its maximum height and width of the crown, high production capacity and adaptation to different climatic conditions of Khorasan province is suitable for areas of the country that are similar to the climatic conditions of Mahvalaat.

INTRODUCTION

Pistachio crop have a great economic potential. The global production of pistachios has increased dramatically over the past few decades, from around 50 thousand tons in 1970 to more than one million tons in 2020 (Zamorano et al., 2022). Iran is the largest producers and exporters of pistachio in the world (Salinas et al., 2021).

Pistachio (*Pistacia vera* L.) is currently cultivated in 22 provinces of Iran and its cultivation areas is gradually increasing (Ahmadi et al., 2021). Khorasan Razavi province with about 112 thousand hectares of pistachio cultivation area is the second pistachio producer province in Iran, while Mahvalat region with more than 19 thousand hectares has the highest pistachio cultivation area in the province (Ahmadi et al., 2021).

Bioactive compounds, present in pistachios, especially polyphenols, which are well-known for their ability to prevent the formation of pro-oxidants by blocking the action of reactive oxygen species are playing an important role in positive health effects such as cardio protective, anti-diabetic, and anti-inflammatory effects (Moreno-Rojas et al., 2022).

Genetic diversity is a vital feature that helps plant species survive in an ever-changing environment. Iran is considered as one of the main centers for genetic diversity of pistachio including a high diversity of female varieties and male genotypes (Qian & Mehri, 2021). It is one of the most prominent horticultural plants from an economic and commercial point of view. The genus *Pistacia* consists of eleven species which only has edible nuts and is commercially important. *Pistacia vera* is native to north Afghanistan, northeast Iran, and Central Asian countries (Qian & Mehri, 2021).

Pistachio is a diploid (2n = 30), dioecious, wind-pollinated tree (Guenni et al., 2016). It has the ability to adapt to arid conditions, representing a typical characteristic of species favored for cultivation in arid and semi-arid areas of Iran. Although pistachio breeding in Iran has occurred for many years, its productivity remains very low. Lack of varietal and rootstock diversity is among the factors contributing to the low productivity (Guenni et al., 2016).

Pistachio is one of the strategic products of Iran. In recent years, due to continuous droughts, orchards have been damaged in major production areas and have affected its production worldwide. To maintain the position of this strategic product in the global market and increase its production, potential areas in other parts of the country should be identified and orchards with suitable cultivars should be developed. Pistachio has different cultivars and the tolerance of these cultivars to live and non-living stresses is different. In order to make better use of water, land and other inputs in each region, it is necessary to determine cultivars that have higher yields and higher compatibility.

In a research, it was stated that 12 commercial and native cultivars of Khorasan Razavi province were investigated and the cultivars: Khanjari, Shahpasand, Mumtaz, Daneshmandi and Fandogi were not in a favorable condition in terms of quantitative and qualitative fruit traits. On the contrary, Akbari, Badami Sefid Feyzabad, Barg Siah, and Garme pistachio cultivars had better adaptability in Feyzabad climatic conditions (Sherafati, 2022).

To determine the differences among pistachio cultivars under saline conditions, in 2020 and 2021 on 16 cultivars an experiment was carried out. A significant difference among pistachio cultivars was observed in the study in terms of all investigated traits. The buds which turned into clusters mostly occurred in Akbari cultivar. The Badami-Sefid cultivar, due to its favorable characteristics such as long-term yielding and good income generation, has attracted the attention of gardeners even at the national level. Badami-Sefid cultivar was classified as medium to late flowering cultivars, with least risk of late spring cold during pollination (Eskandari & Sherafati, 2021).

In terms of the yield index and the number of fruits per cluster, Khanjari cultivar with 62 fruits was identified with the highest amount, followed by Fandoghi cultivar with 54 fruits and Badami Sefid cultivar with 52 fruits per cluster (Sherafati, 2010).

The Badami Sefid cultivar, has the largest size (height and width of the crown) among the commercial cultivars of the Iran, among which 97% of the fruits are split, while it tolerates water and soil salty conditions, with high ability to absorb potassium and does not show the drying of the leaf margin (one of the most obvious symptoms of salinity in pistachio trees), long fruiting period, the highest yield among the commercial cultivars (Sherafati, 2018).

In a study of the pistachio cultivars adaptability in Azar Shahr region of Iran by Bolandnazar et al. (2011), Momtaz cultivar produced the highest dry nut (223.3 g/cluster) while the yield of Kallehgoochi (162.3 g/cluster) and Ouhadi (90.7 g/cluster) were moderate. In the same study, weight of dehulled nuts and kernel weights in Kallegoochi and Momtaz were higher than other cultivars and Fandogi Zodras produced the smallest nut and kernel. In terms of kernel to dehulled nut, Ouhadi and Kallehgoochi were superior to the other cultivars. All cultivars except Fandogi Zodras had less than 27% absurd nuts and also all of cultivars had more than 80% spilt nuts except Fandogi Zodras (Bolandnazar et al., 2011).

To determine suitable pistachio cultivars for irrigated conditions, *Pistacia khinjuk* was used as rootstock and 14 pistachio cultivars and types were compared by Acar et al. (2011) in Southeast of Turkey. Pomological characteristics were observed in the study to determine the nut quality. The best results were obtained from 'Mumtaz' and 'Vahidi' for 100 dry fruits weight; from 'Siirt', 'Tekin', 'Sel 2' and 'Sel 5' for split nuts; and from 'Ohadi', 'Siirt' and 'Tekin' for kernel ratio. Regarding the experiment result, 'Tekin', 'Mumtaz' and 'Sel 5' were determined as suitable pistachio cultivars for irrigated conditions for Southeast of Turkey (Acar et al., 2011).

An initial compatibility study was conducted by Ismaili et al. (2015) on 12 pistachio cultivars in Ilam province, Iran. The rootstock was Badami pistachio, which was grafted in the second year of the cultivars of Kalleghoochi, Mumtaz, Ahmad-aghaei, Farrokhi, Abbas-ali, Shapasand, Akbari, Ouhadi, Ghermez, Cal-khandan and Kallebozi. Tree height, annual branch growth, branch diameter and reproductive bud formation were studied in the mentioned cultivars. Cultivars had significant differences in tree height, annual branch growth, and branch diameter. The best Cultivar was Ahmed-Aghaei. Ahmad-aghaei, Abbas Ali and Shapsand cultivars had the highest tree height with 102 cm, 145 cm and 98 cm, respectively. The highest annual growth of the branch was recorded for Ahmad-aghaei, Abbas Ali and Shapsand cultivars with 61 cm, 72 cm and 58 cm, respectively, and the lowest was related to Ouhadi cultivar with 12 cm. The highest branch diameter was related to Ahmad-aghaei and Shapsand with 34 mm and 26 mm, respectively, and the lowest amount was related to Farrokhi cultivar with 18 mm. The highest number of reproductive buds was formed on Ahmad-aghaei cultivar. Ahmad-aghaei, Gharmez and Abbas Ali cultivars were considered for extension in the region (Ismaili et al., 2015).

To study the compatibility and evaluate the quantitative and qualitative yield of different pistachio cultivars in Buin Zahra region of Qazvin, 32 pistachio cultivars were collected and grafted by Heydari and Hokmabadi (2015) on Akbari 8-years-old seedlings, including Rezaei, Fandoghi Qureshi, Nish Kolaghi, Abbas Ali, Shahpsand, Sefid pistachio Khorasan, Riz Italian, Tajabadi, Pakzadi, Lahijani, Mumtaz, Seif al-Dini, Fandoghi 48, Hazrati, Ameri, Shasti, Khanjari, Ahmad-aghaei, Nazari, Herati, Badami Kaj, Mumtaz 2, Dariush, Akbari, Jabbari, Koleghoochi, Qatravieh, Rahimabadi, Pistachio green, Mohseni, Sirizi and Musabadi.

The highest yields in 2014 and 2015 belonged to Ahmad-aghaei, Jabbari and Nazari cultivars. In terms of quality indices, Hazrati, Akbari and Harati cultivars had the highest weight of 100 seeds, Abbas Ali, Italian Riz and Khanjari cultivars had the highest rate of

splitting and Qatravieh, Rahimabadi, Riz and Hazrati had the lowest null fruit and Hazrati, Harati and Akbari had the best ounces while Rahimabadi, Sabz and Nazari had the highest percentage of kernel. Qureshi and Lahijani cultivars had the highest number of fruits per cluster (Heydari & Hokmabadi, 2015).

It is mentioned that Ahmad Aghaei cultivar, despite its very favourable characteristics, has a relatively severe alternate bearing (Arab, 2022).

Examining the different characteristics of pistachio genotypes in Qazvin Traditional Garden showed that among the seven evaluated genotypes, Kale Bozi genotype has superior characteristics in terms of yield, percentage of splitting and kernel taste. Also, it has alternate-bearing and absurdity lower than the others and the green colour of the kernel is another advantage that is used in the production of traditional cookies of Qazvin (Shaker Ardakani, 2022).

The purpose of this study was to investigate the compatibility of important commercial pistachio cultivars in Khorasan-Razavi to determine suitable cultivars for each/all regions.

MATERIALS AND METHODS

To determine the adaptability of five pistachio cultivars with different climatic conditions of Khorasan-Razavi province, Iran, in a randomized complete block design with three replications during 2019 to 2021, a trial was carried out.

The studies cultivars were: Akbari, Fandoghi, Badami-Sefid, Ahmad-Aghaei and Kalle-Ghoochi, which were investigated in seven selected orchards in the cities of Neyshabour, Bajestan, Torbat-e-Jam, Khoshab, Gonabad, Bardaskan and Mahvalaat. Table 1 shows some geographical and climatic characteristics of experimental orchards.

Each replication of each cultivar included three trees over 18 years old. To measure the traits, 10 clusters were randomly selected from each tree. First, the total number of pistachios was separated from the clusters and the average number of pistachios per cluster was calculated, then the hull of the ripe fruits was separated and weighed, and the percentage of hull was calculated relative to the total weight of the ripe pistachios.

The weight percentage of the absurd fruit was calculated by weighing them and determining the relative weight to the total weight of the fruits of cluster. After the fruits were completely dried, in 100 grams of pistachios, the ratio of kernels to the weight of dry pistachios was considered as percentage of kernels.

Cluster weight, number of fruits per cluster, fruit weight, number and weight of null fruit per cluster, dehulled pistachio weight per cluster, and hull weight per cluster, pistachio kernel weight per 100 g nuts, wastes and tree yield were evaluated.

Averages of 10 samples were used to calculate the traits. Table 2 shows results of analysis of water used for irrigation of orchards. Table 3 shows some physicochemical properties of soil of experimental sites. Also, table 4 shows meteorological statistics of the Mahvalaat Station in the year 2021.

The average of three-year data was used for a further statistical analysis. The first two years were collected and recorded by gardeners. Analysis of variance was performed by Fisher method (Fisher, 1925) and means were compared by Duncan's multiple range test method at the 5% probability level (Duncan, 1955).

Table 1. Description and meteorological information of experimental sites in 2021 (http://www.weather.ir).

Geographical position				Meteorological data			
Location	Latitude N	Longitude E	Altitude	Max. Tem. (˚C)	Min. Tem. (˚C)	Precipitation (mm)	Relative Humidity (%)
Bardaskan	35.2544	57.9659	985	38.6	0.3	146	39.5
Mahvalat	35.0137	58.7807	940	34.7	-1.7	110	41.5
Neyshabour	36.2132	58.7943	1250	35.6	-3.5	223	61.5
Khoshab	36.7458	58.1167	978	38.1	-0.2	175	46.5
Torbatejam	35.0313	60.5201	950.4	36.7	-4.5	163	45.5
Gonabad	34.3530	58.6838	1056	42.0	-1.5	133	42
Bajestan	34.5126	58.1794	1293	37.5	0.1	134	43

Table 2. Analysis results of orchards' irrigation water.

Location	Ec(dS/m)	pH	$(CO_3)^{2-}$	HCO_3^-	Cl^-	$(Ca+Mg)^{2+}$	Ca^{2+}	Mg^{2+}	Na^+	S.A.R
						meq / lit				
Mahvalat	16.3	7.3	0.0	3.2	91.5	40	25.6	14.4	78.6	17.6
Neishabour	0.7	7.1	0.0	2.1	11.6	6.6	4.1	2.5	11.2	1.2
Khoshab	10.5	7.6	0.0	4.9	71.0	32	22.0	10.0	65.2	13.0
Bardaskan	4	7.5	0.0	4.5	19.0	-	-	-	19	6.1
Torbatejam	1.6	7.8	0.0	3.3	16.0	-	-	-	21	5.6
Gonabad	12	7.7	0.0	4.6	68.0	35	26	9	66.9	16.6
Bajestan	13	7.2	0.0	3.5	52.0	-	-	-	24	5.8

Table 3. Some physico-chemical properties of soil from experimental sites.

Location	Texture	Organic matter (%)	Nitrogen (%)	Available P (mg.kg⁻¹)	Available K (mg.kg⁻¹)	pH	EC (dS.m⁻¹)
Bardaskan	Clay loam	0.6	0.03	12	224	7.9	1.6
Mahvalat	Silty Clay	0.3	0.03	11	268	7.7	34
Neyshabour	Clay loam	1.1	0.08	7	180	7.9	0.8
Khoshab	Silty Clay	1.3	0.12	14	185	7.8	23
Torbatejam	Clay loam	0.5	0.05	15	312	7.7	1.3
Gonabad	Clay loam	0.4	0.04	13	243	7.7	32
Bajestan	Clay loam	0.5	0.03	14	285	7.8	12

Table 4. Meteorological statistics of the Mahvalat Station in the year 2021.

Month	Tem. Min. (°C)	Tem. Max. (°C)	mean (°C)	RH Min. (%)	RH Max. (%)	Mean (%)	Rainfall (mm)	Max.Wind speed (m/s)
April	3.5	35.1	20	12	54	33	3.7	20
May	18	32.2	25.1	16.9	51.2	34	58.8	20
June	23.9	39.9	31.9	6.6	23.1	14.9	0	26
July	24.8	40.1	32.4	8.4	26.1	17.2	0	15
August	22.8	38.6	30.7	7.4	23.6	15.5	0	21
September	20.7	36.9	28.8	7.9	28.5	18.2	0	16
October	12.8	29.1	21	10.4	37	23.7	0	12
November	4.7	19.6	12.2	20.5	59.6	40.1	1.3	16
December	3.7	17.3	10.5	27.7	68.8	48.3	7.8	12
January	1.9	13.1	7.5	44.7	86.4	65.6	25	15
February	0.6	14.3	7.4	26.2	77.4	51.8	3.2	18
March	9.3	21.5	15.4	24.4	75.2	49.8	5.1	23

RESULTS AND DISCUSSION

Meteorological statistics of the Mahvalat Station in the year 2021 shows that the wind speed in March was much higher than the optimal speed for pollination (Table 4). The results of analysis variance showed a significant difference between places, pistachio cultivars, and place and cultivar interactions in terms of all studied traits (P<0.01) (Table 5).

Yadollahi (2018) study supports the results of current research, which showed the 4-years average yield of Akbari, Ahmad-aghaei, Sefid Pistachio, Kalleghoochi, and Fandoghi pistachio cultivars had a significant difference (Yadollahi, 2018). Abtahi (2001), had found the same results. This result indicated that there was a great variety between places and cultivars of pistachio. Similar to previous reports (Santana et al., 2020; Taghizadeh et al., 2020), the reaction of pistachio cultivars to environmental conditions of the places was different.

The highest and the lowest cluster yields were obtained in Gonabad and Neishabour (Table 6). Since the electrical conductivity of irrigation water is about 16 dS.m^{-1} in Gonabad (Bargaz region) and fresh water is used in Neishabour, the importance of orchard management during the growing season was found to be negligible in Neishabour. Abtahi (2001) highlighted soil salinity effect on plant growth via osmotic pressure of soil solution and ion type that composed the salt.

Gonabad produced the highest values of number and weight of fruit in the cluster, green skin weight and pistachio wastes. The weight of null fruits was high in Mahvalaat, Neishabour, Gonabad and Torbat-e-Jam. Bajestan produced the highest yield and this location along with Mahvalaat and Bardaskan were located in the first statistical class and then Gonabad and Khoshab had the least product (Table 6).

Table 5. Analysis of variance of studied traits in this experiment.

Mean squares						
Source of variations	Degree of freedom	Cluster weight	Fruit No.	Fruit weight	Null Fruit No.	Null Fruit weight
Location	6	141762.06**	11315.46**	121363.97**	547.59**	985.20**
Error	14	1539.81	225.96	1901.94	29.79	47.21
Cultivar	4	56957.84**	10953.40**	47039.16**	3289.18**	6170.18**
Location × Cultivar	24	49110.10**	4179.38**	45001.21**	655.16**	769.89**
Error	56	4130.44	517.53	4003.91	47.16	101.92
CV (%)	-	18.99	18.85	22.48	24.08	26.15

† ns, ** and * indicate non-significance and significance at the 1% and 5% probability level, respectively.

Table 5. (Continued). Analysis of variance of studied traits in this experiment.

Mean squares						
Source of variations	Degree of freedom	Pistachio weight	Green skin weight	Kernel weight	Wastes	Yield
Location	6	57601.39**	19968.74**	402.53**	43712.02**	166.79**
Error	14	739.46	290.97	6.71	201.45	6.94
Cultivar	4	22140.01**	5832.52**	416.03**	834.06**	131.58**
Location × Cultivar	24	18993.03**	6640.23**	41.56**	2075.66**	123.35**
Error	56	1413.41	478.84	6.89	530.24	4.54
C.V. (%)	-	21.86	21.14	5.07	25.10	21.50

† ns, ** and * indicate non-significance and significance at the 1% and 5% probability level, respectively.

Table 6. Mean comparison of studied traits for seven locations of Khorasan-Razavi province.

Location	Cluster weight (g)	Fruit No./Cluster	Fruit weight/ Cluster (g)	Null Fruit/Cluster	Null Fruit weight/Cluster (g)
Mahvalat	409[ab]	142[ab]	310[bc]	26[bc]	39[a]
Neishabour	201[e]	84[d]	157[d]	35[a]	39[a]
Bardaskan	373[cd]	109[c]	344[ab]	21[c]	33[b]
Khoshab	394[bc]	140[b]	363[a]	34[a]	18[c]
Bajestan	353[d]	130[b]	290[c]	21[c]	28[b]
Gonabad	436[a]	153[a]	364[a]	27[b]	39[a]
Torbat-jam	204[e]	86[d]	159[d]	34[a]	38[a]

† Similar letters in each column indicate non-significant difference at the 5% probability level according to Duncan's multiple range test.

Table 6. (Continued). Mean comparison of studied traits for seven locations of Khorasan-Razavi province.

Location	Seed weight (g)	Hull weight (g)	Kernel weight (g)	Wastes (g)	Yield/Tree (kg)
Mahvalat	198[bc]	111[b]	59[a]	90[c]	13[a]
Neishabour	86[d]	52[c]	47[c]	54[d]	9[c]
Bardaskan	189[c]	123[b]	54[b]	47[d]	11[ab]
Khoshab	248[a]	122[b]	45[d]	21[e]	4[d]
Bajestan	176[c]	124[b]	55[b]	135[b]	14[a]
Gonabad	218[b]	142[a]	55[b]	172[a]	10[bc]
Torbat-jam	88[d]	51[c]	46[c]	55[d]	9[c]

† Similar letters in each column indicate non-significant difference at the 5% probability level according to Duncan's multiple range test.

In terms of cluster weight and number of fruits per cluster, Badami Sefid cultivar had the highest and Ahmad-aghaei cultivar had the lowest (Table 7). Fruit weight, which is more important than the number of fruits per cluster, was high in Badami Sefid and Kaleghoochi cultivars. Ahmad-aghaei and Fandoghi cultivars had the lowest fruit weight. Moin Rad, (2008) and Moin Rad et al. (2002) also achieved similar results.

However, the number and weight of null fruit per cluster were also high in Badami Sefid cultivar and low in Ahmad-aghaei cultivar. Akbari, Kaleghoochi and Ahmad-aghaei cultivars had the lowest null fruit weight.

Pistachio weight was higher in Badami Sefid and Akbari cultivars (Table 7). Moin Rad (2008) study supported our results that Sefid cultivar had the higher yield during 5-year experiment and Fandoghi had the lowest yield in Gonabad and Khaf that had electrical conductivity equal to 11 dSm^{-1}. Accumulation of Chloride ions and specially Sodium and leaf necrosis damage was high in Fandoghi sensitive cultivar (Moin Rad, 2008).

Ahmad-aghaei cultivar had the highest percentage of kernel. This cultivar has a thin and tasty hull (suitable for preparing pistachio skin jam) and has the highest quality of kernels in terms of taste and fat. The highest yield was produced by Badami Sefid cultivar, which was also ranked first in terms of yield components such as cluster weight, number and weight of fruit, pistachio weight and hull weight, followed by Fandoghi, Kalleghoochi, Akbari and Ahmad-aghaei, respectively. Yadollahi (2018) also achieved that Badami Sefid was ranked first followed by Ahmad-aghaei, Akbari, Kalleghoochi and Fandoghi, in terms of quantitative yield. Abtahi (2001) observed that Fandoghi cultivar had lower stem and leaf amounts resulted in lower yield.

Table 7. Mean comparison of studied traits of five pistachio cultivars.

Cultivar	Cluster weight (g)	Fruit No./Cluster	Fruit weight (g)	Null Fruit No./Cluster	Null Fruit weight (g)
Badami-Sefid	407[a]	157[a]	337[a]	49[a]	61[a]
Ahmadaghaei	271[d]	95[c]	229[c]	15[c]	24[c]
Fandoghi	309[cd]	109[bc]	244[c]	27[b]	39[b]
Kalleghoochi	367[b]	120[b]	323[ab]	28[b]	23[c]
Akbari	337[bc]	121[b]	289[b]	24[b]	20[c]

† Similar letters in each column indicate non-significant difference at 5% level of probability.

Table 7. (Continued). Mean comparison of studied traits of five pistachio cultivars.

Cultivar	pistachio weight (g)	Hull weight (g)	Kernel weight (g)	Wastes (g)	Yield/Tree (kg)
Badami-Sefid	211[a]	127[a]	51[b]	87[a]	14[a]
Ahmadaghaei	137[c]	87[d]	59[a]	73[a]	8[c]
Fandoghi	140[c]	89[cd]	51[b]	78[a]	10[b]
Kalleghoochi	178[b]	112[b]	47[c]	88[a]	9[bc]
Akbari	193[ab]	101[bc]	50[b]	83[a]	8[c]

† Similar letters in each column indicate non-significant difference at 5% probability level.

Badami Sefid cultivar had the highest cluster weight in Bardaskan and Mahvalat (Table 8). This cultivar also produced the largest number of fruits per cluster in these two locations. Badami Sefid, in Bardaskan and Akbari cultivar in Khoshab had the highest fruit weight in the cluster. The number and weight of null fruit were highest in the Badami Sefid cultivar among others. The weight of pistachio and its hull was high in Akbari cultivar in Khoshab (Sabzevar). The weight of kernel in 100 g of dried pistachio of Ahmad-aghaei cultivar was the highest in Mahvalat. Kalleghoochi cultivar had the most wastes in Gonabad (Table 8).

Badami Sefid cultivar produced the highest yield in Bajestan (Yonsi region). In an experiment to investigate the effect of salinity on the quantitative yield, absorption and transfer of some main nutritional elements, Moin Rad et al. (2002) observed that two cultivars had a statistical difference of 1% in terms of quantitative yield and the yield of Badami Sefid was higher than that of Fandoghi. Moin Rad et al. (2002) stated that the accumulation of Na$^+$ ion in Fandoghi leaf tissue was significantly higher than that of Badami Sefid. Ca^{2+}, Mg^{2+} and especially Na$^+$ cations as well as Cl$^-$ anion, accumulated more than usual in the leaf tissue. Considering the higher accumulation of ions, especially sodium, in Fandoghi leaves and the occurrence of chlorosis symptoms and leaf margin drying, it seems that the decrease in the yield of this cultivar is related to higher solute storage and greater sensitivity to salinity (Moin Rad et al., 2002).

Badami Sefid, which is native to Feyzabad region of Khorasan-Razavi, has the highest area under cultivation in this region, due to its high vegetative growth and maximum size (height and width of the crown), high production capacity and adaptability seems suitable for areas with similar climate to Mahvalat. But in areas such as Baregaz of Gonabad, where strong winds blow normally, Ahmad-aghaei cultivar, whose cluster has a strong connection to the tree branch and the wind cannot cause much damage to the tree, seems more suitable for cultivation. Moreover, Akbari cultivar has such a characteristic and the Sefid cultivar of Feyzabad is in the third place of importance. There is also a problem of strong winds in Bajestan (Yonsi region), but despite the wind damage in the study year 2021, the Sefid cultivar still had the highest yield.

At Feyzabad Pistachio Research Station, which was one of the sites of the experiment, the electrical conductivity of irrigation water is 16.25 dSm^{-1}, that did not cause any problem for the growth of any of the pistachio cultivars except of Fandoghi. However, the highest

production per unit of a tree was obtained in Ahmad-aghaei cultivar with 18 kg, followed by Sefid and Akbari cultivars, Kalleghoochi, and Fandoghi, with the lowest result (9 kg). Mohamadi et al. (2017) observed that the cultivars of Fandoghi and Kalleghoochi had the highest amount of leaf sodium among ten cultivars. Kalleghoochi cultivar had the lowest amount (1.4%) of leaf potassium. Mohamadi et al. (2017) concluded that the cultivars Kalle Ghoochi and Fandoghi are relatively sensitive and Ahmad Aghaei cultivar is relatively tolerant to salinity. Badami Sefid, Ebrahimi and Saif al-Dini cultivars were moderate in terms of tolerance to salinity (Mohamadi et al., 2017). In another trial under the salinity conditions obtained from sodium chloride, Badami-e Riz were found to be resistant to salinity, and Fandoghi was relatively sensitive (Moin Rad, 2006).

Table 8. Mean comparison of location and cultivar interaction on studied traits.

Location	Cultivar	Cluster weight (g)	Fruit/Cluster	Fruit weight (g)	Null Fruit /Cluster	Null Fruit weight (g)
Mahvalat	Badami-Sefid	594^{ab}	220^a	431^{bc}	71^a	98^a
Mahvalat	Ahmadaghaei	298^{h-l}	110^{f-i}	231^{hij}	24^{ghi}	46^{c-f}
Mahvalat	Fandoghi	324^{g-j}	122^{c-i}	236^{g-j}	7^{klm}	7^{ijk}
Mahvalat	Kalleghoochi	472^{cde}	135^{c-h}	379^{b-f}	12^{i-m}	19^{g-k}
Mahvalat	Akbari	356^{e-i}	121^{d-i}	276^{f-i}	15^{i-l}	23^{g-j}
Neishabour	Badami-Sefid	250^{i-m}	119^{e-i}	233^{hij}	43^{c-f}	65^{bc}
Neishabour	Ahmadaghaei	166^m	61^{jkl}	137^{jk}	11^{i-m}	15^{h-k}
Neishabour	Fandoghi	179^{lm}	46^l	93^{kl}	44^{cde}	62^{bcd}
Neishabour	Kalleghoochi	215^{j-m}	107^{f-i}	196^{ijk}	40	27^{f-i}
Neishabour	Akbari	196^{klm}	95^{h-k}	135^{jk}	35	24^{ghi}
Bardaskan	Badami-Sefid	651^a	203^{ab}	603^a	46^{cde}	67^b
Bardaskan	Ahmadaghaei	258^{i-m}	77^{i-l}	229^{hij}	12^{i-m}	20^{g-k}
Bardaskan	Fandoghi	450^{c-f}	134^{c-h}	414^{bcd}	30^{fgh}	44^{def}
Bardaskan	Kalleghoochi	500^{bcd}	127^{c-h}	466^b	19^{h-k}	31^{fgh}
Bardaskan	Akbari	9^n	5^m	11^l	1^m	1^k
Khoshab	Badami-Sefid	333^{f-j}	137^{c-h}	270^{f-i}	42^{c-f}	16^{h-k}
Khoshab	Ahmadaghaei	294^{h-l}	104^{ghi}	277^{f-i}	10^{j-m}	19^{g-k}
Khoshab	Fandoghi	350^{e-i}	146^{c-g}	328^{c-h}	8^{k-m}	43^{jk}
Khoshab	Kalleghoochi	307^{h-k}	107^{f-i}	286^{e-i}	61^{ab}	24^{ghi}
Khoshab	Akbari	686^a	206^a	655^a	48^{cd}	59^{bcd}
Bajestan	Badami-Sefid	386^{d-h}	150^{c-f}	295^{d-i}	49^{bc}	28^{fgh}
Bajestan	Ahmadaghaei	361^{e-i}	127^{c-h}	297^{d-i}	18^{h-k}	49^{b-e}
Bajestan	Fandoghi	238^{i-m}	104^{ghi}	189^{ijk}	22^{hij}	37^{efg}
Bajestan	Kalleghoochi	324^{g-j}	102^{g-j}	266^{f-i}	3^{lm}	24^{ghi}
Bajestan	Akbari	459^{cde}	164^{cd}	406^{b-e}	15^{i-l}	65^{bc}
Gonabad	Badami-Sefid	384^{d-h}	150^{c-f}	295^{d-i}	99^c	15^{h-k}
Gonabad	Ahmadaghaei	357^{e-i}	127^{c-h}	297^{d-i}	18^{h-k}	62^{bcd}
Gonabad	Fandoghi	444^{c-g}	166^{bc}	357^{b-g}	34^{efg}	27^{f-i}
Gonabad	Kalleghoochi	536^{bc}	156^{cde}	466^b	18^{h-k}	25^{ghi}
Gonabad	Akbari	460^{cde}	164^{bcd}	406^{b-e}	15^{i-l}	65^{bc}
Torbat-jam	Badami-Sefid	249^{i-m}	119^{e-i}	231^{hij}	43^{c-f}	65^{bc}
Torbat-jam	Ahmadaghaei	162^m	61^{kl}	135^{jk}	11^{i-m}	15^{h-k}
Torbat-jam	Fandoghi	178^{lm}	46^l	92^{kl}	45^{cde}	62^{bcd}
Torbat-jam	Kalleghoochi	217^{j-m}	107^{f-i}	200^{ijk}	42^{c-f}	27^{f-i}
Torbat-jam	Akbari	201^{klm}	95^{h-k}	134^{jk}	36^{d-g}	24^{ghi}

† Similar letters in each column indicate non-significant difference at 5% probability level.

CONCLUSION

Badami Sefid cultivar of Feyzabad, due to its high vegetative growth, maximum size (height and width of the crown), high production capacity and high adaptation to different climatic conditions of Khorasan province, for areas of the country that are similar to the climatic conditions of Mahvalat, is identified as the most suitable cultivar.

In areas with strong winds, Ahmad-aghaei cultivar followed by Akbari cultivar are suggested as most suitable cultivars for cultivation. About the Akbari cultivar, its chilling requirement should be considered.

In Bajestan, there is also the problem of strong winds, but despite the wind damage in the year 2021, the Sefid had the highest yield. In order to establish new pistachio orchards in saline water and soil conditions, the genetic diversities of pistachio cultivars should be considered.

Conflict of interest
The author has no conflict of interest to report.

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