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Investigating Quantitative and Qualitative Traits of Edible Seeds in Some Local Populations of Iranian Summer Squash (*Cucurbita pepo* L.)

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ABSTRACT

This study evaluated the quantitative and qualitative traits of 13 local summer squash populations. The experiment was carried out in a randomized block design with 3 replications for two years (2019 to 2020). The following traits were considered in this study: number, weight, length, width, and length/width ratio of fruits, seed yield, seed yield/fruit yield ratio, 1000 seeds weight, percentage of empty seeds, seed length, seed width, seed kernel/whole seed ratio, and seed oil percent. Also, quality tests were conducted including ease of separation of skin from the kernel, taste quality, and desirability of seed shape and size from the consumer's point of view. The analysis of variance showed significant differences in most of the studied traits. Based on the results of the mean comparison of traits, the highest seed yield was observed in Ghalami-Kalaleh#1 and Mashhady-Azadshahr and then Mashhady-Khoy populations. The highest taste quality from the consumer point of view belonged to the Goushti-Kalaleh population. The results represent a positive and highly significant correlation between seed yield and fruit number. No significant correlation was observed between seed yield and other related traits. It is recommended that fruit number trait be considered in selecting programs and modifying high-yielding populations.

Keywords: Edible seed quality, Seed quantitative features, Squash yield.

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INTRODUCTION

The family *Cucurbitaceae* includes 96 genera and 75 species. The genus *Cucurbita* is one of the most economically essential genera (Rakha *et al*., 2012). There are different types for its classification, and they are usually known as *Cucurbita pepo*, *Cucurbita moschata*, *Cucurbita mixta* and *Cucurbita maxima* species (Seymen *et al*., 2012). The varieties of squash and pumpkin have commercial importance (Paris *et al*., 2006). Roasted pumpkin and squash seeds are used as nut in many cultures worldwide. These seeds possess valuable dietary and medicinal qualities. They are a good source of proteins, triterpenes, lignans, phytosterols, polyunsaturated fatty acids, antioxidative phenolic compounds, carotenoids, and tocopherol (Fu *et al*., 2006). A seed extract has been reported to have strong hypotriglyceridemic and serum cholesterol-lowering effects (Fu *et al*., 2006), is used as a vermifuge, treats problems of the urinary system, hypertension, prevents the formation of kidney stones, alleviates prostate diseases, and enhanced the erysipelas skin infection (McGinley, 2011; Dhiman *et al*., 2012). High

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morphological diversity among the genotypes of *Cucurbita pepo* was reported in terms of plant, leaf and fruit characteristics (Dalda-Şekerci *et al*., 2020; Ozturk *et al*., 2022). Diversity in plant materials is essential for developing improved cultivars (Govindaraj *et al*., 2015). Nerson and Paris (2002) classified different cultivars of *Cucurbita pepo* into nine morphotypes and reported a negative correlation between seed yield and fruit length, and in most morphotypes, there was a positive correlation between fruit size and seed size. Commercially, production of *Cucurbita* in Iran is based on local populations that combine several genotypes because of their cross-pollination nature. This non uniformity leads to a reduction in the quantitative and qualitative production yield and reduces the marketability of the nuts. These landraces are an important genetic resource for plant breeders and may be utilized in a breeding program to increase genetic diversity and develop useful inbred lines (Geleta *et al*., 2005; Kasrawi, 1995).

In this study, we collected 13 landraces of *C. pepo* to investigate their quantitative and qualitative features in order to select and introduce better local populations for seed and nuts production and for cultivation in Golestan Province. Also, we aimed to select the base population for near-future breeding programs in order to produce improved open-pollinated cultivars and useful inbred lines for hybrid seed production programs.

MATERIALS AND METHODS

Studied Material and Location

This study was conducted at Gorgan Agricultural and Natural Resources Research Center, Gorgan, Iran, during 2019–2020. The experiment was performed for two years, the first year in Varsan Horticultural Research Station (36° 50′ N latitude; 54° 19′ E) and the second year at the Gorgan Agricultural Research Station (36° 54′ N latitude; 54° 25′ E). Seeds of 13 local populations were collected from important squash growing areas of three provinces, namely, Golestan, Isfahan, and West Azerbaijan (Table 1, and Figure1).

Studied Traits

The following quantitative traits were considered in this study: fruit number, weight, length, width, and fruit length/width ratio, seed yield, seed yield/fruit yield ratio, 1,000 seeds weight, percentage of empty seeds, seed length, width, kernel/whole seed ratio, and seed oil percent. Also, quality tests were done including: easy separation of skin from the kernel, taste quality and desirability of seed shape and size from the consumer's point of view. Panel test was performed to evaluate the suitability of nuts from a consumer perspective for the following traits: easy separation of skin from the kernel, taste quality, and desirability of seed shape and size, with six testers and in the form of roasted seeds. The method used to roast the seeds was the same in all samples. For this purpose, each evaluator was given ten pumpkin nuts per treatment. Seeds of each block were consumed in one day. Assessment scales were rated as 5, 10, 15, and 20, then, converted to weighted mean.

Statistical Analysis

The experiment was performed in a randomized complete block design with three replications. Ten plants were randomly selected from each experimental unit. The experimental data were statistically analyzed for variance using the R version 3.5.1. Duncan's multiple range tests were used to compare the means of each trait. A Pearson correlation analysis was adopted to investigate the relationship between traits.

RESULTS AND DISCUSSION

Data were analyzed separately for two years (each year in one place). The analysis

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Table 1. List of collected local populations of summer squash (*Cucurbita pepo* L.).

Number	Abbreviation	Local population	Province	Altitude (m)	Latitude (°')	Longitude (°')
1	G1	Mashhady-Azadshahr	Golestan	150	55.17	37.08
2	A1	Mashhady-Khoy	West Azerbayjan	1130	44.57	38.33
3	G2	Ghalami- Kalaleh#1	Golestan	194	55.29	37.22
4	G3	Ghalami- Kalaleh#2	Golestan	194	55.29	37.22
5	G4	Nodijeh	Golestan	80	54.16	36.50
6	G5	Radkan	Golestan	1448	54.05	36.38
7	I1	Dehaghan#1	Isfahan	2050	51.65	31.93
8	I2	Goushti- Dehaghan	Isfahan	2050	51.65	31.93
9	A2	Goushti-Khoy	West Azerbayjan	1130	44.57	38.33
10	G6	Goushti- Gonbad	Golestan	52	55.10	37.15
11	G7	Goushti- Azadshahr	Golestan	150	55.17	37.08
12	G8	Goushti- Kalaleh	Golestan	194	55.29	37.22
13	A3	Zabanmari- Khoy	West Azerbayjan	1130	44.57	38.33

of variance presented in Table 2 showed significant differences among populations for most of the traits in both years of the experiment.

Comparing the means of the traits (Figure 2) showed that the highest values in both years of the experiment were as follows:

- FN: Fruit number in G2, G1 and A1
- FW: Fruit weight in I2
- FL: Fruit length in I2 and also G8, A2, G7, just in the first year
- FWi: Fruit width in G5 and G4 just in first year (Not significant differences in the second year)
- FL/Wi: Fruit length/width ratio in G3
- SY: Seed yield in G2 and G1
- SY/FY: Seed yield/fruit yield ratio in G2
- 1000SW: 1000 seeds weight in G7
- ES%: Percentage of empty seeds in G4 just in the second year (Not significant differences in the first year)
- SL: Seed length in G4
- SWi: Seed width in A2 and also G8, I2, G7 just in the first year
- SK/WS: Seed kernel /whole seed ratio in G6 (Not significant differences in the first year)
- SO%: seed oil percent in G7 (measured in the first year)
- TQ: Taste quality in G8
- DS: Desirability of seed shape and size from the consumer's point of view in I2, G7, G8, G6, and A2.

Based on the results of the mean comparison of traits in both years, the highest seed yield was observed in G2 and G1 and then A1 populations. In both years, the highest taste quality from the consumer point of view belonged to the G8 population, and in terms of shape and size, genotypes with wide seeds and medium length were superior to others.

Variation in fruit and seed characteristics of *Cucurbita* accessions were previously confirmed by Wu *et al*. (2011) and Balkaya *et al*. (2010). The positive and negative correlations were found between the 15 quantitative characters by correlation analysis; some correlations varied significantly. Simple correlation coefficients between the studied traits in different local populations are given in Table 3. The table results show that seed yield has a positive (0.85 in year 1 and 69% in year 2) and a very significant (1%) correlation with the fruit number. However, no significant

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Table 2. Analysis of variance of summer squash (*Cucurbita pepo* L.) local populations.

			Mean of squares														
SOV	df	Year	FN	FW	FL	FWi	FL/Wi	SY	SY/FY	SL	SWi	ES%	SK/WS	1000SW	SO%	TQ	ESS	DS
Block	2	1	0.31**	3737^{ns}	12.12**	0.17^{ns}	0.06*	95.6^{ns}	0.03^{ns}	0.52^{ns}	0.023^{ns}	2.33^{ns}	2.66^{ns}	50.5$^{n.s}$	0.001 ^{ns}	0.42 ^{ns}	2.62 ^{ns}	0.11 ^{ns}
		2	0.0445^{ns}	208758^{ns}	25.41*	2.33$^{n.s}$	0.38*	9.7^{ns}	0.06^{ns}	0.13^{ns}	0.69**	1.33$^{n.s}$	0.79 ^{ns}	169.6$^{n.s}$	-	0.98 ^{ns}	0.39 ^{ns}	2.3 ^{ns}
Genotypes	12	1	0.70**	412173**	73.00**	3.67**	0.67**	618.3**	0.39**	3.33**	4.71**	13.26^{ns}	1.59^{ns}	1675.9**	11.39^{ns}	9.654*	3.45 ^{ns}	15.28**
		2	1.32**	495442**	45.66**	1.83^{ns}	0.29**	722.3**	0.93**	5.06**	4.93**	3.94 **	22.21**	2683.2**	-	11.35**	0.26 ^{ns}	17.53**
Error	24	1	0.03	6424	1.95	0.197	0.012	29.2	0.03	0.439	0.14	7.11	2.3	47.9	7.58	3.611	2.58	1.63
		2	0.02	137933	5.38	2.08	0.06	11.7	0.03	0.39	0.08	0.73	2.55	108.2		1.19	0.48	0.65
CV		1	11.54	5.16	6.22	3.63	6.0	10.83	8.56	3.85	4.18	24.28	1.94	4.78	7.79	15.29	12.87	10.01
		2	8.1	18.11	9.71	11.77	12.69	6.6	8.07	3.6	3.3	17.3	2.04	6. 8	-	8. 9	5.75	6.3

FN= Fruit Number, FW= Fruit Weight (g), FL= Fruit Length (cm), FWi= Fruit Width (cm), FL/Wi = Fruit Length/Width, SY= Seed yield, SY/FY= Seed Yield/Fruit Yield, SL= Seed Length (mm), SWi= Seed Width (mm), ES%= Percentage of Empty Seeds, SK/WS= Seed Kernel /Whole Seeds, 1000 SW= 1000 Seeds Weight, SO% = Seed Oil percent, TQ= Taste Quality, ESS= Easy Separation of Skin from the kernel, DS= Desirability of Seed (shape and size). * and ** = Significant level at 5% and 1%, respectively, n.s= Non significant

Table 3. Single correlation coefficient of studied traits in summer squash (*Cucurbita pepo* L.) local populations.

Traits	FN		FW		FL		FWi		FL/Wi		SY/FY		SL		SWi		ES%		SK/WS		1000SW		SO%		TQ		ESS		DS		SY	
FN	1	1																														
FW	-0.64**	-0.44**	1	1																												
FL	-0.66**	-0.55**	0.79**	0.77**	1	1																										
FWi	0.09	0.04	0.24	0.39*	-0.35	0.09	1	1																								
FL/Wi	-0.59*	-0.50**	0.55	0.44**	0.94**	0.82**	-0.64*	-0.47**	1	1																						
SY/FY	0.76**	0.74**	-0.57*	-0.11	-0.53	-0.25	0.11	0.21	-0.51	0.35*	1	1																				
SL	0.26	0.24	-0.22	-0.12	-0.61*	-0.46**	0.73**	0.28	-0.74**	-0.56**	0.29	0.09	1	1																		
SWi	-0.36	-0.31*	0.84**	0.58**	0.74**	0.71**	0.22	0.27	0.52	0.47*	-0.25	0.06	-0.07	-0.21	1	1																
ES%	-0.07	0.06	0.06	0.007	-0.34	-0.21	0.73**	0.39*	-0.51	-0.38*	-0.13	-0.01	0.86**	0.62**	0.08	-0.01	1	1														
SK/WS	-0.21	-0.11	0.11	0.17	0.21	0.15	-0.21	0.005	0.23	0.11	0.09	0.23	-0.30	-0.32*	0.18	0.20	-0.46	-0.43**	1	1												
1000SW	-0.29	-036*	0.77**	0.47**	0.63*	0.59**	0.26	0.18	-0.51	0.42*	-0.23	0.08	0.01	0.19	-0.95**	0.80**	0.11	-0.06	0.27	0.24	1	1										
SO%	-0.04	-	0.37	-	0.37	-	0.08	-	0.28	-	-0.09	-	-0.27	-	0.49	-	-0.13	-	0.11	-	0.53	-	1	-								
TQ	0.06	0.08	0.45	0.22	0.42	0.45**	-0.01	0.001	0.36	0.39*	-0.10	0.26	-0.09	0.42*	-0.55*	0.60**	-0.10	-0.30	0.15	0.30	0.59*	0.39*	0.06	-	1	1						
ESS	0.45	0.19	0.06	-0.25	-0.02	-0.13	0.12	0.22-	-0.05	0.02	0.22	0.22	-0.02	-0.07	0.23	0.01	-0.23	-0.08	0.30	0.13	0.35	0.15-	0.14	-0.73*	0.27		1	1				
DS	-0.29	-0.30	0.78*	0.59**	0.66*	0.69**	0.18	0.23	0.47	0.47**	-0.09	0.1	0	-0.27	0.93**	0.85**	0.05	-0.005	0.17	0.33*	0.90	0.70**	0.41	-	0.53	0.69**	0.16	0.04	1	1		
SY	0.85**	0.69**	-0.25	-0.04	-0.37	-0.2	0.24	0.15	-0.43	-0.28	0.82**	0.86**	0.18	-0.04	0.02	0.17	-0.15	-0.16	0.01	0.4*	0.05	0.09	0.12	-	0.27	0.32*	0.53	0.25	0.13	0.14	1	1

FN=Fruit number, FW=Fruit Weight (g), FL=Fruit length (cm), FWi=Fruit width (cm), FL/Wi =Fruit length/width, SY/FY= Seed yield/fruit yield, SL=Seed length (mm), SWi=seed width (mm), ES% = Percentage of empty seeds, SK/WS= seed kernel /whole seeds, 1000SW =1000 seeds weight, SO% = Seed oil percent, TQ = Taste quality, ESS= Easy separation of skin from the kernel, DS = Desirability of seed (shape and size), SY= Seed yield. * and ** = Significant level at 5% and 1%, respectively correlation was observed between seed yield and other yield-related traits such as fruit weight and size.

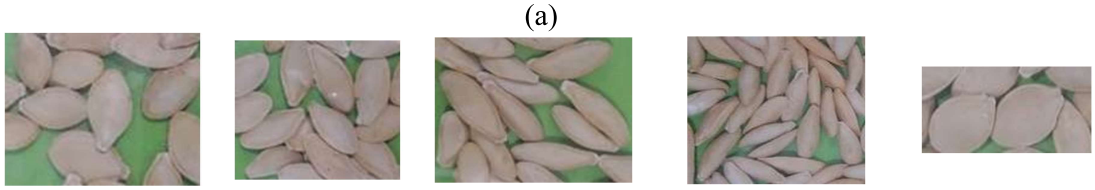
The fruit number had a significant negative correlation with fruit weight, length, and length/width ratio (0.64, 0.66, and 0.59 in year1 and 0.44, 0.55, and 0.50 in year 2, respectively). In this sense, the genotypes with more fruits, fruit weight, and length were smaller than in cultivars with fewer fruits.

Seed length trait had a significant negative correlation with fruit length trait and fruit length to width ratio (0.61 and 0.74 in year 1 and 0.46 and 0.56 in year 2, respectively). Unlike seed length, seed width had a significant positive correlation with fruit length trait (0.74 and 0.58, in the first and second years, respectively). These correlations show that populations with longer fruits have wider seeds, and those with wider fruits have long seeds.

The percentage of empty seeds correlated with fruit width and seed length in the first year of the experiment and with seed length only in the second year was positively significant (0.73, 0.86, and 0.62, respectively), which shows that in populations with wider fruits that have longer seeds, the percentage of empty seeds are more.

A positive and significant correlation was observed in 1000 seeds weight trait with fruit weight, fruit length, and seed width (0.77, 0.63, 0.95 and 0.47, 0.59, 0.80 respectively in years 1 and 2). Based on these correlation coefficients, bigger values of 1,000 seeds weight belong to populations with higher fruit weight, longer fruit length, and wider seeds. Also, these genotypes were more desirable for taste quality (correlation coefficient of taste quality with seed width and 1,000 seeds weight in the first year were: 0.55 and 0.59 and with fruit length, seed width, and 1,000 seed weight in the second year: 0.45, 0.60 and 0.39, respectively), the desirability of seed shape and size (very high positive significant correlation with seed width, fruit weight and fruit length in the first year: 0.93, 0.78, 0.66 and with seed width, fruit weight, fruit length, 1,000 seeds weight and taste quality in the second year: 0.85, 0.59, 0.69, 0.70 and 0.69, respectively) in panel test. Oil percent

(a)



(b)

Figure 1. Variety of fruits shapes and colors (a) and different shapes and sizes of seeds (b) in different summer squash populations.

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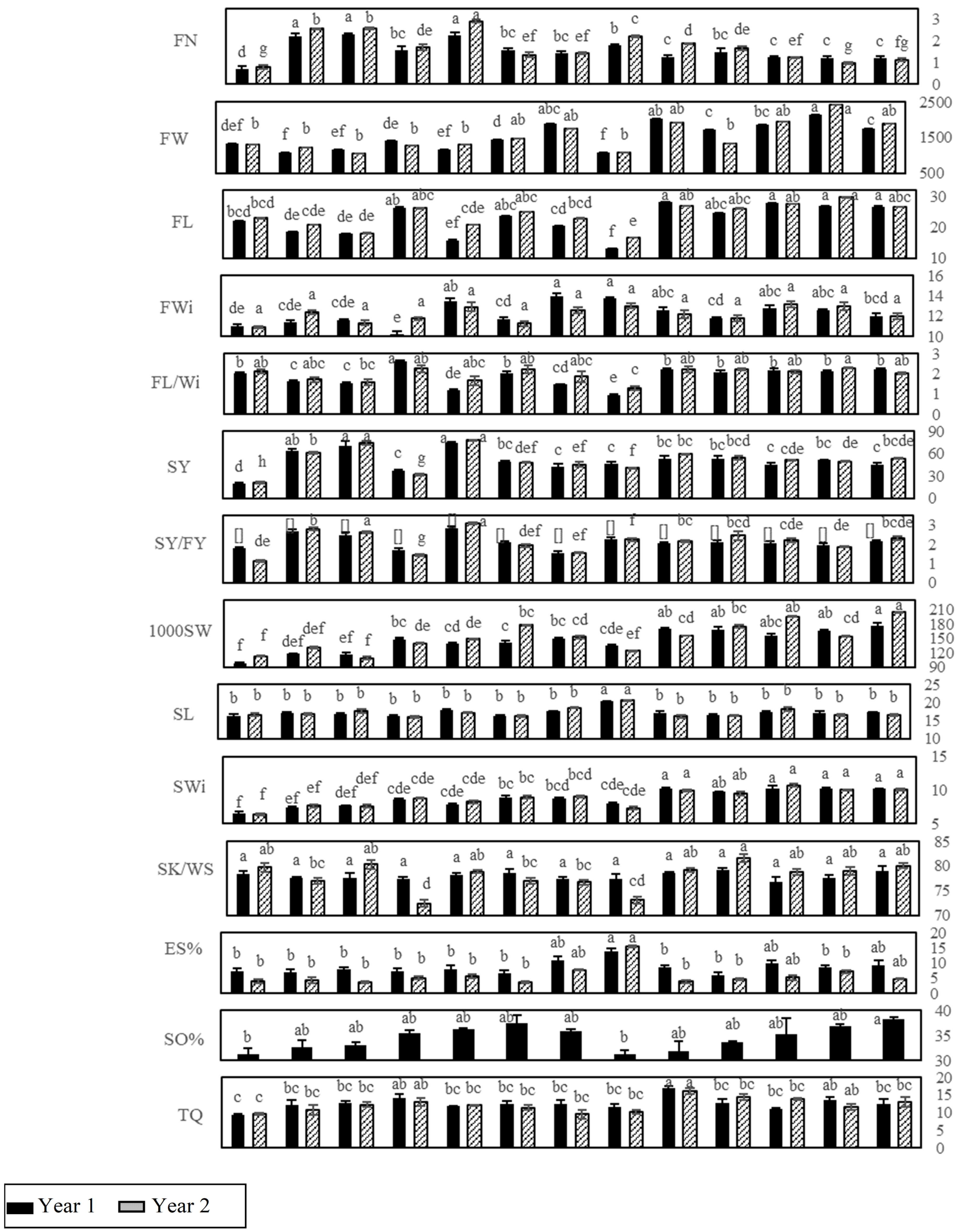

Figure 2. Comparison of the means of the studied traits using Duncan multiple test. FN= Fruit number, FW= Fruit Weight (g), FL= Fruit Length (cm), FWi= Fruit Width (cm), FL/Wi= Fruit Length/Width, SY/FY= Seed Yield/Fruit Yield, SL= Seed Length (mm), SWi= Seed Width (mm), ES%= Percentage of Empty Seeds, SK/WS= Seed Kernel/Whole Seeds, 1000SW= 1000 Seeds Weight, SO%= Seed Oil percent, TQ= Taste Quality, DS= Desirability of Seed (shape and size), SY= Seed Yield.

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was only measured in the first year of the experiment and didn't have any significant correlation with other traits. (Table 3)

The results suggest that populations with larger fruits weight and size produce fewer fruits; as a result, it reduces seed yield. In fruits, as the length-to-width ratio increased, there was a trend toward decreased seed number, especially in the peduncular end of the fruit (Nerson, 2004). The reason is that much of the biomass produced is used to increase the thickness of the fruit flesh. In cucumber, the inverse relationship between fruit length and seed yield was also reported (Nijs and Miotay, 1991). Barzegar *et al*. (2016) reported small size fruit is more suitable for seed yield per area. McCreith *et al*. (1993) reported that fruit size, seed size, and the number of fruits per plant had additive effects in squash populations. Thus, it is expected that squash populations can be improved in terms of the above traits. It seems that breeding and selection for more fruits with less weight on the plant is better than selecting plants with high-weight fruits, which is consistent with Berenji and Popp (2000). Also, managing agricultural operations, which increase the number of fruits, will increase seed yield per unit area.

CONCLUSIONS

The choice of parents for use in a plant breeding program is one of the most important decisions that a breeder makes (Darrudia, 2018). By evaluating all the quantitative and qualitative traits among the studied populations, Ghalami-Kalaleh#1 and Goushti-Kalaleh are suggested for cultivation and proposed as the basis population for starting breeding programs to produce open-pollinated cultivars. Both experiments conducted in two years showed a very high correlation between seed yield and the fruit number. Therefore, "fruit number" trait can be considered in selecting the program and modifying high-yielding populations. It is hoped that seed yield per unit area can be improved by selecting this trait in the base population. Also, considering consumers' opinions, including the size and taste of the roasted seeds, can lead to achieving a commercial cultivar.

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بررسی کمیت و کیفیت دانه‌ی خوراکی برخی از توده‌های بومی کدو آجیلی ایرانی (*Cucurbita pepo* L.)

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چکیده

در این مطالعه صفات کمی و کیفی تعداد ۱۳ جمعیت بومی کدو آجیلی مورد ارزیابی قرار گرفته است. آزمایش در قالب طرح کامل تصادفی با ۳ تکرار و در دو سال انجام شده است. صفات زیر در این مطالعه مورد

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یررسی قرار گرفته‌اند: تعداد میوه، وزن میوه، طول میوه، عرض میوه، نسبت طول/عرض میوه، عملکرد دانه، نسبت عملکرد دانه/کل عملکرد، وزن هزاردانه، درصد دانه‌های پوک، طول دانه، عرض دانه، نسبت مغز/کل دانه، درصد روغن، تست کیفیت شامل آسان جدا شدن پوست از مغز دانه، کیفیت طعم و مقبولیت شکل و اندازه‌ی دانه از نظر مصرف‌کننده. نتایج تجزیه واریانس نشان داد در اغلب صفات مورد مطالعه، جمعیت‌های بومی با هم تفاوت معنی‌دار داشتند. بر اساس مقایسه میانگین صفات، بالاترین عملکرد دانه در توده‌ی بومی قلمی کلاله ۱ و مشهدی آزادشهر و سپس مشهدی خوی مشاهده گردید و بالاترین کیفیت طعم از دید مصرف کننده به جمعیت گوشتی کلاله تعلق داشت. بررسی همبستگی صفات نشان داد همبستگی مثبت و بسیار معنی‌داری بین عملکرد دانه و تعداد میوه در جمعیت‌های مورد بررسی وجود دارد. هیچ همبستگی معنی‌دار دیگری بین عملکرد دانه و سایر صفات مشاهده نگردید. پیشنهاد می‌گردد صفت تعداد میوه در برنامه‌های انتخاب و اصلاح جمعیت‌های با عملکرد بالا مورد توجه قرار گیرد.

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