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Screening of some native and foreign accessions of spinach for spring culture in Isfahan

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ABSTRACT- Spinach is one of the most important green leafy vegetables (*Spinacia oleracea* L.). The qualitative and quantitative traits of the spinach depends on the weather conditions. Screening the foreign accession compared with the Iranian ones is necessary for breeding purposes. In order to study the vegetative characteristics of 44 endemic and foreign accessions, an experiment was conducted in a randomized complete block design (RCBD) with three replications and 18 observations in spring, 2018. Quantitative and qualitative parameters of spinach were evaluated based on descriptors investigated by Bioversity International Plant Genetic Resources Institute. In general, the intensity of the green color in the leaf of foreign accessions was higher than that of the endemic spinach. In this study, the highest yield belonged to "Viroflay" (71.224 ton/ha) among foreign accessions and among Iranian accessions, "Varamin88" (52.6 ton/ha) had the highest performance. Maximum and Minimum yields from 71224 to 8870 (kg/ha) belonged to accessions "Viroflay" and "Virginia savoy blight", respectively. "D'inverno" accession showed the longest period of spring growth (89.66 days) and among the Iranian accessions, "Hamadan2" (77 days), "Varamin88" (72 days) and "Varamin Prickly" (69.66 days) showed the longest growth in Isfahan environmental conditions, respectively. The highest percentage of female plants was observed in "Monatol" accession. Among the endemic accessions, "Lorestan5" showed the highest female plant percentage. Results of this study showed that Iranian accessions such as "Kashan", "Lorestan6" and "Varamin Advanced Prickly" are suitable for mechanical harvesting due to their plant form, leaf and petiole attitude and can be used for plant breeding purposes. According to the cluster analysis, the accessions in this study were divided into two large groups (group I and group II), according to which, "Varamin88" accession was placed beside the foreign outstanding accession in cluster I.
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INTRODUCTION

Spinach (*Spinacia oleracea* L.) is an annual, cold-tolerant plant; anemophily and dioeciously belonging to Chenopodiaceae family. The genus *Spinacia* includes two other species including *S. turkestanica* ilj. and *S. tetrandra* Stev. They are referred to as the potential ancestors of current spinach (Andersen and Torp, 2011). Since ancient Iranians were aware of the nutritional value of spinach, researchers maintain it likely belongs to Iran (Asadi and Hasandokht, 2007; Hochmuth et al., 2003; Imani, 2013). Wild species of spinach are distributed as a vegetable in the Alborz and Zagros mountains of Iran (Imani, 2013).

Spinach is one of the most important green leafy vegetables which contains minerals, is full of iron and vitamins, and is consumed fresh or its leaves and stems are processed. Spinach production in the world was 22 million tons in 2013, 92 percent of which was produced in China and the USA (Sabaghnia et al., 2014; Ebadi-segheloo et al., 2014). The seventh rank among the countries of the world belongs to Iran with 105 thousand tons spinach production per year (Sabaghnia et al., 2014). Kunicki et al. (2010) reported that spinach yield varied from 18.6 to 44.8 tons/ha depending on the environmental conditions and cultivars. Spinach cultivation can be done in the fall and spring, but due to bolting in the spring, it should be cultivated 50 to 60 days before the long day and hot weather (Jafari and Jalali, 2017; Zaferaniye, 2015). Currently, there are various domestic and wild populations of spinach in Iran whose identification can lead to the introduction of high-yielding populations and disease-resistant ones (Eftekhari et al., 2010).

The genetic diversity of spinach in the world has been studied using molecular and biochemical markers

and domestic researchers have studied the morphological traits of this plant (Sabaghnia et al., 2014; Kuwahara et al., 2014; Asadi and Hasandokht, 2007). In a research studied the properties of 54 populations of spinach, the iron concentration, the yield and percentage of female plants were significantly different between the populations (Sabaghnia et al., 2014; Ebadi-segheloo et al., 2014). In another study, Eftekhari et al. (2010) reported that "Varamin2" accession has the highest performance among the Iranian spinach. Also, in the study of agronomic and morphological traits of autumn cultivars between 29 spinach accessions, a significant difference was observed between the traits (Asadi and Hasandokht 2007; Eftekhari et al., 2010). In another study, researchers explained that "Hamadan" accession produced 2128 g/m^2 of fresh yield compared to four native populations of "Shirvan", "Karaj", "Varamin", and "Borojerd" accessions (Ahmadi et al., 2010). However, neither study has been done to identify Iranian accessions in spring planting, nor have morphological comparisons of these masses.

Considering spinach bolting in spring cultivation, it is important to study it in Isfahan climate conditions. This study was conducted based on the amount of spinach cultivation in Iran and the need for farmers to produce high-yielding populations. This study also compared commercial populations of Iranian and foreign spinach accessions. One of the main objectives of this study was to evaluate the most desirable traits of spinach, such as yield, economic benefits, late bolting (a desirable feature in spinach) and male plants traits of Iranian populations compared to foreign populations. The authors believe that this study can lead to determining the best suitable accession for spring cultivation in the conditions of the city of Isfahan as well as finding the best accession for the future breeding program.

MATERIALS AND METHODS

Plant Material

At first in this study, 26 Iranian spinach accessions were collected from the seed and plant improvement institute and the gene bank of Iran (SPII). It should be noted that endemic accessions in this research were selected based on the results of a study (Jafari and Jalali, 2017) conducted on 107 Iranian spinach accessions. They reported that masses of "Varamin88", "Hamedan", "Lorestan", "Varamin Prickly", "Varamin Advanced Prickly" and some other accessions were favorable on the basis of agronomic and morphological features, and these accessions were used in the present study to accurately evaluate the yield, bolting and compare them with foreign trade accessions. The 18 foreign accessions were also provided by the Leibniz Institute of Plant Genetics and Crop Plant Research (IPK) gene bank (IPK, 2018). Details of these accessions are shown in Table 1. Seeds of the accessions, in an experiment based on a randomized complete block design (RCBD) with three replications, were sown in a field located at Isfahan University of Technology, Isfahan, Iran, in March 2018 (spring sowing). Because soil organic matters were weak, fertilization was done by releasing 40 tons/h of organic fertilizers. Each replication consisted of three rows with 25 cm between rows at around 1 cm depth and plot size was 1.75 m^2. After seed germination and plant growth, 18 observations were kept in each plot.

The Measured Parameters

In order to evaluate the morphological characteristics, after plant growth (35-50 days after sowing), 6 plants were randomly selected from each replicate and transferred to the laboratory. In the laboratory, from each plant, four leaves from four directions of the plant were selected and the following characteristics were measured.

Quantitative characteristics studied in this study included germination percentage (when 50 percent of the seeds was germinated), leaf length (cm), leaf width (cm), petiole length (cm), petiole diameter (mm), leaf area (mm^2), plant height (cm), fresh and dry weight (g). In order to calculate the yield of the accessions, after randomly harvesting, plants were weighed and their fresh weight was calculated in grams per plant and finally their average performance which was considered as yield (kg ha^{-1}). In order to estimate the economic yield, the equivalent level of each replication was considered. After harvesting and separating the leaves, they were weighed and their economic yield was calculated in kg per hectare, and leaf numbers, male and female plants percentage, days to flowering were evaluated. In order to measure the shoot dry weight, it was placed in an oven at 70 °C for 48 hours.

Also, the qualitative features were also studied based on descriptors by Bioversity International Plant Genetic Resources Institute (IPGRI) presented in Table 2 (Arif et al., 2013; Jafari and Jalali 2017). These traits consist of type and colour of seed, stem anthocyanin, petiole and leaf attitude, wrinkles of leaf, leaf thickness, leaf sheath attitude, leaf shape, leaf colour, lobed leaf tip, the shape of leaf tip and wave margin of leaf.

Analysis Data

Data were tested by one-way analysis of variance (ANOVA) and analyzed using SAS software (version 9.4). Significant differences between means were tested considering the least significant difference (LSD) test at $P < 0.05$ level of probability. The correlation of the traits was also tested using SAS 9.4 software. Clustering of 44 spinach accessions was done using Statgraphics Centurion (XVII) software. The biplot diagram of the accessions was investigated with the help of the R-software.

RESULTS AND DISCUSSION

Qualitative Traits

Distribution of qualitative traits in this study based on spinach descriptor is presented in Table 2 (Arif et al., 2013; Jafari and 2017). Among the accessions of this study, "Alwaro" samples were not germinated in any of the replications and so, were completely eliminated.

Table 1. The characteristics of 44 spinach accessions which were collected from different regions in the world and used in this study

No.	Accession name	Collecting place	Longitude	Latitude	Altitude (meter)	No.	Accession name	Collecting place	Longitude	Latitude	Altitude (meter)	No.	Accession name	Collecting place	Longitude	Latitude	Altitude (meter)
1	TN-69-22	Yazd	54° 21' E	31° 53' N	1215	16	TN-69-138	Lorestan5	48° 55' E	33° 45' N	1347	31	Subito	Netherland	_	_	_
2	TN-69-31	Fars	52° 22' E	29° 37' N	1540	17	TN-69-139	Lorestan6	48° 29' E	33° 43' N	1148	32	Alwaro	Germany	_	_	_
3	TN-69-57	Hamedan1	48° 31' E	34° 48' N	1850	18	TN-69-140	Lorestan7	48° 24' E	33° 45' N	1179	33	Virginia Savoy Blight Resistant	USA	_	_	_
4	TN-69-58	Lorestan1	48° 21' E	33° 29' N	1200	19	TN-69-149	Hamedan4	48° 51' E	34° 82' N	1774	34	Virginia Savoy Fusarium	USA	_	_	_
5	TN-69-70	Hamedan2	48° 51' E	34° 79' N	1810	20	TN-69-153	Chaharmahal and Bakhtiari	50° 86' E	32° 32' E	2061	35	Garant	Germany	_	_	_
6	TN-69-73	Kerman	57° 05' E	30° 17' N	1775	21	TN-69-163	Razavi Khorasan	59° 36' E	36° 18' N	979	36	Viking	Italy	_	-	_
7	TN-69-74	Lorestan2	48° 35' E	33° 48' N	1118	22	TN-69-172	Qazvin	50° 72' E	36° 27' N	1310	37	Viroflay	Germany	_	_	_
8	TN-69-76	Hamedan3	48° 52' E	34° 77' N	1833	23	Varamin Prickly	Tehran	51° 28' E	35° 70' N	1173	38	Spinagh	Iraq	_	_	_
9	TN-69-78	Tehran	51° 38' E	35° 23' N	1214	24	Varamin 88	Tehran	51° 39' E	35° 19' N	915	39	SPI 108(IPK No.)	Afghanistan	_	_	_
10	TN-69-79	Sistan and Baluchestan	60° 85' E	29° 50' N	1386	25	Kashan	Kashan	51° 27' E	33° 59' N	950	40	SPI 211(IPK No.)	Turkey	_	_	_
11	TN-69-81	Qom	50° 53' E	34° 38' N	930	26	Varamin Advanced Prickly	isfahan	52° 02' E	32° 32' N	1525	41	SPI 79(IPK No.)	Azerbaijan	_	_	_
12	TN-69-88	East Azerbaijan1	46° 18' E	38° 04' N	1366	27	Matador	Germany	_	_	_	42	Late Flower	China	_	_	_
13	TN-69-97	East Azerbaijan2	46° 30' E	38° 07' N	1402	28	D'inverno	Italy	_	_	_	43	Tenjinmaru	Japan	_	_	_
14	TN-69-101	Lorestan3	48° 36' E	33° 47' N	1274	29	Monatol	Germany	_	_	_	44	Kasi Jong	South Korea	_	_	_
15	TN-69-137	Lorestan4	48° 33' E	33° 46' N	1164	30	Wiremona	Germany	_	_	_						

*All foreign accessions were provided from IPK gene bank (IPK, 2018)

Results of the study of qualitative traits divided the seeds into two groups of smooth and prickly of which, 32.5% of the total seeds had prickly seeds, and the rest had smooth seeds (Table 2). The results of studied traits for both smooth and prickly seeds were similar to the results found by previous researches (Asadi and Hasandokht, 2007; Eftekhari et al., 2010). Dominant seed colors were gray-green and gray. Commercial accessions of spinach have a smooth seed. In spite of that, prickly seed during mechanical planting have an uneven distribution (Asadi and Hasandokht, 2007).

Table 2. Distribution of qualitative traits in this study based on spinach descriptor

Plant trait	Description	Frequency	(%)
Seed type	Smooth	29	67.5
	Prickly	14	32.5
Seed color	Yellow-green	11	25.5
	Gray-green	15	34.8
	Gray	17	39.5
Stem Anthocyanin	Yes	1	2.3
	No	42	97.6
Petiole attitude	Erect	9	20.9
	Semi-erect	22	51.1
	Horizontal	12	27.9
Wrinkles of leaf	High	6	13.9
	Intermediate	10	23.2
	Low	17	39.5
	Smooth	10	23.2
Leaf thickness	Very thick	3	6.9
	Thick	7	16.2
	Intermediate	29	67.4
	Fragile	4	9.3
Leaf Sheath attitude	Erect	17	39.5
	Semi-erect	14	32.5
	Horizontal	12	27.9
Leaf shape	Oval	15	34.8
	Broad oval	16	37.2
	Triangular	12	27.9
Leaf color	Very dark green	7	16.2
	Dark green	4	9.3
	Intermediate green	19	44.1
	Light green	13	30.2
Leaf Sheath	Concave	14	32.5
	Bulgy	6	13.9
	Flat	23	53.4
Lobation of leaf tip	Bend	9	20.9
	Flat	25	58.1
	Upward	9	20.9
The shape of leaf tip	Sharp	9	20.9
	Angled	15	34.8
	Circular	19	44.1
Wave margin of leaf	Yes	22	51.1
	No	21	48.8

Results of other qualitative traits are presented in Table 3. It has been reported that accessions that have a petiole standing, wrinkled or slightly wrinkled, were suitable for mechanical harvesting (Splittstoesser, 1990). Accordingly, accessions of "Matador", "D'inverno", and "Monatol" with good performance are unsuitable for mechanized harvesting because their petiole and leaf forms are compact. Accessions of "Kashan", "East Azarbaijan1", "Lorestan4" and "Lorestan7" have all three characteristics of leaf standing, petiole standing and no shrinkage or low shrinkage, which can be used in breeding programs suitable for mechanical harvesting (Table 3). The "Spinagh" also possessed these three characteristics together, but it had a triangular leaf shape (intense arrow) that was not desirable.

In general, it can be said for mechanical harvesting, Iranian accessions were superior to the foreign ones due to better petiole and leaf form, and low shrinkage of leaves. It has been reported in foreign countries that wrinkled leaves of spinach are more marketable than flat leaves (Kuwahara et al., 2014). In confirmation of this report, the majority of foreign populations of Table 3 have wrinkled leaves. Usually, spinach cultivars with lower leaf shrinkage have less nitrate content and there is a direct correlation between leaf shrinkage and nitrate content (Arshi, 2000). So no-shrinkage leaves as a desirable attribute is of interest to researchers. While in Iran, the most favorable spinach has a broad, fleshy, thick and juicy leaf, and according to Table 3, the endemic accessions of "Varamin Prickly" and "Varamin88" have these characteristics. In Iran, the optimal form of spinach leaf is round and in overseas triangular shapes has been reported to be desirable (Kunicki et al., 2010).

Leaf color is very important in leafy vegetables since the presence of green pigments is a desirable and marketable feature for frozen spinach (Eftekhari et al., 2010). Researchers have reported that in spinach, the green color is usually associated with chlorophyll a and b pigment which prevent the appearance of carotenoid pigments (Kidmose et al., 2005). According to data presented in Table 3, leaf color was variable from very dark green to light green, and ideal foreign accessions had darker leaves than the Iranian ones. In Iranian accession, "Hamedan2", "Varamin Prickly" and "Varamin88" had some dark green color (Table 3). In most of the studied accessions in this study, the edge of the leaf was flat, the tip of the leaf was round, and 51.1% of the accessions had a wave at the margin of their leaves (Tables 2 and 3).

Quantitative Traits

In this study, it was shown that high agronomic and morphological diversity exists for most of the measured traits that may be useful to future researchers. The range of variance among the accessions examined in this study indicated the presence of genetic diversity among Iranian and foreign accessions. Analysis of variance of quantitative traits showed that the accessions in the aspect of all morphological characters were different at the 1% level (Table 4).

In this study, Iranian accessions (Yazd, East Azerbayjan1, Lorestan 4, 5 and 6, Varamin88, Varamin Prickly, Varamin Advanced Prickly) were better than foreign accessions concerning leaf characteristics such as leaf number, leaf length and width, petiole length and diameter, leaf area and plant height (Table 5). Leaf area showed a positive correlation with germination percentage (Table 6). It was stated that if spinach has a better germination, it would result in greater leaf area and ultimately more yield (Turner, 2001). Zaferaniye

(2015) observed that the most desirable characteristics of spinach leaves, such as leaf number, were in the "Varamin" population.

Table 3. Qualitative properties of Iranian and foreign spinach accessions

Accession name	Seed type	Seed colour	stem Anthocya-nin	Petiole attitude	Wrinkles of leaf	Leaf thickness	Leaf Sheath attitude	Leaf shape	Leaf colour	Leaf Sheath	Lobation of leaf tip	The shape of leaf tip	Wave margin of leaf
TN-69-22	P	YG	N	SE	L	I	SE	TR	IG	F	F	SH	N
TN-69-31	P	YG	N	SE	L	I	SE	TR	IG	C	UW	SH	N
TN-69-57	S	YG	N	H	I	I	H	TR	IG	C	UW	A	Y
TN-69-58	S	GG	N	H	L	I	H	BO	LG	F	F	CI	N
TN-69-70	S	YG	N	H	L	I	H	TR	DG	C	UW	CI	Y
TN-69-73	S	GG	N	SE	L	I	E	BO	LG	F	F	A	N
TN-69-74	S	YG	N	SE	L	I	E	O	IG	F	F	CI	Y
TN-69-76	S	GG	N	SE	L	I	SE	TR	IG	B	F	A	Y
TN-69-78	P	GG	N	SE	L	I	H	O	LG	F	F	CI	N
TN-69-79	S	GG	N	SE	L	I	SE	O	LG	F	F	CI	N
TN-69-81	S	GG	N	SE	L	I	E	BO	LG	F	F	SH	N
TN-69-88	S	GG	N	E	S	I	E	BO	LG	F	F	SH	Y
TN-69-97	S	GG	N	SE	S	I	E	TR	IG	F	F	SH	Y
TN-69-101	S	GG	N	SE	L	I	SE	O	IG	F	F	A	Y
TN-69-137	S	GG	N	E	L	I	E	BO	IG	C	B	CI	N
TN-69-138	S	GG	N	E	L	FR	E	BO	IG	B	B	A	Y
TN-69-139	S	GG	N	SE	I	I	SE	BO	IG	C	B	CI	Y
TN-69-140	S	GG	N	E	S	I	E	BO	IG	F	F	A	N
TN-69-149	P	YG	N	SE	S	I	SE	TR	LG	F	F	SH	N
TN-69-153	S	YG	N	SE	L	T	SE	O	LG	F	F	A	N
TN-69-163	S	YG	N	SE	S	I	E	O	LG	F	F	A	N
TN-69-172	P	YG	Y	SE	S	I	E	O	LG	F	F	A	Y
Varamin Prickly	P	GG	N	E	I	T	E	BO	DG	C	B	CI	Y
Varamin 88	S	GG	N	E	I	T	E	BO	VDG	B	B	CI	Y
Kashan	S	YG	N	E	L	FR	E	TR	IG	C	F	A	N
Varamin Advanced	P	YG	N	SE	L	T	E	TR	IG	C	B	CI	N
Prickly Matador	S	G	N	H	H	VT	H	O	IG	C	UW	CI	N
D'inverno	S	G	N	H	H	VT	SE	BO	VDG	C	UW	CI	Y
Monatol	S	G	N	H	H	VT	SE	BO	VDG	C	UW	CI	N
Wiremona	S	G	N	H	H	T	H	O	VDG	C	UW	CI	Y
Subito	P	G	N	H	I	T	SE	O	IG	B	UW	CI	Y
Virginia Savoy	S	G	N	H	H	I	H	BO	VDG	B	B	CI	N
Blight Resistant Virginia	S	G	N	H	H	I	H	BO	VDG	B	B	CI	N
Savoy Fusarium	S	G	N	H	I	I	H	O	LG	F	F	CI	N
Garant	S	G	N	H	I	I	H	O	LG	F	F	A	Y
Viking	P	G	N	E	L	FR	E	TR	LG	F	F	SH	Y
Spinagh	P	G	N	SE	I	I	SE	O	DG	F	F	A	N
SPI 108(IPK No.)	P	G	N	SE	S	I	SE	O	IG	F	F	SH	Y
SPI 211(IPK No.)	S	G	N	SE	I	I	H	BO	DG	C	B	A	Y
SPI 79(IPK No.)	P	G	N	SE	S	I	H	TR	IG	F	F	A	Y
Late Flower	P	G	N	SE	S	I	E	TR	IG	F	F	SH	Y
Tenjinmaru	P	G	N	E	S	FR	E	O	IG	F	F	A	N
Kasi Jong													

Abbreviation signs: Smooth (S), Prickly (P), Yellow-green (YG), Gray-green (GG), Gray (G), Yes (Y), No (N), Erect (E), Semi-erect (SE), Horizontal (H), High (H), Intermediate (I), Low (L), Very thick (VT), Thick (T), Fragile (F), Oval (O), Broad oval (BO), Triangular (TR), Very dark green (VDG), Dark green (DG), Intermediate green (IG), Light green (LG), Concave (C), Bulgy (B), Flat (F), Bend (B), Upward (UW), Sharp (SH), Angled (A), Circular (CI).

Table 4. Analysis of variance of traits in different accessions of spinach

Source of Variation	df	MS													
		Leaf number	Plant height	Leaf length	Leaf width	Petiole length	Petiole diameter	Yield	Fresh weight	Dry weight	Leaf area	Germination percentage	Days to flowering	Percent of Male plant	Percent of Female plant
Blocks	2	7.54	135.26	4.53	1.72	2.76	0.93	618266	60.49	0.41	84587	71.79	65.60	5.32	19.60
Accessions	42	31.75**	144.28**	21.57**	5.98**	25.75**	3.15**	160043**	2337.41**	59.21**	11722998**	1265.47**	289.98**	525.77**	535.58**
Error	84	6.85	12.32	2.10	0.87	1.59	0.43	33399	126.26	3.76	496245	9.51	1.56	5.26	6.15
Total	128														
CV		19.66	18.37	12.38	12.90	14.05	18.39	26.11	26.11	24.79	11.15	14.90	14.97	16.10	13.97

** Statistically significant at one-percent level of significance.

The petiole length showed a high correlation with plant height (0.85**) and the leaf length (0.70**) (Table 6). The leaf length, leaf width and number of leaves are important parts of yield in spinach (Asadi and Hasandokht, 2007). As it is observed in this study, accessions such as "D'inverno", "Monatol", "Viroflay", "Matador", "Varamin88", "Varamin Prickly" and "Lorestan5" with a high number of leaves had more yield (Table 5). Accessions with more leaves that enter the reproductive stage usually have more fresh and dry weight and better performance and can be used with late bolting goals in breeding actions (Asadi and Hasandokht, 2007). As the correlation table of the traits shows, the number of leaves has a completely positive relationship with yield and days to flowering (Table 6). By Jafari and Jalali (2017) are also approved a positive correlation between leaf number, yield and fresh and dry weight of spinach.

The highest percentage of yield was observed in the foreign accession of the "Viroflay" (71.224 ton/ha) and the "D'inverno" (64.259 ton/ha), respectively; however, no significant differences were observed between these accessions (Table 5). Then, the native accession of "Varamin88" with 52.590 ton/h was better than other Iranian accessions. The fresh and dry weights of the plants were not significantly different between "Varamin88", "Matador" and "D'inverno" accessions In Isfahan climate conditions, "Varamin88" is recommended to the farmers for cultivation (Table 5). In addition, "Varamin Prickly" and "Varamin Advanced Prickly" have a high potential yield and can be used to improve the performance of spinach since these accessions were considered valuable concerning breeding and gardening programs (Eftekhari et al., 2010; Morelock et al., 2008; Stagnari et al., 2007). Similar results have been reported on the benefit of the performance of "Varamin88" and "Varamin Prickly" accessions (Asadi and Hasandokht, 2007; Eftekhari et al., 2010). Researchers in a study in New Zealand found that the harvest of spring planting was less than the fall planting. They stated that one of the main reasons for reducing the yield of spring crops is to increase the length of the day and to enter the reproductive stage (Chunilall et al., 2006). According to the correlation trait, there is a positive correlation between yield and fresh weight (0.98**), dry weight (0.82**), leaf number (0.66**), leaf area (0.63**) and day to flowering (0.56**) (Table 6). These results of correlations accord with the result of Varalakshmi and Devaraju (2010) about the positive relationship in morphological traits. According to Zaferaniye (2015), there is a positive relationship between yields, fresh and dry weight, leaf area and number of leaves of spinach.

In the present study, most of the accessions which have good dry weight had a low shrinkage in leaf and only the "Spinagh", "Kashan" and "Varamin Advanced Prickly" accessions had a flat leaf (Tables 3 and 5). One of the desirable traits for spinach processing and packaging is dry weight and it has been reported that the high dry matter has a direct relationship with the flat leaf in spinach (Arshi, 2000; Eftekhari et al., 2010). In this study, the dry weight of the accessions was very different (Table 5). It can be argued that the difference in water content in the tissues of different accessions leads to a difference in dry weight. A few researchers have reported that the highest dry weight was observed in "Qom" accession, which differed from the results of the current study. It could be due to differences in the growing season (Asadi and Hasandokht, 2007). Because in the autumn crop, despite the long growing season, cold and moisture stress affected the dry weight of the spinach.

The germination percentage of "Monatol", "Kashan", and "D'inverno" accessions were better than the others (Table 5). Contrary to our results, in another study, "Varamin" had the highest percentage of germination (Zaferaniye, 2015). This could be due to the absence of "Kashan" accession in their study.

Spinach is a leafy vegetable; so, a long time for growing it is favorable. Researchers have divided the spring spinach flowering into three groups including less than 60 days flowering (early flowering), 60 to 70 days flowering (medium flowering) and more than 70 days flowering (long flowering) (Chitwood et al., 2016). The highest growth period among the available accessions was 89.60 days that belonged to the" D'inverno" accession and then the "Viroflay", "Matador", "Hamedan2" and "Spinagh", respectively, were among the long-flowering groups in the weather of Isfahan (Table 5). The medium flowering groups in this study included "Varamin88", "Varamin Prickly", "Varamin

Table 5. Comparison of the average variance of leaf characteristics of native and foreign spinach accessions

Accession No.	Leaf number	Plant height (cm)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Petiole diameter (mm)	Yield (kg/h)	Fresh weight(g)	Dry weight (g)	Leaf area (mm^2)	Germination percentage (%)	Days to flowering	Male plant (%)	Female plant (%)
Yazd	12.13^{h-n}†	16.53^{h-r}	12.80^{e-j}	9.20^{a-e}	9.07^{e-k}	4.82^{a-d}	21079^{f-j}	40.98^{f-j}	8.77^{e-j}	8363^{bc}	45^{p}	66.33^{h-j}	37.70^{n-q}	61.96^{g-j}
Fars	10.33^{l-n}	15.46^{i-r}	14.13^{c-f}	7.53^{f-k}	9.26^{e-i}	4.31^{c-g}	12879^{j-n}	25.04^{j-n}	3.43^{op}	7601^{b-f}	56.85^{lm}	61.66^{no}	37.82^{m-q}	61.51^{g-k}
Hamedan1	17.13^{b-f}	14.66^{k-r}	12.73^{e-j}	7.20^{g-l}	7.60^{g-q}	4.27^{c-g}	15347^{j-n}	29.85^{j-n}	8.87^{e-i}	6751^{e-j}	61.11^{j-l}	68^{f-h}	31.65^{rs}	66.45^{f}
Lorestan1	12.93^{f-n}	10.86^{r}	11.60^{g-n}	6.73^{h-o}	6.60^{m-r}	3.78^{d-m}	13688^{j-n}	26.61^{j-n}	4.15^{n-p}	6175^{g-m}	71.88^{h}	67.66^{f-i}	44.09^{f-j}	56.21^{m-q}
Hamedan2	15.86^{c-h}	16.60^{h-q}	12.60^{f-j}	7.80^{e-j}	7.20^{j-q}	$3.87^{c.k}$	15798^{j-n}	30.72^{j-n}	6.55^{h-o}	6806^{e-i}	61.44^{i-l}	77.00^{d}	45.95^{e-h}	53.71^{o-s}
Kerman	9.60^{mn}	13.53^{m-r}	9.46^{n-r}	7.13^{g-m}	8.26^{f-n}	2.54^{n-r}	13391^{j-n}	26.03^{j-n}	2.71^{p}	7254^{c-g}	66.32^{i}	63.00^{l-o}	45.04^{e-i}	55.38^{m-r}
Lorestan2	10.93^{j-n}	19.86^{f-l}	11.20^{h-o}	6.13^{k-p}	10.06^{d-f}	2.37^{o-r}	16877^{i-n}	32.81^{i-n}	4.29^{n-p}	5981^{i-n}	77.10^{fg}	61.00^{o}	48.26^{c-e}	52.28^{q-t}
Hamedan3	10.40^{l-n}	21.06^{f-i}	11.40^{g-o}	8.00^{d-i}	8.93^{e-l}	3.49^{f-n}	17357^{h-n}	33.74^{h-n}	5.17^{l-p}	7139^{d-h}	61.77^{i-l}	63.00^{l-o}	34.52^{qr}	65.21^{fg}
Tehran	10.66^{j-n}	15.33^{j-r}	9.53^{n-r}	6.20^{k-p}	7.40^{i-q}	3.39^{g-o}	14100^{j-n}	27.41^{j-n}	5.30^{l-p}	4353^{o-s}	38.54^{q}	65.00^{j-l}	48.05^{de}	50.69^{s-v}
Sistan	11.20^{i-n}	11.86^{n-r}	8.40^{qr}	6.66^{i-o}	7.73^{g-q}	2.74^{m-r}	11228^{k-n}	21.83^{j-n}	4.29^{n-p}	3973^{q-t}	44.10^{p}	65.00^{j-l}	38.10^{m-q}	61.56^{g-k}
Qom	10.53^{k-n}	14.80^{k-r}	8.06^{qr}	6.53^{i-o}	9.06^{e-k}	2.78^{l-r}	12029^{J-n}	23.39^{j-n}	4.98^{l-p}	4872^{n-r}	63.44^{i-k}	49.00^{r}	39.72^{k-o}	57.60^{k-o}
East.Az.1	10.40^{l-n}	19.93^{f-l}	10.20^{k-q}	6.73^{h-o}	9.20^{e-j}	3.06^{h-p}	11380^{k-n}	22.13^{k-n}	3.63^{op}	8422^{b}	92.80^{bc}	43.00^{s}	46.62^{e-g}	53.07^{p-t}
East.Az.2	10.80^{j-n}	17.66^{f-l}	12.06^{f-l}	7.00^{g-n}	8.40^{e-m}	4.12^{c-h}	15642^{j-n}	30.41^{j-n}	5.67^{j-p}	6014^{h-n}	51.00^{qr}	61.33^{o}	43.86^{f-j}	53.18^{p-t}
Lorestan3	10.40^{l-n}	17.60^{h-m}	13.26^{e-i}	8.20^{c-h}	10.33^{de}	4.54^{b-f}	13300^{j-n}	25.86^{j-n}	3.71^{op}	7242^{c-g}	54.88^{m-o}	83.66^{c}	46.68^{e-g}	53.33^{p-t}
Lorestan4	12.26^{h-n}	20.33^{f-k}	13.66^{d-g}	8.33^{b-g}	13.06^{bc}	3.89^{c-j}	27795^{e-g}	54.03^{e-g}	5.12^{l-p}	7395^{b-f}	65.66^{ij}	89.66^{a}	48.58^{c-e}	51.58^{r-u}
Lorestan5	19.06^{a-d}	28.33^{cd}	17.53^{a}	9.80^{ab}	12.40^{c}	4.91^{a-c}	26473^{e-h}	51.47^{e-h}	5.77^{i-p}	7613^{b-f}	91.10^{c}	69.00^{fg}	30.10^{s}	70.77^{e}
Lorestan6	17.20^{d-i}	31.26^{bc}	17.00^{ab}	9.53^{a-c}	15.06^{ab}	3.90^{c-j}	25429^{e-i}	49.44^{e-i}	5.30^{l-p}	6514^{f-k}	72.88^{gh}	67.33^{g-i}	60.30^{a}	39.06^{w}
Lorestan7	12.00^{h-n}	27.46^{c-e}	13.33^{e-h}	7.13^{g-m}	11.46^{cd}	5.56^{ab}	17146^{h-n}	33.34^{h-n}	3.31^{p}	7118^{d-i}	80.66^{ef}	64.00^{k-m}	51.52^{b-d}	48.23^{uv}
Hamedan4	12.93^{f-n}	17.66^{h-m}	11.26^{h-o}	7.33^{g-l}	7.46^{i-q}	3.73^{e-m}	18162^{h-n}	35.31^{h-n}	7.93^{g-l}	5508^{k-n}	72.89^{h}	62.00^{m-o}	51.45^{cd}	50.85^{s-v}
Chaharmahal	12.40^{g-n}	15.46^{i-r}	12.26^{f-k}	7.80^{e-j}	8.00^{g-o}	4.06^{c-h}	12572^{j-n}	24.44^{j-n}	4.50^{m-p}	6240^{g-l}	44.77^{p}	61.33^{o}	42.51^{h-l}	56.89^{l-p}
Khorasan	12.00^{h-n}	17.33^{h-o}	10.93^{i-p}	6.53^{i-o}	7.60^{g-q}	2.80^{k-q}	13129^{j-n}	25.53^{j-n}	5.61^{k-p}	5054^{m-q}	65.66^{ij}	63.00^{l-o}	35.95^{pq}	63.71^{f-h}
Qazvin	10.06^{mn}	17.00^{h-p}	10.86^{j-p}	5.40^{op}	8.40^{e-m}	3.08^{h-p}	15278^{j-n}	29.71^{j-n}	3.66^{op}	6038^{h-m}	38.88^{q}	63.66^{k-n}	42.99^{g-k}	58.19^{j-n}
Var-Prickly	15.66^{c-h}	25.00^{d-f}	13.73^{d-g}	7.33^{g-l}	12.66^{c}	4.35^{c-g}	30867^{e}	60.02^{e}	8.63^{f-k}	7120^{d-i}	64.71^{i-k}	87.33^{b}	51.86^{bc}	49.59^{t-v}
Var88	15.80^{c-h}	29.40^{b-d}	16.40^{a-c}	8.86^{b-f}	12.93^{c}	3.81^{d-l}	52590^{b}	102.25^{b}	15.84^{b}	10658^{a}	83.88^{de}	76.00^{d}	38.10^{m-q}	60.46^{h-l}
Kashan	14.40^{e-l}	45.06^{a}	15.86^{a-d}	9.13^{a-e}	15.73^{a}	4.00^{c-i}	34204^{de}	66.50^{de}	9.62^{d-h}	7966^{b-d}	97.56^{ab}	66.66^{h-j}	47.11^{ef}	56.97^{l-p}
Var.Adv.Prickly	10.00^{mn}	35.06^{b}	15.06^{b-e}	9.40^{a-d}	16.20^{a}	4.64^{b-e}	28809^{ef}	56.02^{ef}	9.20^{d-h}	7121^{d-i}	91.09^{c}	62.33^{m-o}	35.67^{pq}	62.96^{f-i}
Matador	19.66^{a-c}	20.60^{f-j}	15.00^{b-e}	10.60^{a}	7.06^{k-q}	5.81^{a}	48436^{bc}	94.18^{bc}	16.11^{b}	8490^{b}	66.99^{ij}	69.00^{fg}	36.06^{o-q}	62.86^{f-i}
D'inveno	22.53^{a}	21.86^{e-h}	15.86^{a-d}	9.06^{b-e}	9.60^{d-g}	5.78^{a}	64259^{a}	124.95^{a}	15.79^{b}	11483^{a}	96.03^{a-c}	65.66^{i-k}	23.63^{t}	76.39^{d}
Monatol	20.20^{ab}	19.66^{f-l}	12.00^{f-m}	9.06^{b-e}	6.20^{o-s}	4.75^{a-e}	42056^{cd}	81.77^{cd}	14.77^{bc}	10781^{a}	98.58^{a}	66.66^{h-j}	3.82^{w}	95.96^{a}
Wiremona	12.80^{g-n}	17.46^{h-n}	11.20^{h-o}	7.40^{f-l}	4.33^{s}	3.96^{c-j}	14854^{j-n}	28.88^{j-n}	5.40^{l-p}	6185^{g-m}	63.2^{i-k}	67.33^{g-i}	7.00^{vw}	94.42^{ab}
Subito	10.40^{l-n}	13.73^{m-r}	8.33^{qr}	5.93^{l-p}	5.86^{q-s}	2.96^{i-q}	10050^{mn}	19.54^{mn}	3.33^{p}	4300^{p-s}	63.34^{i-k}	2.03	14.43^{u}	88.29^{c}
Virginia Savoy blight resistant	12.20^{h-n}	11.13^{qr}	7.30^{r}	5.53^{n-p}	4.93^{rs}	2.93^{j-q}	8870^{n}	17.24^{n}	8.99^{e-h}	2884^{st}	20.24^{r}	43.00^{s}	40.58^{j-n}	59.23^{i-m}
Virginia Savoy fusarium	12.06^{h-n}	13.06^{m-r}	9.20^{o-r}	5.66^{m-p}	7.93^{g-p}	2.40^{o-r}	10667^{l-n}	20.74^{j-n}	5.54^{k-p}	3393^{st}	60.33^{kl}	61.33^{o}	39.17^{l-p}	62.16^{g-j}
Garant	12.53^{g-n}	14.26^{l-r}	9.06^{o-r}	6.53^{i-o}	6.00^{o-s}	2.21^{p-r}	12923^{j-n}	25.12^{j-n}	7.47^{h-m}	4196^{p-s}	50.05^{o}	83.66^{c}	6.65^{vw}	93.66^{ab}
Viking	15.73^{c-h}	11.40^{p-r}	8.73^{p-r}	5.66^{m-p}	5.86^{q-s}	2.77^{l-r}	11632^{k-n}	22.61^{k-n}	10.94^{d-g}	3452^{st}	22.89^{r}	89.66^{a}	9.80^{v}	90.77^{bc}
Viroflay	16.60^{b-c}	18.73^{g-m}	13.47^{e-h}	7.40^{f-l}	9.53^{d-h}	3.81^{d-l}	71224^{a}	138.49^{a}	23.79^{a}	7801^{b-e}	85.86^{d}	69.00^{fg}	29.77^{s}	71.47^{e}
Spinagh	18.46^{a-e}	24.33^{d-g}	12.00^{f-m}	8.00^{d-i}	12.93^{c}	2.90^{j-q}	34503^{de}	67.08^{de}	12.21^{cd}	5660^{j-n}	91.78^{c}	67.33^{g-i}	51.18^{b}	47.49^{v}

Table 5.

Accession No.	Leaf number	Plant height (cm)	Leaf length (cm)	Leaf width (cm)	Petiole length (cm)	Petiole diameter (mm)	Yield (kg/h)	Fresh weight(g)	Dry weight (g)	Leaf area (mm^2)	Germination percentage (%)	Days to flowering	Male plant (%)	Female plant (%)
SPI108	8.93^{n}	14.60^{l-r}	8.40^{qr}	6.46^{j-o}	5.93^{p-s}	2.56^{n-r}	20531^{f-k}	39.92^{f-k}	11.51^{d-f}	5484^{k-o}	61.98^{i-k}	64.00^{k-m}	28.23^{s}	72.45^{de}
SPI211	9.53^{mn}	16.73^{h-q}	9.73^{l-q}	5.93^{l-p}	6.33^{n-s}	2.30^{P-R}	25393^{e-i}	49.37^{e-i}	10.98^{d-g}	5135^{l-p}	54.54^{m-o}	62.00^{m-o}	41.53^{i-m}	59.20^{i-m}
SPI79	14.66^{e-k}	16.93^{h-p}	9.33^{n-r}	5.46^{op}	6.73^{m-r}	3.38^{g-o}	19908^{f-l}	38.71^{f-l}	11.89^{c-e}	5199^{l-p}	51.54^{no}	61.33^{o}	34.85^{qr}	63.84^{f-h}
Late flower	12.86^{g-n}	11.73^{o-r}	7.26^{r}	5.53^{n-p}	6.93^{l-r}	2.28^{p-r}	14467^{j-n}	28.13^{j-n}	7.17^{h-n}	3750^{r-t}	18.40^{r}	63.00^{l-o}	46.90^{ef}	54.67^{n-s}
Tenjinmaru	14.80^{e-j}	14.33^{l-r}	9.66^{m-q}	4.93^{p}	7.53^{h-q}	1.90^{qr}	18968^{g-m}	36.88^{g-m}	6.56^{h-o}	4134^{p-s}	38.90^{q}	63.66^{k-n}	28.78^{s}	71.30^{e}
Kasijong	13.66^{f-m}	24.20^{d-g}	11.66^{g-n}	5.26^{op}	12.86^{c}	1.74^{r}	16431^{i-n}	31.95^{i-n}	8.05^{g-l}	4117^{p-s}	55.16^{mn}	87.33^{b}	46.94^{ef}	51.86^{r-u}
LSD5%	4.25	5.69	2.35	1.52	2.05	1.06	9383	18.24	3.14	1266.2	5.00	76.00^{d}	3.72	4.02

† Different letters defined in each column mean significant differences at the 5% level.

Table 6. The correlation coefficient of quantities traits investigated in 43 spinach accessions

Traits	Leaf number	Plant height	Leaf length	Leaf width	Petiole length	Petiole diameter	Yield	Fresh weight	Dry weight	Leaf area	Germination percentage	Day to flowering	male plant	female plants
Leaf number	1													
Plant height	0.28^{ns}	1												
Leaf length	0.51^{*}	0.74^{**}	1											
Leaf width	0.48^{**}	0.60^{**}	0.82^{**}	1										
Petiole length	0.16^{ns}	0.85^{**}	0.70^{**}	0.5^{ns}	1									
Petiole diameter	0.45^{*}	0.40^{*}	0.73^{**}	0.78^{**}	0.27^{ns}	1								
Yield	0.66^{**}	0.45^{*}	0.56^{**}	0.5^{**}	0.35^{*}	0.42^{*}	1							
Fresh weight	0.66^{**}	0.45^{*}	0.59^{**}	0.55^{**}	0.34^{*}	0.47^{*}	0.98^{**}	1						
Dry weight	0.61^{**}	0.19^{ns}	0.25^{ns}	0.28^{ns}	0.03^{ns}	0.23^{ns}	0.82^{**}	0.84^{**}	1					
Leaf area	0.45^{*}	0.48^{**}	0.73^{**}	0.76^{**}	0.37^{*}	0.73^{**}	0.63^{**}	0.67^{**}	0.37^{*}	1				
Germination percentage	0.38^{*}	0.65^{**}	0.62^{**}	0.60^{**}	0.53^{**}	0.44^{*}	0.58^{**}	0.57^{**}	0.28^{ns}	0.69^{**}	1			
Day to flowering	0.50^{**}	-0.22^{ns}	0.04^{ns}	0.08^{ns}	-0.24	0.14^{ns}	0.56^{**}	0.58^{**}	0.67^{**}	0.24^{ns}	0.05^{ns}	1		
male plants	-0.21^{ns}	0.26^{ns}	0.19^{ns}	0.03^{ns}	0.5^{**}	-0.005^{ns}	-0.11^{ns}	-0.11^{ns}	-0.29^{ns}	-0.04^{ns}	0.02^{ns}	-0.29^{ns}	1	
Female plant	0.2^{ns}	-0.25^{ns}	-0.2^{ns}	-0.04^{ns}	-0.5^{ns}	-0.006^{ns}	0.11^{ns}	0.11^{ns}	0.28^{ns}	0.03^{ns}	-0.01^{ns}	0.28^{ns}	-0.99^{ns}	1

*: Significant at 5% probability levels. **: Significant at 1% probability levels

Advanced Prickly" and foreign accessions consisted of "Monatol", "Wiremona" and "Late flower". In the present study, 50% of Iranian accessions were placed in the group of early flowering, the earliest of which was "Kashan" with a growth period of 45 days. On the other hand, none of the foreign accessions was early flowering (Table 5). Similar to our results, in the study of Zaferaniye (2015), the Iranian masses of spinach were the fastest flowering masses and foreign masses were the latest flowering. Researchers have reported that late flowering spinach is mostly favorable for economic production because their flower stems appear slowly (Asadi and Hasandokht, 2007; Kawazu et al., 2003). Different results have been reported for day to flowering, which may be due to the seasonal mismatch between the studies conducted (Asadi and Hasandokht, 2007). The flowering of spinach occurs early in spring planting due to weather conditions, long day and high temperatures, which is not seen in autumn cropping (Asadi and Hasandokht 2007). Because the spinach plant produces both male and female flowers, spinach spring planting is important if the plant can have female flowers (Zaferaniye, 2015).

Contrary to the reports of other researchers (Arshi, 2000; Asadi and Hasandokht, 2007; Morelock et al., 2008), in this study, spinach was not observed in dioecious plants and all plants were pure males or pure female. It seems that the monoecious plant is likely found in the ancestors or wildlife of this plant. Spinach female plants are valuable in planting; so, these plants are used in breeding programs and seed production (Stagnari et al., 2007).

Relationship Among Genotypes by Cluster analysis and Biplot

Identification and selection of indigenous spinach populations and their comparison with foreign populations is one of the most important methods for evaluating, screening and preserving the genetic resources of this plant (Ebadi-Segheloo et al., 2014). In addition to the mean comparison of traits, the accessions were also divided according to cluster analysis (Fig 1). Cluster analysis can be useful for selecting high-quality accessions for agronomic and breeding purposes. The favorable accession selection in cluster analysis is based on the greater distance between the accessions because the short distance between them represented the slight difference.

The cluster analysis divided the studied accessions into two major groups (cluster I and Π) at a distance of 35 to 60. "Monatol", "Viroflay", "D'inverno", "Matador" and "Varamin88" accessions were grouped in one cluster (Fig 1). All of these accessions (cluster I) had a smooth seed, no anthocyanin in the stem and had a desirable performance compared to others. In terms of flowering time, they were placed in the late and medium flowering group. In general, the accessions in cluster I were superior to cluster Π in morphological traits. Other accessions of this study were placed in a large cluster i.e. cluster Π. Cluster I and Π had a little genetic similarity, and the accessions placed in cluster Π also had different variations of features. As can be seen in Fig. 1, accessions "Varamin Prickly and Varamin Advanced Prickly, Kashan, Lorestan 4, 5, 6, 7, Spinagh", and "Viking, Garant, Subito, and Wiremona" and other accessions were placed in separate subgroups. In spite of the morphological difference between 43 accessions in this study, accessions with similar characteristics belonging to different regions of the world could be grouped together. In subgroups of cluster Π, accessions of "Wiremona", "Subito", "Garant" and "Viking" were placed together, with the most similarity of these accessions being the high percentage of female plant (Fig 1). "Kashan" accession in cluster Π, although had some desirable traits, goes to flower soon. The best accession from cluster Π was "Varamin Advanced Prickly" (endemic accession) which had favorable morphological traits. Other accessions in cluster Π subgroups a little differed in qualitative and quantitative traits so that their features were not desirable. Geographically, accessions collected from different parts of Lorestan and Hamedan provinces were placed almost in the same subgroups. For the effective use of spinach in any breeding or cultivating program, an accurate assessment of various indigenous populations is essential.

To better determine the best accessions and to investigate the relationships between all agro-morphological features, there is a need to biplot the spinach traits. So with the help of (R) software, 43 accessions were checked by biplot classification whose results fully accorded with clustering analysis (Fig 2). PC analysis used in this research has been useful in grouping germplasm in many herbs such as blackpea (Ghafoor et al., 2001), chickpea (Naghavi and Jahansouz 2005), rice (Tripathi et al. 2013) and sorghum (Barro-Kondombo et al., 2010).

Based on biplot, accessions located in region (D), had inappropriate (negative) characteristics which were not considered in the range of useful traits. Most of the Iranian accessions were located in this area (D). As it is observed, these accessions were inappropriate concerning both vegetative yield and mechanical traits. The accessions located in region (C) were negative for the first component (dimension 1) but were positive for the second component (dimension 2). These accessions consisted of the most foreign spinach such as "Garant", "Viking", "Wiremona" and etc. These accessions in region (C) were the rosette form with the high percentage of the female plant. Indeed, accessions in region (C) were very poor for mechanical harvesting. The accessions located in region (B) were positive for the first component (dimension 1) and negative for the second component (dimension 2), which had favorable leaf appearance characteristics and suitable for mechanical harvesting so that these accessions had common traits of plant height, leaf and petiole length, and leaf width. In this region (B), the most suitable accessions for mechanical harvesting were "Kashan", "Lorestan5 and 6", Varamin Advanced Prickly" and "Varamin Prickly". On the other hand, due to the presence of the significant male plant in these accessions, the second component (dimension 2) was placed in negative conditions. The accessions located in region (A) were positive for the first and second

components (dimension1 and 2). These accessions (located in region A) had favorable economic characteristics and a high percentage of the female plant. Finally, it can be said that the optimal accessions such as “D’inverno”, “Viroflay”, “Monatol”, “Matador” and “Varamin88” have the best conditions in this study, which is consistent with the results of clustering analysis. It is worth noting that the scattering pattern of the accessions is shown in Fig. 3. This pattern completes previous evaluations and this result has also approved the bi-plots diagram.

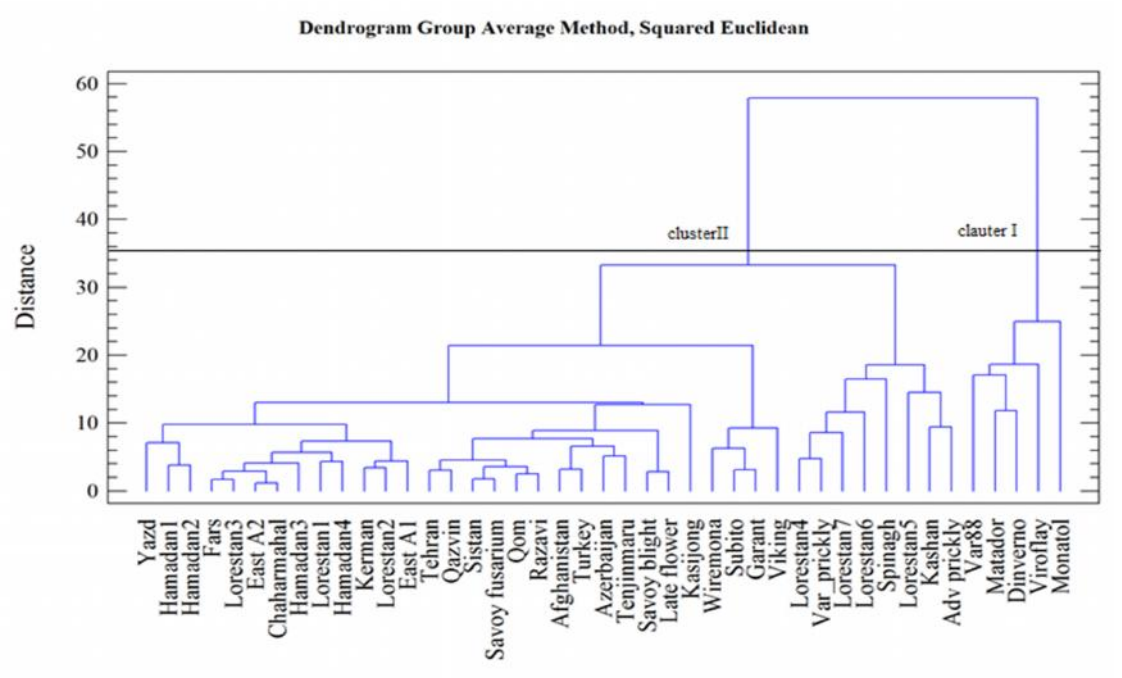

Fig. 1. Cluster analysis of the 43 spinach accessions based on Average method using measured traits.

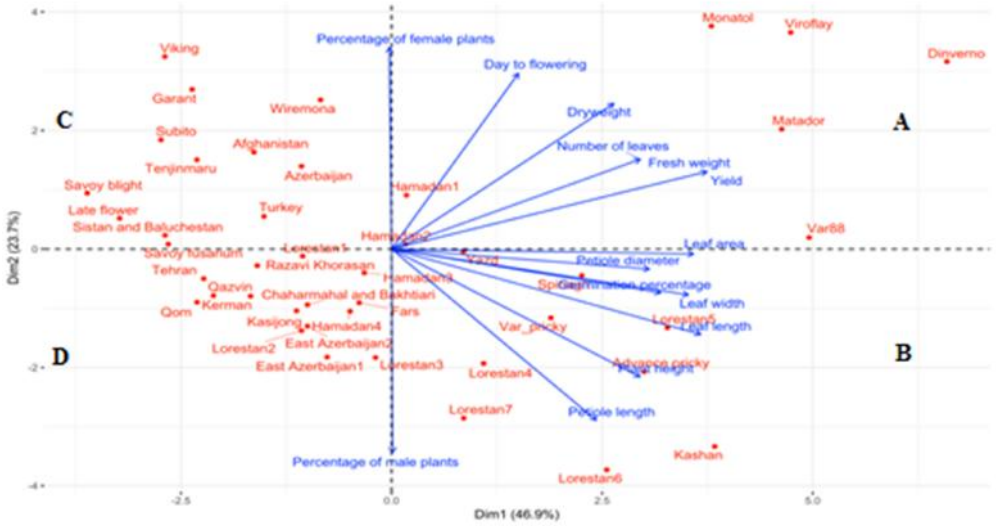

Fig. 2. Biplot diagram of 43 endemic and external spinach accessions. Most of the Iranian accessions were located in this area (D); which were not considered in the range of useful traits. Accessions in region (C) were the rosette form with the high percentage of the female plant. Accessions in region (B) had common traits of plant height, leaf and petiole length, and leaf width. Accessions located in region A had favorable economic characteristics and a high percentage of the female plant.

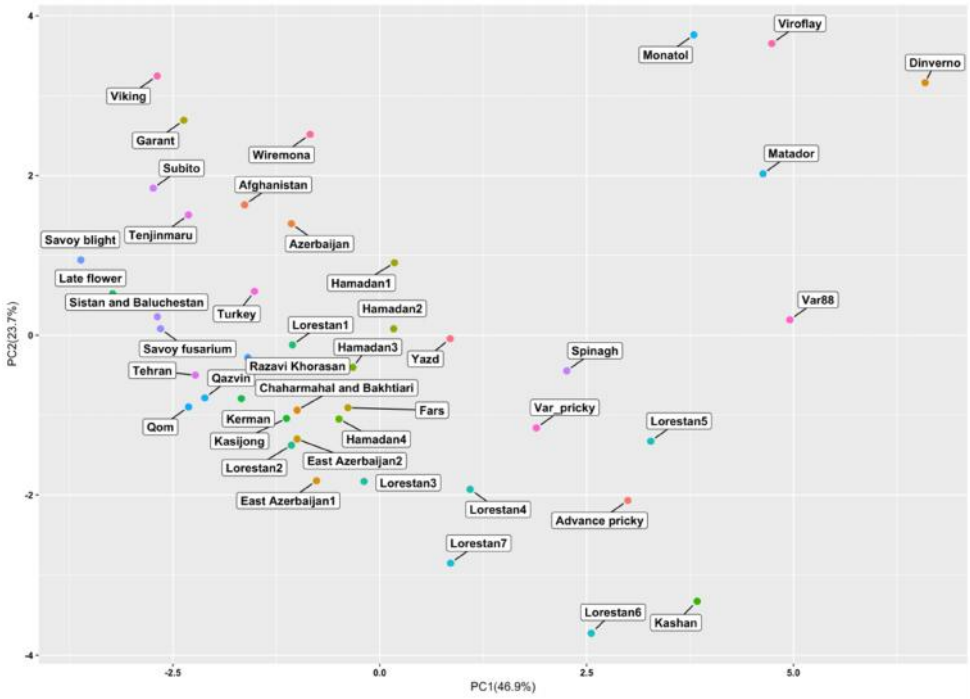

Fig. 3. Scattering patterns of 43 endemic and external spinach accessions.

CONCLUSIONS

Results of this investigation approved that there was diversity in traits of native spinach accessions and therefore, it is very valuable for the researchers. So that, the Iranian accessions like "Varamin88" and "Varamin Advanced Prickly" have a better adaptation to the weather conditions of Isfahan and have shown favorable traits such as yield, fresh and dry weight, petiole size, petiole attitude, and leaf number. Native accessions of "Hamedan2", "Varamin88" and "Varamin Prickly" with the longest growing to flowering period are recommended for spring planting in Isfahan conditions. Among the native accessions of Iran, "Varamin88" is the only optimum accession with thick leaf, desirable performance, and notable fresh and dry weight, which makes it suitable for mechanized cultivation and is adapted to the spring in Isfahan. Generally, "Varamin88" is recommended for planting in Isfahan between studied accessions.

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غربالگری برخی از توده‌های بومی و خارجی اسفناج در شرایط آب و هوایی کشت بهاره اصفهان

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چکیده- یکی از مهمترین سبزیجات برگی سبز، اسفناج (*Spinacia oleracea* L.) است. صفات کیفی و کمی اسفناج بستگی به شرایط آب و هوایی محل رویش دارد. غربالگری توده‌های خارجی در مقایسه با توده‌های ایرانی ضروری است. به‌منظور مطالعه خصوصیات رویشی ۴۴ توده بومی و خارجی اسفناج، آزمایشی در قالب طرح بلوک کامل تصادفی با سه تکرار و ۱۸ مشاهده در شرایط کشت بهاره پایه‌ریزی شد. پارامترهای کمی و کیفی اسفناج براساس توصیف‌های تعریف شده توسط مؤسسه بین المللی تنوع زیستی گیاهی ارزیابی شد. به‌طورکلی شدت رنگ سبز در برگ‌های توده‌های خارجی بیشتر از اسفناج‌های بومی بود. در این تحقیق، بیشترین عملکرد متعلق به توده "Viroflay" به‌میزان ۷۱/۲۲۴ تن در هکتار و در میان گونه‌های ایران توده ورامین ۸۸ به‌میزان ۵۲/۶ تن در هکتار بالاترین عملکرد را داشت. حداکثر و حداقل عملکرد از ۷۱۲۲۴ تا ۸۸۷۰ کیلوگرم در هکتار متعلق به توده‌های "Viroflay" و Virginia Savoy blight بود. توده‌ی "D'inveno" طولانی‌ترین دوره رشد(۸۹/۶۶ روز) کشت بهاره را نشان داد و در میان توده‌های ایرانی، همدان ۲ (۷۷ روز)، ورامین ۸۸ (۷۲ روز) و ورامین خاردار (۶۹/۶۶ روز) به‌ترتیب طولانی‌ترین دوره‌ی رشد در شرایط محیطی اصفهان را نشان دادند. بالاترین درصد گیاهان ماده در توده‌ی "Monatol" مشاهده شد. در میان گونه‌های اندمیک، لرستان ۵ بیشترین درصد گیاه ماده را نشان داد. نتایج حاصل از این مطالعه نشان داد که گونه‌های ایرانی مانند کاشان، لرستان ۶ و ورامین پیشرفته خاردار برای برداشت‌های مکانیکی به‌دلیل فرم گیاه، برگ و دمبرگ مناسب هستند و می‌توانند برای اهداف باغبانی و اصلاحی مورد استفاده قرار گیرند. با توجه به واکاوی خوشه‌ای، توده‌های مورد بررسی در این مطالعه به دو دسته بزرگ ۱ و ۲ تقسیم شدند که توده ورامین ۸۸ در کنار سایر توده‌های مطلوب خارجی در خوشه‌ی ۱ قرار گرفت.