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Agronomic attributes and stability of exotic sunflower hybrids in Iran

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Abstract: In order to identifying of high yielding compatible sunflower hybrids for different regions of Iran, a set of 10 exotic hybrids from Serbia, Turkey, and Italy and four Iranian hybrids were evaluated for agronomic traits; days to flowering and maturity, plant height, head and stem diameter, 1000-achenes weight, achene number per head, oil content and achene, and oil yield. The experiments were conducted as completely randomized block design with four replications in Alborz, Mazandaran, Khuzestan, and West Azerbaijan Provinces for two years (2017–2018). According to the results growing period of the hybrids were variable from 86 days for Dukat to 98 days for Fantaziya. The hybrids Slatki and Dukat had the highest (70 g) and lowest (56 g) 1000-achenes weight. The highest oil content was observed in 08TR003 (45.6%). Among the locations, Miandoab had the highest achene yield (3110 kg/ha). In Sari; the hybrids Barzegar, Fantaziya, and Slatki (3080, 2893, and 2853 kg/ha respectively), In Dezful; Barzegar, Cartago, and

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Oscar (3234, 3409, and 3226 kg/ha respectively), in Karaj; Oscar, Shams, and Fantaziya (3138, 3081, and 3050 kg/ha respectively), and in Miandob Shams, Fantaziya, and Slatki (4093, 4038, and 3895 kg/ha respectively) had the highest achene yield. Considering overall mean Fantaziya, Shams, and Oskar had the highest achene yield (3286, 3145, and 3087 kg/ha respectively), as well as Fantaziya followed by Barzegar and Shams had the highest oil yield (1396, 1335, and 1330 kg/ha respectively). Considering phenotypic variability among the exotic hybrids Fantaziya, Oskar, Slatki, Novak, 08TR003, and Meteor with lower coefficient of variation and higher achene yield considered as the stable higher yielding hybrids in four test locations of Iran. Through identifying high-yielding and compatible hybrids, the results of this study can assists in increasing of sunflower yield and production in Iran.

Keywords: agronomic traits; biplot; exotic hybrids; locations; stability.

Introduction

Sunflower with more than 100 years of cultivation background is one of the most compatible oil crops to the most parts of Iran. Both oil and confectionary types of sunflower are cultivated in Iran, however due to the higher income, confectionary types are more interested. Sunflowers, first confectionary types, introduced to Iran mainly Khoy, Marand, and Meshkinshahr (Safarkhanlo 2011). The main production area of confectionary type is Khoy region in West Azerbaijan Province with more than 20,000 ha cultivation area followed by Kermanshah with about 4500 ha cultivation area annually (Ghaffari et al. 2016). Cultivation of the oil types began since 1965 with RuRssian and Romanian cultivars as Record and Vnimk 8931. Since 1967 following the agreements between Iran and Romanian governments (Lazaroiu et al. 1969) and with former Yugoslavian Institute for Agricultural Research, Novi Sad for research and breeding of sunflower (Vrebalov et al. 1971), cultivation area of this crop increased to more than 100,000 ha in early of 90s. These efforts had remarkable achievement in production of sunflower single cross hybrids with different characteristics (Ghaffari et al. 2019).

Former Yugoslavian researchers had considerable role in sunflower breeding due to providing genetic materials as male sterile lines, which is used in improvement and production of single cross hybrids in Iran (Vrebalov et al. 1971). The first Iranian sunflower hybrids Mehr and Shafagh were released in 1987 and the latest Shams in 2016 (Ghaffari et al. 2016). Cultivation of foreign varieties in Iran

has been common over many years. It was open pollinated cultivars that first time introduced to Iran in 60s then hybrid cultivars introduced to Iran mainly in new millennium and several studies have been conducted on the evaluation of exotic hybrids (Khodabandeh et al. 2000; Nabipour et al. 2008, 2009). There were joint collaborations with former Yugoslavian researchers for improvement and production of common sunflower hybrids (Farrokhi et al. 2001, 2004).

Today, most of the sunflower hybrids are imported from Serbia to Iran and have been considered in some regions. Due to considerable variability of different region of Iran stability of these hybrids depends on special characteristics of these hybrids to adapt in these regions. Objective of this study (Nabipour et al. 2009) was to compare agronomic characteristics of Serbian and Iranian sunflower hybrids and stability of achene yield for theses hybrids in different regions of Iran.

Materials and methods

This study was carried out in four regions of Iran; Alborz, Mazandaran, Khuzestan and West Azerbaijan Provinces in two years (2017–2018). The geographical coordinates of these areas are shown in Table 1. Experimental materials consisted of 10 exotic and four Iranian sunflower hybrids. The experiments were conducted in randomized complete block design with four replications. Each plot consisted of four rows 4 m long with 60 cm between row and 25 cm within row intervals. To prepare the seed bed, following autumn plough supplementary tillage was done before planting. All phosphate and potassium fertilizers and one third of urea fertilizer were distributed before planting and the rest of the nitrogen fertilizer was applied in two splits upto 8–10 leaf stage. Depending on test location, trifluralin herbicide (2 l/ha) was used to control of weeds. During the growing season, phenological and agronomic traits including days to flowering and maturity, plant height, head and stem diameter, 1000-achene's weight, achene number per head, oil content and achene, and oil yield were measured. Phenological characteristics were recorded according to (Schniter and Miller 1981). Plant height, head, and stem diameter were measured on six plants in each plot at the physiological maturity. 1000-achene weight was determined by counting three random samples of each plot. Achene number per head was determined by proportion using mean of head yield and 1000-achene weight. Oil content was analyzed by Soxhlet extractor using 10 g grounded seed sample from each plot (ISO 659 2009). Achene yield were determined after harvesting 3 m of two inner row of each plot excluding 0.5 m of margins. Oil yield determined by multiplying achene yield by oil content. Following combined analysis of variance,

Table 1: Geographical coordinates for locations of the experiments.

Province	Location	Geographical Coordinates
Alborz	Karaj	35.84°N, 50.93°E
Mazandaran	Sari	36.56°N, 53.05°E
Khuzestan	Safi Abad Dezful	32.00°N, 49.38°E
West Azarbaijan	Miandoab	36.95°N, 46.10°E

the means of hybrids for each trait were compared by Least Significant Deference (LSD) test. The statistical analysis was performed in SPSS (Ver. 16). Stability analysis was performed using GGE-Biplot (Ver. 4.1) according to the method of Yan and Kang (2002).

Results and discussion

According to the results of combined analysis of variances for agronomic traits, there were significant differences among two years for phenological traits, oil content, and achene yield and among the locations for phenological traits, stem diameter, achene number per head, and oil content. There were also significant differences among the hybrids for all the analyzed traits (Table 2). The interaction effects of hybrid × location was significant for all the traits too indicating that relative performance of the hybrids varied from one location to another for the related traits (Mafouasson et al. 2018).

Phenology

According to the mean comparison of the hybrids for phenological traits, the hybrid Dukat was the early flowering (49 days) while, Fantazyiya, Hispalis, Barzegar, and Shams were the late flowering hybrids in this study. Growth duration was variable from 86 days for Dukat to 98 days for Fantaziya and Barzegar (Table 3). Sunflower growing is possible as spring or summer cropping in north and summer or winter cropping in south regions of Iran. There is an occasion for sunflower growing from July to October in north temperate regions of Iran. In this condition growth duration decreases considerably which is expressed in growth duration of all studied hybrids. Due to warm condition, growth duration were considerably lower in Dezful and Sari(86–87 days) as warm regions than Miandob (104 days), and Karaj (98 days) as cold regions (Figure 1).

Although there is a negative associations between seed and oil yield and maturity (Kaya et al. 2004), however due to the problems caused by late flowering or maturity, early mature sunflowers is preferred in some conditions as in summer cropping. In other hand, early mature sunflowers are most often susceptible to charcoal rot (Skoric 2009), so higher variability in maturity provides selection of optimum case for different condition. There were early mature hybrids such as Dukat, Ghasem, and Farrokh which could be suitable for second cropping from July to September in temperate regions and from February to June in south of Iran, while the hybrids Shams, Fantasia, Oscar are favorable for planting in March to April in temperate and cold regions of Iran.

Table 2: Combined analysis of variance for agronomic traits in sunflower hybrids.

Sources of variation	DF	Days to flowering	Days to maturity	Plant height	Head diameter	Stem diameter
Year (Y)	1	712.6**	533.8**	16.0^{ns}	91.3^{ns}	26.2^{ns}
Location (L)	3	4076.7**	8571.0**	15,321.0 **	6717.6**	1838.4**
Y × L	3	280.4**	340.4**	5458.2**	95.0^{ns}	20.5^{ns}
Replication/Environment	24	3.6	8.4	213.0	46.5	21.0
Hybrid (H)	13	123.3**	409.0**	6100.2**	23.5**	58.7**
Y × H	13	15.0**	14.9**	153.8^{ns}	4.5^{ns}	1.3 ^{ns}
L × H	39	55.3**	63.7**	1963.4**	9.3*	44.4**
Y × L × H	39	17.4**	17.5**	109.7^{ns}	4.6*	2.5^{ns}
Error	312	0.9	1.4	187.3	2.9	4.2
Coefficient of variation (%)		1.78	1.25	9.55	9.99	10.76
Sources of variation	**DF**	**1000-Achene weight**	**Achene No.head^{-1}**	**Oil content**	**Achene yield**	**Oil Yield**
Year (Y)	1	62.2^{ns}	18,296.4^{ns}	153.4**	2,085,310.8*	21,922.6^{ns}
Location (L)	3	374.5*	3,088,668.8**	1307.2*	4,769,770.5 **	67,133.5^{ns}
Y × L	3	715.2**	98,103.6^{ns}	57.1*	3,496,418.0**	712,583.6**
Replication/Environment	24	105.7	52,015.0	13.0	376,964.6	80,129.4
Hybrid (H)	13	428.9**	602,880.1**	154.2**	2,020,504.6**	447,985.1**
Y × H	13	73.4**	81,740.0**	7.5^{ns}	431,140.6**	67,102.0**
L × H	39	550.7**	644,137.4**	65.8**	1,419,237.4*	312,147.8**
Y × L × H	39	81.3**	38,567.3**	6.5^{ns}	484,523.9**	84,532.2**
Error	312	21.1	18,563.7	10.9	103,861.2	28,814.6
Coefficient of variation (%)		7.66	15.81	7.81	11.36	14.21

ns: not significancens, *and ** denote to the statistical non-significance and significance in probability of 5 and 1% respectively.

Table 3: Mean values of hybrids for agronomic attributes of sunflower in four locations; Karaj, Sari, Safi Abad Dezful, and Miandob and two years (2017–18).

Hybrid	Days to flowering	Days to maturity	Plant height (cm)	Head diameter (cm)	Stem diameter (mm)	1000-Achene weight (g)	Achene No.head^{-1}	Oil content (%)	Achene yield (kg/ha)	Oil Yield (kg/ha)
08TR003	53	93	128.4	16.4	17.7	61.0	887.8	45.6	2850.3	1302.1
Acsun	54	96	132.6	16.3	17.3	57.5	654.4	44.4	2588.7	1147.3
Oscar	55	95	141.9	17.2	18.3	60.0	710.2	42.1	3087.1	1283.2
Fantaziya	56	96	157.5	17.8	19.1	60.4	1097.1	42.5	3286.0	1395.7
Novak	55	98	130.7	16.7	19.7	56.8	883.9	42.8	2892.9	1230.1
Meteor	55	93	142.2	16.4	20.4	56.4	944.7	40.9	2799.4	1136.1
Cartago	54	92	153.0	17.0	16.7	59.0	697.0	42.5	2701.5	1156.3
Dukat	49	86	114.1	15.5	17.7	56.1	860.9	42.3	2547.8	1076.5
Hispalis	56	96	157.4	17.0	17.7	63.3	739.7	42.0	2371.4	999.2
Slatki	52	92	133.9	16.7	17.5	69.8	869.4	36.3	2998.6	1071.3
Farrokh	53	90	147.9	17.9	17.9	58.2	821.1	40.6	2778.6	1127.2
Ghasem	53	90	150.0	18.0	18.3	56.9	903.7	42.3	2676.3	1130.9
Barzegar	56	98	161.9	17.5	20.3	61.6	869.8	44.7	2982.7	1334.7
Shams	56	97	154.7	18.8	21.2	62.2	1126.2	43.0	3145.2	1329.7
LSD 5%	2.8	2.7	4.3	1.2	0.9	5.7	157.9	0.8	446.0	173.5
LSD 1%	3.7	3.6	5.7	1.6	1.3	7.6	208.7	1.2	589.5	229.3

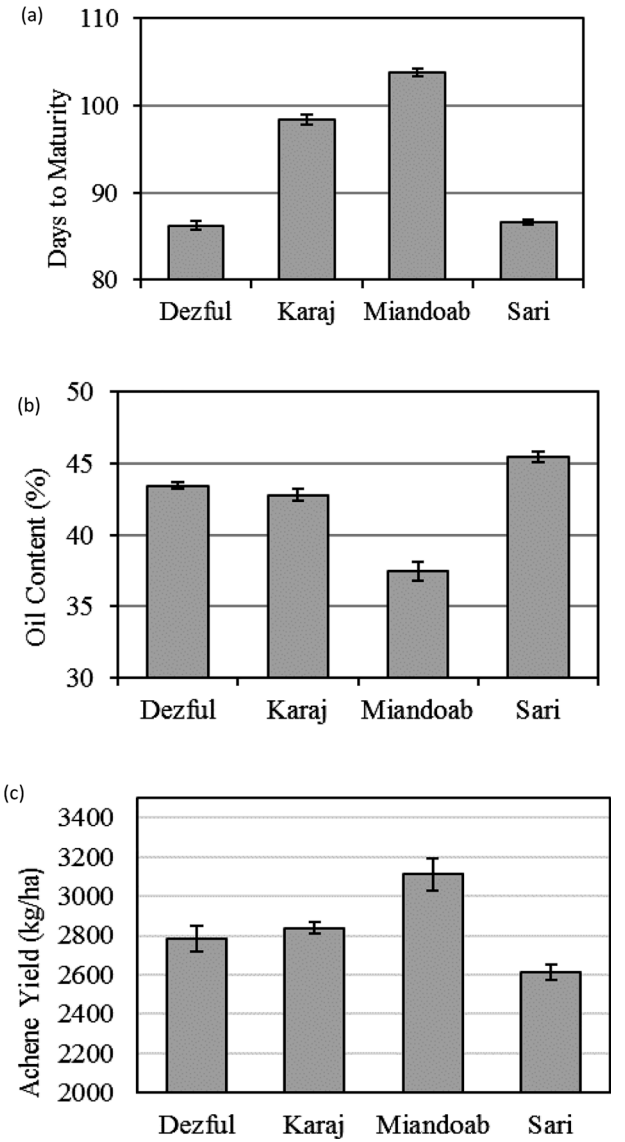

Figure 1: Mean comparison of all the hybrids in four locations of Iran for days to maturity (a) oil content (b) and achene yield (c) Error bars denote to the standard error of the mean (SE ± 1).

Plant characteristics

There were significant differences among the hybrids for plant characteristics i.e. plant height and head and stem diameter (Table 2). The lowest plant height was observed in Dukat (114 cm) an early mature hybrid while the highest in Barzegar (162 cm) (Table 3). Plant height of most of the hybrids was about 140–150 cm. This range of plant height falls into the medium tall classification group defined by (Škorić 2012) and is desirable because of the ease of agricultural operations. The hybrid Dukat had the lowest (15.5 cm) while Shams the highest head diameter (18.8 cm). The least and the most stem diameter was observed in Cartago (16.7 mm) and Shams (21.2 mm) respectively. Stem is the most important source of carbohydrate for sunflower plant (Hocking and Steer 1983). Sadras et al. (1993) also indicated the critical role of stem reservoirs in seed filling of sunflower so thick stems could better provide the plant's carbohydrate needs during grain filling.

Yield components

The highest achene weight was observed for Slatki (70 g) which is a confectionary type and the lowest in Dukat (56 g) (Table 3). Local landraces of confectionary sunflower in Khoy region have higher 1,000 achenes weight more than 200 g (Ghaffari et al. 2016). Big sized achenes are preferred for confectionary use in Iran. Among the oil type Iranian hybrids Farrokh and Ghasem had the lowest (57–58 g), while Barzegar and Shams had the highest (62 g) achene weight. Regarding achene number per head Acsun had the lowest (654), while Fantazyia, and Shams the highest number (1097 and 1126 respectively). Different factors effect achene number on head, among them temperature in flowering time is more important. Planting time has a wide range in different parts of Iran and late planting in winter or spring could result in flowering in hot days, which may bring problems in pollination due to temperature higher than 37°C, which is not suitable for pollinators. This problem is more important in the southern regions of Iran, where experience temperatures above 55°C in summer. In this regions winter planting in February-March was successful in recent years (unpublished reports). There are reports of former Yugoslavian researchers in 1970s who recommended winter planting as a suitable alternative for summer cropping in Khuzestan province (Vrebalov et al. 1971).

Except Slatki (36.3%) which is a confectionary type, Serbian hybrids had almost similar oil content (42.0–42.8%). The highest oil content was observed in

08TR003 (45.6%). Among the Iranian hybrids Barzegar had the highest (44.7%) while Farrokh the lowest oil content (40.6%). Considering significant differences among the locations, it seems that environmental condition had a considerable effect on oil content (Figure 1). The highest oil content was observed in Sari (45.45%) and the lowest in Miandob (37.44%).

Achene and oil yields

According to the combined analysis of data in four locations the highest achene yields were observed for Fantaziya, Shams, and Oscar (3286, 3145, and 3087 kg/ha respectively) with no significant differences among them (Table 3), while for oil yield Fantaziya, Barzegar, and Shams were in the first ranks (1396, 1335, and 1330 kg/ha). This change in rank is due to the higher oil content (44.7%) of Barzegar compared with Oscar (42.1%). These locations are selected as the representative of different regions of Iran and with the least number of locations; most information about the compatibility of varieties to different regions is obtained. The northern regions of Iran, including the provinces of Mazandaran and Golestan, and West Azerbaijan in northwest have long been the main places for planting of oilseeds, including sunflowers.

Among the tropical regions of southern Iran, Dezful was suitable for this study due to its history of cultivation and further research. Based on sunflower testing network of 26 sites in Serbia using sites regression biplot based on grain yield Brankovic et al. (2011) suggested that the same information about the genotypes could be obtained from either of only two test sites. A similar experiment could help identify of representative areas in Iran.

Comparison of achene yields of the hybrids over two years (2017–2018) in four locations demonstrated that the hybrids Barzegar, Fantaziya, and Slatki had the highest achene yield (3080, 2893, and 2853 kg/ha respectively) in Sari. In Dezful; Barzegar, Cartago, and Oscar (3234, 3409, and 3226 kg/ha respectively), in Karaj; Oscar, Shams, and Fantaziya (3138, 3081, and 3050 kg/ha respectively) and in Miandob Shams, Fantaziya, and Slatki (4093, 4038, and 3895 kg/ha respectively) were superior hybrids (Table 4). Among the locations, Miandoab and Sari had the highest and lowest achene yield respectively (Figure 1).

Achene yield of three groups were compared *via* orthogonal comparison. According to the results NS hybrids with 2962 kg/ha were in the first rank (Figure 2) followed by Iranian hybrids (2896 kg/ha) with no significant differences among the two groups, while the other hybrids had a significant lower yield than that of the mentioned groups. Similarly oil yield of Iranian and Serbian hybrids were almost similar and more than other hybrids (1231, 1211, and 1148 kg/ha respectively).

Lower oil yield of Serbian hybrids compared with Iranian hybrids could be due to including Slatki as a confectionary type with oil content of 36%.

Stability of achene yield over regions

The highly significant hybrid by location interaction for achene yield justified the use of Genotype and Genotpe-by-Environment interaction (GGE) biplots to determine the yield potential and stability of the sunflower hybrids over the test locations (Mafouasson et al. 2018). The results showed that most of the hybrids, with lower coefficient of variation (CV) and higher achene yield are stable over the environment of the study (Figure 3). These included Serbian hybrids (Fantazyia, Oscar, and Novak), Iranian hybrids (Shams, Barzegar, and Farrokh) and two hybrids from Turkey (08TR003 and Meteor). As shown in Figure 3 except Dukat, the hybrids with different achene yield and maturity groups accumulated in left hand of the plot. This is in accordance with Cvejić et al. (2019) who reported that hybrid maturity does not affect either productivity or stability. The hybrid Dukat due to the higher achene yield in Miandob (3693 kg/ha) but lower in other locations (2523, 1397, and 2579 kg/ha in Sari, Dezful, and Karaj respectively), had higher CV (Figure 3) and expressed instable for achene yield over the test locations. However early maturity is one of the benefits of this hybrid, which compensate relative lower achene yield and allows for summer cultivation in temperate regions of Iran. All other hybrids had a lower CV and were differentiated by based on achene yield among them Fantziya was distinguished with the highest achene yield and desired CV followed by Shams and Oscar. Despite having a low CV, three hybrids (Hispalis, Ghasem, and Acsun) were placed in undesirable part of the chart due to the lower achene yield than average.

The polygon view of the GGE-biplot based on which-won-where template identifies the best genotype(s) for the regions of the study (Yan and Hunt 2002). The polygon is formed by connecting the markers of the genotypes that are furthest away from the biplot origin such that all other genotypes are contained in the polygon. According to this analysis the hybrid Fantazyia had the highest achene yield in Sari and Karaj and Barzegar in Dezful. No specific hybrid determined for Miandoab although three high yield hybrids Shams, Fantziya, and Saltki were adjutant to this micro-environment. Dukat, Hispalis, and Cartago had the lowest achene yield in all regions (Figure 4). Ranking the hybrids based on achene yield and stability differentiated Oscar and Fantazya as the closest hybrids to imaginary ideal genotype followed by Iranian hybrids Shams and Barzegar and a hybrid from Turkey, which denotes to the higher achene yield and lower Genotype-by-Environment (GE) interaction effect. Stability concept defined as higher yield and

Table 4: Achene yield of exotic hybrids over two years (2017–2018) in four regions of Iran.

No.	Hybrid	Sari	Rank	Dezful	Rank	Karaj	Rank	Miandob	Rank	Mean	Rank
1	08TR003	2839	4	2582	11	3008	5	2973	8	2850	7
2	Acsun	2330	12	2937	6	2814	10	2274	13	2589	12
3	Oscar	2723	5	3226	3	3138	1	3263	6	3087	3
4	Fantaziya	2893	2	3164	4	3050	3	4038	2	3286	1
5	Novak	2703	7	2713	10	2847	7	3309	5	2893	6
6	Meteor	2239	13	2714	9	3017	4	3228	7	2799	8
7	Cartago	2640	8	3234	2	2607	12	2325	12	2702	10
8	Dukat	2523	10	1397	14	2579	13	3693	4	2548	13
9	Hispalis	2391	11	2470	12	2424	14	2200	14	2371	14
10	Slatki	2853	3	2425	13	2822	9	3895	3	2999	4
11	Farrokh	2709	6	2833	8	2672	11	2900	9	2779	9
12	Ghasem	2120	14	2983	5	2840	8	2763	10	2676	11
13	Barzegar	3080	1	3409	1	2854	6	2588	11	2983	5
14	Shams	2535	9	2873	7	3081	2	4093	1	3145	2
LSD 5%		393		906		347		1050		446	
LSD1%		548		1264		484		1464		589	

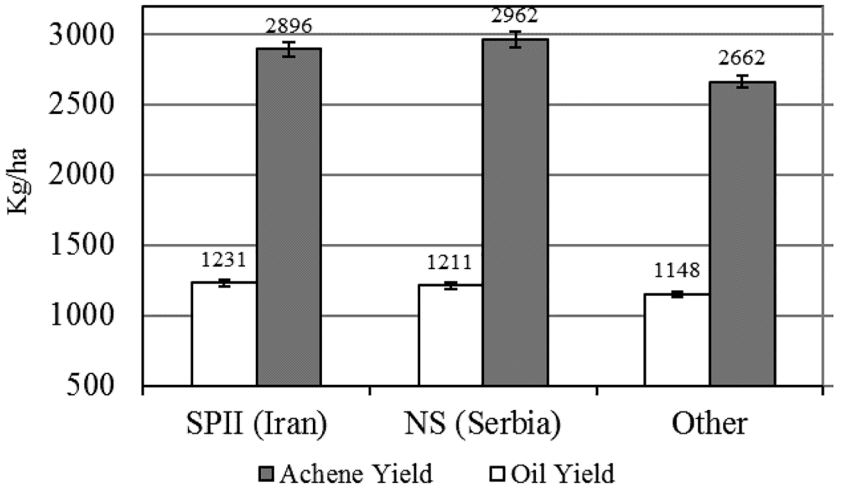

Figure 2: Orthogonal comparison of three groups of the sunflower hybrids for achene and oil yield in different regions of Iran. Grey and white columns represent achene and oil yield respectively. Bars represent ± standard error of the mean for each group.

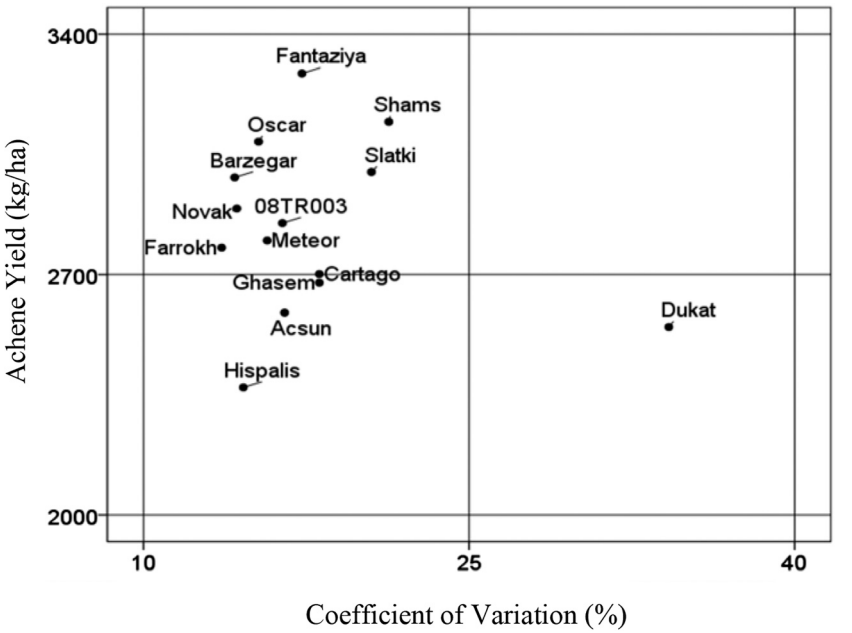

Figure 3: Coefficient of variation for achene yield of sunflower hybrids over the environment.

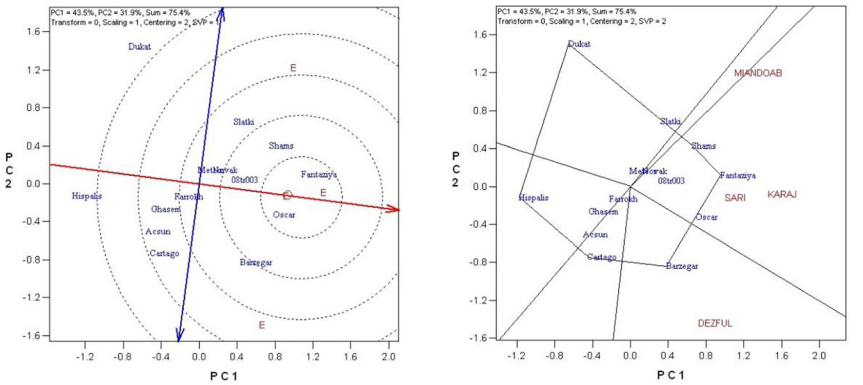

Figure 4: Polygon view of the GGE-biplot showing which-won-where (right) and discrimination of sunflower hybrids based on achene yield and stability compared with ideal genotype using GGE-biplot analysis (left).

stability over test environments as the main challenge and objective of plant breeders (Kang 2002). The imaginary ideal genotype with higher yield and most stability is fixed in the center of concentric circles in Figure 4. In this diagram, the hybrids Oscar and Fantazyia having smaller distance from ideal genotype were discriminated as the higher yielding stable hybrids over the four locations of the study. Projection of the ideal genotype on the vertical axis of diagram is zero which means its absolute stability. In other hand projection of this genotype on the horizontal axis is equal to the longest vector of all genotypes which denote to the higher yield of this genotype (Yan and Kang 2002).

Conclusions

According to the results of this the following results were obtained; In Sari a temperate and humid region in northern of Iran the hybrids Barzegar, Fantaziya, and Slatki had the highest achene yield (3080, 2893, and 2853 kg/ha respectively). The hybrids Barzegar, Cartago, and Oscar (3234, 3409, and 3226 kg/ha respectively) had the highest achene yield in Dezful as a warm region in south west of Iran. In Karaj as a temperate region, the hybrids Oscar, Shams, and Fantaziya (3138, 3081, and 3050 kg/ha respectively) were in the first rank and in Miandob as a cold region, the hybrids Shams, Fantaziya, and Slatki had the highest achene yield (4093, 4038, and 3895 kg/ha respectively). In comparison of overall means in two years and four locations the hybrids

Fantaziya, Shams, and Oskar had the highest achene yield (3286, 3145, and 3087 kg/ha respectively), regarding that Fantaziya had the highest oil yield (1396 kg/ha) followed by Barzegar and Shams. Considering phenotypic variability among the exotic hybrids Fantaziya, Oskar, Slatki, Novak, 08TR003, and Meteor having lowest CV and the highest achene yield considered as the higher yielding hybrids with higher stability over the four locations. According to the GGE-biplot analysis, the hybrid Fantazyia had the highest achene yield in Sari and Karaj and Barzegar in Dezful. No specific hybrid was determined for Miandoab**.** The hybrids Oscar and Fantazyia having smaller distance from ideal genotype were discriminated as the higher yielding stable hybrids over the four locations of Iran.

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