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EVALUATION OF SUNFLOWER GRAIN YIELD COMPONENTS UNDER DIFFERENT LEVELS OF SOIL WATER STRESS IN AZERBAIJAN

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In order to study yield and yield components of sunflower landraces under water deficit conditions, an experiment was conducted in the experimental field of Agricultural Research Center, West-Azerbaijan in 2012-2013 cropping seasons. The selected genotypes were evaluated in a rectangular 7 × 8 lattice design with two replications. They were treated by three irrigation scenarios including optimum irrigation, moderate stress and severe stress where irrigation was done after depletion of 50%, 70% and 90% of available water, respectively. A number of 56 confectionary sunflower landraces were investigated in this experiment. The results of combined analyzes showed that the single and combined effect of water treatments and genotypes on the majority of traits under study were significant. With increasing the severity of drought stress, grain yield, kernel to grain ratio, number of seeds per head, head diameter, 1000-seed's weight, biological yield and harvest index decreased while the hollowness percentage increased. Among the studied landraces, the highest grain yield was obtained from 'Angane 4' in optimum irrigation condition whereas in moderate and severe stress, 'Garagoz 1' and 'Salmas-Sadaghian' produced higher grain yield than the other landraces, respectively. At each level of irrigation, genotypes had different responses so that the suitable genotypes could be chosen for different conditions.

Key words: grain yield, genotype sunflower, water treatments

INTRODUCTION

Sunflower (*Helianthus annuus* L.) is one of the most important oil seed crops in the world due to its high content of unsaturated fatty acids and a lack of cholesterol (ONEMLI and GUCER, 2010). Both oily and confectionary sunflowers belong to Asteraceae (PUT, 1978). Due to the specific structures of its main organs (root, leaves, stem, head), sunflower can be successfully grown on marginal soils and in semi-arid conditions while being more resistant to abiotic stresses

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than other field crops (KIANI *et al*., 2007; SKORIC, 2009). Drought stress is one of the most important and widespread environmental stresses which limits the growth of agricultural products and decreases the production efficiency in semi-arid and rain-fed regions. Growing the drought-tolerant genotypes will contribute to more stable sunflower production. Furthermore, the screening of the response of sunflower cultivars or breeding lines to drought stress can play a crucial role in breeding programs (ONEMLI and GUCER, 2010). It is believed that in order to increase the efficiency of breeding adaptive cultivars, the traits which are effective in increasing grain yield under water deficit conditions should be identified and used as selection criteria along with the grain yield (FARAHVASH *et al*., 2011). Water deficit reduces crop yield regardless of the growth stage at which it occurs in field crops including sunflower (HUSSAIN, 2010). TABATABAEI *et al*. (2012) showed that drought stress significantly affects seed yield, yield components and qualitative traits in sunflower. SOLEIMANZADEH *et al*., (2010) reported that head diameter, number of seeds per head, 1000-grain weight, biological and seed yield as well as harvest index of sunflower declines under drought stress. It has also been reported that harvest index decreases with increasing water stress (SORIANO et al., 2004). According to MEHRPOUYAN *et al*., (2010) the lowest amount of all yield components was obtained by irrigation stop at 6-8-leaf stage. JABARI *et al*., (2007) demonstrated that with drought stress, seed yield decreases about 83 percent due to a reduction in 1000-seed weight and number of seeds per head. According to ALAHDADI *et al*., (2011) water stress decreased seed yield and yield components in all the studied sunflower hybrids. MIRSHEKARI *et al*. (2012) declared that the limited irrigation stress results in a reduction of seed yield due to limiting vegetative and reproductive development periods. The response of confectionary sunflower cultivars to water limitation has not properly been investigated. Therefore, the aim of present study was to determine the effect of drought stress on grain yield and yield components in 56 landraces of sunflower in Urmia climate condition.

MATERIALS AND METHODS

This experiment was carried out in the experimental field of Agricultural Research Center at West-Azerbaijan in 2012-2013 cropping seasons. The 56 confectionary sunflower accessions were evaluated in a rectangular 7 × 8 lattice design with two replications. Three irrigation treatments including optimum irrigation, moderate stress and severe stress were considered for which the irrigation was done after depletion of 50%, 70% and 90% of available water, respectively. The latitude and longitude of region is 37 ^{o} and 44′ north and 45^{o} and 2′ east its elevation is 1352 m above the sea level. Climate of the region is cold and semidry and the average rainfall and the area temperature according to 16 years statistics are 184 mm and 12^{o}C, respectively. Each plot comprised 4 lines with 5 m longs, with a spacing of 60 × 25 cm between lines and plants, respectively. The distance between irrigation treatments was considered 6 m. Sunflowers cultivated under conventional tillage at date of 1-5 may 2012. Soil texture was silty clay loam with the electrical conductivity (EC) of 0.8 DS m^{-1}, the soil acidity (pH) of 8 and the soil apparent specific weight of 1.4 g cm^{-1} (Table 1). Amount of irrigation were applied identical for all treatments from planting to complete establishment of sunflower plants (eight-leaf stage (V8)). After this stage, the plots were irrigated according to their prescribe treatments below (POURTAGHI *et al*., 2011). In order to measure the moisture, soil samples were taken from 2 depths of soil, 0-30 and 30-60 cm. Then, moisture weight percentage was determined by pressure plate (armfield CAT.REF: FEL13B-1 Serial Number: 6353 A 24S98). The field capacity of soil was determined to be 26 with permanent wilting point of 14. In order to obtain the exact irrigation time, soil was sampled by auger from root development depth 48 hours after each irrigation treatment and its moisture was measured. Based on the measurement, the irrigation time was determined to be at soil weight moisture of 20, 17.6 and 15.2. To implement the irrigation operation the water usage volume calculated by the following equation 1:

$$V = \frac{(fc - \theta m) \times \rho \times Droot \times A}{Ei}$$

Where: V= irrigation water volume (m^3), Θm = Soil moisture content before irrigation
A= irrigated area (m^2), FC= field capacity, ρm = soil external specific density (g/cm^3), Droot= root development depth (m)
Therefore the required water volume in each stage of irrigation was calculated and distributed equally based on the water distribution efficiency of 90 percent by flume and chronometer. The final harvesting area was equal to 3.6 m^2 taken from two middle planting lines. Final measurements performed from these samples. The yield components including the number of grains per head and 1000-grain weight were calculated. For calculating kernel to grain ratio, 10 grams of seeds from each treatment were weighed before and after the separation of kernels. Then kernel to grain ratio was calculated by equation 2:

$$Kernels\ to\ grains = \frac{W_1}{10} \times 100$$

Where: W_1= kernels weight. Hollowness percentage was calculated by equation 3:

$$HP = \frac{W_1}{W_2} \times 100$$

Where: HP= hollowness percent, W_1= weight of hollow grains per head, W_2= weight of total grains per head. Harvest index calculated by equation 4:

$$HI = \frac{Ye}{Yb} \times 100$$

Where: HI= harvest index, Ye= economical yield, Yb= biological yield.
Biological yield was calculated by summing up the dry weight of stem, leaf, head and grains. Head diameter was calculated by ruler from 5 head and then averaged. For calculating weight of 1000 grains, 5 replications of 1000-fold from each treatment were selected and averaged. The final harvesting area was equal to 3 m^2 that was done from two middle lines of planting at date of 5-10 September of 2012. Final measurements were conducted from these samples. For moisture measurement grains were located in the oven in the temperature of 72 degrees centigrade for 48 hours. To normalize some traits such as number of seeds per head, square root conversion (SQRT) technique was used. Analysis of variance performed using PROC GLM in the SAS. The comparison of the means was done by Tukey’s test at a probability level of 5 percent.

Table 1. Chemical and physical properties of farm soil at depth of 0-30 cm

Soil texture	Soil density g cm^{-3}	Electrical conductivity (ds/m)	pH	Percentage of saturation (%)	Lime (%)	Clay (%)	Silt (%)	Sand (%)	Carbon organic (%)	Nitrogen (%)	Phosphor (ppm)	potassium (ppm)
Clay loam	1.4	0.8	8	47	17	35	37	28	1.2	0.12	12	375

Table 2 – Monthly climate data during sunflower growing season

	Month					
Meteorological Parameters	Mars	April	May	June	July	August
Maximum Temperature ^{0}C	16.6	23.3	28.2	30.1	33.1	28.6
Minimum Temperature ^{0}C	3.1	8.3	11.9	15.3	16.2	13.1
Mean Temperature ^{0}C	9.9	15.8	20	22.7	24.6	20.9
Total Rainfall (mm)	31.9	15	18.8	9.2	1.8	8.4
Total Evaporation (mm)	81.9	181.9	255.9	269.3	263.4	200.4
Mean relative humidity (%)	58	56	48	52	46	52

Table 3. Names of local landraces

No.	Names of local landraces	No.	Names of local landraces	No.	Names of local landraces
1	Saghez 1	20	Salmas 2	39	Hamadan 2
2	Angane 4	21	Vaghaslou olya 4	40	Shabestar-Kouzeh Kanan 3
3	Urmia-Barouj	22	Salmas-Gharaghashlagh- Pesteii	41	Saghez 4
4	Urmia-maranghalou	23	Lalalou Torab 2	42	Saghez 5
5	Marand – Dizaj ghalami	24	Shirabad 2	43	Saghez 3
6	Jabalkandi 2	25	Gharagoz 1	44	Shahroud 2
7	Salmas - sadaghian	26	Vaghaslou Sofla 1	45	Alibaglou 1
8	Babajange 6	27	Khanneshan 1	46	Baneh 2
9	Miyaneh-basin	28	Heydarlou 1	47	Salmas-Gharaghashlagh- Ghalami
10	Bokan	29	Saribaglou 5	48	Marand-1389-2
11	Urmia - noshinshahr	30	Chongharalou Yekan 4	49	Salmas-Gharaghashlagh- Badami
12	Karimabad	31	Maranghalou 6	50	Shabestar-Kouzeh Kanan 1
13	Vaghaslou olya 1	32	Abajalou 1	51	Sanandaj
14	Vaghaslou olya 3	33	Hamadan 1	52	Shabestar-Kouzeh Kanan 2
15	Ordoshahi 1	34	Saghez 2	53	Baneh 3
16	Marana-yamchi-pesteii	35	Piranshahr Sarvkani	54	Piranshahr Bolban
17	Mazandaran -Tirtash	36	Piranshahr Andizeh	55	Baneh 1
18	Sardasht	37	Mashhad	56	Marand-1389-1
19	Marana-yamchi 4	38	Shahroud 1		

RESULTS AND DISCUSSION

Grain yield

The results of combined analysis of variance showed that the effects of irrigation, genotype and irrigation-genotype interaction on grain yield are significant (Table 4). The comparison of mean values showed that increasing stress intensity from optimum irrigation to moderate and severe stress decreases grain yield by 25% and 49%, respectively (Table 5, 6 and 7). In optimum irrigation the highest and lowest values of grain yield were related to genotypes: Angane 4 (6310.31 kg ha^{-1}) and Mashhad (807.29 kg ha^{-1}), respectively (Table 5). In moderate stress, these values obtained from genotypes: Gharagoz 1 (3778.83 kg ha^{-1}) and Piranshahr Andizeh (493.39 kg ha^{-1}), respectively (Table 6). Moreover, in severe stress, genotypes: Salmas-Sadaghian (2217.95 kg ha^{-1}) and Mashhad (490.16 kg ha^{-1}) produced the highest and lowest grain yields, respectively (Table 7).

Table 4. Combined analysis of variance for traits of sunflower in different drought stress and Genotypes

S.O.V	df	Grain yield	Kernel to Grain	Hollowness Percent	Seeds Number per Head	Head Diameter	Grain 1000 weight	Biological Yield	Harvest Index
(Environment)	2	46277099.58**	1686.06**	10643.95**	847.76**	577.49**	16178.93*	3208244412 **	160.66**
Replication (Environment)	3	540221.39ns	50.63**	12.55ns	25.57ns	15.78**	996.33ns	14957049ns	8.31ns
Block (Environment × Replication)	42	507269.85	48.98	74.09	8.47	10.82	1229.71	22919165	11.14
(Genotype)	55	1380455.49**	178.35**	180.79**	13.60ns	29.20**	2675.40**	69243330**	23.03**
(Environment × Genotype)	110	298849.20*	14.04**	49.06ns	14.68ns	5.44ns	962.71*	19215458**	9.25ns
(E_e)	123	213565.1	0.92	37.46	11.86	4.27	675.89	10694518	7.65
(%) (C.V.)	-	22.58	2.16	31.56	12.93	11.42	20.31	24.09	17.55

** , * and Ns significant at the 1%, 5% probability levels and non significant respectively

Table 5. Combined mean comparison of genotypes for traits of sunflower in Optimum irrigation

Genotype	Grain yield Kg ha^{-1}	Kernel to Grain (%)	Hollowness Percent (%)	Seeds Number per Head	Head Diameter (cm)	Grain 1000 Weight (gram)	Biological Yield Kg ha^{-1}	Harvest Index
Saghez 1	3241.16 fghi	40.27 defgh	8.29 a	985.87 ab	21.63 abcd	165.25 ab	19137.8 k	16.94 abcde
Angane 4	6310.31 a	47.95 abcdefgh	4.93 a	1590 a	28.34 a	169.37 ab	24787 a	25.46 a
Urmia-Barouj	3356.1 efg	43.97 bcdefgh	12.23 a	1185.39 ab	20.85 abcd	129.53 ab	17679.91 n	18.98 abcde
Urmia-maranghalou	3001.29 ijklmn	57.89 abc	11.83 a	644.35 ab	18.27 cd	149.59 ab	16621.36 q	18.06 abcde
Marand – Dizaj ghalami	3055.14 ijkl	39.59 efgh	18.96 a	645.3 ab	19.62 abcd	192.24 a	13249.04 x	23.06 abcde
Jabalkandi 2	2694.85 pqr	53.75 abcdef	15.41 a	748.92 ab	16.49 d	145.39 ab	12369.78 y	21.79 abcde
Salmas - sadaghian	3177.57 ghij	52.12 abcdef	13.64 a	1414.75 ab	21.31 abcd	123.09 ab	22171.77 f	14.33 abcde
Babajange 6	3505.71 cde	49.81 abcdefgh	16.25 a	1064.63 ab	22.27 abcd	127.43 ab	24396.26 b	14.37 abcde
Miyaneh-basin	1222.01 z	47.78 abcdefgh	13.80 a	577.31 b	15.89 d	121.29 ab	6452.78 z	18.94 abcde
Bokan	2103.41 wxy	55.10 abcde	10.31 a	1312.62 ab	23.30 abcd	122.23 ab	15026.76 t	14.00 abcde
Urmia - noshinshahr	3012.69 ijklm	46.02 abcdefgh	8.51 a	625.43 ab	20.57 abcd	180.85 a	24271 bc	12.41 cde
Karimabad	3727.6 c	45.72 bcdefgh	4.84 a	1145.93 ab	22.21 abcd	183.68 a	23070.55 d	16.16 abcde
Vaghaslou olya 1	2767.66 nopq	47.28 abcdefgh	15.74 a	747.85 ab	18.69 cd	160.95 ab	18542.64 l	14.93 abcde
Vaghaslou olya 3	3500.63 cde	47.45 abcdefgh	7.41 a	805.08 ab	19.75 abcd	145.46 ab	19359.88 j	18.08 abcde
Ordoshahi 1	2853.15 lmnop	44.14 bcdefgh	13.21 a	799.44 ab	17.82 d	103.15 ab	14605.62 u	19.53 abcde
Marana-yamchi-pesteii	2802.66 mnopq	47.13 abcdefgh	6.43 a	594.56 b	16.89 d	83.91 ab	15029.26 t	18.65 abcde
Mazandaran -Tirtash	1674.6 z	39.28 efgh	4.07 a	814.13 ab	16.96 d	144.19 ab	13575.87 w	12.34 cde
Sardasht	2356.28 tuv	56.95 abc	9.72 a	595.59 b	16.73 d	136.53 ab	13281.32 x	17.74 abcde
Marana-yamchi 4	1783.79 z	49.45 abcdefgh	18.80 a	1038.69 ab	19.07 bcd	107.10 ab	11549.65 z	15.44 abcde
Salmas 2	3037.05 ijklm	58.41 ab	9.75 a	898.51 ab	17.25 d	138.67 ab	18222.44 m	16.67 abcde
Vaghaslou olya 4	3055.31 klmno	44.03 bcdefgh	17.42 a	873.44 ab	20.46 abcd	162.55 ab	25361.48 b	12.05 de
Salmas-Gharaghashlagh-Pesteii	2691.58 pqr	50.30 abcdefg	10.12 a	784.67 ab	19.82 abcd	144.69 ab	10884.46 z	24.73 ab
Lalalou Torab 2	3418.23 def	45.39 bcdefgh	9.03 a	975.25 ab	21.34 abcd	166.85 ab	20592.76 h	16.60 abcde
Shirabad 2	2591.88 qrst	41.77 cdefgh	14.27 a	1024.75 ab	18.54 cd	150.33 ab	14287.48 v	18.14 abcde
Gharagoz 1	3527.86 cde	44.62 bcdefgh	7.93 a	1201 ab	27.22 abc	195.50 a	24135.32 c	14.62 abcde
Vaghaslou Sofla 1	3635.87 cd	47.82 abcdefgh	6.41 a	818.67 ab	28.02 ab	115.78 ab	17091.65 p	21.27 abcde
Khanneshan 1	3038.18 ijklm	49.32 abcdefgh	7.70 a	1017.89 ab	18.24 cd	141.18 ab	19201.49 jk	15.82 abcde
Heydarlou 1	3103.74 hijk	42.54 bcdefgh	8.53 a	861.72 ab	18.66 cd	136.20 ab	14563.82 u	21.31 abcde
Saribaglou 5	3104.84 hijk	44.55 bcdefgh	13.16 a	977 ab	24.55 abcd	135.01 ab	20619.33 h	15.06 abcde
Chongharalou Yekan 4	2242.85 vwx	55.24 abcde	10.03 a	926.4 ab	18.76 cd	110.68 ab	14117.48 v	15.89 abcde
Maranghalou 6	2961.75 jklmno	48.12 abcdefgh	9.06 a	1100 ab	28.57 a	150.12 ab	20427.45 h	14.50 abcde
Abajalou 1	3505.04 cde	48.34 abcdefgh	11.92 a	956 ab	24.33 abcd	154.25 ab	23060.33 d	15.20 abcde
Hamadan 1	3513.83 cde	35.06 gh	10.80 a	895.83 ab	22.79 abcd	131.16 ab	22816.22 e	15.40 abcde
Saghez 2	2523.74 rstu	44.82 bcdefgh	2.85 a	767.05 ab	21.87 abcd	179.47 ab	18324.66 m	13.77 abcde
Piranshahr Sarvkani	1529.61 z	56.19 abcd	11.07 a	639.23 ab	18.33 cd	99.95 ab	11236.29 z	13.61 abcde

Piranshahr Andizeh	1222.54 z	47.05 abcdefgh	14.00 a	795.25 ab	15.93 d	124.92 ab	4981 z	24.54 ab
Mashhad	807.29 z	62.24 a	3.37 a	519 b	16.80 d	87.83 ab	3874 z	20.84 abcde
Shahroud 1	1700.84 z	45.72 bcdefgh	9.70 a	812.62 ab	16.50 d	86.60 ab	6933 z	24.53 ab
Hamadan 2	2072.38 xy	56.04 abcd	7.56 a	1051.94 ab	17.92 d	116.46 ab	11672.91 z	17.75 abcde
Shabestar-Kouzeh Kanan 3	1425.82 z	51.66 abcdef	16.56 a	563.4 b	18.44 cd	43.90 b	6304.62 z	22.62 abcde
Saghez 4	1458.13 z	46.17 abcdefgh	6.19 a	792 ab	16.06 d	141.29 ab	8455.29 z	17.25 abcde
Saghez 5	3036.85 ijklm	48.24 abcdefgh	4.36 a	895.6 ab	20.57 abcd	175.33 ab	21401.28 g	14.19 abcde
Saghez 3	2381.37 tuv	46.16 abcdefgh	11.56 a	1131.7 ab	16.45 d	121.27 ab	9529.3 z	24.99 ab
Shahroud 2	1942.98 yz	38.10 fgh	11.18 a	959.18 ab	17.42 d	84.90 ab	14660.62 u	13.25 bcde
Alibaglou 1	2332.27 uvw	45.68 bcdefgh	24.51 a	570.68 b	21.52 abcd	114.21 ab	9422 z	24.75 ab
Baneh 2	3241.16 fghi	40.27 abcdefgh	12.57 a	668.69 ab	20.24 abcd	131.85 ab	15812.48 r	20.50 abcde
Salmas-Gharaghashlagh-Ghalami	4283.31 b	47.95 abcdefgh	1.77 a	753.5 ab	22.35 abcd	184.15 a	25458.08 bc	16.82 abcde
Marand-1389-2	3356.1 efg	43.97 abcdefgh	4.75 a	849.95 ab	23.20 abcd	165.54 ab	14856.92 t	22.59 abcde
Salmas-Gharaghashlagh-Badami	3341.03 efgh	33.74 h	6.67 a	686.65 ab	19.09 bcd	180.84 ab	21453.74 g	15.57 abcde
Shabestar-Kouzeh Kanan 1	2389.97 stuv	47.88 abcdefgh	13.15 a	1122.32 ab	21.31 abcd	105.11 ab	9868 z	24.22 abc
Sanandaj	2757.08 opqr	57.26 abc	10.87 a	1160.5 ab	21.82 abcd	127.08 ab	15593.83 s	17.68 abcde
Shabestar-Kouzeh Kanan 2	2030.62 xy	53.15 abcdef	14.40 a	861.34 ab	23.98 abcd	128.90 ab	17353.95 o	11.70 e
Baneh 3	2624.02 pqrs	53.92 abcdef	18.71 a	609.66 b	20.04 abcd	162.76 ab	12049.93 z	21.78 abcde
Piranshahr Bolban	1759.35 z	51.69 abcdef	16.56 a	701.82 ab	17.01 d	97.82 ab	7291.04 z	24.13 abcd
Baneh 1	3141.86 ghijk	47.19 abcdefgh	9.74 a	933.22 ab	24.50 abcd	195.62 a	20187.87 i	15.56 abcde
Marand-1389-1	3307.52 efgh	55.09 abcde	9.34 a	1127.34 ab	21.08 abcd	160.68 ab	18559.56 l	17.82 abcde

Means followed by similar letters in each column are not significantly different at the 5% level of probability according to Tukey's Test.

Evaluation of simple correlation coefficients displayed a positive and meaningful correlation between 1000-grain weight, head diameter, seeds number per head and biological yield with grain yield in all irrigation conditions (Table 8, 9 and 10). These results were in agreement with SAFAVI *et al.* (2011). FARAHVASH *et al.* (2011) showed that with increasing water stress, seed yield ha^{-1}, above-ground dry weight of plant, stem diameter, head diameter, number of seeds per head, 100 seeds weight, harvest index and number of photo synthetically-active leaves decrease. NEZAMI *et al.* (2008) concluded that grain yield under dry and semi-dry conditions declines. ELENA and PAULA (2010) also demonstrated that drought stress reduces grain yield. ESMAEILIAN *et al.* (2012) revealed that seed yield decreases significantly due to water stress when imposed at either of the growth stages. In general, drought stress limits physiological activities of plants, cell division, leaf areal index, stem extension and vegetative growth. This results in a reduction in seed yield (REZAEI–SUKHT ABNADANI *et al.*, 2008). ORAKI *et al.* (2012) and FARAHVASH *et al.* (2011) reported a large genetic variation for grain yield in well watered and water stress conditions.

Table 6. Combined mean comparison of genotypes for traits of sunflower in moderate drought stress

Genotype	Grain yield Kg ha^{-1}	Kernel t Grain (%)	hollowness Percent (%)	Seeds Number per Head	Head Diameter (cm)	Grain 1000 Weight (gram)	Biological Yield Kg ha^{-1}	Harvest Index
Saghez 1	2169.72 hijk	39.09 bcdefgh	16.95 abc	693.66 ab	19.10 abcdef	169.74 ab	12885.78 q	16.07 a
Angane 4	1807.79 nopqr	45.53 abcdefg	22.98 abc	614.08 ab	16.84 cdef	100 ab	13201.07 p	13.32 a
Urmia-Barouj	1883.44 lmnopq	42.34 abcdefgh	17.84 abc	746.98 ab	18.51 cdef	114.29 ab	11700.07 t	15.93 a
Urmia-maranghalou	1615.43 rstu	53.94 abc	20.19 abc	484.46 ab	16.28 cdef	146.52 ab	10441.49 z	15.17 a
Marand – Dizaj ghalami	1917.77 lmnop	38.58 cdefgh	26.46 abc	450.63 ab	15.63 def	85 ab	10145.33 z	20.61 a
Jabalkandi 2	2085.56 ijkl	50.28 abcde	24.93 abc	610.78 ab	16.66 cdef	130.62 ab	12868.97 q	16.46 a
Salmas - sadaghian	2211.75 hij	43.64 abcdefg	22.86 abc	619.27 ab	17.82 cdef	99.73 ab	15021.07 l	15.55 a
Babajange 6	2048.18 jklm	46.63 abcdefg	26.17 abc	789.66 ab	16.80 cdef	116.21 ab	11157.82 vw	18.39 a
Miyaneh-basin	1273.47 wx	44.27 abcdefg	20.75 abc	519.55 ab	13.99 ef	123.08 ab	6537.70 z	18.38 a
Bokan	973.88 y	49.89 abcde	18.91 abc	717.79 ab	14.66 ef	91.99 ab	4660.45 z	18.80 a
Urmia - noshinshahr	2482.86 fg	43.38 abcdefg	16.21 abc	669.27 ab	18.48 cdef	143.18 ab	14139.87 o	16.96 a
Karimabad	3611.45 a	41.63 bcdefgh	6.83 bc	914.79 ab	22.68 abcde	180.86 ab	23090.46 a	15.27 a
Vaghaslou olya 1	1328.74 vwx	44.12 abcdefg	22.66 abc	383.24 b	16.11 cdef	132.84 ab	10058.10 z	14.08 a
Vaghaslou olya 3	2686.43 ef	42.48 abcdefg	15.48 abc	731.33 ab	18.82 bcdef	140.18 ab	18783.20 gh	14.94 a
Ordoshahi 1	2208.24 hij	47.01 abcdefg	20.58 abc	532.07 ab	13.78 ef	122.29 ab	11819.28 t	19.72 a
Marana-yamchi-pesteii	2889.97 de	42.46 abcdefg	13.33 abc	699.57 ab	18.43 cdef	138.32 ab	18636.36 h	15.32 a
Mazandaran -Tirtash	1832.44 mnopqr	38.42 cdefgh	5.12 bc	826.84 ab	17.64 cdef	128.04 ab	12424.41 r	14.37 a
Sardasht	1816.67 mnopqr	55.36 ab	23.07 abc	516.33 ab	13.96 ef	111.85 ab	11416.58 u	16.23 a
Marana-yamchi 4	1299.26 vwx	46.01 abcdefg	29.19 ab	535.85 ab	16.41 cdef	110.4 ab	10911.17 xy	12.53 a
Salmas 2	2367.56 gh	55.40 ab	18.21 abc	924.29 ab	16.69 cdef	127.42 ab	14439.31 n	16.68 a
Vaghaslou olya 4	1927.74 lmnop	25.96 h	22.68 abc	655.14 ab	16.45 cdef	87.07 ab	14172.91 o	14.04 a
Salmas-Gharaghashlagh-Pesteii	2371.90 gh	47.59 abcdefg	15.85 abc	623.23 ab	21.83 abcde	141.59 ab	12844.03 q	18.32 a
Lalalou Torab 2	2002.13 jklmno	44.49 abcdefg	18.71 abc	756.68 ab	18.53 cdef	146.55 ab	11231.61 uvw	17.12 a
Shirabad 2	2026.19 jklmno	32.33 fgh	23.78 abc	586.41 ab	19.27 abcdef	147.59 ab	12920.91 q	14.82 a
Gharagoz 1	3778.83 a	41.94 abcdefgh	9.14 abc	1140.79 ab	27.60 ab	205 a	18826.33 gh	20.42 a
Vaghaslou Sofla 1	2965.42 cd	35.59 efgh	10.56 abc	688.65 ab	24.16 abcd	192.12 ab	18937.92 g	15.02 a
Khanneshan 1	2467.21 fg	49.28 abcde	16.29 abc	888.75 ab	19.89 abcdef	141.86 ab	20109.56 d	11.52 a
Heydarlou 1	2908.40 cde	35.45 efgh	16.11 abc	763.20 ab	18.64 bcdef	145.95 ab	17122.16 i	17.13 a
Saribaglou 5	2853.26 de	40.34 bcdefgh	22.96 abc	628.33 ab	22.43 abcde	122.14 ab	19379.32 f	14.73 a
Chongharalou Yekan	2344.98 gh	50.55 abcde	17.46 abc	1030.43 ab	18.93 abcdef	112.91 ab	16071.41 k	14.07 a

4								
Maranghalou 6	3146.80 bc	44.18 abcdefg	20.58 abc	825.46 ab	27.91 a	184.89 ab	21198.45 b	14.60 a
Abajalou 1	3596.70 a	43.50 abcdefg	16.75 abc	799.05 ab	24.94 abc	195.11 ab	19360.20 f	19.66 a
Hamadan 1	3033.53 bcd	34.69 efgh	14.92 abc	956.91 ab	24.46 abcd	188 ab	19680.96 e	14.84 a
Saghez 2	1799.07 opqr	40.43 bcdefgh	10.09 abc	495.15 ab	18.38 cdef	111.2 ab	11066.85 wx	17.36 a
Piranshahr Sarvkani	1439.76 tuvw	50.60 abcde	15.56 abc	671.30 ab	15.94 cdef	134.98 ab	13271.46 p	11.31 a
Piranshahr Andizeh	493.39 z	38.07 cdefgh	18.71 abc	477.50 ab	11.77 f	86.64 ab	3433.45 z	14.64 a
Mashhad	515.86 z	58.07 a	1.41 c	428.60 ab	15.12 ef	91.58 ab	1239.29 z	21.88 a
Shahroud 1	1315.93 vwx	36.71 defgh	15.43 abc	784.03 ab	14.31 ef	68.2 b	6999.08 z	17.02 a
Hamadan 2	1285.08 vwx	52.57 abcd	10.75 abc	815.57 ab	20.33 abcdef	117.61 ab	7461.58 z	16.31 a
Shabestar-Kouzeh Kanan 3	1324.07 vwx	48.32 abcdef	17.50 abc	487.76 ab	16.99 cdef	108.22 ab	6681.01 z	18.00 a
Saghez 4	1177.20 xy	45.06 abcdefg	12.39 abc	678.32 ab	14.98 ef	171.7 ab	9096.48 z	15.05 a
Saghez 5	1645.39 qrst	45.62 abcdefg	1.61 c	648.52 ab	14.28 ef	107.53 ab	14754.59 m	12.26 a
Saghez 3	2183.06 hijk	42.66 abcdefg	13.16 abc	1034.52 ab	16.04 cdef	148.39 ab	10895.22 xy	19.59 a
Shahroud 2	1502.04 stuvw	36.66 defgh	13.01 abc	921.97 ab	17.69 cdef	75.29 ab	12023.56 s	12.10 a
Alibaglou 1	1948.10 klmnop	42.10 abcdefgh	35.83 a	447.00 ab	16.73 cdef	98.29 ab	9185.35 z	19.42 a
Baneh 2	2009.26 jklmno	41.02 bcdefgh	17.05 abc	567.24 ab	18.60 bcdef	152.83 ab	10169.35 z	18.90 a
Salmas-Gharaghashlagh-Ghalami	1987.24 jklmno	45.01 abcdefg	12.40 abc	436.73 ab	17.57 cdef	123.15 ab	11777.77 t	16.95 a
Marand-1389-2	1721.08 pqrs	45.76 abcdefg	10.62 abc	694.25 ab	19.23 abcdef	128.89 ab	11759.11 t	16.62 a
Salmas-Gharaghashlagh-Badami	2949.06 cd	31.61 gh	10.66 abc	575.39 ab	17.76 cdef	178.07 ab	20522.35 c	14.91 a
Shabestar-Kouzeh Kanan 1	2305.50 ghi	45.52 abcdefg	19.96 abc	1176.35 ab	21.43 abcde	152.06 ab	11300.74 uv	20.32 a
Sanandaj	2045.97 jklmn	53.42 abc	14.17 abc	1198.81 a	19.08 abcdef	130.2 ab	10767.08 y	18.23 a
Shabestar-Kouzeh Kanan 2	1403.79 uvwx	49.46 abcde	17.59 abc	886.19 ab	17.66 cdef	125.21 ab	9510.12 z	13.29 a
Baneh 3	1979.44 jklmno	49.08 abcde	30.96 ab	789.73 ab	19.14 abcdef	111.49 ab	11067.62 wx	17.08 a
Piranshahr Bolban	1522.93 stuv	48.57 abcdef	22.86 abc	889.86 ab	18.45 cdef	116.81 ab	7955.54 z	18.07 a
Baneh 1	1902.77 lmnop	40.52 bcdefgh	17.68 abc	866.08 ab	18.96 abcdef	184.95 ab	16465.88 j	11.55 a
Marand-1389-1	3228.56 b	52.31 abcd	11.60 abc	1090.18 ab	21.48 abcde	197.4 ab	18758.02 gh	17.66 a

Means followed by similar letters in each column are not significantly different at the 5% level of probability according to Tukey's Test.

Table 7. Combined mean comparison of genotypes for traits of sunflower in severe drought stress

Genotype	Grain yield Kg ha^{-1}	Kernel to Grain (%)	hollowness Percent (%)	Seeds Number per Head	Head Diameter (cm)	Grain 1000 Weight (gram)	Biological Yield Kg ha^{-1}	Harvest Index
Saghez 1	1272.33 opqrstuvwx	36.94 cdefg	31.36 abcdef	577.69 ab	17.58 abcd	116.84 ab	9154.97 t	13.90 abc
Angane 4	1461.19 klmnopq	44.66 abcdef	28.82 abcdef	654.61 a	18.37 abcd	127.24 ab	12247.2 e	11.93 bc
Urmia-Barouj	1575.41 ghijklm	39.47 abcdefg	36.23 abcde	701.9 a	18.68 abcd	133.69 ab	11584.79 g	13.60 bc
Urmia-maranghalou	1170.91 tuvwxyz	45.00 abcdef	20.98 cdef	468.7 ab	14.82 bcd	132.11 ab	7864.54 yz	14.89 abc
Marand – Dizaj ghalami	2065.43 ab	34.31 cdefg	36.73 abcde	454.38 ab	13.67 bcd	98.69 ab	9943.4 pq	20.77 ab
Jabalkandi 2	1415.56 lmnopqrs	48.82 abcd	36.96 abcde	667.26 a	16.41 bcd	94.22 ab	12656.63 d	11.18 bc
Salmas - sadaghian	2217.95 a	40.49 abcdefg	40.91 abcd	615.34 a	20.02 ab	135.87 ab	15385.93 b	14.42 abc
Babajange 6	1002.17 yz	44.24 abcdefg	41.54 abcd	560.81 ab	12.62 bcd	93.12 ab	6653.72 z	15.06 abc
Miyaneh-basin	1462.42 klmnop	42.55 abcdefg	44.71 abc	564.98 ab	15.34 bcd	125.96 ab	9683.92 rs	15.10 abc
Bokan	769.14 z	47.56 abcde	44.72 abc	448 ab	13.51 bcd	109.27 ab	5480.51 z	14.03 abc
Urmia - noshinshahr	1783.14 defgh	41.14 abcdefg	29.07 abcdef	652.71 a	16.10 bcd	126.86 ab	11790.26 f	15.12 abc
Karimabad	1982.66 abcd	39.55 abcdefg	26.12 abcdef	647.84 a	17.45 abcd	146.06 ab	12496.61 d	15.87 abc
Vaghaslou olya 1	1439.29 lmnopqr	28.01 gh	24.55 bcdef	441.58 ab	15.93 bcd	87.28 ab	8014.35 xy	17.96 abc
Vaghaslou olya 3	1453.18 lmnopqr	40.48 abcdefg	25.85 bcdef	569.21 ab	13.34 bcd	126.85 ab	8165.15 wx	17.80 abc
Ordoshahi 1	1611.69 fghijkl	45.23 abcdef	44.45 abc	441.38 ab	12.03 bcd	143.98 ab	9858.61 pqr	16.35 abc
Marana-yamchi-pesteii	1434.58 lmnopqr	41.62 abcdefg	12.56 ef	607.43 a	13.77 bcd	115.58 ab	8382.58 v	17.11 abc
Mazandaran -Tirtash	996.16 yz	37.25 bcdefg	6.58 f	708.63 a	15.77 bcd	136.58 ab	9781.91 qr	10.18 bc
Sardasht	1500.16 ijklmno	51.98 ab	23.28 bcdef	501.43 ab	11.86 bcd	145.40 ab	9984.66 op	15.02 abc
Marana-yamchi 4	1177.18 stuvwxyz	43.74 abcdefg	27.28 abcdef	555.91 ab	14.16 bcd	121.48 ab	9022.01 t	13.05 bc
Salmas 2	965.81 z	47.40 abcde	35.76 abcde	555.65 ab	12.45 bcd	98.05 ab	6435.74 z	15.01 abc
Vaghaslou olya 4	1693.70 efghijk	14.87 h	33.76 abcde	438.93 ab	13.36 bcd	114.14 ab	10169.55 no	16.65 abc
Salmas-Gharaghashlagh-Pesteii	1901.66 bcde	34.21 cdefg	17.08 def	539.38 ab	19.36 abc	100.80 ab	11126.46 i	17.09 abc
Lalalou Torab 2	1056.05 xyz	41.91 abcdefg	24.39 bcdef	680.18 a	15.94 bcd	94.28 ab	8155.93 wx	12.95 bc
Shirabad 2	1588.41 ghijklm	30.62 fgh	33.60 abcde	590.7 ab	17.88 abc	135.69 ab	10815.16 j	14.69 abc
Gharagoz 1	1746.63 defgh	40.11 abcdefg	29.36 abcdef	759.08 a	18.29 abc	128.28 ab	11467.5 gh	15.23 abc
Vaghaslou Sofla 1	1471.15 jklmnop	33.87 cdefg	16.01 def	685.96 a	18.69 abc	113.82 ab	9553.85 s	15.40 abc
Khanneshan 1	1703.78 efghij	45.28 abcdef	22.94 bcdef	742.7 a	16.08 bcd	119.82 ab	10282.09 mn	16.57 abc
Heydarlou 1	981.17 z	32.45 defg	49.54 ab	516.78 ab	14.33 bcd	86.57 ab	7730.89 z	12.69 bc
Saribaglou 5	2030.66 abc	38.85 abcdefg	27.17 abcdef	546.27 ab	16.19 bcd	104.27 ab	13936.21 c	14.57 abc
Chongharalou Yekan 4	1567.05 hijklmn	46.04 abcdef	25.08 bcdef	807.07 a	17.12 abcd	119.55 ab	12078.18 e	12.97 bc
Maranghalou 6	1985.41 abcd	38.96 abcdefg	32.25 abcdef	603.29 a	26.11 a	213.08 a	18842.41 a	10.54 bc
Abajalou 1	1115.13 wxyz	41.37 abcdefg	31.31 abcdef	505.17 ab	14.58 bcd	82.03 ab	8766.5 u	12.72 bc
Hamadan 1	1453.90 lmnopqr	33.81 cdefg	13.56 ef	772.86 a	17.37 abcd	115.09 ab	10648.85 jk	13.65 bc
Saghez 2	1807.28 cdefg	37.72 bcdefg	16.98 def	498.59 ab	16.36 bcd	160.54 ab	10001.34 op	18.07 abc
Piranshahr Sarvkani	860.42 z	47.84 abcd	42.08 abcd	504.32 ab	12.86 bcd	98.07 ab	6850.89 z	12.56 bc

Piranshahr Andizeh	497.26 z	35.61 bcdefg	40.73 abcd	456.45 ab	10.59 cd	69.83 b	6151.98 z	8.08 c
Mashhad	490.16 z	55.21 a	20.84 cdef	432.89 ab	14.22 bcd	73.52 b	3169.45 z	15.47 abc
Shahroud 1	1242.51 pqrstuvwx	31.17 efgh	32.05 abcdef	546.06 ab	15.66 bcd	81.46 ab	10489.68 kl	11.85 bc
Hamadan 2	1217.73 rstuvwxyz	50.13 abc	20.81 cdef	708.35 a	16.98 bcd	103.55 ab	8666.77 u	14.05 abc
Shabestar-Kouzeh Kanan 3	689.73 z	38.86 abcdefg	32.16 abcdef	360.15 ab	15.37 bcd	75.42 b	6093.02 z	11.32 bc
Saghez 4	525.13 z	41.33 abcdefg	29.49 abcdef	189 b	9.91 d	66.06 b	3201.36 z	16.40 abc
Saghez 5	1801.78 cdefgh	42.45 abcdefg	13.24 ef	603.79 a	14.76 bcd	142.54 ab	12627.91 d	14.27 abc
Saghez 3	2143.35 a	42.20 abcdefg	25.99 abcdef	753.85 a	14.83 bcd	138.33 ab	8305.84 vw	25.81 a
Shahroud 2	1062.24 xyz	34.39 cdefg	15.35 def	807.3 a	16.17 bcd	63.86 b	7388.81 z	14.38 abc
Alibaglou 1	1396.10 lmnopqrst	40.71 abcdefg	48.91 ab	463.51 ab	17.26 abcd	111.02 ab	9173.54 t	15.22 abc
Baneh 2	1727.82 efghi	39.02 abcdefg	28.32 abcdef	534.65 ab	18.13 abcd	154.34 ab	10408.63 lm	16.60 abc
Salmas-Gharaghashlagh-Ghalami	1134.32 vwxyz	41.90 abcdefg	52.67 a	409.55 ab	15.51 bcd	127.86 ab	10337.38 lmn	10.97 bc
Marand-1389-2	1377.34 lmnopqrstu	42.76 abcdefg	28.97 abcdef	615.13 a	16.51 bcd	120.96 ab	9914.73 pq	13.89 abc
Salmas-Gharaghashlagh-Badami	1788.36 defgh	30.79 fgh	31.85 abcdef	539.25 ab	16.21 bcd	158.16 ab	11422.27 gh	15.66 abc
Shabestar-Kouzeh Kanan 1	1370.58 mnopqrstuv	41.07 abcdefg	31.44 abcdef	555.6 ab	16.14 bcd	98.84 ab	8795.72 u	15.58 abc
Sanandaj	1335.47 nopqrstuvw	49.61 abc	28.05 abcdefg	726.85 a	15.42 bcd	74.88 b	8209.19 vw	16.27 abc
Shabestar-Kouzeh Kanan 2	1222.83 qrstuvwxy	45.08 abcdef	35.26 abcde	456.52 ab	14.66 bcd	92.25 ab	8162.42 wx	14.98 abc
Baneh 3	1153.55 uvwxyz	43.29 abcdefg	38.37 abcde	455.8 ab	15.28 bcd	134.18 ab	10678.52 jk	10.80 bc
Piranshahr Bolban	828.05 z	46.12 abcdef	38.42 abcde	706.95 a	15.42 bcd	68.50 b	6884.77 z	12.03 bc
Baneh 1	1844.57 bcdef	27.83 gh	23.17 bcdef	577.44 ab	16.12 bcd	135.06 ab	11309.62 hi	16.31 abc
Marand-1389-1	1489.70 ijklmno	46.44 abcdef	32.05 abcdef	687.22 a	16.76 bcd	120.25 ab	10338.35 lmn	14.41 abc

Means followed by similar letters in each column are not significantly different at the 5% level of probability according to Tukey's Test.

Kernel to grain

The effect of irrigation, genotype and their combined effect on kernel to grain ratio were considerable (Table 4). The comparison of mean values showed that with increasing stress intensity kernel to grain ratio decreases by 9% for moderate stress and 17% for severe stress (Table 5, 6 and 7). In optimum irrigation, the highest and lowest values of kernel to grain ratio were related to genotypes: Mashhad (62.24 %) and Salmas-Garaghashlagh-Badami (33.74%), respectively (Table 5). In moderate stress, these values were obtained from genotypes: Mashhad (58.07%) and Salmas-Garaghashlagh-Badami (31.61%), respectively (Table 6). Moreover, in severe stress, genotypes: Mashhad (55.21%) and Vaghaslou-Olya 4 (14.87%) produced the highest and lowest kernel to grain, respectively (Table 7). Higher ratios of kernel to grain in some of the genotypes can be related to their thin shell. There was negative and meaningful correlation between kernel to grain with grain 1000 weight and biological yield (Table 7, 8 and 9). Furthermore, no significant correlation was observed between kernel to grain and other traits in severe drought stress (Table 9). Our findings are in agreement with HADI et al. (2012) studies.

Hollowness percentage

Factors like non-fertilization of flowers, high temperature, low relative water content, unsuitable environment, low soil humidity, lack of nutrition and insects for pollination result in grain hollowness. The results of combined analysis of variance showed that the effects of irrigation and genotype on hollowness percentage are significant at probability level of 1% (Table 4). Water deficit affects grain yield through its impact on reproductive organs and increasing the hollowness and the number of grains per head (KHOMARI *et al*., 2008). In optimum irrigation the highest and lowest values of hollowness percentage were achieved for genotypes Alibaghlou 1 (24.51 %) and Salmas-Garaghashlagh-Ghalami (1.77%), respectively (Table 5). The comparison of mean values showed that increasing stress intensity from optimum irrigation to moderate and severe stress, increases the hollowness percentage by 40% and 67%, respectively (Table 5, 6 and 7). In moderate stress, these values were obtained from genotypes: Alibaghlou 1 (35.83%) and Mashhad (1.41%), respectively (Table 6). In severe stress, genotypes: Salmas-Garaghashlagh-Ghalami (52.67%) and Mazandaran-Tirtash (6.58%) produced the highest and lowest level of hollowness, respectively (Table 7). AFKARI BAJEBAJ *et al*. (2009) reported that drought stress or water deficit causes the hollowness percentage to increase. In addition, VALADABADI *et al*. (2008) demonstrated that by imposing water deficit condition, percentage of hollowness of grains in sunflower decreases significantly.

Number of seeds per head

The results of combined analysis of variance showed that the effect of irrigation on number of seeds per head is significant at probability level of 1% (Table 4). In optimum irrigation, the highest and lowest values measured for the number of seeds per head were related to genotypes: Angane 4 (1466.92) and Shabestar-Kouzeh-Kanan 3 (563.40), respectively (Table 5). The comparison of mean values showed that with increasing stress intensity from optimum irrigation to moderate to severe stress, the number of seeds per head decreases by 19% and 35%, respectively (Table 5, 6 and 7). In moderate stress, the maximum and minimum numbers of seeds per head were obtained from genotypes: Sanandaj (1198.81) and Vaghaslou-Olya 1 (383.24), respectively (Table 6). Whereas in severe stress, genotypes: Chongharalou-Yekan 4 (807.07) and Saghez 4 (389.72) produced the highest and lowest values, respectively (Table 7). SOLEIMANZADEH *et al*. (2010) also reported that drought stress decreases the number of seeds per head, biological yield, grain yield, head diameter and 1000-grain weight significantly. Our results are also in agreement with those obtained by KASSAB *et al*. (2012) and ALAHDADI *et al*. (2011).

Head diameter

The results of combined analysis of variance showed that the effects of irrigation and genotype on head diameter are significant at probability level of 1% (Table 4). The highest and lowest head diameters were observed under no-stress and severe drought stress conditions, respectively. In optimum irrigation, the highest and lowest measured values were related to genotypes: Angane 4 (28.34 cm) and Miyaneh-Basin (15.89 cm), respectively (Table 5). The comparison of mean values showed that with increasing stress intensity from optimum irrigation to moderate and severe stress, head diameter decreases by 10% and 25%, respectively (Table 5, 6 and 7). In moderate stress, the maximum and minimum head diameters were obtained from genotypes: Maranghalou 6 (27.91 cm) and Piranshahr Andizeh (11.77 cm), respectively (Table 6). In severe stress, these values were obtained from genotypes: Maranghalou 6 (26.11 cm) and Saghez 4 (9.91

cm), respectively (Table 7). The decrease in head diameter is caused by the reduction in stem diameter. The reducing effect of drought stress on head diameter has also been reported in other studies (FARAHVASH *et al.,* 2011). Head diameter is one of the essential traits of sunflower landraces which is decreased under moisture stress and adversely affects yield components like number of seeds per head. GHOLINEZHAD *et al*. (2009) found that drought stress always has negative effect on the head diameter. Selection of genotypes with larger head diameter is one of the objectives in sunflower breeding programs. KASSAB *et al*. (2012) reported that imposing drought stress decreases head diameter and grain yield. These findings are in agreement with our results.

1000-seed weight

Results of combined analysis of variance (ANOVA) showed that drought stress causes significant decrease in 1000-grain weight so that the maximum and minimum 1000-grain weight were obtained in optimum irrigation and severe drought stress, respectively (Table 5, 6 and 7). The results also confirmed that the effects of irrigation and irrigation-genotype were significant at probability level of 5% while the effect of genotype on 1000-grain weight was considerable at probability level of 1% (Table 4). In optimum irrigation, the highest and lowest values of 1000-grain weight were related to genotypes: Baneh 1 (195.62 gram) and Shabestar-Kouzeh-Kanan 3 (43.90 gram), respectively (Table 5). The comparison of mean values showed that with increasing stress intensity from optimum irrigation to moderate and severe stress, the 1000-grain weight decreases by 5% and 17%, respectively (Table 5, 6 and 7). In moderate stress, the maximum and minimum values for 1000-grain weight were calculated from genotypes: Gharagoz 1 (201.72 gram) and Shahroud 1 (68.20 gram), respectively (Table 6). In severe stress, however, these were obtained from genotypes: Maranghalou 6 (213.08 gram) and Saghez 4 (66.06 gram), respectively (Table 7). AFKARI BAJEBAJ (2010) reported that the 1000-grain weight of ‘Airfloure’ is significantly lower than that of the other sunflower cultivars. According to DANESHIAN *et al*. (2005) 1000-grain weight decreases due to drought stress. Furthermore, NAZARLI *et al*. (2010) showed that with increasing drought stress 1000-grainweight decreases considerably. Our finding agrees well with these results.

Biological yield

The results of combined analysis of variance showed that the effect of irrigation, genotype and irrigation-genotype on biological yield is significant at probability level of 1% (Table 4). In optimum irrigation, the highest and lowest values of biological yield were related to genotypes: Angane 4 (24787 kg ha^{-1}) and Mashhad (3874 kg ha^{-1}), respectively (Table 5). The comparison of mean values showed that with increasing stress intensity form optimum irrigation to moderate and severe stress, biological yield decreases by 20% and 40%, respectively (Table 5, 6 and 7). In moderate stress, the maximum and minimum biological yields were obtained from genotypes: Karimabad (23090.46 kg ha^{-1}) and Mashhad (3433.45 kg ha^{-1}), respectively (Table 6). In severe stress, genotypes: Maranghalou 6 (18842.41 kg ha-1) and Mashhad (3169.45 kg ha^{-1}) produced the maximum and minimum biological yields, respectively (Table 7). AFKARI BAJEBAJ (2010) found that with increasing drought stress the number of grains per plant and the biological yield decreases. In their research severe water stress (210 mm evaporation) reduced the grain yield by 43.71% and “Armawirski” was a superior cultivar under all irrigation treatments. Low water availability causes the plant growth inhibitors such as abscisic acid (ABA) to increase and the growth regulator hormones to decrease. Reduction of plant regulator hormones is one of the most crucial factors in plant growth suppression (KALAMIAN *et al*., 2006). NAZARIYAN *et al*. (2009) reported that drought stress has a severe effect on biological yield decreasing its quantity. Similar deductions can be made from our results.

Harvest Index

Harvest index is one of important physiological parameters that indicate the percentage of photosynthetic material transferring from organs to seeds. It implies the relative distribution of photosynthetic products between economic sinks and other existing sinks in the plant. The results of combined analysis of variance showed that the effects of irrigation and genotype on harvest index are significant at probability level of 1% (Table 4). In optimum irrigation, the highest and lowest harvest indices were related to genotypes: Angane 4 (25.46%) and Shabestar-Kouzeh-Kanan 2 (11.70%), respectively (Table 5). The comparison of mean values showed that with increasing stress intensity from optimum irrigation to moderate and severe stress, harvest index decreases by 9% and 18%, respectively (Table 5, 6 and 7). In moderate stress, the maximum and minimum harvest indices were obtained from genotypes: Mashhad (21.88 %.) and Piranshar-Sarvkani (11.31%), respectively (Table 6). In severe stress, genotypes: Saghez 3 (25.81%) and Piranshar-Andizeh (8.08%) yielded the highest and lowest harvest index, respectively (Table 7). There is a negative and meaningful correlation between harvest index and biological yield (Table 8, 9 and 10). Furthermore, harvest index and grain yield exhibit a positive and meaningful correlation (Table 9). GHOLINEZHAD *et al*. (2009 and 2014) and DARVISHZADEH *et al*. (2014) stated that drought stress is one of the limiting factors of plant growth and development that not only reduces production of biological yield but also causes a disorder to the partitioning of carbohydrates to grains thus reducing the harvest index. AFKARI BAJEBAJ (2010) showed that the water deficit stress decreases harvest index significantly. MIRSHEKARI *et al*. (2012) also reported that drought stress causes a decrease in the harvest index through reducing the grain yield. These findings are confirmed by the results of this work.

Table 8. Matrix of simple correlation coefficient among different traits in optimum irrigation

	Grain yield	Kernel to Grain	hollowness Percent	Seeds Number per Head	Head Diameter	Grain 1000 weight	Biological Yield	Harvest Index
Grain yield	1							
Kernel to Grain	-0.25*	1						
hollowness Percent	-0.13^{ns}	0.03^{ns}	1					
Seeds Number per head	0.47**	-0.01^{ns}	-0.05^{ns}	1				
Head Diameter	0.58**	-0.12^{ns}	-0.08^{ns}	0.44**	1			
Grain 1000 weight	0.58**	-0.27*	-0.25^{ns}	0.17^{ns}	0.40**	1		
Biological Yield	0.79**	-0.27*	-0.22^{ns}	0.42**	0.61**	0.64**	1	
Harvest Index	-0.02^{ns}	0.05^{ns}	-0.27*	-0.14^{ns}	-0.24^{ns}	0.27*	-0.59**	1

** , * and Ns significant at the 1%, 5% probability levels and non significant respectively.

Table 9. Matrix of simple correlation coefficient among different traits in moderate drought stress

	Grain yield	Kernel to Grain	hollowness Percent	Seeds Number per Head	Head Diameter	Grain 1000 weight	Biological Yield	Harvest Index
Grain yield	1							
Kernel to Grain	-0.25*	1						
hollowness Percent	-0.11ns	- 0.005ns	1					
Seeds Number per head	0.43**	0.08ns	-0.24ns	1				
Head Diameter	0.26*	-0.17ns	-0.31**	- 0.05ns	1			
Grain 1000 weight	0.70**	-0.10ns	-0.27*	0.38**	0.38**	1		
Biological Yield	0.89**	-0.30*	-0.15ns	0.36**	0.24ns	0.64**	1	
Harvest Index	0.07ns	0.19ns	0.04ns	0.006ns	0.06ns	- 0.004ns	-0.34**	1

*** , * and Ns significant at the 1%, 5% probability levels and non significant respectively.*

Table 10. Matrix of simple correlation coefficient among different traits in severe drought stress

	Grain yield	Kernel to Grain	hollowness Percent	Seeds Number per Head	Head Diameter	Grain 1000 weight	Biological Yield	Harvest Index
Grain yield	1							
Kernel to Grain	-0.29*	1						
hollowness Percent	-0.17ns	0.07ns	1					
Seeds Number per head	0.34**	0.10ns	-0.39**	1				
Head Diameter	0.52**	-0.16ns	-0.16ns	0.46**	1			
Grain 1000 weight	0.64**	-0.07ns	-0.10ns	0.15ns	0.49**	1		
Biological Yield	0.79**	-0.21ns	-0.06ns	0.38*	0.73**	0.69**	1	
Harvest Index	0.49**	- 0.11ns	- 0.21ns	0.01ns	-0.12ns	0.11ns	-0.11ns	1

** , * and Ns significant at the 1%, 5% probability levels and non significant respectively.

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EVALUACIJA KOMPONENATA PRINOSA SUNCOKRETA POD RAZLIČITIM USLOVIMA STRESA NEDOSTATKA VODE

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Izvod
Vršena su ispitivanje prinosa i komponenata prinosa 56 sorata suncokreta u uslovima deficita vode u Istraživačkom centru za poljoprivredu Zapadnog Azerbejdžana u sezonama 2012 – 2013. Tesstiranja su vršena u optimalnim uslovima navodnjavanja, umerenog i jakog stresa suše posle potpuno strošenih 50%. 70% i 90% dostupnih zaliha vode. Utvrđeno je da su pojedinačni i kombinovani efekti tretmana i genotipa na ispitivane osobine bili značajni. Povećanjem intenziteta stresa prinos zrna, odnos zrna i prinosa, broja zrna po glavi, prečnik glave, težina 1000 zrna, i biološki i prinos i žetveni indeks su smanjeni dok je procenat udubljenja glave povećan. Na svakom nivou stresa reakcija genotipoa je bila različita tako da je moguće izvršiti izbor genotipova za gajenje u različitim uslovima.

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