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Evaluation of Drought Tolerance Indices for Selection of Confectionery Sunflower (*Helianthus anuus* L.) Landraces under Various Environmental Conditions

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Abstract

In order to study the response of 56 landraces of confectionery sunflower to drought stress, an experiment was conducted in the experimental field of Agricultural Research Center of West-Azerbaijan in 2012-2013 cropping seasons. The genotypes were evaluated in three separated rectangular 7 × 8 lattice design with two replications in three irrigation treatments including optimum irrigation, moderate stress and sever stress where irrigation was done after depletion of 50%, 70% and 90% of available water, respectively. Nine drought tolerance indices including mean productivity (MP), stress tolerance index (STI), geometric mean productivity (GMP), harmonic mean (HARM), stress non-stress production index (SNPI), yield index (YI), drought resistance index (DI), modified stress tolerance index in optimum irrigation (M_PSTI), and modified stress tolerance index in moderate and severe stress (M_sSTI) were calculated based on grain yield under well-watered (Y_P), moderate drought stress (Y_S-mild) and severe drought stress (Y_S-severe) conditions. Grain yield in well-watered (YP), mild and severe stress conditions was significantly and positively correlated with MP, STI, GMP, HARM, SNPI, YI, DI, M_PSTI and M_SSTI. Results of this study showed that in moderate drought stress conditions the indices MP, STI, GMP and HARM could be used as the most suitable indicators for screening drought tolerant genotypes. Based on cluster analysis, the studied genotypes were grouped in 3 clusters in each one of water treatment conditions. To select drought tolerant genotypes in severe drought stress conditions, it is suggested to use indices MP, STI, GMP, HARM, SNPI and M_SSTI because these indices supports stable and high yield in both non-stress and stress conditions.

Keywords: biplot presentation, confectionary sunflower, cluster analysis, landraces

Introduction

Sunflower (*Helianthus annuus* L.) is one of the 67 species in the genus *Helianthus*. Nowadays, two main types of sunflower are grown: for oilseed production and non-oilseed or confectionery types (Salunkhe *et al.,* 1999). Confectionery sunflower produces large seeds with low oil content and is used in baking and snack applications (Lu and Hoeft, 2007). Confectionery kernels are roasted and salted, or roasted and no salt added and marketed as edible chips. The confectionery type is one of the most popular and important crops in Iran. It is cultivated in all parts of the country especially in the northwest regions. Abiotic stresses such as cold, salinity, heat and water stress is the principal cause of crop failure worldwide which dipping average yields by more than 50% (Jaleel, 2007).

The different strategies have been suggested for selecting resistant and relatively resistant genotypes to drought stress. Fisher and Maurer (1978) stated that seed yield in drought environment could be considered as drought resistant index. Blum (1988) reported that selection of genotypes for drought resistant must be associated with high yield in non-stress environments. Drought indices based on loss of yield under stress conditions compared to normal state have been used for screening drought tolerant genotypes (Mitra, 2001). Several selection indices such as geometric mean productivity (GMP) and stress tolerance index (STI) by Fernandez (1992), mean productivity (MP) and tolerance index (TOL) by Rosielle and Hamblin (1981), harmonic mean (HARM) by Jafari et al. (2009), stress susceptibility index (SSI) by Fisher and Maurer (1978), yield stability index (YSI) by Bouslama and Schapaugh (1984) and yield index (YI) by (Gavuzzi *et al.,* 1997) were used for screening drought tolerant genotypes.

Khodarahmpour *et al.* (2011) showed that the STI and GMP indices were the more accurate criteria for selection of heat tolerant and high yielding genotypes. Eivazy *et al.* (2013) indicated that MP index was the best criterion for selecting genotypes with high grain yield at both well watered and drought stressed conditions. According to Ganjali *et al.* (2009), there were positive and highly significant correlations among MP, GMP, STI and HARM with yield in stressed and non-stressed conditions. Jabbari *et al.* (2008) studied drought tolerant indices in sunflower genotypes and found significant and positive correlation between STI and grain yield under non-stressed as well as mild and severe drought stresses conditions. Daneshian and Jonoubi (2008) reported that MP, GMP and STI are the most useful indices for evaluating tolerance to drought stress in sunflower. In some researches, YI led to ranking genotypes based on yield in stress conditions (Sio-Se Mardeh *et al.,* 2006). Drikvand *et al.* (2012) exhibited that the most suitable criteria for the identification of genotypes under irrigated and rain fed conditions were GMP, MP and STI. Anwar *et al.* (2011) observed that there were positive and significant correlations between grain yield and MP, HARM, GMP, STI and K1STI under irrigated and stressed conditions. Farshadfar *et al.* (2013) reported that K_1STI, K_2STI, SSPI, RDI, ATI, SNPI and DI could be used as the most suitable indicators for screening drought tolerant cultivars in wheat. Pourdad *et al.* (2008) indicated that cluster analysis based on STI, MP, GMP, YS and YP classify genotypes into three groups with different susceptibility to drought stress.

According to Fernandez (1992) report, genotypes can be classified into four groups based on their performance in stressed and non-stressed conditions: group A: genotypes with high yield under both stressed and non-stressed conditions, group B: genotypes with high yield under non-stressed conditions, group C: genotypes with high yield under stressed conditions, group D: genotypes with poor performance under both stressed and non-stressed conditions. A suitable index must be able to distinguish group A from the other groups. Biplot is an exploratory data visualization technique to display the multivariate data into a two dimensional scatter plot. The concept of biplot was first developed by Gabriel (1971). This technique has extensively been used in the analysis of multi-environmental trails (Ahmadi *et al.,* 2000; Farshadfar *et al.,* 2001; Golabadi *et al.,* 2006). The objectives of the present study were to evaluate several drought tolerance indices and identify drought- tolerant genotypes in confectionery sunflower.

Materials and methods

In order to evaluate the effect of drought stress on grain yield of confectionery sunflower, an experiment was carried out in the experimental field of Agricultural Research center of West-Azerbaijan in 2012-2013. 56 confectionery sunflower accessions were evaluated in three separated rectangular 7 × 8 lattice design with two replications under three irrigation treatments including optimum irrigation (irrigation after depletion of 50% of available water), moderate stress (irrigation after depletion of 70% of available water) and sever stress (irrigation after depletion of 90% of available water).

The soil physical and chemical characteristic of the experimental area is presented in Tab. 1. Mean monthly rainfall, humidity and temperature were recorded through the growing period (Tab. 2). Soil moisture samples were taken from 0-30 and 30-60 cm depth. Weight moisture percentage was determined by pressure plate (armfield CAT.REF: FEL13B-1 Serial Number: 6353 A 24S98). Field capacity and wilting point were 26 and 14, respectively. In order to obtain the irrigation times, soil samples were taken by auger from root development depth in each irrigation regimes 48 hours post irrigation. Irrigation intervals were determined from soil moisture percentage 20, 17.6 and 15.2 days for severe, moderate and well-watered conditions, respectively. Irrigation volume was calculated by equation 1 (Alizadeh, 2009):

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

where:

V= irrigation water volume (m^3), Θm = soil moisture weight percentage per replication, A= irrigated area (m^2), FC= field capacity, ρm = soil density (g cm^{-3}), Droot= developmental root depth (m).

Required water volume per irrigation regimes calculated and distributed equally by flume and chronometer with water distribution efficiency of 90 percent. Plants were harvested at maturity, and then the grain yield was recorded for every plot. Harvesting area was 3.6 m^2 from the two middle lines. The drought tolerance indices were calculated for every genotype using the corresponding well-watered and water-stressed plots. Drought tolerance indices were calculated by using the equations cited in Tab. 3.

Analysis of variance performed using PROC GLM in the SAS software (SAS Institute Inc., Cary, NC, USA). The comparison of the means was done by Tukey's test at 5% probability level. Correlations between grain yield per plot in each of the water regimes and drought tolerance indices were determined using SAS PROC CORR. The classification of genotypes using grain yield per plot in each of the water regimes and drought tolerance indices data was performed by Ward algorithm based on squared Euclidean distances. Biplot analysis was used to classify the drought tolerance indices as well as the confectionery sunflower landraces (Mohammadi et al., 2010). Data processing was performed using SPSS 20.00 statistical software (SPSS/PC-20, SPSS Inc., Chicago, IL, USA; http://www.spss.com).

Tab. 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

Tab. 2. Monthly climate data during sunflower growing season

Meteorological Parameters	Month					
	Mars	April	May	June	July	August
Maximum Temperature (°C)	16.6	23.3	28.2	30.1	33.1	28.6
Minimum Temperature (°C)	3.1	8.3	11.9	15.3	16.2	13.1
Mean Temperature (°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

Tab. 3. Names of local landraces

Names of local landraces					
No.		No.		No.	
1	Saghez 1	20	Salmas 2	39	Hamadan 2
2	Anghane 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	Babaghanje 6	27	Khanneshan 1	46	Baneh 2
9	Miyaneh-Basin	28	Heydarlou 1	47	Salmas-Gharagheshlagh- Ghalami
10	Boucan	29	Saribaglou 5	48	Marand-1389-2
11	Urmia - Nuoshinshahr	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-Serokani	54	Piranshahr-Baleban
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

Comparing landraces based on the resistance / tolerance indices

To investigate suitable drought tolerance indices for screening confectionery sunflower landraces under drought stress conditions, different indices were calculated based on grain yield under stressed and non-stressed environments (Tab. 6 and 7). A suitable index must have a significant correlation with grain yield under both non-stress and stress conditions (Mitra, 2001). Based on the stress tolerance index (STI) and grain yield, the landraces: 2, 12, 14, 16, 25, 28, 29, 31, 32, 33, 47, 49 and 56 were found drought tolerance with the highest STI and grain yield under mild stressed and non-stressed conditions while the landraces: 37 and 38 displayed the lowest amount of STI and grain yield under mild stressed and non-stressed conditions (Tab. 6). Landraces: 2, 7 and 12 had the most STI and grain yield under severe and non-stress conditions while the landraces 36 and 37 had the lowest amount of STI and grain yield under severe and non-stress conditions (Tab. 7). Khodarahmpour *et al.* (2011) and Khalili *et al.* (2012) reported that STI and GMP indices were the more accurate criteria for selection of heat tolerant and high yielding genotypes.

The highest GMP and MP were shown in landraces: 2, 12, 14, 25, 26, 28, 31, 32, 33, 49 and 56 under mild stressed and non-stressed conditions (Tab. 6). The lowest GMP and MP were observed in landraces: 36 and 37 under severe stressed and non-stressed conditions (Tab. 6). Under severe and non-stress conditions, the highest and lowest GMP and MP were observed in the accessions (2 and 12) and (36 and 37), respectively (Tab. 7). Based on Rosiele and Hamblin (1981) decline, the stress tolerance index (STI) and mean productivity (MP) are defined as the difference in yield and the average yield between stressed and non-stressed conditions, respectively.

The highest and lowest HARM were observed in the landraces: (12, 25, 26, 32, 33, 49 and 56) and (9, 10 and 41), respectively, in the mild stressed and non-stressed conditions (Tab. 6). Under severe stressed and non-stressed conditions, the highest and lowest HARM were related to landraces: (5, 7, 12 and 29) and (36, 37, 40 and 41), respectively (Tab. 7). Mevlut and Sait (2011) indicated that the genotypes with high STI usually present high difference in yield between two different conditions. They reported in general, common ranks for studied landraces by GMP, MP and STI, which suggests that these three indices are similar for screening drought tolerant landraces.

Based on the yield index (YI), the landraces 12, 25, 32 and 56 were the most tolerant landraces under mild stressed and non-stressed conditions (Tab. 6). Landraces: 5, 7, 12, 29, 31 and 43 had the highest YI under severe stressed

Tab. 4. Drought tolerance indices

Index name	Outcome	Equation	Reference
Mean Productivity (MP)	the landraces with high value of this index will be more desirable	$MP = \frac{Y_S + Y_P}{2}$	(Rosielle and Hamblin, 1981)
Geometric Mean Productivity (GMP)	the landraces with high value of this index will be more desirable	$GMP = \sqrt{(Y_S)(Y_P)}$	(Kristin *et al.*, 1997)
Stress Tolerance Index (STI)	The landraces with high STI values will be tolerant to drought stress	$STI = \frac{(Y_S)(Y_P)}{(\bar{Y}_P)^2}$	(Fernandez, 1992)
Harmonic Mean (HARM)	the landraces with high value of this index will be more desirable	$HARM = \frac{2(Yp \times Ys)}{Yp + Ys}$	(Jafari *et al.*, 2009)
Yield Index (YI)	the landraces with high value of this index will be suitable for drought stress condition	$YI = \frac{Y_S}{\bar{Y}_P}$	(Gavuzzi *et al.,* 1997)
Drought Resistance Index (DI)	the landraces with high value of this index will be suitable for drought stress condition	$DI = \frac{[Y_S \times (\frac{Y_S}{Y_P})]}{\bar{Y}_S}$	(Lan, 1998)
Stress Non-Stress Production Index	the landraces with high value of this index will be suitable for drought stress condition	$SNPI = \left[\frac{Yp+Ys}{Yp-Ys}\right]^{\frac{1}{3}} \times [Yp \times Ys \times Ys]^{\frac{1}{3}}$	(Moosavi *et al.,* 2008)
Modified Stress Tolerance Index in Optimum Irrigation ($M_P STI$)	the landraces with high value of this index will be suitable for drought stress condition	$MpSTI = \frac{[(Y)]p)^2}{[(\bar{Y})]p)^2} \times STI$	(Farshadfar and Sutka, 2002)
Modified Stress Tolerance Index in Moderate and Severe Stress ($M_S STI$)	the landraces with high value of this index will be suitable for drought stress condition	$MsSTI = \frac{[(Y)]s)^2}{[(\bar{Y})]s)^2} \times STI$	(Farshadfar and Sutka, 2002)

YS and *YP* are stress and optimal (potential) yield of a given genotype, respectively. $\bar{Y}$ s and $\bar{Y}$ p are average yield of all genotypes under stress and optimal conditions, respectively.

Tab. 5. Simple and combined analyses of variance for grain yield in 56 Iranian confectionery sunflower landraces under non-stressed, moderate and severe drought stressed conditions.

Source of variation	Individual				Combined	
	df	MS Optimum conditions	MS Mild stressed conditions	MS Severe stressed conditions	df	MS
(Environment)	-	-	-	-	2	46277099.58**
Replication	1	1293418.65*	707.52 ns	326538 **	-	-
Replication (Environment)	-	-	-	-	3	540221.39
Block (Replication)	14	195166.60 ns	250894.24 ns	119807.47 **	-	-
Block (Environment × Replication)	-	-	-	-	42	507269.85**
Genotype	55	878661.58 **	813047.52 **	286444.80 **	55	1380455.49**
(Environment × Genotype)	-	-	-	-	110	298849.20*
Error	41	326456.17	263024.93	51214.32	123	213565.1
C.V.(%)	-	21.32	24.84	16.23	-	22.58

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

conditions (Tab. 7). Based on $M_P STI$ and $M_S STI$ the landraces 2, 8, 12, 14, 25, 26, 32, 33 and 47 were the most tolerant under mild stressed conditions (Tab. 6). Under severe stressed conditions, the highest $M_P STI$ and $M_S STI$ were related to landraces 7, 12, 25, and 49 (Tab. 7). With regard to stress non-stress production index (SNPI) under mild and severe stressed conditions: landraces (2, 8, 14, 26 and 47) and (5, 7, 22, 29, 31, 34 and 43) were the most tolerant accessions, respectively (Tab. 6 and 7). Based on drought index (DI) under mild stressed conditions, the high tolerant landraces were 12, 16, 25, 31, 32 and 56 (Tab. 6). Based on drought index (DI) under severe stressed conditions, the most tolerant landraces were 5, 7, 9 and 43 (Tab. 7). Ilker et al. (2011) concluded that MP, GMP and STI are convenient indices to choose high yielding wheat genotypes in both stressed and non-stressed conditions.

Farshadfar et al. (2013) reported that K1STI, K2STI, SNPI and DI indices can be used as the most suitable indicators for screening drought tolerant cultivars in wheat.

Totally, based on MP, STI, GMP, HARM, YI, DI and MSSTI indices and ranking method the landraces: 2, 12, 25, 26, 31, 32, 33 and 56 were as the most drought tolerant and the landraces: 9, 10, 19, 35, 36, 37, 38, 40 and 41 were as the most susceptible under mild stressed conditions (Tab. 6). Under severe stressed conditions, based on MP, STI, GMP, HARM, YI, DI, SNPI and MSSTI indices and ranking method the landraces: 2, 5, 7, 12, 29 and 31 were as the most drought tolerant and the landraces: 9, 10, 17, 35, 36, 37, 40, 41 and 54 were as the most susceptible landraces (Tab. 7).

Cluster analysis

To determine the most desirable drought tolerance criteria, the correlation coefficient between Y_P, Y_S and other quantitative drought tolerance indices in mild and severe stressed conditions were calculated (Tab. 8 and 9). The results indicated that in moderate and severe drought stressed conditions there were positive and significant correlations among Y_P and MP, STI, GMP, HARM, SNPI, YI, DI, MPSTI and MSSTI. Also in moderate and severe drought stressed conditions, there were positive and significant correlations among Ys and MP, STI, GMP, HARM, YI, DI, MPSTI and MSSTI. However, indices

Tab. 6. Resistance/tolerance indices for 56 Iranian confectionery sunflower landraces under moderate drought stressed and non-stressed conditions.

No	Genotype	Rank	HARM	Rank	GMP	Rank	STI	Rank	MP	Rank	Ys-mild	Rank	Yp
1	Saghez 1	19	2.60	19.5	2.65	19.5	0.93	18.5	2.71	22	2169.72	15	3241.94
2	Anghane 4	13	2.81	4	3.38	4	1.51	1	4.06	38	1807.79	1	6310.77
3	Urmia-Barouj	25	2.41	24.5	2.51	24	0.84	23	2.62	35	1883.44	12	3355.65
4	Urmia-Maranghalou	39.5	2.10	38	2.20	38	0.64	34.5	2.31	42	1615.43	26	3001.82
5	Marand-Dizaj-Ghalami	27	2.36	27	2.42	27	0.78	28	2.49	33	1917.77	21	3055.23
6	Jabalkandi 2	29	2.35	31	2.37	31	0.74	31	2.39	23	2085.56	33	2695.38
7	Salmas - Sadaghian	18	2.61	19.5	2.65	19.5	0.93	21	2.69	19	2211.75	17	3177.21
8	Babaghanje 6	20	2.59	17.5	2.68	17.5	0.95	15	2.78	24	2048.18	7	3505.74
9	Miyaneh-Basin	54	1.25	54	1.25	54	0.21	54	1.25	52	1273.47	55	1221.97
10	Boucan	52	1.33	51	1.43	51	0.27	48.5	1.54	54	973.88	43	2103.75
11	Urmia - Nuoshinshahr	14.5	2.72	16	2.73	15.5	0.99	16.5	2.75	13	2482.86	25	3012.03
12	Karimabad	1	3.67	1	3.67	1	1.78	2	3.67	2	3611.45	3	3728.20
13	Vaghaslou-Olya 1	42	1.80	42	1.92	42	0.49	42	2.05	47	1328.74	31	2768.42
14	Vaghaslou-Olya 3	9	3.04	9	3.07	9	1.25	9	3.09	12	2686.43	9	3500.27
15	Ordoshahi 1	23	2.49	24.5	2.51	25	0.83	25.5	2.53	20	2208.24	29	2852.48
16	Marana-Yamchi-Pesteii	12	2.85	13	2.85	13.5	1.07	14	2.85	10	2889.97	30	2802.96
17	Mazandaran-Tirtash	43	1.75	43	1.75	43	0.41	43	1.75	36	1832.44	50	1675.26
18	Sardasht	41	2.05	41	2.07	41	0.57	41	2.09	37	1816.67	40	2356.11
19	Marana-Yamchi 4	48	1.50	48	1.52	48	0.31	48.5	1.54	50	1299.26	47	1783.27
20	Salmas 2	17	2.66	17.5	2.68	17.5	0.95	20	2.70	16	2367.56	22.5	3037.67
21	Vaghaslou-Olya 4	31	2.33	29.5	2.38	29.5	0.75	29	2.43	32	1927.74	28	2935.50
22	Salmas-Gharaghashlagh-Pesteii	22	2.52	23	2.53	23	0.85	25.5	2.53	15	2371.90	34	2691.73
23	Lalalou-Torab 2	21	2.53	21	2.62	21	0.91	18.5	2.71	28	2002.13	10	3418.40
24	Shirabad 2	35	2.27	33.5	2.29	33.5	0.70	34.5	2.31	26	2026.19	36	2591.75
25	Gharagoz 1	2	3.65	2	3.65	2	1.77	3	3.65	1	3778.83	5	3528.58
26	Vaghaslou-Sofla 1	4.5	3.27	5	3.28	5	1.43	5	3.30	7	2965.42	4	3635.39
27	Khanneshan 1	14.5	2.72	15	2.74	15.5	0.99	16.5	2.75	14	2467.21	22.5	3037.68
28	Heydarlou 1	10	3.00	11	3.00	11	1.20	12	3.01	9	2908.40	20	3103.55
29	Saribaglou 5	11	2.97	12	2.98	12	1.17	13	2.98	11	2853.26	19	3105.27
30	Chongharalou-Yekan 4	32	2.29	33.5	2.29	33.5	0.70	37	2.29	17	2344.98	42	2243.27
31	Maranghalou 6	8	3.05	10	3.05	10	1.23	10	3.05	5	3146.80	27	2961.98
32	Abajalou 1	3	3.55	3	3.55	3	1.67	4	3.55	3	3596.70	8	3505.17
33	Hamadan 1	6	3.26	7	3.26	6.5	1.41	6.5	3.27	6	3033.53	6	3513.70
34	Saghez 2	39.5	2.10	39.5	2.13	39.5	0.60	39	2.16	39	1799.07	37	2523.31
35	Piranshahr-Serokani	49.5	1.48	50	1.48	50	0.29	51	1.48	45	1439.76	51	1529.26
36	Piranshahr Andizeh	55	0.70	55	0.78	55	0.08	55	0.86	56	493.39	54	1222.34
37	Mashhad	56	0.63	56	0.65	56	0.06	56	0.66	55	515.86	56	807.34
38	Shahroud 1	49.5	1.48	49	1.50	49	0.30	50	1.51	49	1315.93	49	1700.66
39	Hamadan 2	47	1.59	47	1.63	46.5	0.35	46	1.68	51	1285.08	44	2071.94

40	Shabestar-Kouzeh-Kanan 3	51	1.37	52	1.37	52	0.25	52	1.38	48	1324.07	53	1426.11
41	Saghez 4	53	1.30	53	1.31	53	0.23	53	1.32	53	1177.20	52	1458.54
42	Saghez 5	37	2.13	37	2.24	37	0.66	33	2.34	41	1645.39	24	3036.84
43	Saghez 3	33.5	2.28	35.5	2.28	35.5	0.69	38	2.28	21	2183.06	39	2381.37
44	Shahroud 2	44	1.69	44	1.71	44	0.39	44.5	1.72	44	1502.04	46	1942.53
45	Alibaglou 1	38	2.12	39.5	2.13	39.5	0.60	40	2.14	31	1948.10	41	2331.95
46	Baneh 2	24	2.48	22	2.55	22	0.86	22	2.63	27	2009.26	16	3241.56
47	Salmas-Gharagheshlagh-Ghalami	16	2.67	14	2.85	13.5	1.07	11	3.03	29	1987.24	2	4076.50
48	Marand-1389-2	33.5	2.28	28	2.40	28	0.77	24	2.54	40	1721.08	11	3356.18
49	Salmas-Gharaghashlagh-Badami	7	3.13	8	3.14	8	1.30	8	3.14	8	2949.06	13	3340.35
50	Shabestar-Kouzeh Kanan 1	29	2.35	32	2.35	32	0.73	32	2.35	18	2305.50	38	2390.03
51	Sanandaj	29	2.35	29.5	2.38	29.5	0.75	30	2.40	25	2045.97	32	2756.99
52	Shabestar-Kouzeh-Kanan 2	45	1.66	45	1.69	45	0.38	44.5	1.72	46	1403.79	45	2030.41
53	Baneh 3	36	2.26	35.5	2.28	35.5	0.69	36	2.30	30	1979.44	35	2624.47
54	Piranshahr-Baleban	46	1.63	46	1.64	46.5	0.35	47	1.64	43	1522.93	48	1759.33
55	Baneh 1	26	2.37	26	2.44	26	0.79	27	2.52	34	1902.77	18	3141.23
56	Marand-1389-1	4.5	3.27	6	3.27	6.5	1.41	6.5	3.27	4	3228.56	14	3307.31

Tab. 6. (Continued)

No	Genotype	Rank	M_SSTI	Rank	M_PSTI	Rank	DI	Rank	YI	Rank	SNPI
1	Saghez 1	19	1.03	16	1.30	28	0.70	22	0.79	9	4.45
2	Anghane 4	16	1.16	1	7.97	53	0.25	38	0.66	1	9.08
3	Urmia-Barouj	30	0.70	17	1.25	42	0.51	34.5	0.69	8	4.50
4	Urmia-Maranghalou	41	0.39	31	0.77	50	0.42	42	0.59	21	3.68
5	Marand-Dizaj- Ghalami	32	0.67	26	0.96	37.5	0.58	32.5	0.70	15	3.99
6	Jabalkandi 2	28	0.76	33	0.72	23	0.78	23	0.76	26	3.24
7	Salmas - Sadaghian	18	1.07	18	1.24	25	0.75	19.5	0.81	12	4.32
8	Babaghanje 6	22	0.94	11	1.55	37.5	0.58	24.5	0.75	5	4.91
9	Miyaneh-Basin	52	0.08	54	0.04	31.5	0.64	52	0.46	51	-0.63
10	Boucan	54	0.06	46	0.16	54	0.22	54	0.36	39	1.91
11	Urmia - Nuoshinshahr	13	1.43	21	1.19	16	0.99	13	0.91	18	3.77
12	Karimabad	2	5.46	2	3.28	3	1.70	2	1.32	23	3.46
13	Vaghaslou-Olya 1	43.5	0.20	39	0.49	52	0.31	48	0.48	29	3.06
14	Vaghaslou-Olya 3	11	2.11	9	2.02	15	1.00	12	0.98	4	5.02
15	Ordoshahi 1	21	0.96	27	0.90	21	0.83	19.5	0.81	22	3.56
16	Marana-Yamchi-Pesteii	12	2.10	24	1.12	6	1.45	10	1.05	53	-2.29
17	Mazandaran-Tirtash	42	0.32	47.5	0.15	18	0.97	36	0.67	44.5	1.47
18	Sardasht	39	0.44	42	0.42	29	0.68	38	0.66	34	2.59
19	Marana-Yamchi 4	49.5	0.12	49	0.13	46.5	0.46	50.5	0.47	42	1.65
20	Salmas 2	15	1.25	22	1.16	20	0.90	16.5	0.86	16	3.95
21	Vaghaslou-Olya 4	34	0.65	28	0.86	34	0.61	32.5	0.70	19.5	3.76
22	Salmas-Gharaghashlagh-Pesteii	17	1.12	29.5	0.81	14	1.01	15	0.87	32	2.90
23	Lalalou-Torab 2	25	0.85	15	1.40	39	0.57	28	0.73	6	4.71
24	Shirabad 2	32	0.67	35	0.62	24	0.77	26	0.74	30	3.03
25	Gharagoz 1	1	5.92	3	2.91	1	1.96	1	1.38	56	-4.57
26	Vaghaslou-Sofla 1	6	2.95	5	2.50	12	1.17	7.5	1.08	3	5.20
27	Khanneshan 1	14	1.42	19	1.21	18	0.97	14	0.90	17	3.87
28	Heydarlou 1	9	2.37	12	1.53	7	1.32	9	1.06	27	3.13
29	Saribaglou 5	10	2.24	13	1.50	8.5	1.27	11	1.04	25	3.36
30	Chongharalou-Yekan 4	24	0.90	40	0.46	11	1.19	16.5	0.86	52	-1.78
31	Maranghalou 6	7	2.87	14	1.43	4	1.62	5	1.15	55	-3.18
32	Abajalou 1	3	5.07	4	2.72	2	1.79	3	1.31	54	-3.07
33	Hamadan 1	5	3.05	7	2.31	8.5	1.27	6	1.11	7	4.66

34	Saghez 2	38	0.46	38	0.51	33	0.62	38	0.66	31	2.94
35	Piranshahr-Serokani	47.5	0.14	51	0.09	30	0.66	45	0.53	47	0.94
36	Piranshahr Andizeh	55.5	0.00	55	0.02	56	0.10	56	0.18	49	0.72
37	Mashhad	55.5	0.00	56	0.00	55	0.16	55	0.19	50	0.44
38	Shahroud 1	49.5	0.12	50	0.11	43	0.49	48	0.48	43	1.51
39	Hamadan 2	47.5	0.14	44	0.20	51	0.39	50.5	0.47	37	2.08
40	Shabestar-Kouzeh-Kanan 3	51	0.10	52	0.07	35.5	0.60	48	0.48	48	0.89
41	Saghez 4	53	0.07	53	0.06	46.5	0.46	53	0.43	46	1.14
42	Saghez 5	40	0.42	29.5	0.81	48.5	0.43	41	0.60	19.5	3.76
43	Saghez 3	27	0.77	37	0.52	18	0.97	21	0.80	36	2.17
44	Shahroud 2	43.5	0.20	45	0.19	40.5	0.56	44	0.55	40	1.88
45	Alibaglou 1	36	0.54	41	0.43	22	0.79	31	0.71	35	2.44
46	Baneh 2	26	0.82	20	1.20	35.5	0.60	28	0.73	10	4.38
47	Salmas-Gharagheshlagh-Ghalami	20	0.99	6	2.36	44.5	0.47	28	0.73	2	5.88
48	Marand-1389-2	37	0.53	23	1.14	48.5	0.43	40	0.63	11	4.35
49	Salmas-Gharaghashlagh-Badami	8	2.66	10	1.93	10	1.26	7.5	1.08	13.5	4.14
50	Shabestar-Kouzeh Kanan 1	23	0.91	36	0.55	13	1.08	18	0.84	41	1.71
51	Sanandaj	29	0.73	32	0.75	26	0.74	24.5	0.75	24	3.40
52	Shabestar-Kouzeh-Kanan 2	46	0.17	43	0.21	44.5	0.47	46	0.51	38	2.05
53	Baneh 3	35	0.63	34	0.63	27	0.72	30	0.72	28	3.12
54	Piranshahr-Baleban	45	0.19	47.5	0.15	31.5	0.64	43	0.56	44.5	1.47
55	Baneh 1	32	0.67	25	1.03	40.5	0.56	34.5	0.69	13.5	4.14
56	Marand-1389-1	4	3.46	8	2.05	5	1.53	4	1.18	33	2.61

Tab. 7. Resistance/tolerance indices for 56 Iranian confectionery sunflower landraces under severe drought stressed and non-stressed conditions.

No	Genotype	Rank	HARM	Rank	GMP	Rank	STI	Rank	MP	Rank	Ys-mild	Rank	Yp
1	Saghez 1	19	2.60	19.5	2.65	19.5	0.93	18.5	2.71	22	2169.72	15	3241.94
2	Anghane 4	13	2.81	4	3.38	4	1.51	1	4.06	38	1807.79	1	6310.77
3	Urmia-Barouj	25	2.41	24.5	2.51	24	0.84	23	2.62	35	1883.44	12	3355.65
4	Urmia-Maranghalou	39.5	2.10	38	2.20	38	0.64	34.5	2.31	42	1615.43	26	3001.82
5	Marand-Dizaj-Ghalami	27	2.36	27	2.42	27	0.78	28	2.49	33	1917.77	21	3055.23
6	Jabalkandi 2	29	2.35	31	2.37	31	0.74	31	2.39	23	2085.56	33	2695.38
7	Salmas - Sadaghian	18	2.61	19.5	2.65	19.5	0.93	21	2.69	19	2211.75	17	3177.21
8	Babaghanje 6	20	2.59	17.5	2.68	17.5	0.95	15	2.78	24	2048.18	7	3505.74
9	Miyaneh-Basin	54	1.25	54	1.25	54	0.21	54	1.25	52	1273.47	55	1221.97
10	Boucan	52	1.33	51	1.43	51	0.27	48.5	1.54	54	973.88	43	2103.75
11	Urmia - Nuoshinshahr	14.5	2.72	16	2.73	15.5	0.99	16.5	2.75	13	2482.86	25	3012.03
12	Karimabad	1	3.67	1	3.67	1	1.78	2	3.67	2	3611.45	3	3728.20
13	Vaghaslou-Olya 1	42	1.80	42	1.92	42	0.49	42	2.05	47	1328.74	31	2768.42
14	Vaghaslou-Olya 3	9	3.04	9	3.07	9	1.25	9	3.09	12	2686.43	9	3500.27
15	Ordoshahi 1	23	2.49	24.5	2.51	25	0.83	25.5	2.53	20	2208.24	29	2852.48
16	Marana-Yamchi-Pesteii	12	2.85	13	2.85	13.5	1.07	14	2.85	10	2889.97	30	2802.96
17	Mazandaran-Tirtash	43	1.75	43	1.75	43	0.41	43	1.75	36	1832.44	50	1675.26
18	Sardasht	41	2.05	41	2.07	41	0.57	41	2.09	37	1816.67	40	2356.11
19	Marana-Yamchi 4	48	1.50	48	1.52	48	0.31	48.5	1.54	50	1299.26	47	1783.27
20	Salmas 2	17	2.66	17.5	2.68	17.5	0.95	20	2.70	16	2367.56	22.5	3037.67
21	Vaghaslou-Olya 4	31	2.33	29.5	2.38	29.5	0.75	29	2.43	32	1927.74	28	2935.50
22	Salmas-Gharaghashlagh-Pesteii	22	2.52	23	2.53	23	0.85	25.5	2.53	15	2371.90	34	2691.73
23	Lalalou-Torab 2	21	2.53	21	2.62	21	0.91	18.5	2.71	28	2002.13	10	3418.40
24	Shirabad 2	35	2.27	33.5	2.29	33.5	0.70	34.5	2.31	26	2026.19	36	2591.75

25	Gharagoz 1	2	3.65	2	3.65	2	1.77	3	3.65	1	3778.83	5	3528.58
26	Vaghaslou-Sofla 1	4.5	3.27	5	3.28	5	1.43	5	3.30	7	2965.42	4	3635.39
27	Khanneshan 1	14.5	2.72	15	2.74	15.5	0.99	16.5	2.75	14	2467.21	22.5	3037.68
28	Heydarlou 1	10	3.00	11	3.00	11	1.20	12	3.01	9	2908.40	20	3103.55
29	Saribaglou 5	11	2.97	12	2.98	12	1.17	13	2.98	11	2853.26	19	3105.27
30	Chongharalou-Yekan 4	32	2.29	33.5	2.29	33.5	0.70	37	2.29	17	2344.98	42	2243.27
31	Maranghalou 6	8	3.05	10	3.05	10	1.23	10	3.05	5	3146.80	27	2961.98
32	Abajalou 1	3	3.55	3	3.55	3	1.67	4	3.55	3	3596.70	8	3505.17
33	Hamadan 1	6	3.26	7	3.26	6.5	1.41	6.5	3.27	6	3033.53	6	3513.70
34	Saghez 2	39.5	2.10	39.5	2.13	39.5	0.60	39	2.16	39	1799.07	37	2523.31
35	Piranshahr-Serokani	49.5	1.48	50	1.48	50	0.29	51	1.48	45	1439.76	51	1529.26
36	Piranshahr Andizeh	55	0.70	55	0.78	55	0.08	55	0.86	56	493.39	54	1222.34
37	Mashhad	56	0.63	56	0.65	56	0.06	56	0.66	55	515.86	56	807.34
38	Shahroud 1	49.5	1.48	49	1.50	49	0.30	50	1.51	49	1315.93	49	1700.66
39	Hamadan 2	47	1.59	47	1.63	46.5	0.35	46	1.68	51	1285.08	44	2071.94
40	Shabestar-Kouzeh-Kanan 3	51	1.37	52	1.37	52	0.25	52	1.38	48	1324.07	53	1426.11
41	Saghez 4	53	1.30	53	1.31	53	0.23	53	1.32	53	1177.20	52	1458.54
42	Saghez 5	37	2.13	37	2.24	37	0.66	33	2.34	41	1645.39	24	3036.84
43	Saghez 3	33.5	2.28	35.5	2.28	35.5	0.69	38	2.28	21	2183.06	39	2381.37
44	Shahroud 2	44	1.69	44	1.71	44	0.39	44.5	1.72	44	1502.04	46	1942.53
45	Alibaglou 1	38	2.12	39.5	2.13	39.5	0.60	40	2.14	31	1948.10	41	2331.95
46	Baneh 2	24	2.48	22	2.55	22	0.86	22	2.63	27	2009.26	16	3241.56
47	Salmas-Gharagheshlagh-Ghalami	16	2.67	14	2.85	13.5	1.07	11	3.03	29	1987.24	2	4076.50
48	Marand-1389-2	33.5	2.28	28	2.40	28	0.77	24	2.54	40	1721.08	11	3356.18
49	Salmas-Gharaghashlagh-Badami	7	3.13	8	3.14	8	1.30	8	3.14	8	2949.06	13	3340.35
50	Shabestar-Kouzeh Kanan 1	29	2.35	32	2.35	32	0.73	32	2.35	18	2305.50	38	2390.03
51	Sanandaj	29	2.35	29.5	2.38	29.5	0.75	30	2.40	25	2045.97	32	2756.99
52	Shabestar-Kouzeh-Kanan 2	45	1.66	45	1.69	45	0.38	44.5	1.72	46	1403.79	45	2030.41
53	Baneh 3	36	2.26	35.5	2.28	35.5	0.69	36	2.30	30	1979.44	35	2624.47
54	Piranshahr-Baleban	46	1.63	46	1.64	46.5	0.35	47	1.64	43	1522.93	48	1759.33
55	Baneh 1	26	2.37	26	2.44	26	0.79	27	2.52	34	1902.77	18	3141.23
56	Marand-1389-1	4.5	3.27	6	3.27	6.5	1.41	6.5	3.27	4	3228.56	14	3307.31

Tab. 7. (Continued)

No	Genotype	Rank	M_SSTI	Rank	M_PSTI	Rank	DI	Rank	YI	Rank	SNPI
1	Saghez 1	31	0.46	22.5	0.76	40.5	0.36	35	0.46	36.5	2.29
2	Anghane 4	8	1.34	1	6.44	46.5	0.24	25	0.53	22	2.78
3	Urmia-Barouj	18	0.90	11	1.04	28.5	0.53	19.5	0.57	21	2.84
4	Urmia-Maranghalou	36.5	0.33	28	0.56	43	0.33	39.5	0.43	39	2.11
5	Marand-Dizaj- Ghalami	3	1.84	12.5	1.03	4	1.00	3	0.75	3	4.06
6	Jabalkandi 2	30	0.52	35	0.49	28.5	0.53	30.5	0.51	30	2.59
7	Salmas - Sadaghian	1	2.37	5	1.25	3	1.11	1	0.81	2	4.44
8	Babaghanje 6	43	0.24	22.5	0.76	52.5	0.21	47	0.36	46	1.85
9	Miyaneh-Basin	40.5	0.26	51.5	0.05	2	1.26	25	0.53	56	-3.08
10	Boucan	51	0.07	46	0.13	54	0.20	52	0.28	51	1.39
11	Urmia - Nuoshinshahr	13	1.17	19	0.85	12.5	0.76	11.5	0.65	11	3.34
12	Karimabad	2	1.98	2	1.80	12.5	0.76	5.5	0.72	8	3.63
13	Vaghaslou-Olya 1	27.5	0.56	30	0.54	26	0.54	28.5	0.52	25	2.63
14	Vaghaslou-Olya 3	23	0.73	9	1.09	35.5	0.43	25	0.53	28	2.61
15	Ordoshahi 1	19	0.82	26	0.66	19.5	0.66	17	0.59	19	2.98

16	Marana-Yamchi-Pesteii	27.5	0.56	29	0.55	28.5	0.53	28.5	0.52	28	2.61
17	Mazandaran-Tirtash	49	0.11	49.5	0.08	35.5	0.43	47	0.36	45	1.87
18	Sardasht	29	0.54	39	0.34	17	0.69	21	0.55	20	2.88
19	Marana-Yamchi 4	45.5	0.20	47	0.12	25	0.56	39.5	0.43	36.5	2.29
20	Salmas 2	47	0.19	37	0.47	50.5	0.22	49	0.35	48	1.76
21	Vaghaslou-Olya 4	17	0.97	24	0.75	14.5	0.70	15.5	0.62	15.5	3.15
22	Salmas-Gharaghashlagh-Pesteii	11	1.26	27	0.65	5	0.97	7	0.69	6	3.83
23	Lalalou-Torab 2	39	0.27	25	0.74	48.5	0.23	45	0.38	44	1.93
24	Shirabad 2	24	0.71	35	0.49	14.5	0.70	18	0.58	18	3.01
25	Gharagoz 1	10	1.28	3.5	1.35	22	0.62	13	0.64	13	3.17
26	Vaghaslou-Sofla 1	20	0.79	6	1.24	35.5	0.43	25	0.53	24	2.65
27	Khanneshan 1	15	1.03	20.5	0.84	17	0.69	15.5	0.62	15.5	3.15
28	Heydarlou 1	45.5	0.20	32	0.51	50.5	0.22	47	0.36	47	1.79
29	Saribaglou 5	4	1.78	10	1.07	6.5	0.96	4	0.74	4	3.94
30	Chongharalou-Yekan 4	26	0.59	41.5	0.31	9	0.79	19.5	0.57	17	3.14
31	Maranghalou 6	6	1.58	16.5	0.91	6.5	0.96	5.5	0.72	5	3.89
32	Abajalou 1	36.5	0.33	20.5	0.84	45	0.26	42.5	0.41	42	2.03
33	Hamadan 1	22	0.74	8	1.11	35.5	0.43	25	0.53	28	2.61
34	Saghez 2	16	1.02	32	0.51	8	0.93	9.5	0.66	7	3.68
35	Piranshahr-Serokani	51	0.07	51.5	0.05	42	0.35	50	0.31	49	1.59
36	Piranshahr Andizeh	55	0.01	55	0.02	55	0.15	55.5	0.18	55	0.90
37	Mashhad	55	0.01	56	0.00	52.5	0.21	55.5	0.18	54	0.93
38	Shahroud 1	44	0.22	48	0.11	21	0.65	36	0.45	31	2.56
39	Hamadan 2	40.5	0.26	43	0.19	31	0.51	37.5	0.44	38	2.28
40	Shabestar-Kouzeh-Kanan 3	53	0.03	53	0.04	46.5	0.24	53	0.25	52	1.25
41	Saghez 4	55	0.01	54	0.03	56	0.14	54	0.19	53	0.95
42	Saghez 5	12	1.21	18	0.89	11	0.77	9.5	0.66	10	3.38
43	Saghez 3	5	1.60	32	0.51	1	1.39	2	0.78	1	5.91
44	Shahroud 2	48	0.16	45	0.14	38	0.42	44	0.39	43	1.95
45	Alibaglou 1	33	0.43	41.5	0.31	23	0.60	30.5	0.51	26	2.62
46	Baneh 2	14	1.14	12.5	1.03	19.5	0.66	14	0.63	14	3.16
47	Salmas-Gharagheshlagh-Ghalami	35	0.41	3.5	1.35	48.5	0.23	42.5	0.41	40	2.10
48	Marand-1389-2	25	0.60	16.5	0.91	39	0.41	32.5	0.50	33	2.48
49	Salmas-Gharaghashlagh-Badami	9	1.30	7	1.17	17	0.69	11.5	0.65	12	3.28
50	Shabestar-Kouzeh Kanan 1	34	0.42	40	0.33	24	0.57	32.5	0.50	32	2.55
51	Sanandaj	32	0.45	35	0.49	33	0.47	34	0.49	34	2.42
52	Shabestar-Kouzeh-Kanan 2	42	0.25	44	0.18	28.5	0.53	37.5	0.44	35	2.30
53	Baneh 3	38	0.28	38	0.37	40.5	0.36	41	0.42	41	2.08
54	Piranshahr-Baleban	51	0.07	49.5	0.08	44	0.28	51	0.30	50	1.50
55	Baneh 1	7	1.35	14	1.00	10	0.78	8	0.67	9	3.45
56	Marand-1389-1	21	0.75	15	0.95	32	0.48	22	0.54	23	2.68

such as MP, STI, GMP, HARM, SNPI, YI, DI and M_SSTI were the best predictors of Y_P and Y_S than other indices. The observed relationship between YP, MP, STI, YS, MP and STI are in consistent with those reported by Fernansez (1992) in mungbean and Farshadfar *et al.* (2013) in wheat. Toorchi *et al.* (2012) showed that correlation between MP, GMP and YS and YP is positive. Ebrahimzadeh Banayjedi et al. (2012) introduced STI, MP and GMP as the best indices for yield predicting. Dehghani *et al.* (2009) reported that GMP, MP STI were significantly and positively correlated with stress yield. Farshadfar *et al.* (2001) showed that the most appropriate index for selecting stress tolerant cultivars is an index which has partly high correlation with grain yield under stress and non-stressed conditions. There were negative and significant correlations between YP and YSI in moderate and severe drought stressed conditions.

Correlation analysis

Based on cluster analysis, the studied landraces were grouped into 3 clusters in mild and severe drought stressed conditions. Therefore, there was considerable variation among landraces for drought tolerance. The dendrogram of accessions did not divide the accessions into distinct groups resembling the similar geographical distribution (Fig. 1 and 2). Therefore, it is suggested that selection of parents for hybridization does not need to be based on geographic diversity. Hybridization/crossing between any distantly related populations is expected to yield more heterosis and vigorous plants. According to the dendrogram 1, 30% of landraces situated in groups 1, 34% situated in groups 2 and 36% in group 3 under mild drought stressed conditions

(Fig. 1). In severe drought stressed conditions, 30% of landraces placed in groups 1, 21% situated in groups 2 and 45% in group 3 (Fig. 2). Cluster analysis has been used in drought tolerance studies by other researchers (Safahani Langroodi *et al.,* 2013; Dehbalaei *et al.,* 2013; Zaheri and Bahraminejad, 2012; Ajalli and Salehi, 2012; Zare, 2012; Tabatabaei, 2013). Golabadi *et al.* (2006) in characterizing durum wheat segregating populations with cluster analysis distinguished groups with superior lines in both drought stress and well-watered conditions, superior lines in only drought stressed conditions as well as superior lines only in well-watered conditions considering their grain yield. Sajad Bakaei et al. (2008) showed that based on cluster analysis, in normal conditions genotypes were divided into two groups while in mild and severe stressed conditions genotypes were divided into 4 and 5 groups, respectively. Based on results of Zahravi (2009) regarded to cluster analysis, genotypes were divided into three groups resistant, semi-resistant and susceptible.

Using the biplot diagram (Fig. 3) the landraces 2, 12, 14, 25, 26, 28, 31, 32, 33, 49 and 56 under mild stressed conditions were identified as tolerant and the landraces 9, 10, 35, 36, 37, 38, 40 and 41 were detected as sensitive to drought. In severe stressed conditions the landraces 2, 5, 7, 12, 25 and 29 were identified as tolerant and the landraces 10, 35, 36, 37, 40 and 41 were detected as sensitive to drought (Fig 4). According to the biplot presentation there is positive correlation between indices MP, GMP, HARM, STI and yield in three environments that, confirm the observed simple correlations between them. Accordingly, in this study four above indices are the most appropriate indices to screening drought tolerant genotypes. The results of this study are compatible with Fernandez (1992), Golabadi et al. (2006), Kaya *et al.* (2002) and Farshadfar *et al.* (2012).

Conclusion

Abiotic stress tolerance is a key component and in some cases the major factor in improving yield in crops (Tollenaar and Wu, 1999). Drought stress is considered as one of the most visible factors, which affect grain yield, and some of the constituents of the grain oil of sunflower (Razi and Assad, 1999; Ali et al., 2009). In this evaluation, based on cluster analysis, the studied genotypes were grouped in 3 clusters in each one of water treatment conditions. To select drought tolerant genotypes in severe drought stress conditions, it is suggested to use indices MP, STI, GMP, HARM, SNPI and M_SSTI because these indices supports stable and high yield in both non-stress and stress conditions.

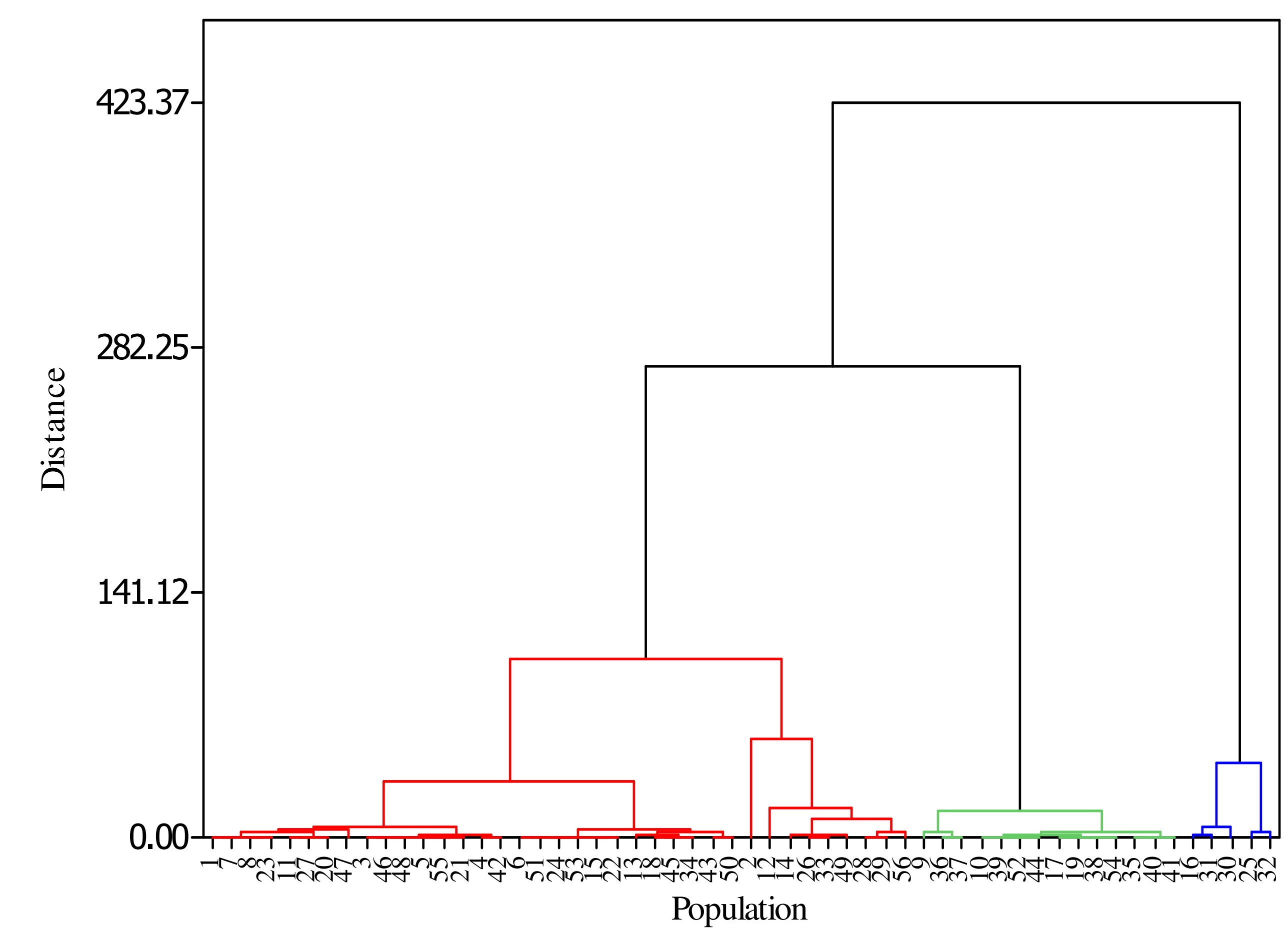

Fig. 1. Cluster diagram Dendrogram of 56 Iranian sunflower landraces generated by Wards clustering method by square Euclidean distance after data normalization based on drought tolerance indices (MP, STI, GMP, HARM, SNPI, YI, DI and M_SSTI) in moderate drought stress conditions

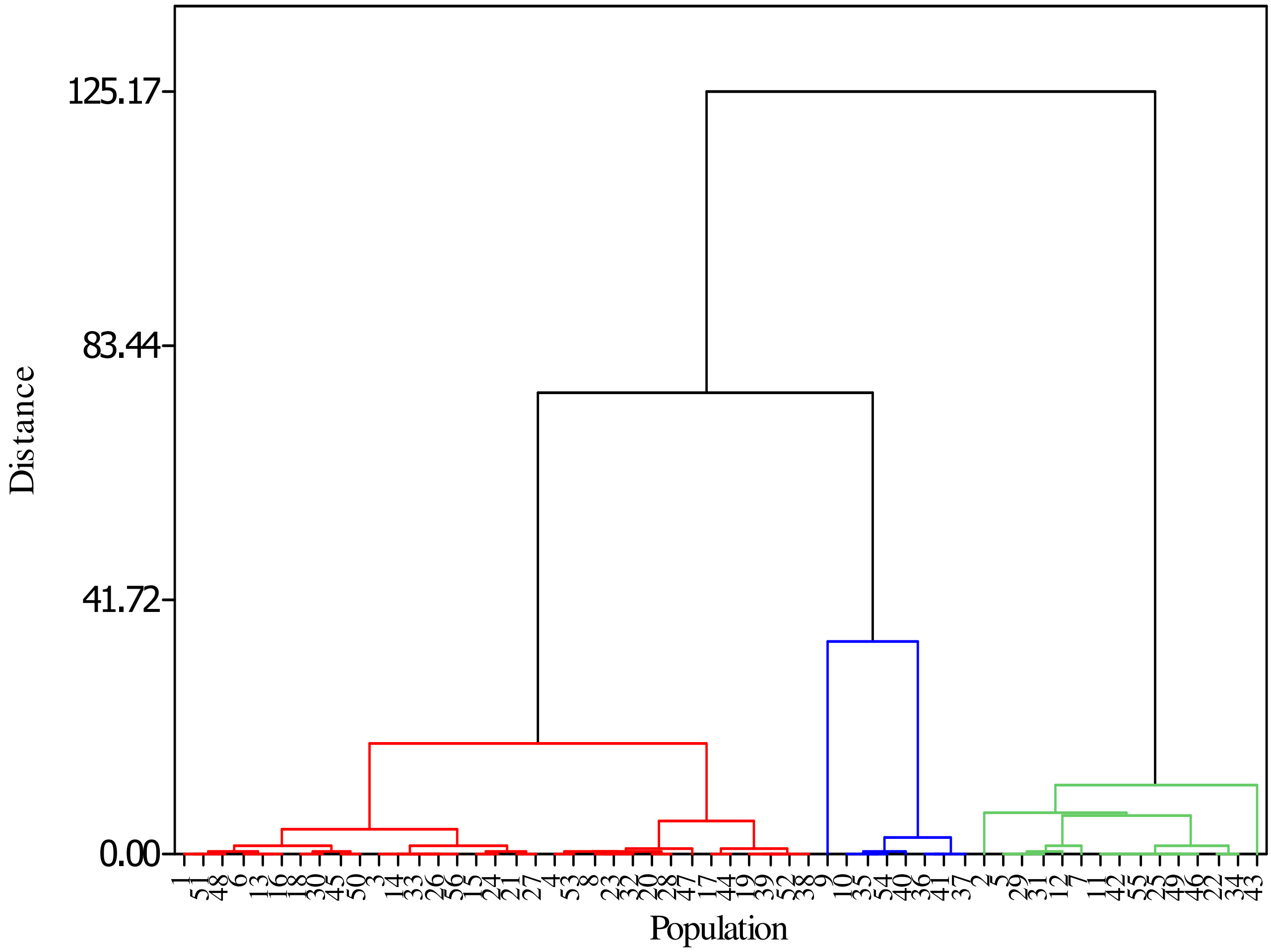

Fig. 2. Cluster diagram Dendrogram of 56 Iranian sunflower landraces generated by Wards clustering method by square Euclidean distance after data normalization based on drought tolerance indices (MP, STI, GMP, HARM, SNPI, YI, DI and M_SSTI) in severe drought stress conditions.

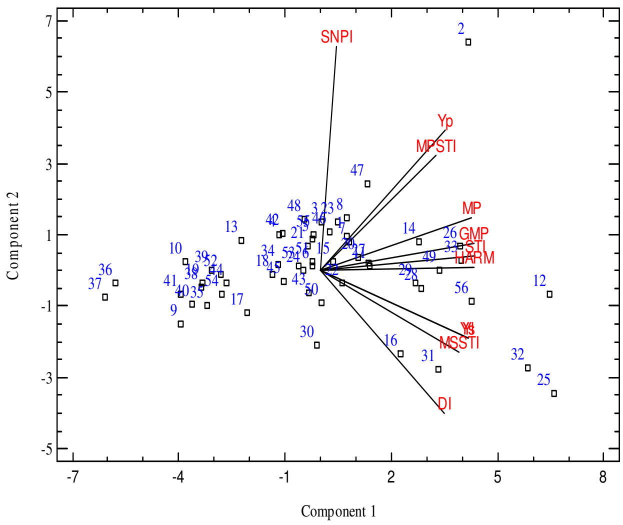

Fig. 3. Biplot for determination of the superior indices and genotypes in 56 Iranian sunflower landraces in moderate drought stress conditions.

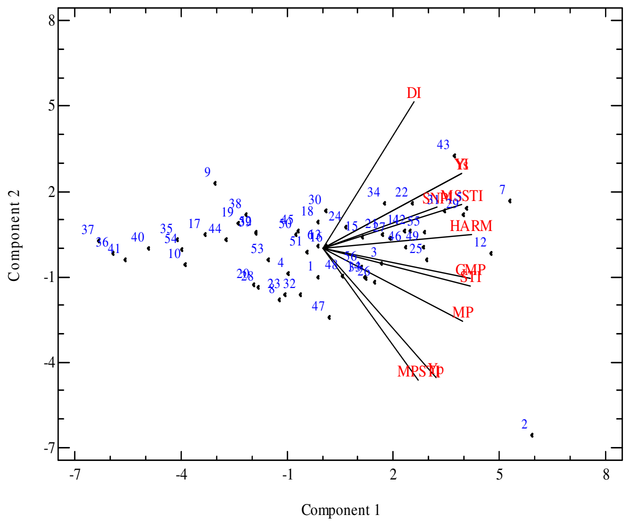

Fig. 4. Biplot for determination of the superior indices and genotypes in 56 Iranian sunflower landraces in severe drought stress conditions.

Tab. 8. Correlation coefficients between drought tolerance indices and grain yield in both moderate and sever drought stress conditions

	YP	YS	MP	STI	GMP	HARM	SNPI	YI	DI	MPSTI	MSSTI
YP	1										
YS	0.58**	1									
MP	0.91**	0.86**	1								
STI	0.82**	0.91**	0.97**	1							
GMP	0.85**	0.91**	0.99**	0.98**	1						
HARM	0.79**	0.95**	0.96**	0.97**	0.99**	1					
SNPI	0.53**	- 0.10^{ns}	0.28*	0.14^{ns}	0.21^{ns}	0.15^{ns}	1				
YI	0.58**	0.99**	0.86**	0.91**	0.91**	0.95**	- 0.09^{ns}	1			
DI	0.28*	0.93**	0.64*	0.75**	0.72**	0.78**	- 0.40**	0.93**	1		
MPSTI	0.88**	0.52**	0.80**	0.78**	0.73**	0.66**	0.37*	0.52**	0.31**	1	
MSSTI	0.51**	0.90**	0.77**	0.88**	0.81**	0.83**	- 0.23^{ns}	0.90**	0.87**	0.57**	1

Tab. 9. Correlation coefficients between drought tolerance indices and grain yield in both optimum and sever drought stress conditions

	YP	YS	MP	STI	GMP	HARM	SNPI	YI	DI	MPSTI	MSSTI
YP	1										
YS	0.45**	1									
MP	0.94**	0.72**	1								
STI	0.84**	0.83**	0.96**	1							
GMP	0.84**	0.85**	0.97**	0.98**	1						
HARM	0.70**	0.94**	0.89**	0.95**	0.97**	1					
SNPI	0.42**	0.72**	0.59**	0.67**	0.69**	0.74**	1				
YI	0.45**	0.99**	0.71**	0.83**	0.85**	0.94**	0.72**	1			
DI	- 0.02^{ns}	0.84**	0.29*	0.45**	0.47**	0.62**	0.46**	0.84**	1		
MPSTI	0.84**	0.33**	0.77**	0.74**	0.66**	0.52**	0.27*	0.33**	- 0.008^{ns}	1	
MSSTI	0.52**	0.91**	0.74**	0.88**	0.84**	0.89**	0.74**	0.91**	0.70**	0.48**	1

Tab 10. Ranking of 56 Iranian confectionery sunflower landraces based on the best indices in optimum and stress drought stressed conditions

No	Genotype	Yield			Rank	
		Ys- severe	YS - mild	YP	Normal-severe stress	Normal-mild stress
1	Saghez 1	1272.33	2169.72	3241.94	26.5	19.5
2	Anghane 4	1461.19	1807.79	6310.77	1	4
3	Urmia-Barouj	1575.41	1883.44	3355.65	14	24
4	Urmia-Maranghalou	1170.91	1615.43	3001.82	35.5	38
5	Marand-Dizaj- Ghalami	2065.43	1917.77	3055.23	4.5	27
6	Jabalkandi 2	1415.56	2085.56	2695.38	31	31
7	Salmas - Sadaghian	2217.95	2211.75	3177.21	3	19.5
8	Babaghanje 6	1002.17	2048.18	3505.74	35.5	17.5
9	Miyaneh-Basin	1462.42	1273.47	1221.97	48	54
10	Boucan	769.14	973.88	2103.75	50	51
11	Urmia - Nuoshinshahr	1783.14	2482.86	3012.03	12.5	15.5
12	Karimabad	1982.66	3611.45	3728.20	2	1
13	Vaghaslou-Olya 1	1439.29	1328.74	2768.42	28.5	42
14	Vaghaslou-Olya 3	1453.18	2686.43	3500.27	19	9
15	Ordoshahi 1	1611.69	2208.24	2852.48	23	25
16	Marana-Yamchi-Pesteii	1434.58	2889.97	2802.96	28.5	13.5
17	Mazandaran-Tirtash	996.16	1832.44	1675.26	49	43
18	Sardasht	1500.16	1816.67	2356.11	35.5	41
19	Marana-Yamchi 4	1177.18	1299.26	1783.27	45.5	48
20	Salmas 2	965.81	2367.56	3037.67	42	17.5
21	Vaghaslou-Olya 4	1693.70	1927.74	2935.50	20	29.5
22	Salmas-Gharaghashlagh- Pesteii	1901.66	2371.90	2691.73	17	23
23	Lalalou-Torab 2	1056.05	2002.13	3418.40	33	21
24	Shirabad 2	1588.41	2026.19	2591.75	26.5	33.5

25	Gharagoz 1	1746.63	3778.83	3528.58	6	2
26	Vaghaslou-Sofla 1	1471.15	2965.42	3635.39	12.5	5
27	Khanneshan 1	1703.78	2467.21	3037.68	15	15.5
28	Heydarlou 1	981.17	2908.40	3103.55	40.5	11
29	Saribaglou 5	2030.66	2853.26	3105.27	4.5	12
30	Chongharalou-Yekan 4	1567.05	2344.98	2243.27	35.5	33.5
31	Maranghalou 6	1985.41	3146.80	2961.98	8	10
32	Abajalou 1	1115.13	3596.70	3505.17	30	3
33	Hamadan 1	1453.90	3033.53	3513.70	17	6.5
34	Saghez 2	1807.28	1799.07	2523.31	25	39.5
35	Piranshahr-Serokani	860.42	1439.76	1529.26	52	50
36	Piranshahr Andizeh	497.26	493.39	1222.34	55	55
37	Mashhad	490.16	515.86	807.34	56	56
38	Shahroud 1	1242.51	1315.93	1700.66	45.5	49
39	Hamadan 2	1217.73	1285.08	2071.94	43.5	46.5
40	Shabestar-Kouzeh-Kanan 3	689.73	1324.07	1426.11	53	52
41	Saghez 4	525.13	1177.20	1458.54	54	53
42	Saghez 5	1801.78	1645.39	3036.84	11	37
43	Saghez 3	2143.35	2183.06	2381.37	17	35.5
44	Shahroud 2	1062.24	1502.04	1942.53	47	44
45	Alibaglou 1	1396.10	1948.10	2331.95	38.5	39.5
46	Baneh 2	1727.82	2009.26	3241.56	10	22
47	Salmas-Gharagheshlagh-Ghalami	1134.32	1987.24	4076.50	23	13.5
48	Marand-1389-2	1377.34	1721.08	3356.18	23	28
49	Salmas-Gharaghashlagh-Badami	1788.36	2949.06	3340.35	7	8
50	Shabestar-Kouzeh Kanan 1	1370.58	2305.50	2390.03	38.5	32
51	Sanandaj	1335.47	2045.97	2756.99	32	29.5
52	Shabestar-Kouzeh-Kanan 2	1222.83	1403.79	2030.41	43.5	45
53	Baneh 3	1153.55	1979.44	2624.47	40.5	35.5
54	Piranshahr-Baleban	828.05	1522.93	1759.33	51	46.5
55	Baneh 1	1844.57	1902.77	3141.23	9	26
56	Marand-1389-1	1489.70	3228.56	3307.31	21	6.5

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