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Evaluation of Sunflower Inbred Lines under Drought Stress

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Abstract:

Productivity of sunflower is strongly depended on availability of water and greatest yield losses occur when water shortage occurs at flowering stage. In the present study eleven sunflower (*Helianthus Annuus*) inbred lines were evaluated under stress and non-stress conditions for sensitivity and resistance to drought. The experiment was laid out in a split plot based on a completely randomized design with three replications. Based on grain yield in the stress and non-stress conditions, drought resistance indices including geometric mean productivity (GMP), stress tolerance index (STI), mean productivity (MP), tolerance index (TOL), harmonic mean (HM), stress susceptibility index (SSI), yield stability index (YSI) and yield index (YI) were calculated for each genotype. High grain yield per plant in non-stress and stress environments was exhibited by genotypes B147 (33.72 g) and R46 (14.2 g), respectively. The maximum value of STI (0.61), GMP (21.32) and HM (19.67) was belonging to genotype R46 and highest value of MP (23.19) was observed for genotype B147. Three dimensional and bi-plot graphs indicated that genotypes B147 and R46 have positive characteristics and are suitable for crossing to produce high yielding as well as drought resistant hybrids. STI, GMP, MP and HM indices showed high correlation with grain yield under stress and non-stress conditions and therefore could be used in breeding program for drought tolerance. SSI index due to ability to separate the sensitive genotype from the others is relatively efficient index for genotypic screening.

Keywords: bi-plot, *Helianthus Annuus*, inbred lines, tolerance indices

1. Introduction:

Drought stress is the most important environmental stresses reduce the performance of field crops. Therefore, breeding for resistance to drought stress is among of the main objectives of plant breeding programs. Sunflower is one of the most important oil crops with desirable cooking oil due to its high content of unsaturated fatty acids and lack of cholesterol (Razi and Asad 1998). Under dry conditions compared with other crops it can absorb water from deeper soil layers (Angadi and entz 2002). Hence one of sunflower breeding goals is establishing resistance to environmental stresses such as drought. Although, improvement for drought tolerance has been a major goal of breeding programs but, success hampered because drought tolerance is controlled by several genes and difficulty of simultaneous selection (Richards, 1996; Yeo, 1998; Flowers *et al.*, 2000). Breeding for resistance to drought is complicated by the lack of fast and reproducible screening techniques as well as the inability to create a water stress condition in which a large population could be evaluated efficiently (Ramirez and Kelly, 1998).

The different strategies have been suggested for selecting resistant and relatively resistant genotypes to drought stress. Fisher and Maurer (1978) reported that achieve yield in drought environment could be considered as drought resistance index. While Blum (1988) mentioned that selection of genotypes for drought resistance must be associated with high yield in non-stress environments. Drought indices based on loss of yield under stress conditions compare with normal conditions have been used for screening drought tolerant genotypes (Mitra, 2001). Furthermore, several selection indices *viz*. 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 (HM) by Jafari et al. (2009), stress susceptibility index (SSI) by Fischer and Maurer (1978), yield stability index (YSI) by Bouslama and Schapaugh (1984) and yield index (YI) by Gavuzzi et al. (1997) were suggested for screening drought resistant genotypes. According to Fernandez (1992) theory, genotypes classified into four groups based on their performance in stress and non-stress conditions: A: genotypes producing high yield under both stress and non-stress conditions, B: genotypes with high yield under non-stress condition, C:

genotypes with high yield under stress condition, D: genotypes with poor performance under both stress and non-stress conditions. A suitable index must be able to distinguish the genotypes in group A from the other groups. In the present study we evaluated different drought tolerance indices for screening of inbred lines in sunflower.

2. Material and Methods:

Eleven sunflower inbred lines as listed in table 1 were chosen for this study. Experiment was conducted at the research farm in University of Tabriz (northwest of Iran) during growing season of 2011. Each genotype was sown in two rows of 3 m length and distance between rows of 60 cm. Two seeds of sunflower were planted in each hole by hand and thinned to single plant at seedling stage. In the normal condition, plants were watered daily throughout the cropping period, while in the stress condition; water stress was created from R_4 stage to the end of physiological maturity by withholding irrigation and preventing rainwater using a rainout shelter. The experiment was laid out in a split plot fashion based on randomized complete block design with 3 replications. Drought stress and normal irrigation were considered as the main and the genotypes as sub-factor in the experiment. Five randomly selected plants were taken from each plot to measure grain yield. Grain yield of inbred lines under normal and stress conditions were denoted as Y_P and Y_S, respectively, in the following formula:

Stress susceptibility index (SSI) $SSI = [1-(Y_S/Y_P)] / [1-(\overline{Y_S}/\overline{Y_P})]$

Geometric mean productivity (GMP) $GMP = (Y_P \times Y_S)^{0.5}$

Mean productivity (MP) $MP = (Y_P + Y_S) / 2$

Harmonic mean (HM) $HM = 2(Y_P \times Y_S) / (Y_P + Y_S)$

Tolerance index (TOL) $TOL = (Y_P - Y_S)$

Stress tolerance index (STI) $STI = (Y_P \times \overline{Y_S}) / (Y_P)^2$

Yield index (YI) $YI = (Y_S / \overline{Y_S})$

Yield stability index (YSI) $SI = (Y_S / Y_P)$

In the above relationships Y_P and Ys are the mean yields of all genotypes under stress and non-stress conditions, respectively. Correlations between grain yield per plant and drought tolerance indices were determined in each of the water regimes. Multivariate statistical analysis as principle component analysis, biplot display, three dimensional plots and multivariate analysis of variance (MANOVA) were performed using the SAS software (Sharma, 1996).

3. Results and Discussion:

To investigate suitable stress resistance indices for screening of genotypes under drought condition, grain yield of genotypes under both non-stress and stress conditions were measured for calculating different sensitivity and tolerance indices (Table 1). The best resistance indices were determined from the correlations coefficients between grain yield under both stress and non-stress conditions and drought resistance indices. A suitable index must have a significant correlation with grain yield under both the conditions (Mitra, 2001). Correlation coefficients matrix revealed that GMP, STI, HM and MP indices could effectively be used for screening of drought resistant genotypes (Table 2). Sio-Se Mardeh *et al*. (2006) suggested that selection for drought tolerance in wheat under moderate stress could be conducted based on any of the MP, GMP and STI indices under stress and non-stress conditions. Fernandez (1992) reported that STI and GMP indices are suitable for selection resistant genotypes of sunflower. Darvishzadeh *et al.* (2010) reported GMP, MP and HM indices are the best indices screening of resistant genotype in sunflower. The maximum value for stress susceptibility index (SSI) was obtained for genotypes R50 (1.13), R19 (1.12), R26 (1.09) and B221 (1.09) indicating sensitivity of these genotypes to drought stress. As shown in table 1, selection based on SSI index identified genotypes with relatively high Y_P but low Y_S and this is in agreement with sio-se marde *et al*. (2006) in wheat and darvishzadeh *et al*. (2010) in sunflower. Among the examined indices only TOL have positive and high significant correlation with yield in non-stress condition (Table 2) indicating suitability of this index for selection of genotypes under non-stress condition. It has been found that by decreasing TOL and increasing MP, the relative tolerance increases (Rosielle and Hamblin, 1981; Fernandez, 1992). Among the stress tolerance indices, a larger value of TOL and SSI represent relatively more sensitivity to stress, thus a smaller value of TOL and SSI are favored (golabadi *et al.* 2006). Darvishzadeh *et al.* (2010) reported that GMP is more powerful than MP in separating group A genotypes and has a lower susceptibility to different amounts of Y_S and Y_P. Therefore MP, which is based on arithmetic mean, will be biased when the difference between Y_S and Y_P is high. YI index has positive and high significant correlation with yield under stress condition but, this index has low correlation with yield under non-stress condition. Sio-Se Marde *et al.* (2006) reported that YI classify genotypes only based on their yield under stress condition and therefore cannot discriminate genotypes belonging to group A. YSI index has low correlation with yield in both stress and non-stress conditions so this index could not be suitable for selection of resistant genotypes. In fact, high values of this index belong to genotypes that maintain their performance by changing the environmental conditions. Hence YSI is an index of stability. The genotypes that have highest values for this index (R46, B355, B349, B329 and B110) showed lower performance reduction compare with other genotypes. In this experiment calculated correlation coefficient between indices STI and GMP was 0.996. STI index is calculated based on GMP index, high positive correlation between these indices is expectable (sio-se mardeh *et al.* 2006). High yield value in non-stress and stress environments was exhibited by genotypes B147 (33.72 g) and R46 (14.2 g), respectively. The maximum value of STI (0.61), GMP (21.32) and HM (19.67) was observed for genotype R46 and highest value for MP (23.19) was obtained for genotype B147 (Table 1).

Table 1. Mean of grain yield and different drought tolerance indices of sunflower inbred lines under normal and drought stress conditions

Code	Genotype	Y_S	Y_P	SSI	TOL	MP	GMP	STI	HM	YI	YSI
1	R19	9.14	32.13	1.12	22.98	20.64	17.14	0.39	14.24	0.92	0.28
2	R26	8.47	28.24	1.09	19.76	18.35	15.46	0.32	13.03	0.86	0.30
3	R50	8.18	29.80	1.13	21.62	18.99	15.61	0.32	12.84	0.83	0.27
4	R56	10.78	31.13	1.02	20.35	20.96	18.32	0.45	16.01	1.09	0.34
5	B147	12.66	33.72	0.97	21.06	23.19	20.66	0.57	18.40	1.28	0.37
6	B221	8.19	27.21	1.09	19.02	17.70	14.93	0.30	12.59	0.83	0.30
7	B329	11.21	26.45	0.90	15.24	18.83	17.22	0.40	15.75	1.13	0.42
8	B349	9.26	22.10	0.91	12.84	15.68	14.30	0.27	13.05	0.94	0.41
9	B355	7.82	17.15	0.85	9.327	12.49	11.58	0.18	10.75	0.79	0.45
10	R46	14.2	32.02	0.87	17.82	23.11	21.32	0.61	19.67	1.44	0.44
11	B110	8.30	19.22	0.88	10.91	13.76	12.63	0.21	11.60	0.84	0.43

Y_S: Yield in stress condition (g plant $^{-1}$); Y_p: Yield in normal condition (g plant $^{-1}$); SSI: Stress Susceptibility Index; TOL: Tolerance; MP: Mean Productivity; GMP: Geometric Mean Productivity; STI: Stress Tolerance Index; HM: Harmonic Mean; YI: Yield Index; YSI: Yield Stability Index

Table 2. Correlation coefficients between different drought tolerance indices and grain yield under normal and drought stress conditions

Characteristics	Y_P	Y_S	SSI	TOL	MP	GMP	STI	HM	YI
Y_S	.588	1							
SSI	.545	-.352	1						
TOL	.929**	.248	.814**	1					
MP	.970**	.768**	.326	.811**	1				
GMP	.883**	.899**	.090	.646*	.971**	1			
STI	.848**	.924**	.022	.594	.951**	.996**	1		
HM	.752**	.975**	-.138	.455	.890**	.974**	.984**	1	
YI	.588	1**	-.352	.248	.768**	.899**	.924**	.975**	1
YSI	-.545	.352	-1**	-.814**	-.326	-.090	.022	.138	.352

*and ** : Significant at 5% and 1% probability levels, respectively. Y_S: Yield in stress condition (g plant $^{-1}$); Y_p: Yield in normal condition (g plant $^{-1}$); SSI: Stress Susceptibility Index; TOL: Tolerance; MP: Mean Productivity; GMP: Geometric Mean Productivity; STI: Stress Tolerance Index; HM: Harmonic Mean; YI: Yield Index; YSI: Yield Stability Index

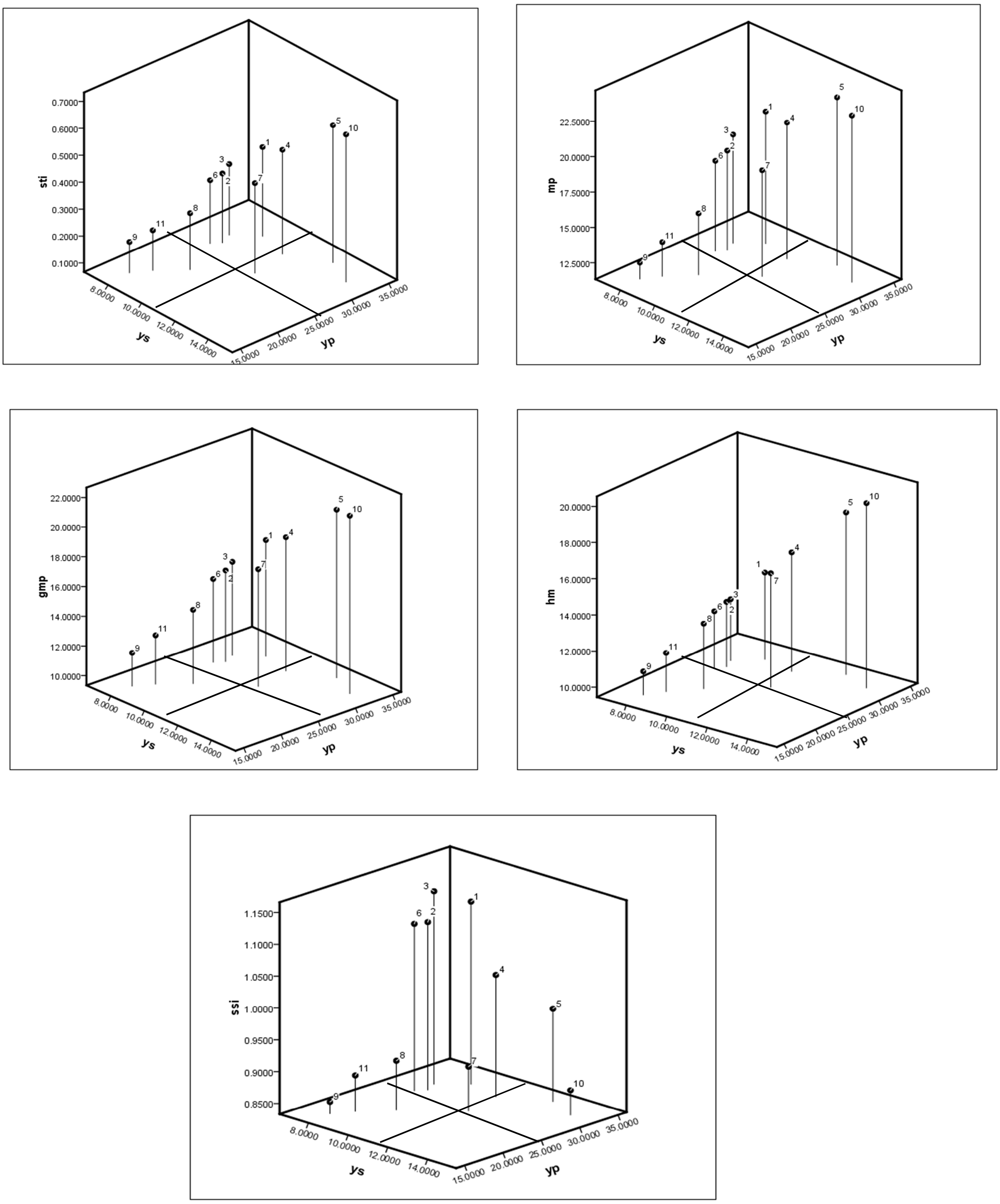

Fig. 1. Tree dimension scheme of potential yield (Y_P), stress yield (Y_S) and stress tolerance index (STI), mean productivity (MP), geometric mean productivity (GMP), harmonic mean (HM) and stress susceptibility index (SSI) for sunflower inbred lines.

Table 3. Eigen values and vectors of drought tolerance indices for sunflower inbred lines

Component	Eigen values	Cumulative Proportion (%)	Drought tolerance indices									
			Y_P	Y_S	SSI	TOL	MP	GMP	STI	HM	YI	YSI
1	6.730	64.330	.755	.974	-.135	.459	.892	.974	.986	1.000	.974	.135
2	3.258	35.553	.655	-.224	.990	.887	.451	.224	.158	-.004	-.224	-.990

Y_S: Yield in stress condition (g plant $^{-1}$); Y_p: Yield in normal condition (g plant $^{-1}$); SSI: Stress Susceptibility Index; TOL: Tolerance; MP: Mean Productivity; GMP: Geometric Mean Productivity; STI: Stress Tolerance Index; HM: Harmonic Mean; YI: Yield Index; YSI: Yield Stability Index

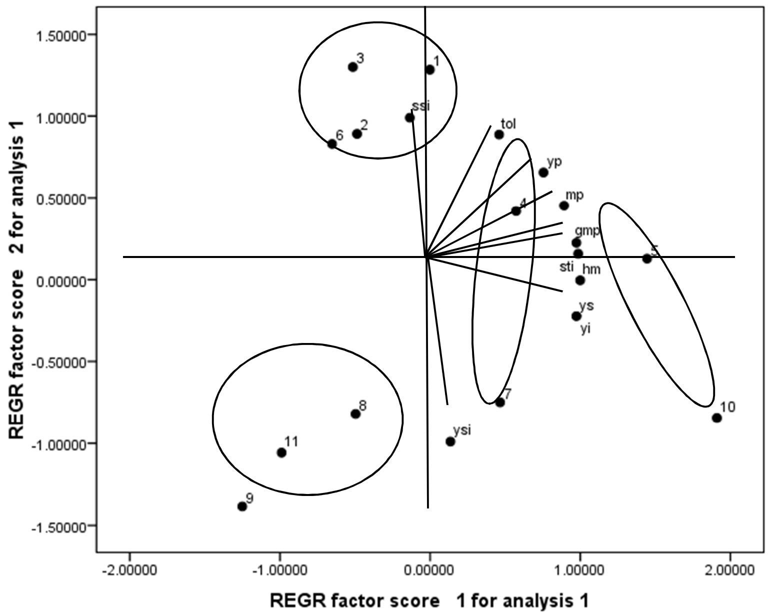

Fig. 2. Distribution of sunflower inbred lines based on two principal components and vectors of drought tolerance indices

Three dimensional graphs for each index were also employed for identification of the best indices for selection resistant genotypes (Fig. 1). These graphs showed the ability of these indices to detect Fernandez (1992) groups. Three dimensional graphs for STI, GMP, HM and MP indices were located genotypes R46, B147, R56 and B329 in group A. In the principal component analysis (PCA) the first two components with eigenvalues of greater than one explained 99.88% of total data variation. First PCA explained 64.33% of the total data variation and had positive correlation with the performance under both stress and non-stress conditions. Thus, the first dimension is indicating yield potential and drought tolerance. In other words, this component was able to separate the genotypes with higher yield under both stress and non-stress conditions. The second PCA explained 35.55 % of the total data variation and had negative correlation with yield under stress condition but, positive correlation with SSI. Therefore, it seems that this component confer sensitivity to stress. Therefore, selection of genotypes that have high PCA1 and low PCA2 are suitable for both stress and non-stress condition. In the bi-plot graph, angles between the vectors show correlation between them. Distribution graph of genotypes (Fig. 1 and 2) shows that genotypes B147 and R46 have high yield in both stress and non-stress conditions. Negative correlation of R46 with SSI index and near to zero of the same for B147 with SSI index indicating high performance and relatively high resistance to drought stress of these genotypes in the group of high product and resistant. High values of PCA_2 in figure 2 is found for genotypes R50, R26, R19 and B221 also these genotypes are close to SSI index. these genotypes in category fernandez (1992) in the figure 2 were in group B so they are placed in group of sensetive to stress. Genotypes B355, B349 and B110 in the figure 1 located in group D indicating low grain yield in the both normal and stress conditions but because of negative values of PCA_2 relatively high performance under drought stress. This group could be named as resistant but low yield under stress condition. Genotypes B329 and R56 have relatively moderate performance whereas genotype B329 and R56 exhibited negative and positive value for PCA_2, respectively. The values of SSI index for these genotypes indicated more yield stability under stress condition. B329 is also close to YSI index in the bi-plot graph. This group can be named as genotypes with moderate yield. It can be concluded that genotypes B147 and R46 have positive characteristics and are suitable for crossing and producing of high yielding hybrids and resistant to drought stress (Fig. 1 and 2). Genotype B329 located in the group A and achieve relatively good resistance to drought stress could be considered to produce drought tolerant hybrids. Distribution of genotypes in figures 1 and 2 also indicating genetic variation among the genotypes.

To confirm the validity of groupings made by bi-plot diagram we used MANOVA. The values of four significant test for MANOVA including Roy's Largest Root, Hotelling's Trace, Wilks' Lambda and Pillai's Trace were 1237.4, 1253.9, 0 and 2.6, respectively. Tests of Roy's Largest Root, Pillai's Trace, Wilks' Lambda were significant at 1% and Hotelling's Trace test at 5% probability levels conforming the validity of grouping (Table 4). STI, GMP, MP and HM indices have high correlation with yield under stress and non-stress conditions therefore these indices can be introduced as the best indices for selection of drought tolerant inbred lines in sunflower in the target environment. SSI index due to the ability for separating the sensitive genotypes is relatively efficient index for genotypic screening. In general various indices confer different aspects of sensitivity and resistance to drought stress and would have high efficiency for selection of resistant and high yielding genotypes.

4. Conclusions:

Among different resistance and sensitivity indices were evaluated STI, GMP, MP, and HM have high correlation with grain yield under stress and non-stress condition indicating more suitability of these indices for selection of resistant genotype. These indices could identify B147 and R46 as the most tolerant genotypes for drought condition. These genotypes were also placed in the high product and resistant group based on the bi-plot graph. The result of both the bi-plot and three dimensional graphs, B147 and R46 exhibited better characteristics than others and could be suitable inbred lines for producing drought resistant hybrids.

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