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Evaluation of drought Tolerance in Sunflower (*Helianthus annuus* L.) Inbred Lines and Synthetic Varieties under Non Stress and Drought Stress Conditions

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ABSTRACT: To evaluate some of agronomic and physiological characteristics under drought stress, determining the best quantitative indices for drought resistance, and identifying drought resistant of sunflower genotypes, field experiment with 15 sunflower genotypes was carried out in 2014 at the research farm of Dryland Agricultural Research Institute (Sararood). 15 genotypes of sunflower were tested based on Randomized Complete Blocks Design (RCBD) with three replications in under two different water conditions at flowering and seed development stages. Some of agronomic and physiological characteristics under drought stress were measured during the growing season. Based on the results of correlation between drought indices with seed yield in stress and non-water stress environment, stress tolerance index (STI), mean productivity (MP), Geometric mean productivity (GMP), harmonic mean (HAR) and yield index (YI) exhibited a high correlation with seed yield in either environment. These indices were recognized as the best for selecting cultivars with high yield potential in either of the stress of non-stress environments. The genotypes SIL-140 and SIL-54 had the highest drought resistance based on HAR, GMP, MP, YI and STI. The genotypes SIL-140 and SIL-54 revealed the highest yield in non stress and stress conditions. Cluster analysis grouped the 15 genotypes within 4 clusters, each of which having 4, 3, 5 and 3 genotypes.

Key words: Correlation analysis, Biplot analysis, drought tolerance, cluster analysis

INTRODUCTION

Drought is one of the major physical factors of environmental stresses which limits growth and distribution of natural vegetation more than that of any other factors viz. extreme temperature, cold, heavy metals, drought and salinity (Athar and Ashraf, 2005). Drought stress determines the success or failure of plant establishment. The adverse effects of drought on growth and development of crop plants are of multifarious nature and could affect at all the growth stages of plant growth. The susceptibility, severity and duration of plants exposition to drought stress varies in dependence of stress degree, different accompanying stress factors, plant species and their developmental stages but germination is regarded as most critical stage of plant life (Demirevska *et al*., 2009).

Crop responses to drought stresses involve processes modulated by water deficit at morphological, anatomical, cellular and molecular levels. The changes which occur in all plant organs in response to water stress decrease plant photosynthesis resulting in grain yield deduction (De la vega *et al*., 2007; Richards, 2006). It would be very useful to develop effective strategies to reduce drought stress damage to crop plants. A strategy involves producing a high yielding genotype with traits leading toward drought tolerance (Tardieu and Tuberosa, 2010).

Sunflower (*Helianthus annuus* L.) has become an important oil crop in the world with annual production of 20 to 25 million hectares worldwide in present decade (Machikowa and Saetang, 2008).Sunflower (*Helianthus annuus* L.) is an important oilseed crop (Pourdad and Beg, 2008). It ranks third after Soybean and palm oil in worldwide vegetable oil production (Iqbal *et al*., 2009). Turkey, Morocco, Pakistan, Iran, Iraq and Sudan were the leading producers in WANA (Beg *et al*., 2007).Water stress and high temperature can reduce crop yield by affecting both source and sink for assimilates (Mendham and Salsbury, 1995). Because of water deficit in most arid regions, resistance of crop plants against drought has always been of great importance and has taken into account as one of the breeding factors (Talebi, 2009). A long term drought stress effects on plant metabolic reactions associate with plant growth stage, water storage capacity of soil and physiological aspects of plant.

Drought tolerance in crop plants is different from wild plants. In case crop plant that encounters with severe water deficit, they die or seriously lose yield while in wild plants, they survive under this conditions but yield losses is not taken into consideration (Khayatnezhad *et al*., 2010). Achieving a genetic increase in yield under these environments has been recognized to be a difficult challenge for plant breeders while progress in yield grain has been much higher in favorable environments (Richards *et al*., 2002). Thus, drought indices which provide a measure of drought based on yield loss under drought conditions in comparison to normal conditions have been used for screening drought tolerant genotypes (Mitra, 2001).

To evaluate response of plant genotypes to drought stress, some selection indices based on a mathematical relation between stress and optimum conditions have been proposed (Clarke *et al*., 1992; Fernandez, 1992; Sio-se mardeh *et al*., 2006; Shirani rad and Abbasian., 2011). Rosielle and Hamblin (1981) defined stress tolerance (TOL) as the differences in yield between the stress (Ys) and non-stress (Yp) environments and mean productivity (MP) as the average yield of Ys and Yp. Fischer and Maurer (1978) proposed a stress susceptibility index (SSI) of the cultivar. Fernandez (1992) defined a new advanced index (STI = stress tolerance index), which can be used to identify genotypes that produce high yield under both stress and non-stress conditions. Geometric mean productivity (GMP) and stress tolerance index (STI) (Fernandez, 1992) have been employed under various conditions. Fischer and Maurer (1978) explained that genotypes with an SSI of less than a unit are drought resistant, since their yield reduction in drought conditions is smaller than the mean yield reduction of all genotypes (Bruckner and Frohberg, 1987). Other yield based estimates of drought resistance,are harmonic mean (HM) (Dehdari, 2003; Yousefi, 2004), yield index (YI) (Gavuzzi *et al*., 1997), yield stability index (YSI) (Bouslama and Schapaugh, 1984). Sio-se mardeh *et al*. (2006) reported that under moderate stress, MP, GMP and STI were more effective in identifying high yielding cultivars in both drought-stressed and irrigated conditions (group A cultivars). Under severe stress, none of the indices used were able to identify group A cultivars, although regression coefficient (b) and SSI were found to be more useful in discriminating resistant cultivars. So, the effectiveness of selection indices in differentiating resistant cultivars varies with the stress severity.

The present investigation was carried out for screening quantitative criteria of drought tolerance using wheat substitution lines.

MATERIAL AND METHODS

Current study was carried out with 15 genotypes based on Randomized Complete Blocks Design (RCBD) with three replication at the research in Sararood station, Kermanshah, Iran, 2014 cropping season. 15 genotypes of sunflower were tested in under two different water conditions at flowering and seed delopment stages. Some of agronomic and physiological characteristics under drought stress were measured during the growing season. The genotypes used in this study are given in Table 1.

Table 1: 15 Genotypes of sunflower that used in current study.

Genotype Number	Genotype Name	Genotype Type
1	Sil – 276	inbred lines
2	Sil – 221	inbred lines
3	Sil – 237	inbred lines
4	Sil – 292	inbred lines
5	Sil – 198	inbred lines
6	Sil -238	inbred lines
7	Sil – 215	inbred lines
8	Sil -42	inbred lines
9	Sil - 96	synthetic varietie
10	Sil - 54	synthetic varietie
11	Sil - 94	synthetic varietie
12	Sil -140	synthetic varietie
13	Lakomka	Control varietie
14	zaria	Control varietie
15	Armaviski	Control varietie

A. Calculate Indices

Drought tolerance indices were calculated based on grain yield per plot for stress (Ys), non-stress (Yp) and total mean of grain yield for stress ($\bar{Y}s$) and non-stress ($\bar{Y}p$) conditions as follows:

1- Stress susceptibility index (SSI) (Fischer and Maurer, 1978):

$$SSI = \frac{1-\left(\frac{Y_S}{Y_P}\right)}{SI} . SI = 1-\frac{\bar{Y}_S}{\bar{Y}_P}$$

2- Tolerance (TOL) and mean productivity (MP) (Rosielle and Hambelen, 1981):

$$TOL = YP - YS$$

$$MP = \frac{Yp+YS}{2}$$

3- Stress tolerance index (STI) and geometric mean productivity (GMP) (Fernandez, 1992):

$$STI = \frac{YS \times YP}{\bar{Y}p\ 2}$$

$$GMP = \sqrt{(YS \times YP)}$$

4- Drought Response Index: DRI (Bidinger *et al.*1987):

$$DRI=(Y_A-Y_{ES})/S_{ES}$$

5- Yield Stability Index: YSI (Bouslama and Schapaugh, 1984):

$$YSI = \frac{Ys}{Yp}$$

6- Stress Susceptibility Percentage Index: SSPI (Moosavi *et al.*, 2008):

$$SSPI = \left[\frac{(Yp - Ys)}{2\bar{Y}p}\right]$$

B. Statistical analysis

Analysis of variance, mean comparison using Duncan,s multiple range test (DMRT), correlation analysis between mean of the characters measured were performed by MSTAT-C, SPSS ver. 16 and STATISTICA ver. 8.

RESULTS AND DISCUSSION

Resistance indices were calculated on the basis of grain yield of cultivars (Table 2). Selection based on a combination of indices may provide a more useful criterion for improving drought resistance of wheat but study of correlation coefficients is useful in finding the degree of overall linear association between any two attributes. Accordingly, high levels indicators STI, MP, GMP, YI and YSI values and low index of TOL and SSI indicator of resistance to stress conditions were figured (Fernandez,1992). To determine the most desirable drought resistance criteria, Spearman's rank correlation between yield under stress and non-stress conditions and indices of drought resistance were calculated (Table 2). The results indicated that STI, MP, GMP, YI and HM had a significant (P<0.01) positive correlation with yield under stress condition. The indices STI, MP, GMP, YI and HM revealed a significant (P<0.01) positive correlation with yield under non-stress condition. Some researchers believe in selection based on only favorable condition (Betran *et al.* 2003), and/or only stress condition (Gavuzzi *et al.*, 1997) but others have chosen a mid-point and believe in selection based on both favorable and stress conditions (Fernandes, 1992; Byrne, 1995).

Table 2: Correlation between different drought tolerance indices and seed yield under normal and drought stress conditions.

Traits	Y_S	Y_P	TOL	STI	MP	GMP	SSI	HAR	DRI	YSI	SSPI
YP	0.866**	1									
TOL	^{ns} -0.164	^{ns} 0.351	1								
STI	0.986**	0.932**	^{ns} 0.008	1							
MP	0.964**	0.968**	^{ns} 0.104	0.992**	1						
GMP	0.971**	0.961**	^{ns} 0.077	0.994**	0.998**	1					
SSI	^{ns} -0.334	^{ns} 0.175	0.972**	^{ns} -0.184	^{ns} -0.075	^{ns} -0.101	1				
HAR	0.977**	0.953**	^{ns} 0.051	0.996**	0.998**	**-0.995	^{ns} -0.127	1			
DRI	^{ns} 0.416	^{ns} 0.000	-0.780**	^{ns} 0.291	^{ns} 0.209	^{ns} 0.234	-0.772**	^{ns} 0.257	1		
YSI	^{ns} 0.333	^{ns} -0.176	-0.973**	^{ns} 0.184	^{ns} 0.075	^{ns} -0.101	-0.996**	^{ns} 0.127	0.775**	1	
SSPI	-0.164 ^{ns}	^{ns} 0.351	1.00**	^{ns} -0.008	^{ns} 0.104	^{ns} 0.077	0.972**	^{ns} 0.051	-0.780**	-0.973**	1
YI	1.00**	0.866**	^{ns} -0.163	0.986**	0.964**	0.971**	^{ns} -0.334	0.977**	^{ns} 0.412	^{ns} 0.333	^{ns} -0.163

ns,* and **: Not significant, significant at 1% and 5% level of probability respectively.

Farshadfar *et al*., believe that most suitable indices for selection of drought resistance cultivars, is an indicator which has a relatively high correlation with grain yield in both conditions (Farshadfar *et al*., 2001). Farshadfar *et al*., (2001) believed that most appropriate index for selecting stress-tolerant cultivars is index which has partly high correlation with seed yield under stress and non-stress conditions. The observed relations were consistent with those reported by Fernandez (1992) in mungbean, Farshadfar and Sutka (2002) in maize. The results of calculated seed from indirect selection in moisture stress environment would improve yield in moisture stress environment better than selection from non-moisture stress environment. Wheat breeders should, therefore, take into account the stress severity of the environment when choosing an index. STI, GMP and YI were able to identify cultivars producing high yield in both conditions. It is concluded that the effectiveness of selection indices depends on the stress severity supporting the idea that only under moderate stress conditions, potential yield greatly influences yield under stress (Blum, 1996; Panthuwan *et al*., 2002).

The results indicated that the identification of drought-resistance genotypes based on a single index was contradictory in comparison with other indices, therefore genotype selection was done considering correlation (Table 3).

Table 3: Mean of seed yield and different drought tolerance indices under normal and drought stress conditions.

Genotypes	Y_P	Y_S	TOL	STI	MP	GMP	SSI	HAR	DRI	YSI	SSPI	YI
Sil - 276	680.5	560.9	119.6	0.75	620.7	617.8	0.92	614.9	0.49	0.82	42774.3	0.97
Sil - 221	740.5	545.5	194.9	0.79	643	635.6	1.38	628.2	-0.66	0.74	69729.7	0.94
Sil - 237	873.9	725.7	148.3	1.24	799.8	796.3	0.89	792.9	0.80	0.83	53025.1	1.25
Sil - 292	726.2	501.3	224.9	0.71	613.8	603.4	1.63	593.2	-1.44	0.69	80434.4	0.87
Sil - 198	798.5	568.5	230.1	0.89	683.5	673.8	1.51	664.2	-1.46	0.71	82283/0	0.98
Sil -238	696.6	498.9	197.7	0.68	597.8	589.5	1.49	581.4	-0.33	0.72	70692.8	0.86
Sil - 215	723.1	577.8	145.3	0.82	650.4	646.4	1.06	642.3	0.21	0.80	51973.5	1.00
Sil -42	740.8	634.2	106.7	0.92	687.5	685.4	0.76	683.4	0.66	0.86	38158.2	1.09
Sil - 96	477.5	456.3	21.2	0.43	466.9	466.8	0.23	466.7	0.25	0.96	7582.1	0.79
Sil - 54	926.8	895.2	31.6	1.62	910.9	910.8	0.18	910.7	1.13	0.97	11301.6	1.55
Sil - 94	458	451.4	6.6	0.40	454.7	454.7	0.08	454.7	0.73	0.99	2360.5	0.78
Sil -140	977	855.3	121.7	1.63	916.2	914.2	0.65	912.1	0.70	0.88	43525.4	1.48
Lakomka	539	453.2	85.8	0.48	496.1	494.1	0.84	492.4	0.14	0.84	30685.9	0.78
zaria	757.9	518.5	239.5	0.77	638.2	626.9	1.66	615.7	-1.79	0.68	85648.3	0.90
Armaviski	613	446.4	166.7	0.53	529.7	523.1	1.43	516.6	0.54	0.73	59600.7	0.77

The genotypes SIL-140 and SIL-54 had the highest drought resistance based on HAR, GMP, MP, YI and STI. The genotypes SIL-140 and SIL-54 revealed the highest yield in non stress and stress conditions.

A. Biplot analysis

To better understand the relationships, similarities and dissimilarities among the physiological indicators of drought tolerance, principal component analysis (PCA), based on the rank correlation matrix was used. The main advantage of using PCA over cluster analysis is that each statistics can be assigned to one group only (Khodadadi *et al*., 2011). The relationships among different indices are graphically displayed in a biplot of PCA1 and PCA2 (Fig. 1). The PCA1 and PCA2 axes which justify 97.35% of total variation, mainly distinguish the indices in different groups. One interesting interpretation of biplot is that the cosine of the angle between the vectors of two indices approximates the correlation coefficient between them. The cosine of the angles does not precisely translate into correlation coefficients, since the biplot does not explain all of the variation in a dataset. Nevertheless, the angles are informative enough to allow a whole picture about the interrelationships among the *in vivo* indices (Yan and Kang, 2003).

The first component consists of 58.73% of the total variation in the components of a high positive values for Yp, Ys, GMP, STI, MP, HAR and YI found. The positive values of these components can be varieties with high yield in both stress and non-stress environment is selected. The second component of 38.98% of total variation accounted for and positive for high levels of SSI, TOL and SSPI and the amount of negative and DRI, YSI was high. This component genotypes with low yield in both stress and non-stress and high levels of indices TOL, SSI and SSPI to isolate them. Biplot indicated that the genotypes G3 (SIL-237) in the vicinity of the vectors of drought tolerance indices, namely GMP, STI, MP, HAR and YI and also to vectors yield under normal and stress is also very close. This genotype had the highest grain yield in drought stress conditions, and the highest yield stress of genotypes G10 (SIL-54), respectively. The genotype G10 (SIL-54) had the highest amount of first component and a second component was negative. This genotype has the highest performance and highest yield in drought stress conditions after genotype G12 (SIL-140), but was farthest from the main indicator of stress tolerance.

The genotypes G5, G14, G4, G6 and G2 (include SIL-198, Zaria, SIL-292, SIL-238 and SIL-221) in the area with negative values of the first component and the second component had high levels of sensitivity indices were close to land, so as genotypes with lower performance on both the environment and sensitive to drought stress were identified.

Ward's hierarchical clustering for grouping genotypes based on ranks of drought resistance indices and yield of stress and non-stress conditions (Fig. 2), Cluster analysis grouped the 15 genotypes within 4 clusters, each of which having 4,3,5 and 3 genotypes.

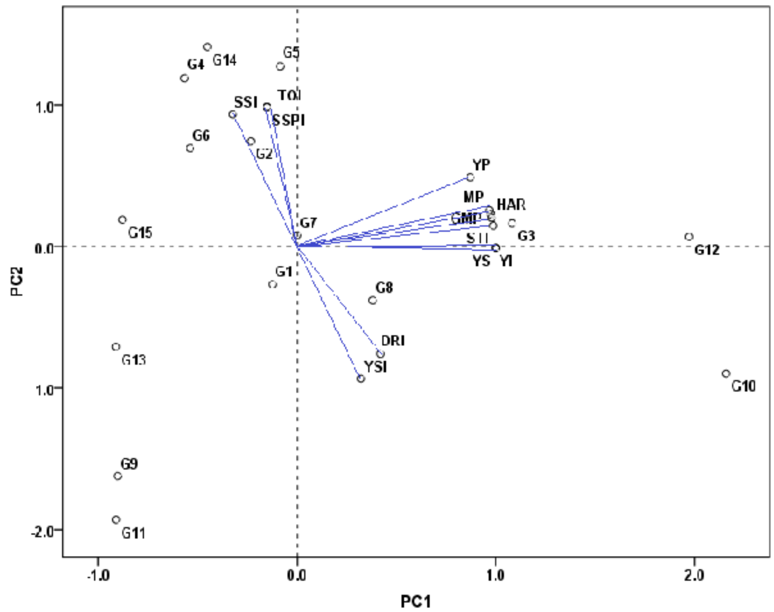

Fig. 1. Screening drought tolerance indicators using biplot analysis.

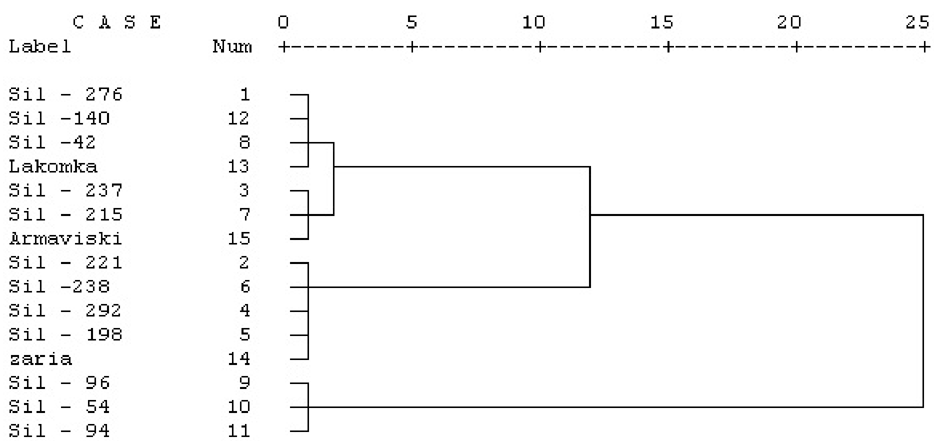

Fig. 2. Dendrogram developed by cluster analysis based on drought tolerance indices for sunflower genotypes.

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