INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print), 2222-3045 (Online)
http://www.innspub.net
Vol. 6, No. 1, p. 580-586, 2015

RESEARCH PAPER OPEN ACCESS

Evaluation of drought tolerance in sunflower (Helianthus annus L.) under non stress and drought stress conditions

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Key words: Sunflower genotypes, stress tolerance index, drought tolerance, cluster analysis.

Article published on January 01, 2015

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 lines, field experiment with 36 sunflower genotypes was carried out in 2010 at the research farm of Dryland Agricultural Research Institute (Sararood). 36 lines of sunflower were tested in a 6×6 lattice design with two replications 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, MP, GMP, Harm and STI 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 genotype SIL-237 had the highest drought resistance based on Harm, GMP, MP and STI. The genotype SIL-237 revealed the highest yield in non stress and stress condition. Cluster analysis grouped the 36 genotypes within 3 clusters, each of which having 17, 18 and 1 genotypes.

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Introduction

Sunflower (*Helianthus annuus* L.) is grown on 22 million ha in the world, producing 27 million tones total grain yield (FAO STAT Database., 2007). 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 annus* 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) and % reduction (Choukan *et al.*, 2006). 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 36 genotypes based on lattice design with two replication at the research in Sararood station, Kermanshah, Iran, 2010 cropping season. 36 lines of sunflower were tested in a 6×6 lattice design 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. 36 lines of sunflower that used in current study.

Lines	
SIL-20	SIL-210
SIL-42	SIL-215
SIL-53	SIL-217
SIL-54	SIL-222
SIL-75	SIL-224
SIL-80	SIL-226
SIL-82	SIL-227
SIL-94	SIL-237
SIL-96	SIL-238
SIL-97	SIL-254
SIL-99	SIL-259
SIL-114	SIL-260
SIL-140	SIL-280
SIL-162	SIL-196
SIL-200	SIL-218
SIL-203	SIL-231
SIL-205	SIL-240
SIL-206	SIL-211

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) (Fernandes, 1992):

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

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

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

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

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

Comparing Lines based on the resistance / tolerance indices

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 and HM had a significant ($P<0.01$) positive correlation with yield under stress condition, while SSI and DRI showed a significant ($P<0.01$) negative correlation. The indices GMP, STI, MP, TOL, DRI 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) . 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).

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

Traits	YS	YP	GMP	STI	MP	TOL	Harm	SSI	DRI
YS	1								
YP	0.645**	1							
GMP	0.931**	0.877**	1						
STI	0.932**	0.823**	0.973**	1					
MP	0.846**	0.953**	0.981**	0.943**	1				
TOL	0.100	0.825**	0.454**	0.381*	0.615**	1			
Harm	0.977**	0.786**	0.986**	0.970**	0.935**	0.301	1		
SSI	-0.490**	0.291	-0.162	-0.194	0.009	0.741**	-0.307	1	
DRI	-0.400*	0.442**	-0.041	-0.108	0.150	0.871**	-0.205	0.924**	1

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).

Correlation analysis

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 2) .

The genotype SIL-237 had the highest drought resistance based on Harm, GMP, MP and STI. The genotype SIL-237 revealed the highest yield in non stress and stress condition.

Cluster analysis

Ward's hierarchical clustering for grouping genotypes based on ranks of drought resistance indices and yield of stress and non-stress conditions (Fig. 1), Cluster analysis grouped the 36 genotypes within 3 clusters, each of which having 17, 18 and 1 genotypes.

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

NO	Line	YS	YP	SSI	TOL	STI	MP	GMP	HM	DRI
1	SIL-20	1222 bcde	2777 abcdefgh	1.068481	1554.35	0.584208	1999.56	1842.34	1697.487	1.013
2	SIL-42	1473 bcde	2313 bcdefgh	0.692876	839.48	0.586382	1892.89	1845.77	1799.815	-0.384
3	SIL -53	636.1 de	1424 fgh	1.055857	787.50	0.155873	1029.88	951.64	879.3391	0.479
4	SIL -54	952.7 bcde	1586 defgh	0.762072	633.15	0.260043	1269.28	1229.16	1190.317	-0.118
5	SIL-75	579.1 e	1888 cdefgh	1.323391	1309.17	0.188203	1233.67	1045.68	886.341	1.357
6	SIL-80	994 bcde	1792 defgh	0.850202	798.35	0.306645	1393.18	1334.76	1278.803	0.094
7	SIL-82	1009 bcde	2421 abcdefgh	1.113089	1412.08	0.420699	1715.44	1563.41	1424.848	1.032
8	SIL-94	780.5 bcde	1379 fgh	0.828563	598.68	0.185277	1079.84	1037.52	996.8606	0.022
9	SIL-96	1538 bcde	2680 abcdefgh	0.813341	1141.88	0.70934	2108.84	2030.08	1954.266	0.015
10	SIL-97	1081 bcde	1966 cdefgh	0.859227	884.97	0.365778	1523.47	1457.79	1394.947	0.130
11	SIL-99	948.7 bcde	2886 abcdefgh	1.281415	1937.77	0.471315	1917.57	1654.79	1428.018	1.919
12	SIL-114	674.6 cde	2546 abcdefgh	1.402965	1871.27	0.29562	1610.27	1310.55	1066.62	2.125
13	SIL-140	1832 bc	2302 bcdefgh	0.389673	470.05	0.726191	2067.46	2054.05	2040.738	-1.364
14	SIL-162	968.5 bcde	1534 efgh	0.70348	565.25	0.25565	1251.08	1218.73	1187.228	-0.242
15	SIL-200	452.7 e	1489 efgh	1.328364	1036.17	0.11602	970.82	821.02	694.3338	1.074
16	SIL-203	763.9 bcde	2042 cdefgh	1.194566	1277.67	0.268419	1402.72	1248.80	1111.772	1.100
17	SIL-205	924.2 bcde	1874 cdefgh	0.967564	950.07	0.298134	1399.22	1316.11	1237.94	0.408
18	SIL-206	1535 bcde	2679 abcdefgh	0.814727	1143.45	0.707978	2107.18	2028.13	1952.053	0.020
19	SIL-210	1818 bcd	2813 abcdefgh	0.675244	995.05	0.88002	2315.26	2261.17	2208.342	-0.529
20	SIL-215	1470 bcde	3409 abcdef	1.085624	1939.00	0.862676	2439.68	2238.77	2054.412	1.333
21	SIL-217	856.5 bcde	3127 abcdefg	1.385986	2270.63	0.460965	1991.77	1636.52	1344.63	2.543
22	SIL-222	1205 bcde	3852 abc	1.31161	2647.22	0.799161	2528.84	2154.78	1836.055	2.736
23	SIL-224	1526 bcde	3498 abcde	1.076042	1971.90	0.918733	2511.95	2310.37	2124.961	1.321
24	SIL-226	783.5 bcde	1734 defgh	1.046358	950.60	0.233843	1258.78	1165.60	1079.313	0.567
25	SIL-227	1479 bcde	2856 abcdefgh	0.920576	1377.42	0.726826	2167.29	2054.95	1948.435	0.449
26	SIL-237	2872 a	4347 a	0.647577	1474.73	2.148818	3609.47	3533.35	3458.831	-0.972
27	SIL-238	1293 bcde	2419 abcdefgh	0.888571	1125.95	0.538163	1855.71	1768.25	1684.912	0.267
28	SIL-254	683.7 cde	1334 gh	0.930464	650.30	0.156992	1008.88	955.05	904.088	0.212
29	SIL-259	1145 bcde	1868 cdefgh	0.73915	723.28	0.367933	1506.14	1462.08	1419.306	-0.194
30	SIL-260	823 bcde	1034 h	0.389817	211.22	0.14651	928.64	922.62	916.6295	-0.629
31	SIL-280	678.8 cde	1365 gh	0.959638	686.35	0.159506	1022.01	962.67	906.7716	0.274
32	SIL-196	1148 bcde	2855 abcdefgh	1.141206	1707.12	0.564273	2001.74	1810.63	1637.774	1.335
33	SIL-218	1874 b	3614 abcd	0.918748	1739.50	1.16594	2744.18	2602.70	2468.518	0.567
34	SIL-231	952.9 bcde	4222 ab	1.477917	3268.65	0.692366	2587.21	2005.64	1554.81	3.988
35	SIL-240	1511 bcde	2492 abcdefgh	0.751278	980.70	0.647984	2001.30	1940.30	1881.157	-0.205
36	SIL-211	831.1 bcde	2357 abcdefgh	1.235802	1526.17	0.337191	1594.17	1399.67	1228.896	1.411

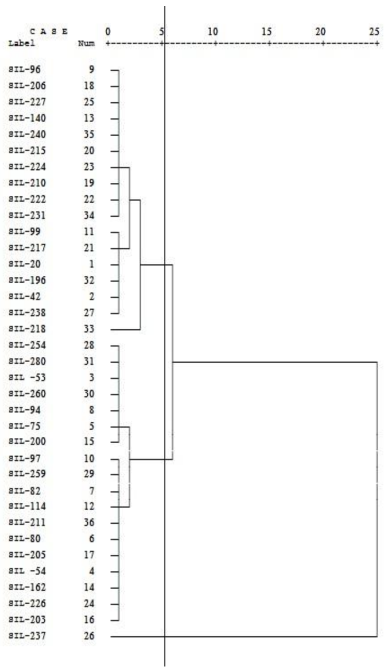

Fig. 1. Dendrogram developed by cluster analysis based on MP, STI, GMP and HM indices for sunflower lines.

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