Archives of Agriculture Sciences Journal
Print ISSN: 2535-1680
Online ISSN: 2535-1699

ARCHIVES OF AGRICULTURAL SCIENCES JOURNAL

Volume 1, Issue 2, 2018, Pages 79–90

Available online at www.agricuta.edu.eg

The 1st International Conference on Applied Agricultural Sciences and Prospective Technology

Evaluation of eight white maize inbred lines and their diallel crosses to study the variation in response to water deficit

Gabr Afaf A.I., Abdallah T.A.E., Abd El-Latif M.S.*

Maize Research Department, Field Crops Research Institute, Agricultural Research Center, Giza, Egypt

Abstract

A half diallel was done among eight white maize inbred lines. Two experiments were laid out in randomized complete block design (RCBD) with three replications to evaluate the eight parental lines and their 28 crosses at both normal and drought stress conditions at Mallawi Agricultural Research Station, Minia, Egypt. Data were recorded for the following traits from 10 guarded plants of each genotype: silking and tassel date to estimate anthesis-silking interval (ASI), plant height (cm), leaf senescence, leaf proline content (mg/g) and grain yield per plant (g) which was adjusted for 15.5% moisture. The effect of irrigation treatments was highly significant for all traits under study except for anthesis-silking interval (ASI), indicating that these traits were affected by water stress. All studied materials were affected by water stress. Nine crosses were selected based on the percentage of yield reduction, three crosses out of them, i.e. Gz-6×Gz-7, Gz-5×Gz-7 and Gz-5×Sd-3 were performed as best crosses under both irrigation systems and selected as tolerant crosses based on mean productivity (MP), stress tolerance index (STI), Geometric mean productivity (GMP) and harmonic mean (M_{HAR}) indices. While, based on drought sensitive index (DSI) and stress tolerance indices, the crosses Gz-6×Sd-3, Gz-2×Gz-4 and Gz-4×Sd-2 were identified as tolerant crosses. Thus, we can use to detect crosses which had high performance under water stress or which had less yield reduction in drought maize breeding programs and can be cultivated in new lands under drip or sprinkler irrigation system.

Keywords: white maize, diallel crosses, water deficit.

*Corresponding author: Abd El-Latif M.S.
E-mail address: mshawky1982@gmail.com

1. Introduction

Maize (*Zea mays* L.) is a staple food for vast number of people around the world. It is ranked third after wheat and rice in production, it is a monoecious and highly cross pollinated crop mostly used as food, feed, green forage, fuel (ethanol), vegetable oil and starch and is the backbone of the poultry feed industry (Saif-ul-malook *et al*., 2016). The crop is adapted to tropical, sub-tropical and temperate areas, but little is known about drought stress response within tropical and sub-tropical maize cultivars. Maize is affected by many biotic and abiotic factors, the air pollution, heavy metal, pesticides and soil ph are major limiting factors in crop production because they affect almost all plant functions (Lawlor and Cornic, 2002), Drought is the major abiotic factor that limits agricultural crop production (Bruce *et al*., 2002; Lea *et al*., 2004), affecting plant growth from seedling to maturity and maize is more susceptible to drought compared to other cereal crops except for barley (Banziger and Araus, 2007). Drought occurs when moisture around the root is so reduced that a plant is not able to absorb enough water, or in other words transpiration of water absorption (Benjamin, 2007). Several studies have shown that drought stress had significant influence on number of rows in ear, number of seed per row, 1000 seed weight, seed yield and yield components (Moser *et al.*, 2006; Mostafavi *et al*., 2011; Mohmmadai *et al*., 2012). Whereas, Edmeades *et al*. (1992) stated that water stress affects on extends the anthesis-silking interval (ASI), which ultimately lead to lower crop yield. Roson and Scott (1992) suggested that an overwhelming situation of drought stress in South Africa in 1991-1992 reduced maize production by about 60 percent, whereas, Edmedes *et al*. (1998) reported that the drought assessed to cause average annual yield losses in maize of about 17 percent in tropics. The best option for crop production, yield improvement and yield stability under drought stress conditions is to develop drought tolerant crop varieties. One of the main goals in breeding program is selection of the best genotypes under drought conditions (Richards et *al*., 2002). Although yield is principle selection index used commonly under drought stress conditions, the use of selection index is more efficient than direct selection for grain yield alone and the relative efficiencies could be better when two or more traits are merged than using each of the single traits independently (Muhe, 2011). Many investigations used selection indices to evaluate the maize hybrids for drought tolerance *i.e*. Jafari *et al.* (2009), Song *et al.* (2010), Abd El-Latif *et al.* (2011) and Mostafavi *et al.* (2011). The objectives of this investigation were to study the effect of water deficit on the yield and some other agronomic traits of new maize hybrids and to identify more tolerant and stable hybrid for drought stress.

2. Materials and methods

Eight white inbred lines of maize (*Zea mays* L.) were developed under drought stress from diverse sources at Sids Agricultural Research Station, Bani

Sweif, Egypt. Line 1 was derived from Giza-2 population (EV-8), the lines 2, 3 and 4 were derived from TEP-5 population, whereas line 5 was derived from open pollinated variety American Early Dent and the line 6, 7 and 8 were derived from Mexico Drought Tolerance population (DTP-C7). These lines exhibited a good performance under stress and non-stress environments for drought. In 2015 growing season, a half diallel was used among eight maize inbred lines, which grown in two planting dates in order to overcome the differences in flowering time for parental lines. In 2016 season, two experiments were laid out in randomized complete block design (RCBD) with three replications to evaluate the eight parental lines and their 28 crosses at both normal and drought stress conditions at Mallawi Agricultural Research Station, Minia, Egypt. The normal experiment (Control) was irrigated every 12 days, while drought experiment was irrigated every 20 days. Plot size was one row with 6 m. length and the plant-to-plant and row-to-row distance were 25 cm and 80 cm, respectively. Data were recorded for the following traits from 10 guarded plants of each genotype: silking and tassel date to estimate anthesis-silking interval (ASI), plant height (cm), leaf senescence (scale from 0 to 10, where 0 indicated no any senescence and 10 indicated complete death, using relative area of senescence to total area of leaves), leaf proline content (mg/g) and grain yield per plant (g) which was adjusted to 15.5% moisture. The data for each trail was performed according to analysis of variance technique (Steel *et al.*, 1997) to evaluate the differences in performance among the genotypes. The combined analysis of the two experiments was carried out whenever homogeneity of error variance was detected. Drought tolerance indices were calculated using the following equations (Fischer and Maurer, 1978; Rosielle and Hamblin, 1981; Fernandez, 1992; Sio-Se *et al.*, 2006):

1. Drought Susceptibility Index (DSI) = $(1- (Y_S / Y_P)) / (1- \overline{Y}_S / \overline{Y}_P)$
2. Tolerance Index (TOL) = $Y_P - Y_S$
3. Mean Productivity (MP) = $(Y_P + Y_S) / 2$
4. Geometric Mean Productivity (GMP) = $\sqrt{((YP)(YS))}$
5. Stress Tolerance Index (STI) = $(Y_P \times Y_S) / (\overline{Y}_P)^2$
6. Harmonic Mean (H_{ARM}) = $2(Y_P \times Y_S) / (Y_P + Y_S)$

Where, Y_S and Y_P are stress and non-stress (potential) yield of a given genotype, respectively. $\overline{Y}_S$ and $\overline{Y}_P$ re average yields of all genotypes under stress and non-stress conditions, respectively.

3. Results and Discussion

The result of analysis of variance for all studied traits under two different irrigation treatments as well as the combined data is presented in (Table 1). The effect of irrigation treatments was highly significant for all traits under study except for anthesis-silking interval (ASI), indicating that these traits were affected by water stress. Highly significant differences were obtained among genotypes, parents and and crosses for all traits under study except for ASI specially under water stress and combined data across the two irrigation treatments. This indicates that, both parental lines and their crosses varied in their response to water stress. Highly significant differences were also obtained for the interaction between genotypes, parents and crosses with the two irrigation treatments, indicating that the performance of these studied materials differed under the two irrigation treatments (normal and stress irrigation).

Table (1): Mean squares for anthesis-silking interval, plant height, Leaf senescence, leaf proline content and Grain yield per plant under normal irrigation (N), drought stress (D) and over both irrigations treatment (C).

S.O.V.	d.f.		Anthesis-silking interval			Plant height (cm)			Leaf senescence		
	S	C	N	D	C	N	D	C	N	D	C
Irrigations (I)		1			43.56			1420.91**			198.38**
Rep/(I)	2	4	44.53**	39.37	41.95	26.25	30.18	33.22	0.29	0.18	0.23
Genotypes (G)	35	35	6.22*	14.94	11.25	6752.50**	6222.00**	12133.75**	1.49**	5.70**	4.15**
Parent (P)	7	7	12.57**	7.60	14.56	1255.81**	897.52**	1768.90**	1.42**	17.79**	10.52**
Cross (C)	27	27	4.65	13.51	8.03	1047.20**	1258.49**	1354.97**	1.42**	2.77**	2.58**
P *vs.* C	1	1	4.02	104.76*	74.93**	199272.60**	176778.97**	375714.90**	4.13**	0.01	1.96*
G×I		35			9.9			840.75**			3.04**
P×I		7			5.61			384.43*			8.69**
C×I		27			10.13			977.72**			1.61**
P *vs.* C×I		1			33.86			336.67*			2.17**
Error	70	140	3.63	16.99	10.31	186.33	152.93	169.63	0.32	0.26	0.29

S.O.V.	d.f.		leaf proline content			Grain yield per plant		
	S	C	N	D	C	N	D	C
Irrigations (I)		1			17981.73**			193632.76**
Rep/(I)	2	4	43.19**	18.45**	30.82	53.52	33.13	43.33
Genotypes (G)	35	35	48.35**	443.15**	325.77**	9718.78**	6808.43**	15385.44**
Parent (P)	7	7	56.03**	428.22**	375.90**	158.24	439.16**	464.78**
Cross (C)	27	27	41.52**	401.96**	270.58**	982.32**	2590.42**	2557.70**
P *vs.* C	1	1	179.22**	1659.76**	1464.90**	312526.88**	165279.33**	466178.78**
G×I		35			165.73**			1141.77**
P×I		7			108.34**			132.63
C×I		27			172.89**			1015.04**
P *vs.* C×I		1			374.09**			11627.43**
Error	70	140	0.23	1.82	1.03	160.78	132.41	146.60

* and ** indicate significant differences at 0.05 and 0.01 probability levels, respectively.

Considerable differences exist among all studied genotypes in their performance under two different irrigation treatments (Table 2). All genotypes were affected by water stress in all studied traits. Generally, water stress reduced both plant height and grain yield, while increased the ASI, leaf senescence and leaf proline content. Based on combined data, parental lines Gz-2 and Sd-3 obtained the lowest values for ASI, whereas, for plant height the parental lines Sd-1, Sd-2 and Sd-3 exhibited the highest values for this trait. For leaf senescence, three inbred lines *i.e.* Gz-2 and Gz-7 and sd-3 showed the lowest values for this trait, whereas, for leaf proline content, parental lines Gz-2, Gz-4 and Sd-3 exhibited the highest values. For grain yield, four parental lines *i.e.* Gz-7 followed by Gz-2 and Gz-4 then Sd-3 exhibited the highest values and significant out yielded that the other parental lines (Gz-5, Gz-6, Sd-1 and Sd-2). When screening the crosses responses for ASI, it was found that all hybrids except for Gz-6×Sd-1 performed well without any significant differences among them, the lowest values were obtained for the two crosses *i.e.* Gz-6×Sd-2 and Gz7×Sd-2. Clear crosses differences in plant height were obtained among crosses, the crosses Gz-5×Gz-7, Gz-7×Sd-2 and Gz-4×Gz-7 showed the highest value for plant height, while, the lowest values were observed for crosses Gz-6×Sd-2, Sd-1×Sd-3, Gz-7×Sd-3 and Gz-2×Sd-1. Whereas, the best crosses for leaf senescence that were Gz-6×Sd-3 followed by Gz-5×Gz-7 and Gz-6×Gz-7, while, the highest values for this trait were obtained for the crosses Gz-4×Gz-5 and Sd-2×Sd-3. With respect to leaf proline content, two cresses *i.e.* Gz-5×Gz-7 and Gz-6×Gz-7 showed the highest value, while, the crosses Gz-2×Sd-2 and Gz-2×Sd-3 had the lowest value for this trait. Also, differences in grain yield as responses to drought stress were obtained among the crosses. Among all crosses, crosses Gz-6×Gz-7, Gz-5×Gz-7 and Gz-4×Sd-3 produced the highest grain yield. While the lowest value for grain yield was obtained for the cross Gz-6×Sd-2 followed by Gz-2×Sd-2. From the previous results, we can note that, the most genotypes which produced the highest grain yield such as parental line Gz-2 and two crosses Gz-6×Gz-7 and Gz-5×Gz-7, had also high content for leaf proline and showed lower value for leaf senescence, indicating that material can be used in hybrid maize program for drought stress. Several investigation have reported that water stress during the vegetative stage produced an increase of ASI (Bolaoos and Edmeades, 1993; Lawlor and Cornic, 2002) and produced increasing in ASI, leaf senescence and leaf proline content and reduced the plant height (Camacho and Caraballo 1994) this usually associates with reduction in grain yield (Edmeades *et al.*, 1992; Golbashy *et al.,* 2010). Results of this investigation also indicated that water stress reduced both plant height and grain yield traits, increase of proline levels (Singh *et al.*, 1973; Bohnert and Jensen 1996) for all studied materials. The percent of total reduction in stress condition was 47.85% and 34.46% for parental lines and crosses, respectively for grain yield per plant, while, it was -7.59%% and -9.03% in plant height trait, 32.60% and 123.83% in ASI, 107.51% and 69.88% in leaf senescence and 130.33% and 147.52% in leaf proline content (Table 2). The percent of yield reduction of each parental and each crosses (Table 3) revealed that, the highest percentage of reduction was observed for parental lines Sd-1 and Sd-2, while, the lowest percentage was observed for Gz-4 followed by Gz-2 and Sd-3. With respect to the crosses, the lowest percentage was observed for cross Gz-6×Sd-3 followed by Gz-2×Gz-4 and Gz-4×Sd-2. While the highest percentage was observed for the crosses Sd-1×Sd-3 followed by Sd-1×Sd-2 and Gz-6×Sd-1. As responses to drought, the parental lines Gz-2 and Gz-4 performed better performance than the other parental materials, where exhibited the highest mean value for grain yield (based on combined data) and associated with lowest percentage of reduction. Whereas, there are eight crosses did not differ Significant among them for grain yield per plant and exhibited the lowest percentage for reduction (ranged from -11.27% to -25.88%) these crosses are Gz-

6×Sd-3, Gz-2×Gz-4, Gz-4×Sd-2, Gz-4×Sd-3, Gz-5×Sd-3, Gz-6×Gz-7, Gz-4×Gz-7 and Gz-5×Gz-7 All of these crosses had high leaf proline content and either moderate or high leaf senescence except single cross Gz-6×Sd-3 which had moderate leaf proline content and lower leaf senescence.

Table (2): Mean performance and Trait variation percentage (TVP) of eight parental line and 28 F1's crosses for studied traits under normal irrigation (N), drought stress (D) and over both irrigation treatments (C).

Genotypes	Anthesis-silking interval			Plant height (cm)			Leaf senescence			leaf proline content (mg/g)			Grain yield per plant (g)		
	N	D	C	N	D	C	N	D	C	N	D	C	N	D	C
Gz-2	0.00	0.33	0.17	118.33	110.00	114.17	1.00	1.67	1.33	18.85	39.73	29.29	72.00	46.20	59.10
Gz-4	1.00	2.00	1.50	126.67	125.00	125.83	2.67	3.00	2.83	12.48	34.87	23.68	70.20	49.00	59.60
Gz-5	1.33	1.67	1.50	125.00	123.33	124.17	1.33	5.00	3.17	5.74	10.64	8.19	70.00	31.00	50.50
Gz-6	3.67	3.67	3.67	140.00	113.33	126.67	3.00	5.67	4.33	5.42	13.95	9.69	53.27	27.47	40.37
Gz-7	1.33	2.67	2.00	137.33	130.67	134.00	2.67	2.00	2.33	10.52	26.68	18.60	78.13	44.33	61.23
Sd-1	1.33	1.67	1.50	160.00	155.00	157.50	2.33	7.67	5.00	9.63	12.23	10.93	64.00	19.67	41.83
Sd-2	1.67	1.33	1.50	160.00	153.67	156.83	2.00	7.67	4.83	7.73	14.93	11.33	65.27	20.33	42.80
Sd-3	0.67	1.33	1.00	170.00	140.00	155.00	2.00	2.67	2.33	11.41	35.31	23.36	69.27	44.70	56.98
Mean of parent	1.38	1.83	1.60	142.17	131.38	136.77	2.13	4.42	3.27	10.22	23.54	16.88	67.77	35.34	51.55
TVP for parent	32.60			-7.59			107.51			130.33			-47.85		
Cross															
Gz-2× Gz-4	0.33	4.00	2.17	251.33	207.33	229.33	2.67	4.00	3.33	21.41	44.81	33.11	194.60	165.67	180.13
Gz-2× Gz-5	0.00	4.00	2.00	240.67	200.00	220.33	3.00	3.67	3.33	16.74	33.68	25.21	207.20	145.63	176.42
Gz-2× Gz-6	2.00	6.33	4.17	244.33	205.00	224.67	3.00	4.33	3.67	8.41	26.31	17.36	181.60	104.43	143.02
Gz-2× Gz-7	2.33	2.67	2.50	257.33	218.33	237.83	3.67	4.67	4.17	12.38	45.45	28.91	184.00	126.00	155.00
Gz-2× Sd-1	0.67	3.00	1.83	230.00	203.33	216.67	2.33	3.00	2.67	9.74	25.53	17.64	187.80	137.00	157.90
Gz-2× Sd-2	2.33	2.33	2.33	262.00	221.67	241.83	2.00	5.00	3.50	9.72	14.87	12.30	171.80	99.47	135.63
Gz-2× Sd-3	3.00	3.33	3.17	230.00	200.00	215.00	2.00	5.67	3.83	11.58	14.54	13.06	172.00	106.47	139.23
Gz-4× Gz-5	1.67	5.00	3.33	242.33	235.00	238.67	4.33	5.00	4.67	11.30	52.87	32.09	213.90	155.27	184.58
Gz-4× Gz-6	1.33	1.67	1.50	258.67	243.33	251.00	3.33	3.33	3.33	18.56	38.62	28.59	184.23	140.83	162.53
Gz-4× Gz-7	1.33	4.67	3.00	268.67	241.67	255.17	3.33	4.67	4.00	10.46	50.66	30.56	208.50	155.47	181.98
Gz-4× Sd-1	1.00	5.00	3.00	265.00	220.00	242.50	2.00	5.33	3.67	15.41	29.66	22.54	182.90	108.47	145.68
Gz-4× Sd-2	1.67	4.00	2.83	258.67	244.00	251.33	1.67	3.33	2.50	16.30	39.05	27.67	198.00	162.90	180.45
Gz-4× Sd-3	2.00	3.00	2.50	252.00	236.67	244.33	3.33	3.67	3.50	18.21	32.31	25.26	211.80	165.30	188.55
Gz-5× Gz-6	3.00	6.00	4.50	256.67	233.33	245.00	2.33	5.33	3.83	7.40	20.50	13.95	203.60	107.87	155.73
Gz-5× Gz-7	2.67	3.33	3.00	274.67	265.33	270.00	1.33	3.33	2.33	16.79	50.50	33.64	229.90	170.40	200.15
Gz-5× Sd-1	3.67	4.33	4.00	254.33	243.00	248.67	2.67	5.33	4.00	17.76	24.72	21.24	194.20	107.80	151.00
Gz-5× Sd-2	0.67	6.33	3.50	244.67	223.33	234.00	2.33	4.33	3.33	10.93	19.11	15.02	205.40	107.57	156.48
Gz-5× Sd-3	2.33	6.67	4.50	255.00	225.00	240.00	2.00	4.00	3.00	16.40	40.40	28.40	218.80	169.33	194.07
Gz-6× Gz-7	2.33	6.00	4.17	256.67	250.00	253.33	2.00	2.67	2.33	14.44	54.17	34.30	229.03	175.60	202.32
Gz-6× Sd-1	4.00	8.33	6.17	248.67	228.33	238.50	2.67	5.67	4.17	10.30	24.49	17.39	214.73	105.63	160.18
Gz-6× Sd-2	1.33	1.00	1.17	220.00	203.33	211.67	2.33	4.33	3.33	8.85	40.49	24.67	154.00	96.00	125.00
Gz-6× Sd-3	1.33	4.33	2.83	241.67	221.67	231.67	1.67	2.33	2.00	13.41	23.66	18.53	184.90	164.07	174.48
Gz-7× Sd-1	3.00	4.67	3.83	246.67	237.00	241.83	2.33	5.33	3.83	16.49	39.80	28.15	182.20	109.93	146.07
Gz-7× Sd-2	0.33	2.33	1.33	262.00	251.67	256.83	2.33	5.00	3.67	11.31	33.59	22.45	188.50	105.70	147.10
Gz-7× Sd-3	2.33	5.67	4.00	218.33	214.67	216.50	3.33	4.00	3.67	13.30	32.19	22.74	210.90	148.83	179.87
Sd-1× Sd-2	1.67	3.00	2.33	230.00	213.33	221.67	2.67	5.00	3.83	12.30	21.42	16.86	206.30	93.70	150.00
Sd-1× Sd-3	3.33	6.33	4.83	216.67	213.33	215.00	2.67	5.33	4.00	15.51	27.42	21.47	208.83	77.80	143.32
Sd-2× Sd-3	2.33	3.67	3.00	265.33	225.00	245.17	3.33	5.67	4.50	7.54	22.44	14.99	199.83	111.03	155.43
Mean of cross	1.93	4.32	3.12	248.30	225.88	237.09	2.59	4.40	3.50	13.32	32.97	23.15	197.48	129.43	163.30
TVP for crosses	123.83			-9.03			69.88			147.52			-34.46		
L.S.D. 5%	3.05	6.60	3.63	21.84	19.79	14.74	0.91	0.82	0.61	0.77	2.16	1.15	20.29	18.41	13.70

Table (3): Trait variation percentage (TVP) of the eight parents and their 28 F_1's for anthesis-silking interval, plant height (cm), Leaf senescence, leaf proline content (mg/g) and grain yield per plant (g).

Genotypes	Anthesis-silking interval			Plant height (cm)			Leaf senescence			leaf proline content (mg/g)			Grain yield per plant (g)		
	N	D	C	N	D	C	N	D	C	N	D	C	N	D	C
Parents															
Gz-2	0.00	0.33	230.00	118.33	110.00	-7.04	1.00	1.67	67.00	18.85	39.73	110.77	72.00	46.20	-35.83
Gz-4	1.00	2.00	100.00	126.67	125.00	-1.32	2.67	3.00	12.36	12.48	34.87	179.41	70.20	49.00	-30.20
Gz-5	1.33	1.67	25.56	125.00	123.33	-1.34	1.33	5.00	275.94	5.74	10.64	85.37	70.00	31.00	-55.71
Gz-6	3.67	3.67	0.00	140.00	113.33	-19.05	3.00	5.67	89.00	5.42	13.95	157.38	53.27	27.47	-48.43
Gz-7	1.33	2.67	100.75	137.33	130.67	-4.85	2.67	2.00	-25.09	10.52	26.68	153.61	78.13	44.33	-43.26
Sd-1	1.33	1.67	25.56	160.00	155.00	-3.13	2.33	7.67	229.18	9.63	12.23	27.00	64.00	19.67	-69.27
Sd-2	1.67	1.33	-20.36	160.00	153.67	-3.86	2.00	7.67	283.50	7.73	14.93	93.14	65.27	20.33	-68.85
Sd-3	0.67	1.33	98.51	170.00	140.00	-17.65	2.00	2.67	33.50	11.41	35.31	209.47	69.27	44.70	-35.47
Cross															
Gz-2× Gz-4	0.33	4.00	1112.12	251.33	207.33	1694.62	2.67	4.00	49.81	21.41	44.81	109.29	194.60	165.67	-14.87
Gz-2× Gz-5	0.00	4.00	3900.00	240.67	200.00	1411.19	3.00	3.67	22.33	16.74	33.68	101.19	207.20	145.63	-29.72
Gz-2× Gz-6	2.00	6.33	216.50	244.33	205.00	1723.76	3.00	4.33	44.33	8.41	26.31	212.84	181.60	104.43	-42.49
Gz-2× Gz-7	2.33	2.67	14.59	257.33	218.33	1531.35	3.67	4.67	27.25	12.38	45.45	267.12	184.00	126.00	-31.52
Gz-2× Sd-1	0.67	3.00	347.76	230.00	203.33	1379.75	2.33	3.00	28.76	9.74	25.53	162.11	187.80	137.00	-27.05
Gz-2× Sd-2	2.33	2.33	0.00	262.00	221.67	1397.41	2.00	5.00	150.00	9.72	14.87	52.98	171.80	99.47	-42.10
Gz-2× Sd-3	3.00	3.33	11.00	230.00	200.00	1981.76	2.00	5.67	183.50	11.58	14.54	25.56	172.00	106.47	-38.10
Gz-4× Gz-5	1.67	5.00	199.40	242.33	235.00	1384.90	4.33	5.00	15.47	11.30	52.87	367.88	213.90	155.27	-27.41
Gz-4× Gz-6	1.33	1.67	25.56	258.67	243.33	1320.64	3.33	3.33	0.00	18.56	38.62	108.08	184.23	140.83	-23.56
Gz-4× Gz-7	1.33	4.67	251.13	268.67	241.67	1187.75	3.33	4.67	40.24	10.46	50.66	384.32	208.50	155.47	-25.43
Gz-4× Sd-1	1.00	5.00	400.00	265.00	220.00	1182.33	2.00	5.33	166.50	15.41	29.66	92.47	182.90	108.47	-40.69
Gz-4× Sd-2	1.67	4.00	139.52	258.67	244.00	1445.11	1.67	3.33	99.40	16.30	39.05	139.57	198.00	162.90	-17.73
Gz-4× Sd-3	2.00	3.00	50.00	252.00	236.67	1666.39	3.33	3.67	10.21	18.21	32.31	77.43	211.80	165.30	-21.95
Gz-5× Gz-6	3.00	6.00	100.00	256.67	233.33	1841.59	2.33	5.33	128.76	7.40	20.50	177.03	203.60	107.87	-47.02
Gz-5× Gz-7	2.67	3.33	24.72	274.67	265.33	1801.78	1.33	3.33	150.38	16.79	50.50	200.77	229.90	170.40	-25.88
Gz-5× Sd-1	3.67	4.33	17.98	254.33	243.00	1533.85	2.67	5.33	99.63	17.76	24.72	39.19	194.20	107.80	-44.49
Gz-5× Sd-2	0.67	6.33	844.78	244.67	223.33	1307.52	2.33	4.33	85.84	10.93	19.11	74.84	205.40	107.57	-47.63
Gz-5× Sd-3	2.33	6.67	186.27	255.00	225.00	1462.08	2.00	4.00	100.00	16.40	40.40	146.34	218.80	169.33	-22.61
Gz-6× Gz-7	2.33	6.00	157.51	256.67	250.00	1452.99	2.00	2.67	33.50	14.44	54.17	275.14	229.03	175.60	-23.33
Gz-6× Sd-1	4.00	8.33	108.25	248.67	228.33	1789.99	2.67	5.67	112.36	10.30	24.49	137.77	214.73	105.63	-50.81
Gz-6× Sd-2	1.33	1.00	-24.81	220.00	203.33	1618.04	2.33	4.33	85.84	8.85	40.49	357.51	154.00	96.00	-37.66
Gz-6× Sd-3	1.33	4.33	225.56	241.67	221.67	1977.70	1.67	2.33	39.52	13.41	23.66	76.44	184.90	164.07	-11.27
Gz-7× Sd-1	3.00	4.67	55.67	246.67	237.00	1506.78	2.33	5.33	128.76	16.49	39.80	141.36	182.20	109.93	-39.67
Gz-7× Sd-2	0.33	2.33	606.06	262.00	251.67	1540.12	2.33	5.00	114.59	11.31	33.59	196.99	188.50	105.70	-43.93
Gz-7× Sd-3	2.33	5.67	143.35	218.33	214.67	1838.06	3.33	4.00	20.12	13.30	32.19	142.03	210.90	148.83	-29.43
Sd-1× Sd-2	1.67	3.00	79.64	230.00	213.33	1503.16	2.67	5.00	87.27	12.30	21.42	74.15	206.30	93.70	-54.58
Sd-1× Sd-3	3.33	6.33	90.09	216.67	213.33	1540.12	2.67	5.33	99.63	15.51	27.42	76.79	208.83	77.80	-62.74
Sd-2× Sd-3	2.33	3.67	57.51	265.33	225.00	1737.90	3.33	5.67	70.27	7.54	22.44	197.61	199.83	111.03	-44.44

Clear crosses differences in the drought tolerance indices, which were calculated, based on grain yield under drought and normal conditions to identify the tolerant crosses were observed among the crosses in Table 4. With respect to drought susceptibility index (DSI) and tolerance index (TOL), three crosses exhibited lowest values for these traits *i.e.* Gz-6×Sd-3, Gz-2×Gz-4 and Gz-4×Sd-2, followed by Gz-4×Sd-3, Gz-5×Sd-3 and Gz-6×Gz-7. While for geometric mean productivity (GMP), stress tolerance index (STI) and harmonic mean (M_{HAR}), three crosses exhibited the highest values for these traits, and their average grain yield is highest. These crosses are Gz-6×Gz-7, Gz-5×Gz-7 and Gz-5×Sd-3 them followed by Gz-4×Sd-3 and Gz-4×Gz-5. Several investigations have shown that, it seems these indices enable the breeder to identify high-yielding and drought tolerant materials under stress and drought tolerant conditions (Shirinzade *et* *al.,* 2009; Mohammadai *et al.,* 2012). To determine good criteria for screening the best hybrid and indices use, the correlation coefficients was done between yield in both irrigation systems (normal and stress irrigations) and other indices of drought tolerance (Table 5). The results showed that, the yield under stress condition was positively and highly significant correlated with GMP, STI and M_{HAR}, while it was also significantly but negatively correlated with DSI and TOL.

Table (4): Average yields of crosses under normal irrigation (Y_P), drought stress (Y_S) conditions, and calculated different drought tolerance indices.

No.	Crosses	Y_P	Y_S	DSI	TOL	MP	GMP	STI	M_{HAR}
1	Gz-2× Gz-4	194.60	165.67	0.43	28.93	180.14	179.55	0.83	178.97
2	Gz-2× Gz-5	207.20	145.63	0.86	61.57	176.42	173.71	0.77	171.04
3	Gz-2× Gz-6	181.60	104.43	1.23	77.17	143.02	137.71	0.49	132.60
4	Gz-2× Gz-7	184.00	126.00	0.91	58.00	155.00	152.26	0.59	149.57
5	Gz-2× Sd-1	187.80	137.00	0.79	50.80	162.40	160.40	0.66	158.43
6	Gz-2× Sd-2	171.80	99.47	1.22	72.33	135.64	130.72	0.44	125.99
7	Gz-2× Sd-3	172.00	106.47	1.11	65.53	139.24	135.32	0.47	131.52
8	Gz-4× Gz-5	213.90	155.27	0.80	58.63	184.59	182.24	0.85	179.93
9	Gz-4× Gz-6	184.23	140.83	0.68	43.40	162.53	161.07	0.67	159.63
10	Gz-4× Gz-7	208.50	155.47	0.74	53.03	181.99	180.04	0.83	178.12
11	Gz-4× Sd-1	182.90	108.47	1.18	74.43	145.69	140.85	0.51	136.18
12	Gz-4× Sd-2	198.00	162.90	0.51	35.10	180.45	179.59	0.83	178.74
13	Gz-4× Sd-3	211.80	165.30	0.64	46.50	188.55	187.11	0.90	185.68
14	Gz-5× Gz-6	203.60	107.87	1.36	95.73	155.74	148.20	0.56	141.02
15	Gz-5× Gz-7	229.90	170.40	0.75	59.50	200.15	197.93	1.00	195.73
16	Gz-5× Sd-1	194.20	107.80	1.29	86.40	151.00	144.69	0.54	138.64
17	Gz-5× Sd-2	205.40	107.57	1.38	97.83	156.49	148.64	0.57	141.19
18	Gz-5× Sd-3	218.80	169.33	0.66	49.47	194.07	192.48	0.95	190.91
19	Gz-6× Gz-7	229.03	175.60	0.68	53.43	202.32	200.54	1.03	198.79
20	Gz-6× Sd-1	214.73	105.63	1.47	109.10	160.18	150.61	0.58	141.60
21	Gz-6× Sd-2	154.00	96.00	1.09	58.00	125.00	121.59	0.38	118.27
22	Gz-6× Sd-3	184.90	164.07	0.33	20.83	174.49	174.17	0.78	173.86
23	Gz-7× Sd-1	182.20	109.93	1.15	72.27	146.07	141.52	0.51	137.13
24	Gz-7× Sd-2	188.50	105.70	1.27	82.80	147.10	141.15	0.51	135.45
25	Gz-7× Sd-3	210.90	148.83	0.85	62.07	179.87	177.17	0.80	174.51
26	Sd-1× Sd-2	206.30	93.70	1.58	112.60	150.00	139.03	0.50	128.87
27	Sd-1× Sd-3	208.83	77.80	1.82	131.03	143.32	127.46	0.42	113.37
28	Sd-2× Sd-3	199.83	111.03	1.29	88.80	155.43	148.95	0.57	142.75

DSI: drought susceptibility index, TOL: tolerance index, MP: mean productivity, GMP: geometric mean productivity, STI: stress tolerance index and MHAR: harmonic mean.

In other word the same trend was observed between the mean of genotype yield in both conditions (MP), which as index directs breeders to select in stress and non-stress condition and the other indices of drought tolerance, indicating that these indices were more effective in identifying high yield hybrids under different water conditions. Similar findings were observed by Iftikhar *et al.* (2012) and El-Rawy and Hassan (2014). The parameters of TOL and DSI, which indicate in lower amounts relative tolerance to stress (lowest percentage of reduction), had significantly positive correlation with each other. Rosielle and Hamblin (1981), Fischer and Maurer (1978), Clarke *et al.* (1992) and Akcura *et al.* (2011) proposed a DSI of the cultivar for evaluation of drought tolerance in genotypes. Whereas, Fernandez (1992), Sio-Se *et al.* (2006), Shirinzade *et al.* (2009) and Drikvand *et al.* (2012) defined STI, which can be used to identify high-yielding genotypes under stress and non-stress condition.

Table (5): Correlation coefficient between average yields of crosses under normal irrigation (Y_P), drought stress (Y_S) conditions and drought susceptibility index (DSI), tolerance index (TOL), mean productivity (MP), geometric mean productivity (GMP), stress tolerance index (STI) and harmonic mean (M_{HAR}).

Indices	Y_P	Y_S	DSI	TOL	MP	GMP	STI	M_{HAR}
Y_P	1							
Y_S	0.495**	1						
DSI	-0.106	-0.914**	1					
TOL	0.127	-0.798**	0.971**	1				
MP	0.785**	0.927**	-0.697**	-0.514**	1			
GMP	0.701**	0.966**	-0.779**	-0.617**	0.991**	1		
STI	0.702**	0.964**	-0.774**	-0.614**	0.990**	0.998**	1	
M_{HAR}	0.631**	0.984**	-0.831**	-0.687**	0.947**	0.995**	0.993**	1

** indicate significant differences at 0.05 probability levels.

4. Conclusion

In this investigation, all studied traits were affected by water stress. Among the nine crosses which were selected based on the percentage of yield reduction, three crosses out of them, i.e. Gz-6×Gz-7, Gz-5×Gz-7 and Gz-5×Sd-3 were the best crosses under both irrigation system and selected as tolerant crosses based on mean productivity (MP), stress tolerance index (STI), Geometric mean productivity (GMP) and harmonic mean (M_{HAR}) indices. While, based on drought sensitive index (DSI) and stress tolerance indices, which indicate lower amounts relative tolerance to stress, the crosses Gz-6×Sd-3, Gz-2×Gz-4 and Gz-4×Sd-2 had identified crosses as tolerance. Thus, we can use to detect crosses which had high performance under water stress or which had less yield reduction in drought maize breeding programs and can be cultivated in new lands under drip or sprinkler system irrigation.

References

Abd El-Latif, M. S., Esmail, A. M., Ahmed, M. F. and El-Sherbeiny, H. Y. (2011), "Variation, combining ability and biochemical genetic marker for drought tolerance in maize", *Journal of Biological Chemistry and Environmental Sciences*, Vol. 6 No. 4, pp. 143–166.

Akçura, M., Partigoç, F. and Kaya, Y. (2011), "Evaluating of drought stress tolerance based on selection indices in Turkish bread wheat landraces", *Journal of Animal and Plant Sciences*, Vol. 21 No. 4, pp. 700–709.

Bänziger, M. and Araus, J. L. (2007), "Recent advances in breeding maize for drought and salinity stress tolerance", In: Jenks M.A., Hasegawa P.M., and Mohan S. editors, *Advances in molecular* *breeding towards drought and salt tolerant crops*, Springer, the Netherlands, pp. 587–601.

Benjamin, J. (2007), *Effects of water stress on corn production*, USDA Agricultural Research Service, Akron, Ohio, USA, pp. 3–5.

Bohnert, H. J. and Jensen, R. G. (1996), "Strategies for engineering water stress tolerance in plants", *Trends in Biotechnology*, Vol. 14, pp. 89–97.

Bolaoos, J. and Edmedes, G. O. (1993), "Eight cycles of selection for drought tolerance in Lowland tropical maize. 1. Responses in grain yield, biomass and radiation utilization", *Field Crops Research*, Vol. 31, pp. 233–252.

Bruce, W. B., Edmeades, G. O. and Baker, T. C. (2002), "Molecular and physiological approaches to maize improvement for drought tolerance", *Journal of Experimental Botany*, Vol. 53, pp. 13–25.

Camacho, R. G. and Caraballo, D. F. (1994), Evaluation of morphological characteristics in venezueland maize (*Zea mays* L.) genotypes under drought stress", *Scientia Agricola*, Vol. 51 No. 3, pp. 453–458.

Clarke, J. M., De Pauw, R. M. and Townley-Smith, T. M. (1992), "Evaluation of methods for quantification of drought tolerance in wheat", *Crop Science*, Vol. 32, pp. 728–732.

Drikvand, R., Behrooz, D. and Tahmaseb, H. (2012), "Response of rainfed wheat genotypes to drought stress using drought tolerance indices", *Journal of Agricultural Science*, Vol. 4 No. 7, pp. 126–131.

Edmeades G. O., Bolanos, J., Hernades, M. and Bello, S. (1992), "Causes for silk delay in Iowland tropical maize population", *Crop Science*, Vol. 33, pp. 1029–1035.

Edmeades, G. O., Bolans, M., Banziger, M., Ribaut, J. M., White, J. W., Reynolds, M. P. and Lafitte, H. R. (1998), *Improving crop yields under water deficits in the tropics*, Proceedings of the 2nd International Crop Science Conference, pp. 437–451.

El-Rawy, M. A. and Hassan, M. I. (2014), "Effectiveness of drought tolerance indices to identify tolerant genotypes in bread wheat (*Triticum aestivum* L.)", *Journal of Crop Science and Biotechnology*, Vol. 17 No. 4, pp. 255–266.

Fernandez, G. C. J. (1992), *Effective selection criteria for assessing plant stress tolerance*, Proceedings of the International Symposium on Adaptation of Vegetables and other Food Crops in Temperature and Water Stress, Shanhua, Taiwan, pp. 257–270.

Fischer, R. A. and Maurer, R. (1978), "Drought resistance in spring wheat cultivars. Part 1: grain yield response", *Australian Journal of Agricultural Research,* Vol. 29, pp. 897–912.

Golbashy, M., Ebrahimi, M., Khorasani, S. K. and Choukan, R. (2010), "Evaluation of drought tolerance of some corn (*Zea mays* L.) hybrids in Iran", *African Journal of Agricultural Research*, Vol. 5 No. 19, pp. 2714–2719.

Iftikhar, R., Khaliq, I., Kashif, M., Anwar Ahmad, M. and Smiullah (2012), "Study of morphological traits affecting grain. yield in wheat (*Triticum aestivum* L.) under field stress condition", *Middle East Journal of Scientific Research,* Vol. 11, pp. 19–23.

Jafari, A., Pakngjad, F. and Jami, M. A. (2009), "Evaluation of selection indices for drought tolerance of corn (*Zea mays* L.) hybrids", *International Journal of Plant Production,* Vol. 3 No. 4, pp. 33–38.

Lawlor, D. W. and Cornic, G. (2002), "Photosynthetic carbon assimilation and associated metabolism in relation to water deficits in higher plants", *Plant, Cell & Environment*, Vol. 25, pp. 275–295.

Lea, P. J., Parry, M. A. J. and Medrano, H. (2004), "Improving resistance to drought and salinity in plant", *Annals of Applied Biology*, Vol. 144, pp. 249–250.

Mohammadai, H., Aoleyman, S. and Shams, M. (2012), "Evaluation of drought stress effects on yield components and seed yield of three maize cultivars (*Zea mays* L.) in Isfahan region", *International Journal of Agriculture and Crop Sciences,* Vol. 4 No. 19, pp. 1436–1439.

Moser, S. B., Feil, B., Jampatong, S. and Stamp, P. (2006), "Effect of pre-anthesis drought nitrogen fertilizer rate and variety on grain yield, yield components and harvest index of tropical maize", *Agricultural Water Management,* Vol. 81, pp. 41–58.

Mostafavi Kh, Sadeghi, G. H., Dadresan, M. and Zarabi, U. (2011), "Effects of drought stress on germination indices of corn hybrids (*Zea mays* L.)", *International Journal of Agricultural Science,* Vol. 1 No. 2, pp. 10–18.

Mostafavi, Kh., Shoahosseini, M. and Sadeghi Geive, H. (2011), "Multivariate analysis of variation among traits of corn hybrids traits under drought stress", *Intel. J Agri Sci.,* Vol. 1 No. 7, pp. 416–422.

Muhe, K. (2011), "Selection index in durum wheat (*Triticum turgidum* var. *durum*) variety development", *Academic Journal of Plant Sciences,* Vol. 4 No. 3, pp. 77–83.

Richards, R. A., Rebetzke, G. J., Condon, A. G. and Van Herwaarden, A. F. (2002), "Breeding opportunities for increasing the efficiency water use and crop yield in temperate cereals", *Crop Science*, Vol. 42, pp. 111–121.

Rosen, S. and Scott, L. (1992), "Famine gripe sub-Saharan Africa", *Agricultural Outlook*, Vol. 191, pp. 20–24.

Rosielle, A. A. and Hamblin, J. (1981), "Theoretical Aspects of Selection for Yield in Stress and Non-Stress Environment", *Crop Science*, Vol. 21, pp. 943–946.

Saif-ul-malook, Ali, Q., Ahsan, M., Shabaz, M. K., Waseem, M. and Mumtaz, A. (2016), "Combining ability analysis for evaluation of maize hybrids under drought stress", *Journal of the National Science Foundation of Sri Lanka*, Vol. 44 No. 2, pp. 223–230.

Shirinzade, E., Zarghami, R. and Shiri, M. R. (2009), "Evaluation of drought tolerance in late and medium maize hybrids-using stress tolerance indices", *Iranian Journal of Crop Sciences*, Vol. 10, pp. 416–427.

Singh, T. N., Aspinall, D., Paleg, L. G. and Boggess, S. F. (1973), "Changes in proline concentration in excised plant tissues", *Australian Journal of Biological Sciences*, Vol. 26, pp. 57–63.

Sio-Se, M. A., Ahmadi, A., Poustini, K. and Mohammadi, V. (2006), "Evaluation of drought resistance indices under various environmental conditions", *Field Crops Research*, Vol. 98, pp. 222–229.

Steel, R. G. D., Torrie, J. H. and Dicky, D. A. (1997), *Principles and procedures of Statistics: A Biometrical Approach*, 3rd edition, McGraw Hill Book Co. Inc., New York, USA, pp. 400–428.

Song, Y., Birch, C., Qu, S., Doherty, A. and Hanan, J. (2010), "Analysis and modelling of the effects of water stress on maize growth and yield in dryland conditions", *Plant Production Science*, Vol. 13, pp. 199–208.