J.Soil Sci. and Agric. Eng., Mansoura Univ., Vol. 8 (2): 41 - 48 , 2017

Performance of Ten Maize Hybrids Under Water Stress and Calcareous Soil Conditions.

Habliza A. A. [1] **and A. K. Abdelhalim** [2]
[1]**Maize Res. Dept., Field Crops Res. Inst., ARC, Egypt**
[2]**Water Req. and Field Irri . Res. Dept., Soils, Water and Env. Res. Inst., ARC, Egypt**

ABSTRACT

A field experiment was conducted at Nubaria agricultural research station during the 2007 and 2008 summer seasons. Two irrigation regimes e.g. 100 and 75% of maize water requirements, respectively, under drip irrigation system and ten (5 single-cross (SC) plus 5 three-way cross (TWC) maize hybrids and their interaction were assessed. The experimental design was a split-plot with three replications, where the main plots represented two irrigation regimes and the sub-plots were assigned to the ten maize hybrids. The main findings could be summarized as follows: Significant decreases in grain yield were observed under deficit irrigation comparing with adequate one in 1st and 2nd seasons. Plant height and ear height exhibited similar trends, however, the differences did not reach the significant level due to irrigation regimes. An opposite trend was recorded for number of days to mid-silking, anthesis -silking interval and leaf proline content traits, where 75% irrigation regime resulted in higher values of such traits in the two seasons of study, comparable with 100% irrigation regime.As for maize hybrid types, notable opposite trends in grain yield were found, where TWC hybrids average increased by 1.80% more than SC hybrids in 2007 season, meanwhile SC hybrids averaged surpassed that of TWC hybrids average by 1.87% in 2008 season. Additionally, TWC hybrids exhibited shorter values of days to mid-silking and anthesis- silking interval (day) compared with SC hybrids, in the two seasons of study. The average of leaf proline content was higher for SC hybrids, comparable with TWC hybrids. On average basis, SC hybrids exhibited higher value of (DSI) than TWC hybrids in 1st and 2nd seasons, and SC10 maize hybrid exhibited the potentiality of grain yield with the adequate irrigation regime, in 1st and 2nd seasons. Under 75% irrigation regime, TWC.321, TWC.324, TWC.327 and SC.162 exhibited higher grain yield in 2007, while in 2008, TWC.321, SC.10 and SC.162 gave higher grain yield.The amounts of applied irrigation water were 8000 and 6070 m^3 ha^{-1} for the 100% and 75% irrigation treatments, respectively. Average crop water productivity values increased with decreasing applied water, where, under 75% irrigation regime CWP was increased in 1st and 2nd seasons, comparable with 100% irrigation regime. Under stress conditions, average CWP value for the TWC hybrids was higher by 13.48% in 2007, and seemed to be negligible (0.79%) in 2008 season comparing with SC hybrids, respectively. An opposite trend was notable under 100% irrigation regime, where average CWP value for the SC hybrids was higher by 5.26 and 3.62%, respectively, in 1st and 2nd seasons. The highest CWP values (3.39 and 2.88 kg m^{-3}), respectively, in 2007 and 2008 seasons were obtained with SC10 hybrid as irrigated at 100% regime interaction.
Keywords: Maize hybrid, Deficit irrigation, DTE%, DSI, ASI, Crop Water productivity, leaf proline content

INTRODUCTION

Water scarcity is a growing global problem challenging sustainable development and inducing a constraint on producing satisfactory foods to meet increasing food requirements. Egypt is mainly an agricultural country depending on the River Nile as the main resource for water, and agriculture consumes about 85% of the available water resources. Maize (*Zea mays* L.) is one of the most important cereal crops wide world. Maize is still a major traditional food and feed crop, and the grain is a key industrial raw material for very diverse purposes. Egypt lies in arid region, and crop production in such circumstances is faced by the prevalence of a number of rather extreme and detrimental conditions such as limited water supply and drought conditions. In order to mitigate maize production – consumption gab, as an important national issue, great attention must be paid to increase its productivity. This could be achieved by adopting high yielding cultivars, efficient water management…. etc. Edmeades *et al.* (1989) stated that, drought is estimated to cause average annual yield losses in maize of about l7% in the tropics. El-Tantawy *et al.* (2007) in 2 – season research work, found that irrigating maize with 0.8 or 1.0 pan evaporation coefficient induced yield reductions reached to (36.07 and 35.97%) and (6.15 - 8.05%), respectively, comparable with1.2 pan evaporation coefficient. The author added that, the highest water use efficiency was obtained under either irrigation with 1.2 pan evaporation coefficient or 1.0 pan evaporation coefficient in the 1st and 2nd seasons. Karasu *et al.* (2015) showed that, irrigation levels significantly affected the maize grain yield, all morphological and quality parameters. Roth *et al.* (2013) stated that periods of drought at critical growth stages can negatively impact yield even if soil moisture is not limiting at other stages of development. In addition, Adee *et al.* (2016) reported that the yield advantage of DT hybrids was positively correlated with evapotranspiration (ET), such that the DT hybrids yielded more than non-DT hybrids in high and medium ET environments. Oyekale *et al.* (2008) stated that the usefulness of DSTI as a useful index for determining drought stress and suggest that maize hybrids with DSTI values around 0.6 from field trials have potentials for satisfactory productivity under drought stress. Adebayo and A. Menkir (2014) reported that maize hybrids differed significantly for grain yield and other measured traits under both drought stress and well-watered conditions. El Sabagh *et al.* (2015) found that significant differences were observed among maize hybrids with respect to yield and yield traits. Proline has been suggested to play multiple roles in plant stress tolerance. Additionally, Blum (2005) stated that apparent genotypic variations in WUE are normally expressed mainly due to variations in water use, and reduced WU, which is reflected in higher WUE, is generally achieved by plant traits and environmental responses that reduce yield potential. Bogess *et al.* (1976). Marjorie and Nicholas (2002) showed that the proline which accumulates at low water potential may be translocated from the endosperm of germinating seedlings, and the rate of proline utilization in maize roots exceeds the biosynthesis capacity even at low water potential. El- Sayed (1998) reported that water stress caused a significant delay in silking date when water stress was imposed at pre-flowering, flowering, and post-flowering stages. Abayomi *et al.* (2012) reported that there were no appreciable differences between the two maturity maize groups (5 extra-early and 12 early genotypes) for most measured parameters. However, across the two groups, crop establishment parameters, morpho -physiological growth parameters, yield components and grain yield were significantly reduced by soil moisture deficit, while flowering characteristics were significantly delayed by soil moisture stress with significant variable genotypic responses.

The objectives of the present study are to assess the grain yield, level of tolerance to water stress, and the water productivity and leaf proline content of ten maize hybrids under deficit irrigation conditions, comparing adequate irrigation, in the calcareous soils at Nubaria region, Egypt.

MATERIALS AND METHODS

A field experiment was conducted at Nubaria agricultural research station, during 2007 and 2008 summer seasons to evaluate the effect of water stress on performance and productivity of ten maize hybrids in the calcareous soils. Some physical and chemical characteristics of the soil at the experimental site were determined as described by klute (1986) and are Page *et al.* (1982), and presented in Tables 1 and 2.

Table 1. Main physical properties of the studied soil.

Soil depth (cm)	Bulk density (Mgm^{-3})	Hydraulic conductivity (ms^{-1})	Particle size distribution (%) Sand	Silt	Clay	Texture class
00 - 15	1.35	$5.4x10^{-6}$	58.9	24.2	16.9	Sandy loam
15 - 30	1.37	$4.9x10^{-6}$	60.3	24.5	15.2	Sandy loam
30 - 45	1.45	$5.8x10^{-6}$	56.7	26.1	17.2	Sandy loam

Table 2. Main chemical properties of the studied soil.

Soil depth (cm)	pH, 1:2.5	EC, dS m^{-1}	CEC, cmol kg^{-1}	CaCO3, %	OM, %
00 - 15	8.5	3.86	14	25.9	0.12
15 - 30	8.3	4.89	20	24.9	0.14
30 - 45	8.2	5.37	17	26.7	0.26

Soil depth (cm)	Soluble cations (cmol m^{-1}) Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Soluble anions (cmol m^{-1}) CO_3^{-2}	HCO_3^{-}	Cl^{-}	SO_4^{-2}
00 - 15	20.0	13.0	4.8	0.8	--	10.0	25.0	3.6
15 - 30	9.6	5.1	29.6	5.4	--	11.6	30.2	7.9
30 - 45	29.7	10.5	37.0	6.4	--	20.0	35.0	28.6

Experimental design and adopted treatments:

The experimental design was a split-plot with three replications. The main plots represented two irrigation regimes and the sub-plots were assigned to the ten maize hybrids listed in Table 3. The tested treatments were as follows:

1- Applying 100% of water requirement of maize crop, based on ETo at Nubaria region (Adequate irrigation). and
2- Applying 75% water requirement of maize crop, based on ETo (Deficit irrigation).

Table 3. Maize hybrids (name, type and seed color) used in this study.

NO.	HYBRID	NAME	TYPE	SEED COLOR
1	Single Cross Giza-10	SC.10	Single Cross	White
2	Single Cross Giza-125	SC.125	,,	White
3	Single Cross Giza-129	SC.129	,,	White
4	Single Cross Giza-155	SC.155	,,	Yellow
5	Single Cross Giza-162	SC.162	,,	Yellow
6	Three-way Cross Giza-311	TWC.311	Three-way Cross	White
7	Three-way Cross Giza-321	TWC.321	,,	White
8	Three-way Cross Giza-324	TWC.324	,,	White
9	Three-way Cross Giza-327	TWC.327	,,	White
10	Three-way Cross Giza-352	TWC.352	,,	Yellow

Reference evapotranspiration (ETo) was calculated using average climatic data of Nubaria region, Table 4. The climatic, soil, and maize crop data were used as inputs for the CROPWAT model (FAO, 1998) to obtain water requirement of maize crop in the area.

Table 4. Main Agro - climatological data at the experimental site (average 1999 - 2006)*

Month	Max T (C^{O})	Min T (C^{O})	Wind Speed ($msec^{-1}$)	Relative Humidity (%)	Rail Fall ($mmmonth^{-1}$)	Solar Radiation ($Mjm\text{-}1day^{-1}$)	Epan ($mmday^{-1}$)
January	19.0	9.0	3.0	81	69.3	12.28	1.6
February	19.8	8.6	3.1	79	16.6	13.75	2.0
March	22.5	10.5	3.2	75	7.7	15.18	3.2
April	26.1	13.4	2.9	72	3.0	23.96	4.4
May	28.9	16.0	2.8	76	00	27.47	6.3
June	30.5	19.6	2.8	79	00	28.64	5.9
July	31.6	22.3	3.0	79	00	29.23	6.2
August	32.9	22.2	2.7	78	00	26.86	5.4
September	32.3	20.4	2.5	77	0.8	23.17	5.0
October	29.4	17.5	2.2	76	6.4	17.95	3.7
November	26.4	13.7	2.3	77	11.5	13.07	2.3
December	20.6	10.0	2.8	80	40.1	11.44	1.7

***Supplied by Water Requirements and Field Irrigation Research Department, SWERI**

Irrigation system and cultural practices:

Drip Irrigation system was adapted and consists of a conveying pipeline system PVC main line 63 mm and PVC sub-main line 50.8 mm and PE manifold 38.1 mm. The drip lateral lines of 16 mm diameter are connected to the manifold line and containing emitters at 50 cm apart with 4 L/h discharge rate for each. The drip irrigation lines were arranged as one irrigation line for each line of plants with 6 m long. Irrigation treatments were initiated 25 days post planting, and irrigation water was daily applied and continued throughout the entire growing season. The amounts of water applied per irrigation event were calculated according to Vermeiren and Jopling (1984) as follows:

$$AIW = \frac{ETo \times Kc \; X \; I}{Ea \; (1 - LR)}$$

Where:

AIW = depth of applied irrigation water in mm

ETo = reference evapotranspiration in mm d^{-1}

Kc = crop coefficient

I = irrigation intervals (days)

Ea= irrigation application efficiency of the drip system and

L.R.=leaching requirements

During seed - bed preparation, basal doses of P and K fertilizers at 50 and 60 P_2O_5 and K_2O kgha^{-1} rates, respectively, were incorporated into the soil surface. Starter dose of N fertilizer equals to 36 kgNha^{-1} was added at planting time, and the remainder N fertilizer dose (about 300kg N ha^{-1}) was applied as recommended. The sub plot was 6 m long by 1.4 m wide, containing two rows spaced at 0.7 m, and each hybrid was seeded at a density of 47619 plants ha^{-1}. Planting dates were April, 20 and 25 in 2007 and 2008, respectively. Weed control was executed through the proper herbicide application and manual soil surface hoeing and the pests were controlled with pesticide applications as needed.

Drought tolerance indices, Water Productivity and Leaf free proline content:

Drought Susceptibility Index (DSI) was calculated by the formula given by Fisher and Maurer (1978) as follows:

$$DSI = (1 - \frac{Yd}{Yp}) \,/\, D$$

Where

Y_d:Grain yield of the genotype under moisture stress condition

Y_p: Grain yield of the genotype under irrigated condition

D: Mean yield of all genotype under stress / Mean yield of all genotype under non-stress

Drought Tolerance Efficiency (DTE) was estimated by using the formula given by Fisher and Wood (1981) as follows:

$$DTE\ (\%) = \frac{Yield\ under\ stress}{Yield\ under\ non-stress} X\ 100$$

Free proline content was determined in the genotypes leaves according to the procedure outlined by Bates *et al.* (1973).

Water Productivity (WP):

Water Productivity (WP) values were estimated according to Iskandar and David (2004) as follows:

$$\textbf{Water Productivity (WP, Kgm}^{-3}\textbf{)} = \frac{\text{Grain Yiled (kg/fad)}}{\text{Water applied (m3/fad)}}$$

Statistical analysis:

Analysis of variance for the studied characters were performed using SAS software (version 8.1, 1997), PROC MIXED (Little *et al.* 1996). Irrigation treatments and maize hybrids were treated as fixed effects and replication as random effects. Treatment means were compared by FLSD and calculated using SAS software.

RESULTS AND DISCUSSION

On a general overview basis, results in Table 5 show that, the adopted irrigation regimes significantly affected all of the studied traits, except plant and ear heights in 2007 and 2008 seasons. In addition, significant differences were observed among the evaluated hybrids for all the studied traits in 2007 and 2008 seasons. Furthermore, the water x hybrid interaction was also significant for all the studied traits except for plant height and ear height in 2007and grain yield and ear height in 2008.

Table 5. Mean square of grain yield and other traits for I0 hybrids evaluated under 100 and 75% irrigation regimes, maize hybrids and interaction in 2007 and 2008 seasons

Source of Variation	D f	Grain Yield	Number of Days to Mid-Silking	Anthesis-Silking Interval	Plant Height	Ear Height	Leaf Proline Content
2007 season							
Replicates	2	1.61	0.52	0.05	34.52	151.65	3.41
Irrigation regimes (w)	1	73.40"	16.02"	20.42"'	3360.01	1837.07	1572.86**
Error (a)	2	1.86	0.22	0.22	395.41	256.71	21.79
Hybrids (H)	9	2.49 "	21.02"	2.44"	182.24***	93.01**	97.31**
W x H	9	2.18"	6.49"	1.31**	36.9	41.4	60.85**
Error (b)	36	0.51	0.33	0.28	27.52	28.94	I 1.65
CV		8.20	1	7.9	2.2	4.1	7.11
2008 season							
Replicates	2	0.89	0.47	0.51	63.45	34.59	0.96
Irrigation regimes (w)	1	18.77**	29.40*	9.60*	3630. I5	7549.7	715.53**
Error (a)	2	0.12	0.8	0.35	256.57	544.41	15.43
Hybrids (H)	9	6.49**	15.62**	1.58**	125.25**	145.53*	154.39**
W x H	9	0.64	5.14**	1.34**	234.94 "	71.99	39.04**
Error (b)	36	4.57	0.5	0.45	30.51	52.36	8.54
CV		10.7	1.1	5.5	2.5	7.4	6.55

***, **Indicate significant at 0.05 and 0.01 levels of probability, respectively.**

Effect of irrigation regimes

Data in Table 6 reveal that the grain yield average was higher in 2007 than 2008 under both irrigation regimes and averaged, across hybrids, 7.73 and 6.48 Mg ha^{-1} and 9.83 and 7.57 Mg ha^{-1}, respectively, under deficit and adequate irrigation regimes. Significant decrease in grain yield were observed under deficit regime comparing with adequate one, and reached to 2.10 and 1.09 Mg ha^{-1}, which represented 21.36 and 14.40%, respectively, in 2007 and 2008 seasons. El-Hendawy *et al.* (2008) found that the increases in grain yield of drip-irrigated corn (TWC 321) under 100 ETc regime ranged 47.79 - 49.62% higher than 80 ETc regime. In addition, Mehasen and El-Gizawy (2010) found that grain yield of either SC10 and SC haitic or TWC haitic and TWC 324 maize hybrids tended to reduction as irrigation level decreased. In the present study, plant height and ear height exhibited similar trends in the two seasons of study, however, the differences did not reach the significant level due to irrigation regimes. An opposite trend was recorded for number of days to mid-silking, anthesis - silking interval and leaf proline content traits, where 75% irrigation regime resulted in higher values of such traits in the two seasons of study. The increase values, in 2007 and 2008 seasons, amounted to (3.53 and 3.56%), (48.58 and 42.74%) and (23.87 and 14.02%) for the abovementioned traits, respectively, under 75% irrigation regime higher than 100% irrigation regime. Hermalina Sinay and Ritha Lusian Karuwal (2014) reported that the highest proline value was obtained with the drought stress condition (12 days watering interval), and the lowest in the control (every 2 days watering interval).

Table 6. Means of grain yield (Mg ha^{-1}) and other traits with I00 and 75% irrigation regimes in 2007 and 2008 seasons

	Grain yield (Mg ha^{-1})		Number of days to mid-silking (d)		Anthesis-silking interval (d)	
Irrigation regimes	2007	2008	2007	2008	2007	2008
100%	9.83	7.57	62.3	61.8	2.36	2.34
75%	7.73	6.48	64.5	64.0	3.53	3.34
Loss value	2.10*	1.09*	2.2*	2.2*	1.17*	1.19*
Loss%	27.2	16.8	3.5	3.5	49.5	50.8
LSD $_{0.05}$	1.51	0.38	0.51	0.99	0.51	0.62
	Plant height (cm)		Ear height (cm)		Leaf proline content (mgg^{-1})	
Irrigation regimes	2007	2008	2007	2008	2007	2008
100%	244.50	225.59	137.63	105.34	42.86	42.14
75%	229.53	210.04	126.56	89.96	53.09	48.05
Loss value	14.97	15.55	11.07	15.36	10.23*	6.91*
Los%	6.5	7.4	8.70	17,1	23.8	16.8
LSD $_{0.05}$	22.09	17.79	17.80	28.09	5.18	4.36

***, **Indicate significant at 0.05 and 0.01 levels of probability, respectively.**

2. Effect of maize hybrids

Regarding to the tested maize hybrids affecting grain yield, data reveal that grain yield average in 2007 season was higher by 24.61% more than 2008 season, regardless the hybrid types, Table 7. Grain yield mean of TWC hybrids ranged from 8.42 – 9.63 Mgha^{-1} and 5.63 – 8.08 Mg ha^{-1}, respectively, in 2007 and 2008 seasons. As for SC hybrids, grain yield mean ranged 7.00 – 9.63 Mgha^{-1} and 5.21 – 8.60 Mgha^{-1}, respectively, in 2007 and 2008 seasons. Additionally, with hybrid types notable opposite trends in grain yield were found, where TWC hybrids average increased by 1.80% more than SC hybrids in 2007 season, meanwhile SC hybrids averaged surpassed that of TWC hybrids average by 1.87% in 2008 season. Mehasen and El-Gizawy (2010) stated that the varietal differences on grain yield of maize was significantly affected by the five maize varieties under study i.e. SC Hitec, SC 10, TWC Hitec, TWC 329 and Giza 2. The authors added that SC hybrids averaged TWC ones by 9.79%.

Table 7. Means of grain yield, days to mid-silking, anthesis- silking interval, leaf proline content, drought susceptible index (DSI) and drought tolerance efficiency (DTE) for the evaluated 10 hybrids in 2007 and 2008 seasons.

Maize hybrid	Grain yield (Mgha^{-1})	Days to mid-silking	Anthesis-silking interval	leaf proline content (mgg^{-1})	DSI	DTE %
2007 season						
SC10	9.24	60.0	3.65	53.7	0.48	62.3
SC125	9.03	65.2	3.00	44.5	0.34	73.6
SC129	8.73	63.2	3.10	44.2	0.26	79.4
SC155	7.00	62.2	3.85	44.9	0.39	69.6
SC162	9.42	65.8	2.65	55.1	0.29	76.8
Mean	8.68	63.3	3.25	48.5	0.35	72.3
TWC311	8.42	62.1	3.50	43.7	0.19	84.7
TWC3321	8.98	62.9	2.25	47.8	0.08	93.4
TWC3324	9.63	63.7	3.05	54.2	0.24	81.1
TWC3327	8.44	63.5	2.26	46.7	0.11	91.6
TWC3352	8.72	61.5	2.20	45.3	0.25	80.4
Mean	8.84	62.7	2.65	47.5	0.17	86.2
2008 season						
SC10	8.60	62.8	3.90	51.4	0.26	77.7
SC125	7.15	64.2	3.00	42.9	0.14	88.3
SC129	7.01	63.1	3.00	39.1	0.11	90.4
SC155	5.21	61.0	3.50	43.0	0.31	73.9
SC162	7.49	66.0	1.95	51.5	0.13	89.1
Mean	7.09	63.4	3.07	45.6	0.19	83.9
TWC311	6.71	62.0	3.50	39.4	0.15	87.3
TWC3321	8.08	62.4	2.35	41.4	0.06	94.6
TWC3324	7.85	63.2	3.00	51.8	0.25	78.6
TWC3327	6.53	63.4	2.15	42.5	0.07	93.6
TWC3352	5.63	61.0	3.00	43.2	0.19	83.4
Mean	6.96	62.4	2.80	43.7	0.14	77.7

Data also reveal that TWC hybrids exhibited shorter values of days to mid-silking and anthesis-silking interval (day) compared with SC hybrids, and such findings were true in 2007 and 2008 seasons. In connection, Adebayo and Menkir (2014) reported that maize hybrids differed significantly for grain yield and other traits under both drought stress and well-watered conditions. In addition, El Sabagh *et al.* (2015) observed significant differences among maize hybrids with respect to yield and yield traits. The average of leaf proline content was higher for SC hybrids, with increases amounted to 2.11 and 4.35, respectively, in 2007 and 2008 seasons, comparable with TWC hybrids. Accumulation of proline under stress in many plant species has been correlated with stress tolerance, and its concentration has been shown to be generally higher in stress-tolerant than in stress-sensitive plants, Demiral and Turkan (2004). In addition, Moharramnejad *et al.* (2015) found that the osmotic stress markedly enhanced the levels of proline in both maize inbreds lines (B73 and MO17), but this was more pronounced in MO17. Faheed *et al.* (2016) reported that leaf proline content (2 – season mean) for TWC maize hybrid exceeded that of SC Pioneer 30K09 by 5.92%.

On average basis, data in Table 7 reveal that SC hybrids exhibited higher value of (DSI) than TWC hybrids in 2007 and 2008 seasons, and higher figures (0.48 and 0.26) were recorded for SC10 hybrid, respectively, in 2007 and 2008 seasons. An opposite trend was noticed with DTE %, where TWC hybrids average was increased in 2007 and decreased in 2008, compared with SC hybrids. In this sense, Oyekale *et al.* (2008) suggested that maize hybrids with Drought stress tolerance index (DSTI) values around 0.6 from field trials have potentials for satisfactory productivity under drought stress.

Interactions

The SC10 maize hybrid exhibited the potentiality of grain yield with the adequate irrigation regime, and produced 11.38 and 9.67 $Mgha^{-1}$ of grains, respectively, in 2007 and 2008 seasons, Table 8.

Table 8. Means of grain yield ($Mg\ ha^{-1}$), reduction, reduction %, drought susceptible index (DSI) and drought tolerance efficiency (DTE) as affected by interaction of the adopted irrigation regimes and the tested 10 maize hybrids in 2007 and 2008 seasons

Maize Hybrids	100%	75%	Reduction	Reduction%	DSI	DTE%
	2007 season					
SC10	11.38	7.09	3.29*	46.4	0.48	62.3
SC125	10.40	7.66	2.74*	35.8	0.34	73.6
SC129	9.73	7.73	2.00*	25.9	0.26	79.4
SC155	8.25	5.74	2.51*	43.7	0.39	69.6
SC162	10.65	8.18	2.47*	30.2	0.29	76.8
Means	10.08	7.28	2.60	36.4		
TWC311	9.11	7.72	1.39*	18.0	0.19	84.7
TWC 321	9.28	8.67	0.61	7.0	0.08	93.4
TWC3324	10.63	8.62	2.01*	23.3	0.24	81.1
TWC3327	8.81	8.07	0.74	9.2	0.11	91.6
TWC3352	9.66	7.77	1.89*	24.3	0.25	80.4
Means	9.59	8.17	1.33	16.4		
	2008 season					
SC10	9.67	7.52	2.15*	28.6	0.26	77.7
SC125	7.59	6.70	0.89*	13.3	0.14	88.3
SC129	7.36	6.65	0.71	10.7	0.11	90.4
SC155	5.99	4.43	1.56*	35.2	0.31	73.9
SC162	7.92	7.06	0.86	12.2	0.13	89.1
Means	7.71	6.47	1.29	20.0		
TWC311	7.16	6.25	0.91*	14.5	0.15	87.3
TWC321	8.30	7.85	0.45	5.7	0.06	94.6
TWC324	8.79	6.91	1.88*	27.2	0.25	78.6
TWC327	6.74	6.31	0.43	6.8	0.07	93.6
TWC352	6.14	5.12	1.01*	19.7	0.19	83.4
Means	6.72	6.49	0.94	14.8		

Meanwhile, lower grain yields resulted from SC 155 under deficit irrigation regime, and reached to 5.74 and 4.43 $Mgha^{-1}$, respectively, in 2007 and 2008 seasons. Under 75% irrigation regime, TWC.321 exhibited higher grain yield in 2007 and 2008 e.g. 8.67 and 7.85 $Mg\ ha^{-1}$, respectively. However, such figures were decreased by 7.00 and 5.70%, comparable with those under100% irrigation regime, respectively, in 2007 and 2008. In addition, lower DSI (0.11 and 0.06) and higher DTE (93.4 and 94.6%) values were recorded for TWC321 hybrid, respectively, in 2007 and 2008. Azeez *et al.* (2005) and Balbaa (2007) reported significant differences among maize genotype under differed drought treatments for grain yield. In addition, Oyekale *et al.* (2008) emphasized the usefulness of Drought Stress Tolerance Index (DSTI) as a useful index for determining drought stress and suggest that maize hybrids with DSTI values around 0.6 from field trials have potentials for satisfactory productivity under drought stress

Data in Table 9 reveal that interaction of SC 155 or SC 10 hybrids and 75% irrigation regime exhibited the higher figures (5.0 and 4.8) of anthesis-silking interval, respectively, in 2007 and 2008 seasons. On the contrary, the lower values i.e. 1.7 and 1.7 were recorded for TWC 352 and SC 162 hybrids as interacted with 100% irrigation regime, respectively, in 2007 and 2008 seasons.

Table 9. Means of anthesis - silking interval (day) and days to mid-silking as affected by interaction of adopted irrigation regimes and tested 10 maize hybrids in 2007 and 2008 seasons

Maize Hybrids	2007 100%	2007 75%	2007 Increase	2008 100%	2008 75%	2008 Increase
anthesis-silking interval (day)						
SC10	3.0	4.3	1.3*	3.0	4.8	1.8*
SC125	2.0	4.0	2.0*	2.0	4.0	2.0*
SC129	2.7	3.5	0.8*	2.7	3.3	0.6
SC155	2.7	5.0	2.3*	2.7	4.3	1.6*
SC162	2.3	3.0	0.7*	1.7	2.2	0.5
Means	2.5	3.9	1.4	2.4	3.7	1.3
TWC311	3.0	4.0	1.0*	3.0	4.0	1.0*
TWC321	2.0	2.5	0.5	2.0	2.7	0.2
TWC324	2.3	3.8	1.5*	2.3	3.7	1.4*
TWC327	2.0	2.5	0.5	2.0	2.3	0.3
TWC352	1.7	2.7	1.0*	2.0	4.0	2.0*
Means	2.2	3.1	0.9	2.3	3.3	1.0
days to mid-silking (day)						
SC10	64.0	65.0	1.0*	62.3	63.3	1.0*
SC125	62.7	67.7	5.0*	62.0	66.3	4.3*
SC129	63.0	63.3	0.3*	62.7	63.5	0.8
SC155	60.0	64.3	4.3*	59.0	63.0	4.0*
SC162	65.3	66.3	1.0*	65.3	66.7	1.4*
Means	63.0	65.3	2.3*	62.3	64.7	2.3
TWC311	60.7	63.5	3.8*	60.0	63.2	3.2*
TWC321	62.7	63.0	0.3	62.0	62.7	0.7
TWC324	62.3	65.0	2.7*	62.0	64.3	2.3*
TWC327	63.3	63.7	0.4	63.0	63.8	0.8
TWC352	59.7	63.3	3.6*	59.3	62.7	2.9*
Means	61.7	63.7	1.9	61.3	63.4	1.9

LSD $_{(0.05)}$ value is 0.62 and 0.91 for 2007 and2008 seasons, respectively. *Significant at the 0.05 level of probability.

Regarding days to mid-silking trait, higher values e.g. 67.7 and 66.7 were noticed as SC 125 and SC 162 hybrids interacted with 75% irrigation regime, respectively, in 2007 and 2008 seasons. Nevertheless, TWC 352 and SC 155 hybrids as interacted with 100% irrigation regime resulted in lower days to mid-silking trait comprised 59.7 and 59.0, respectively, in 2007 and 2008 seasons. Abayomi *et al.* (2012) found that flowering characteristics were significantly delayed by soil moisture stress with significant variable maize genotypic responses.

The interaction data in Table 10 indicate that higher leaf proline contents were observed with TWC 324 hybrid as interacted with 75% irrigation regime, which reached to 59.4 and 56.6 mgg^{-1}, respectively, in 2007 and 2008 seasons. On the other hand,interaction of TWC 327 hybrid and 100% irrigation regime exhibited lower figures amounted to 35.9 and 34.3 mgg^{-1}, respectively, in 2007 and 2008 seasons.

Table 10. Means leaf proline content (mg/g) as affected by interaction of adopted irrigation regimes and 10 maize hybrids in 2007 and 2008 seasons

Maize Hybrids	2007 100%	2007 75%	2007 Increase	2007 Increase%	2008 100%	2008 75%	2008 Increase	2008 Increase%
SC10	50.8	56.5	5.7	11.2	49.2	53.5	4.3	8.7
SC125	44.0	44.9	0.9	2.0	42.3	43.5	1.2	2.8
SC129	38.2	50.1	11.9	31.2	36.7	41.4	4.7	12.8
SC155	43.4	46.4	3.0	6.9	41.7	44.2	2.5	6.0
SC162	51.3	58.8	7.5	14.6	49.0	53.9	4.9	10.0
Means	45.5	51.3	5.8	12.7	43.8	47.3	3.5	8.0
TWC311	38.9	48.5	9.6	24.7	38.2	40.6	2.4	6.3
TWC321	37.4	58.2	20.8	55.6	35.4	47.4	12.0	33.9
TWC324	48.9	59.4	10.5	21.5	47.0	56.6	9.6	20.4
TWC327	35.9	57.4	*21.5*	59.9	34.3	50.6	16.3	47.5
TWC352	39.8	50.7	10.9	27.4	37.4	48.9	11.5	30.7
Means	40.2	54.8	14.6	36.3	38.4	48.7	10.3	26.8

LSD $_{(0.05)}$ value is 3.99 and 3.42 for 2007 and 2008 seasons, respectively. *Significant at the 0.05 level of probability.

Crop Water Productivity (CWP):

Regardless the assessed maize hybrids, the amounts of applied irrigation water calculated using the CROPWAT model were 8000 and 6070 m^{3}ha^{-1} under 100 and 75% irrigation regimes, respectively. Results Table 11 indicate, in general, that average crop water productivity values increased with decreasing water application, where CWP, under 75% irrigation regime, was increased by 3.07 and 7.72% in 2007 and 2008 seasons, respectively, comparable with 100% irrigation regime. Karasu *et al.* (2015) reported that deficit irrigation improved the efficient use of irrigation water. Moreover, EL- Hendawy *et al.* (2008) found that irrigation water use efficiency of drip – irrigated maize (TWC 321) was higher under 80% ETc regime by 22.17% (2 – season mean) than that with 100% ETc regime. In the present study, two seasons average for CWP of TWC maize hybrids under 70% irrigation regime was higher by 1.89 and 13.83% than of SC maize hybrids, compared with 100% irrigation regime. Under stress conditions, average CWP value for the TWC hybrids was higher by 13.48% in 2007, and seemed to be negligible (0.79%) in 2008 season comparing with SC hybrids, respectively. In this sense, Blum (2005) and Adee *et al.* (2016), indicated that difference between CWP values may be due to the fact that SC hybrids require more water than the TWC hybrids. In this sense, Faheed *et al.* (2016) found that transpiration rate (mmolm^{-2}s^{-1}) of SC Pioneer 30K09 was higher by 14.91% than that of TWC 321. In addition, Adee *et al.* (2016) reported that WUE advantage of DT compared to non-DT hybrids was different depending on the level of ET for the season. The authors added that DT hybrids had greater WUE, producing more yield for a given amount of moisture in the high and medium ET environments. The present results indicate that under 100% irrigation regime, an opposite trend was notable, where average CWP value for the SC hybrids was higher by 5.26 and 3.62%, respectively, in 2007 and 2008 seasons. The highest CWP values (3.39 and 2.88 kgm^{-3}), respectively, in the two seasons were obtained due to SC10 hybrid as irrigated at 100% regime interaction. Meanwhile, the lowest figures e.g. 2.25 and 1.74 kgm^{-3} were recorded due to SC 155 hybrid and 75% regime interaction, respectively, in 2007 and 2008 seasons.

Table 11. Water productivity as affected by interaction of adopted irrigation regimes and tested 10 maize hybrids in 2007 and 2008 seasons

Hybrids	Water productivity (kg m^{-3} water), 2007		Water productivity (kg m^{-3} water), 2008		Average water productivity (kg m^{-3} water)	
	100%	75%	100%	75%	100%	75%
SC10	3.39	2.78	2.88	2.95	3.14	2.87
SC125	3.10	3.00	2.26	2.63	2.68	2.82
SC129	2.90	3.03	2.19	2.61	2.55	2.82
SC155	2.46	2.25	1.78	1.74	2.12	2.00
SC162	3.17	3.21	2.36	2.77	2.77	2.99
Means	3.00	2.85	2.29	2.54	2.65	2.70
TWC311	2.71	3.03	2.13	2.45	2.42	2.74
TWC321	2.76	3.40	2.47	3.08	2.62	3.24
TWC324	3.16	3.38	2.62	2.71	2.89	3.05
TWC327	2.62	3.16	2.01	2.47	2.32	2.82
TWC352	2.88	3.05	1.83	2.01	2.36	2.53
Means	2.85	3.20	2.21	2.56	2.53	2.88

CONCLUSION

Under water stress conditions TWC hybrids 321, 324 and 327 as well as the SC hybrids 162 gave higher values of grain yield in the 2007 season (8.67 and 8.62 and 8.07 and 8.18 Mg/ha, respectively), while in the 2008 season TWC321 and SC10 and 162 gave the highest yield of grain (7.85 and 7.52 and 7.06 Mg/ha, respectively)

The SC 129 and SC 162 hybrids and TWC hybrids 321 and 327 are less affected by stress condition.

The TWC 321 and 327 the highest values of DTE% i.e. 93.4 and 91.6% in 2007 season and 94.6 and 93.6% in 2008 season. In addition, lower values of DSI were obtained and reached to 0.08 and 0.11 in 2007, and 0.06 and 0 07 in 2008, respectively.

Crop water productivity (CWP) was increased with reducing the amount of applied water, which comprised 2.93 to 3.03 kg m^{-3} in 2007 and 2.25 to 2.55 kg m^{-3} of water in 2008 for treatments of 100% and 75%, respectively.

As for yield potential and higher CWP, SC 10 and both TWC 321 and 327 hybrids were superior under adequate and deficit irrigation conditions, respectively.

REFERENCES

Abayomi, Y. A.; C. D. Awokola and Z. O. Lawal (2012). Comparative evaluation of water deficit tolerance capacity of extra-early and early maize genotypes under controlled conditions. Journal of Agricultural Science Vol. 4, No. 6:54 – 71.

Adebayo, M. A. and A. Menkir (2014). Assessment of hybrids of drought tolerant maize (*Zea mays* L.) inbred lines for grain yield and other traits under stress managed conditions. Nigerian Journal of Genetics, Volume 28, Issue 2:19–23.

Adee, E.; K. Roozeboom; G.R. Balboa, A. Schlegel and I.A. Ciampitti (2016). Drought-tolerant corn hybrids yield more in drought-stressed environments with no penalty in non-stressed environments. Front. Plant Sci., 7, Article 1534.

Azeez, J.O., D. Chikoyg, Y. Kamara, A. Menkir, and M.T. Adetunji (2005).Effect of drought and weed management on maize genotypes and the tensiometric soil water content of an eutric nitisol in south western Nigeria.Plant and Soil,276:61-68.

Balbaa,M.G. (2007). Physiological bases of drought tolerance for some maize hybrids and populations. Ph.D. Thesis, Alexandria University, Egypt.

Bates, I.S., R.P. Waldern and I.D. Teare (1973). Rapid determination of free Proline for water stress. Plant Soil, 39: Z0S - 207.

Blum, A. (2005). Drought resistance, water-use efficiency, and yield potential—are they compatible, dissonant, or mutually exclusive. Australian Journal of Agricultural Research, 56, 1159–1168

Bogess, S.F., C. R. Stewarl D. Aspinall and L.G. paleg (1976). Effect of water stress on proline synthesis from radioactive precursors. Plant physiol., 58:398-401.

Demiral, T. and I. Turkan (2004). Does exogenous glycinebetaine affect antioxidative system of rice seedlings under NaCl treatment? J. Plant Physiol., 161: 1089-1110.

Edmeades, G.O., J. Bolanos, H.R. Lafitte, S. Rajararn, W. Pfeiffer, and R.A. Fischer (1989). Traditional approaches to breeding for drought resistance in ' cereals. p. 27-52. In F.W.G. Baker (ed.) Drought resistance in cereals. ICSU and CABI" Wallingford, UK.

El Sabagh, A, C. Barutçular, H. Saneoka (2015). Assessment of drought tolerance maize hybrids at grain growth stage in Mediterranean area. International Journal of Biological, Biomolecular, Agricultural, Food and Biotechnological Engineering, Vol. 9 (9):1005-1008.

El-Hendawy, S. E., E. A. Abd El-Lattief, M. S. Ahmed, U. Schmidhalter (2008). Irrigation rate and plant density effects on yield and water use efficiency of drip-irrigated corn. Agricultural water management, 95(7): 836 – 844.

El-Sayed, M.Y.M. 1998. Studies on drought tolerance in maize. M.Sc. Thesis, Fac. Agric, Cairo Univ., Egypt.

El-Tantawy, Manal M., Samiha. A. Ouda, and F. A. Khalil (2007). Irrigation scheduling for maize grown under Middle Egypt conditions. Research Journal of Agriculture and Biological Sciences, 3(5): 456-462.

Faheed, Fayza A.; E.I. Mohamed and Huda M. Mahmoud (2016). Improvement of maize crop yield (Zea mays L.) by using of nitrogen fertilization and foliar spray of some activators. Journal of Ecology of Health & Environment, 4, No. 1, 33-47.

FAO, Food and Agriculture Organization (1998). Crop evapotranspiration: Guidelines for computing crop water requirements. Authors, Allen RG, Pereira LS, Raes D. and Smith M. Irrigation and Drainage Paper 56. Rome, Italy.

Fisher, K.S., and G. Wood (1981). Breeding and selection for drought tolerance in tropical maize. ln: Proc. Symposium: *"Principles and Methods in Crop Improvement for Drought Resistance: With Emphasis on Rice" at the International Rice Research Institute (IRRI), May 4-8. 1981.*

Fisher, R.A., and R. Maurer (1978). Drought resistance in spring wheat cultivars. I. Grain yield responses in spring wheat. Australian J. Agric. Sci., 29: 892-912.

Hermalina Sinay and Ritha Lusian Karuwal (2014). Proline and total soluble sugar content at the vegetative phase of six corn cultivars from Kisar Island Maluku, grown under drought stress conditions Int. J. Adv. Agric. Res. IJAAR 2:77-82.

Iskandar A. and David M. (2004). Spatial and temporal variability of water productivity in the Syr Darya basin, Central Asia. Water Resources Research.

Karasu, Abdullah; H. Kuscu, M. ÖZ and G. Bayram (2015). The Effect of different irrigation water levels on grain yield, yield components and some quality parameters of silage maize (Zea mays indentata Sturt.) in Marmara Region of Turkey. Not Bot Horti Agrobo, 43(1):138-145.

Klute, A. (1986). Methods of Soil Analysis. Part-1: Physical and Mineralogical Methods (2^{nd}ed.) American Society of Agronomy, Madison, Wisconsin. U.S.A.

Little, R.C., G.A. Miliken, W.W. Stroup and R.D. Wolfinger (1996). SAS systems for mixed models. SAS Inst., Cary, NC., USA: SAS Institute.

Marjorie, J.R. and S. Nicholas (2002). Proline metabolism and transport in maize seedlings at low water potential. Annals of Botany, 89:8i3-823.

Mehasen, S. A. S. and N. Kh. El-Gizawy (2010). Evaluation of some maize varieties to soil moisture stress. The international conference of agronomy, ELArish, 26 – 38.

Moharramnejad, S.; O. Sofalian; M. Valizadeh; A. Asgari and M. Shiri (2015). Proline, glycine betaine, total phenolics and pigment contents in response to osmotic stress in maize seedling. J. BioSci. Biotechnol. 4(3): 313-319.

Oyekale, K. O., I. O. Daniel, A. Y. Kamara, D. C. A. Akintobi, A. E. Adegbite and M. O. Ajala (2008). Evaluation of tropical maize hybrids under drought stress. Journal of Food, Agriculture & Environment, Vol. 6(2): 260-264.

Roth, J. A., I. A. Ciampitti and T. J. Vyn (2013). Physiological evaluation of recent drought-tolerant maize hybrids at varying stress levels. Agron. J., 105: 1129–1141.

Vermeiren, L. and G.A. Jopling (1984). Localized Irrigation. FAO. Irrigation and Drainage paper no. 36, Rome, Italy.

أداء بعض هجن الذرة الشامية تحت ظروف الاجهاد المائي في الاراضي الجيرية

احمد عبدالمنعم حبليزة [1] و عبدالهادي خميس عبدالحليم [2]
[1]برنامج بحوث الذرة الشامية – معهد بحوث المحاصيل الحقلية – مركز البحوث الزراعية – مصر
[2]قسم بحوث المقننات المائية والري الحقلي – معهد الاراضي والمياه والبيئة – مركز البحوث الزراعية – مصر

اجريت هذه الدراسة بالمزرعة البحثية لمحطة بحوث النوبارية موسمي 2007 و2008 واحتوت المعاملات علي معاملتي الري (100% و75% من الاحتياجات المائية المقررة) يالاضافة الي 10 هجن من الذرة الشامية. اوضحت النتائج بصفة عامة أن نقص مياه الري ادت الي نقص معنوي في كمية محصول الحبوب ، وان النقص في محصول الحبوب في الهجن الفردية كان اكثر منه في الهجن الثلاثية. تحت ظروف الري المثلي اعطي هجين فردي 10 اعلي محصول للحبوب في كلا الموسمين (11.38 و 9.67 ميجاجرام/هكتار، علي التوالي). تحت ظروف نقص المياه اعطت الهجن الثلاثية 321 و324 و 327 وكذلك الهجين الفردي 162 اعلي محصول للحبوب في موسم 2007 (8.67 و 8.62 و 8.07 و8.18 ميجاجرام/هكتار علي التوالي) بينما في موسم 2008 اعطي الهجين الثلاثي 321 والهجن الفردية 10 و 162 اعلي محصول للحبوب (7.85 و 7.52 و 7.06 ميجاجرام/هكتار علي التوالي). كان الهجين الفردي 129 اقل الهجن تأثرا بنقص المياه من حيث عدد الايام حتي متوسط ظهور الحراير كما ان الهجن الثلاثية 321 و 327 لم تظهر تأثيرا معنويا في هذه الصفة بنقص المياه.بالنسبة للفترة بين انتثار حبوب اللقاح وظهور الحرائر كانت الهجن الفردية 129 و 162 هي اقل الهجن تاثرا بنقص مياه الري وايضا لم تتاثر الهجن الثلاثية 321 و 327 معنويا بنقص مياه الري. اعطت الهجن الثلاثية 321 و 327 اعلي محتوي من البرولين في الاوراق تحت ظروف نقص المياه. اعطت الهجن الثلاثية 321 و 327 اعلي القيم لكفاءة تحمل الجفاف (DTE%) حيث اعطت 93.4 و91.6 % في موسم 2007 واعطت 94.6 و 93.6 % موسم 2008 علي الترتيب ، كما انها اعطت اقل القيم لمعامل حساسية الجفاف (DSI) حيث اعطت 0.08 و 0.11 في موسم 2007 و 0.06 و 0.07 موسم 2008 علي الترتيب، بالاضافة ان هذه الهجن اظهرت اقل انخفاض في محصول الحبوب تحت ظروف نقص مياه الري (7.0 و 9.2 و 5.7 و 6.8 علي الترتيب)اظهرت نتائج معدل انتاجية مياه الريCWP ان هناك زيادة مع تقليل كمية المياه حيث زادت من 2.93 الي 3.03 كجم/م^3 في 2007 ومن 2.25 الي 2.55 كجم/م^3 في 2008 للمعاملات 100% و75% علي الترتيب. اظهرت الدراسة ان الهجين الفردي 10 هو افضل الهجن تحت ظروف الري المثلي بينما كانت الهجن الثلاثية 321 و 327 هي افضل الهجن تحت ظروف نقص مياه الري.