Water-Stress in Relation to Maize (*Zea mays* L.) Grain Yield, Plant Height and Proline Content

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ABSTRACT

Two experiments were carried-out in Research Farm of Nubaria Agricultural Resear- ch Station (46 Km. south west of Alexandria), Agricultural Research Center, Ministry of Agri- cultural. In 2014 and 2016 seasons to study the potential of some maize genotype to waterstress through yield, yield components, some agrono- mic and physiological characteristics. Four maize hybrids (T.W.C321, S.C 162, S.C 10, S.C 129), its parent (Gm. 2, Sd. 7, Sd. 63, Gz. 628, Gz 612, Gz 639, Gz 653) and four populations (DTP-1-C_7-yellow, DTP-1-C_7-white, DTP-2-C_5-yellow, DTP-2-C_5-white) were grown in a split-plot design in 4 replicates under three irrigation treatments (control, moderate and severe). Imposition of severe water treatment decreased the plant height and grain yield but increased proline content in leaves. Results showed signif-icant differences among genotypes and water deficiency treatments for grain yield and proline content.

Keywords: zea maize, water stress, grain yield, leaves proline content.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important food and feed crops in the world. In Egypt, it is used primarily as a feed crop and as industrial crop for oil and starch extraction. IN literature, maize has been reported as having high irrigation requirements (Rhoads and Bennett 1990; Stone et al. 2001). In arid and semi-arid regions, the daily evapotranspiration of maize often exceed 10 mm day^{-1} for signif- icant time periods (Howell et al. 1995). Furthermore, maize is sensitive to water stress, especially at flowering and pollination stages. Nesmith and Ritchie (1992) reported that, the reductions in maize yield exceeded 90 % due to water stress during flowering and pollination stages. Proline and quaternary ammonium com-pounds, e.g. Glycinebetaine, choline, proline betaine are keyosmolytes contributing osmotic adjustment (Huang et al., 2000 and Kavikishore *et* al., 2005).

Frederick *et al.* (1989) reported a decrease in maize yield due to drought stress associated with a number of barren plants, a lower number of kernels.ear^{-1} and a short grain filling period. Nigem (1998) reported positive and significant correlations between maize grain yield and each of the leaf area index, ear length and number of kernels row^{-1} under drought stress. Moursi (1997) reported that, under water stress condit-ions grain yield per faddan was positively correlated with ear weight and kernel weight/ear, therefore, he concluded that, grain yield of maize under stress conditions might be improved through selection for ear weight and kernel weight/ear. Ear weight was positively and significantly correlated with kernel weight/ear. Abd El-Gawad*et al.* (1980) investigates the effect of skipping one of six irrigations on yield of maize hybrid D.C. 355. They found that, grain yield, ear diameter, 100-kernel weight, ear number, and the percentage of double-eared plants were decreased. How-ever, the number of kernels/row was not affected. Skipping the third, fourth, or fifth irrigation reduced grain yield by 21, 19.9, and 17%, respectively. Skipping the third or fourth irrigation decreased the number of ears/faddan. The greatest reduction in 100-kernel weight resulted from omitting the fifth or sixth irri-gation. Moustafa and Seif El-Yazal (1980) studied the effect of irrigation intervals ofnine, 12, 15, 18, or 21 days at vegetative, flowering or maturity growth stages on hybrid D.C. 186. They found that grain yield was decreased with increased irrigation intervals at all growth stages. The greatest effect on grain yield was resulted from the effect on flowering stage. The best irrigation intervals of 12, nine, and 15 days were recommended, respectively, for vegetative, flowering, and maturing stages.

Porro and Cassel (1986) reported that delaying irrigation during a dry growing season reduced plant height.El-Ganayni*et al.* (2000) mentioned that, flowering stage was the most sensitive to water stress, where, the reduction was 67% in grain yield and 53% in number of ears per plant. They added that, grain-filling stage was also sensitive to water stress. The pre-flowering and flowering stages were equal in sensitivity to water stress effect on anthises to silking interval and number of rows/ear. When water stress elongated, it reduced number of rows/ear by 4% as compared to the control. Moreover, severe stress experienced from the beginning of flowering stage until maturity showed maximum reductions in grain yield (75%), ears/plant (56%), and rows/ear (5%) as compared to the control. Also, prolonged irrigation interval of 22 days significantly reduced grain yield/plant and number of kernels/ear as compared to irrigation at 12-days. Reduction occurred also in plant height, ear height, and leaf area. Asch *et al.*, (2001), found that, plant height was significantly reduced by 40 and 25%, respectively, in the two most severe drought treatments. Long drying cycles resulted in significant yield reductions up to 70% of the fully watered controls. Kernel number per cob was reduced up to 60% under long drought conditions and not affected under short-term drought.

Soltani, *et al* (2013), showed that, water deficiency induced significant increase of leaves proline. Also, Water deficiency led to significant decrease in chlorophyll content. Efeoĝlu, *et al*, (2009), found that, the Fresh and dry biomass, fluorescence and Chlorophyll decreased with drought but the proline contents was increased. Tarighaleslami, *et al* (2012), found that Proline also increased significantly under drought stress conditions showing that osmotic adjustment mechanism had been activated. Lama, and Chakraborty, (2013), Showed that, with increasing in the intensity of drought there was an increase in both proline and ascorbate content. Heidari, and Moaveni, (2009), indicated that, drought stress affected different activity levels of the proline and abscisic acid (ABA).

The aim of this study was to investigate the effect of water stress treatments on yield, yield components and some agronomic characteristics using 4 hybrids with its parents and four populations (white and yellow) in the two summer growing seasons (2014-2016).

MATERIAL AND METHODS

The present study was carried-out at Nubaria Agricultural Research Station (46 Km. south west of Alexandria), Agricultural Re-search Center, Ministry of Agricultural, Egypt. The site of experiment was chosen to represent irrigation problem in newly reclaimed lands of Nubaria region with soil PH 8.4,organic matter 0.60%, $CaCO_3$ 31.8%, and electrical conductivity of 0.55 ds.m^{-1}. The experimental design was a split-plot with 4 replicates. Irrigation treatments (10 days, 15 days and 20 days) were assigned to main plots. Genotypes used in this study were four commercial hybrids, their parents, and four populations are shown in table (1), and were assigned to sub-plot. The sub-plot consisted of four rows of three meter long and 0.7m apart. Two central rows were harvested for yield and yield components data. Sowing date was normal at the two successive seasons (2014 and 2016), respectively. Two seeds were hand sown per hill. Spaced at 25 cm. Hills were thinned to one plant/hill after 21 days from planting. Nitrogen fertilization at rat of 120 kg /fad (ammonium nitrate 33.5) was applied in two equal doses before the first and second irrigation. Harvest was done after 120 days from sowing.

The study characters were

1-Plant height (cm): measured from ground to the point of flag leaf insertion.

2- Grain yield plant $^{-1}$ (g) adjusted at 15.5% grain moisture.

Table 1: The lines, hybrids and drought tolerant populationswere used in this study.

Genotypes	Abridged	Origin	Color	Pedigree
		Lines		
Gemmeiza 2	Gm-2	Mexican	white	Pop. 7421 CIMMYT (Pop21)
Sides 7	Sd 7	ARC	white	A.E.D × an exotic composite, A4
Sides 63	Sd 63	Mexican	white	Teplacinco # 5 (Tep-5)
Giza 612	Gz 612	ARC	white	B73 (P-90 Bsss-1) x Sd7
Giza 628	Gz 628	ARC	white	B73 (P-90 Bsss-1) x Sd-62
Giza 639	Gz 639	ARC	yellow	B73 (P-90 Bsss-1) xSd 62(s_5)
Giza 653	Gz 653	ARC	yellow	EXP 9281
Hybrid				
Single cross 10	S.C. 10	ARC	white	Sd – 7 X Sd - 63
Single cross 129	S.C. 129	ARC	white	Gz – 612 X Gz - 628
Single cross 162	S.C. 162	ARC	yellow	Gz – 653 X Gz - 639
Three way cross 321	T.W.C. 321	ARC	white	[S.C.21(Gm-2 X Sd 63)] X Sd - 7
		Population		
Drought tolerant population one	DTP-1-C_7(W1)	ARC	white	TL 95b-6677/9
Drought tolerant population one	DTP-1-C_7(Y1)	ARC	yellow	TL95b-6677/10
Drought tolerant population two	DTP-2-C_5(W2)	ARC	white	TL 95b-6677/11
Drought tolerant population two	DTP-2-C_5(Y2)	ARC	yellow	TL 95b-6677/12

Agriculture Research Center (ARC).

3-Leaf proline content; three fresh-leaf samples were taken for determining leaf proline content (mg/g) as physiological indicators of plant status under the implemented water stress treatments. Sampling time was at 65 days after planting representing flowering stages. Samples were collected between 11:00 am and 2:00 pm. Leaf disks were taken from two plants in each plot. The leaf disks were immersed immediately in the cooled proline extraction solution (3% aqueous sulfosalicylic acid solution).

Samples were taken to cooled conditions and were kept in refrigerator until the extraction and determination of leaf proline content (Bates et al., 1973). Samples were measured by spectrophotometer and repeated twice.

Statistical analysis

Statistical analysis was performed according to steel and torrei (1982), by using ANOVA at SAS software (SAS. Software Rel 6.12, 1997). Water treatments and genotypes were treated as fixed effects, while replications as random effects. Treatments means were compared by $LSD_{0.05}$ and calculated using SAS software. Test for homogeneity of error variances were carried out according to snedecor and chochran (1981). Heterogeneity differences were observed between the years error variances; therefore, theseparte analysis of variance for each year was done.

RESULTS AND DISCUSSION

The analysis of variance for grain yield, plant height and proline content in 2014 and 2016 seasons were recorded in Table (2). Highly significant variances were observed among water deficiency treatments for all the studied traits at the two tested seasons for all studied traits. The treatments by genotypes interaction were significant for the studied traits at the two seasons, except for grain yield at 2016 season (Table 2).

Grain yield (ard/fad)

Means of grain yield and the other studied traits of the evaluated 15 maize genotypes at three water stress treatment were presented in Table (3). the results showed that, water stress treatments affected on all studied traits, where, 10 days treatment gave the highest grain yield in 2014 and 2016 seasons (11.01 and 10.63 ard/fad), respectively, 15 days treatments had significantly lower yield in 2014 season and insignificant difference in 2016 season (8.97 and 9.13ard/fad),respectively. The 20 days water treatment had the least significant grain yield at both seasons (7.72 and 7.78 ard/fad), respectively. Generally, the single crosses had more significant grain yield than the tested populations and lines, while the tested lines had the lowest significant grain yield (Table 4). Non-significant differences were observed among S.c. 10, 162 and Twc. 321 in 2014 season (16.57, 16.11 and 15.88 ard/fad respectively), while at 2016 season Sc.10 had significantly more grain yield than the other crosses (16.82ard/fad). Also, Sc.162 and Twc.321had insignificant differences at 2016 season (15.18 and 14.55 ard/fad), respectively, while Sc.129 was significantly lower yield (13.45ard/fad).

Table 2: Mean square of grain yield, plant height and proline content for 15 maize genotypes evaluated under stress water treatments in 2014 and 2016 seasons.

S.O.v	d.f	Grain yield (ard/fad)		Plant height (cm)		Proline content (mg/g)	
		2014	2016	2014	2016	2014	2016
Rep	3	5.35	2.76	31.48	0.37	0.64	2.55
Trt	2	165.57**	121.44 **	12771.67**	9196.25 **	7440.32**	6929.30 **
Error a	6	0.31	0.41	2.14	3.12	0.21	0.78
Gen	14	200.28**	180.82 **	16729.23**	19367.21 **	525.38**	531.02 **
Trt*gen	24	2.33**	0.99 ns	226.43**	631.67 **	69.10**	67.87 **
Error	126	0.84	0.98	5.39	7.95	0.75	2.14

*,** significant and highly significant differences at 0.05 and 0.01 levels of probability

Table 3: Means of grain yield, plant height and proline content at three water stress during 2014 and 2016 seasons.

Character / treatment	Grain yield (ard/fad)		Plant height (cm)		Proline content (mg/g)	
	2014	2016	2014	2016	2014	2016
10 days	11.01 a	10.63 a	187.84 a	184.50 a	30.74 c	30.60 c
15 days	8.97 b	9.13 a	172.50 b	172.75 b	41.63 b	42.17 b
20 days	7.72 b	7.78 b	158.67 c	159.75 c	53.01 a	52.07 a
$LSD_{0.05}$	1.69	1.95	4.45	5.37	1.39	2.68

As For, the populations, in significant differences were detected at 2014 season, while at 2016 season W_2 and Y_1 populations had significantly more grain yield (9.27 and 9.57 ard/fad). Among tested lines, Sd.7 and Gz.653 lines had the highest significant grain yield at both seasons (7.48, 7.30 and 6.84, 7.41ard/fad, respectively), (Table 4). The interaction between water stress treatments and genotypes is shown in table (5, 6). Similar results were in agreement trend with those reported by Frederick *et al.* (1989)**.**, Nigem (1998),Moursi (1997), Abd El-Gawad*et al.* (1980), Moustafa and Seif El-Yazal (1980).

Plant height (cm)

Plant height was reduced when water stress treatments applied, where, 20 days treatment had the least plant heights at both seasons (158.67 and 159.75 cm, respectively).The 15 days treatment had 172.50 and 172.75cm of plant height at both seasons, respectively, (Table3). On the other hand, the tallest plants were observed for 10 days treatment (187.84 and 184.50 cm, respectively). Sc.10 gave the tallest plants while Twc.321 had the lowest plant height than Sc.162 and Sc.129 in 2014 and 2016, (239.58 and 237.50 cm), (212.50 and 213.75 cm), (221.25 and 222.50 cm), (205.42 and 204.17cm), respectively. For populations, Y_2 had significant difference of plant height in 2014 season, while Y_2 and W_2had significant difference in 2016 season (Table 4). For lines tested, Gz.653 and Sd.63 had significant difference in both seasons from the others, where Gz.653 line gave the highest values (182.50 and 183.75 cm, respectively) but Sd.63 line gave the lowest values (110.84 and 87.92 cm, respectively).The interaction between water stress treatments and genotypes is shown in table (5,6). Similar data was obtained by Porro and Cassel (1986), El-Ganayni*et al.* (2000) and Asch *et al.* (2001).

Proline content (mg/g)

For proline content, the water stress treat-ments increased proline content in leaves, where the 20 days treatment had the highest values at both seasons (53.01and 52.07 mg/g). The 15 days treatment had 41.63and 42.17mg/g at both seasons, while, the least values of proline content were detected for 10 days water stress treatment (Table 3). Twc. 321 had the highest values among hybrids. On the other hand, Sc.10 gives the least values of proline content in leaves, (50.45, 51.03 mg/g) and (31.66, 30.88 mg/g) in 2014 and 2016 respectively. Population, W_2 and Y_2 had in significant differences in both seasons but showed highly values than the other popula-tions, where, population W_1 gave the least val-ues in the two seasons, (Table 4). On the other hand Gm-2 line enjoyed the highest leaves proline content in both seasons (54.73and 53.81 mg/g, respectively), however Gz.639 line gave low values in the two seasons (32.35and 32.19 mg/g, respectively).The interaction between water stress treatments and genotypes is shown in table (5, 6). Similar results were reported by Adel Soltani, *et al* (2013), Efeoĝlu,B. *et al* (2009), Mohsen Tarighaleslami, *et al* (2012), Lama, R. and Chakraborty, U. (2013), Heidari, Y. and Moaveni, P. (2009).

Table 4: Means of maize genotypes for grain yield, plant height and proline content at three water stress during 2014 and 2016 seasons.

Character / genotypes	Grain yield (ard/fad)		Plant height (cm)		Proline content (mg/g)	
	2014	2016	2014	2016	2014	2016
			Lines			
Gm 2	5.37 e	5.41 f	124.58L	126.67J	54.73a	53.81 a
Sd 7	7.48 d	7.30 e	144.58J	141.25i	40.47g	40.12 e
Sd 63	6.42 d	6.44 f	110.84m	87.92k	44.42d	44.57 d
Gz 612	5.57 e	5.76 f	168.34h	170.00g	37.91h	37.46 g
Gz 628	5.81 e	6.00 f	134.17k	138.34i	41.75f	41.67 e
Gz 639	5.61 e	5.56 f	143.34J	141.67i	32.35i	32.19 h
Gz 653	6.84 d	7.41 e	182.50f	183.75f	46.87c	47.44 c
			Hybrid			
Sc 10	16.57 a	16.82 a	239.58a	237.50a	31.66i	30.88 h
Sc 129	13.14 b	13.45 c	205.42d	204.17d	43.32e	43.17 d
Sc 162	16.11 a	15.18 b	221.25b	222.50b	40.47g	41.13 e
Twc 321	15.88 a	14.55 b	212.50c	213.75c	50.45b	51.03 b
			Population			
W 1	8.06 c	7.91 e	159.17 i	162.50h	31.87i	32.09 h
W 2	8.17 c	9.27 d	186.25e	189.17e	45.53d	43.97 d
Y 1	8.57 c	9.57 d	173.34g	176.25f	40.15g	39.52 f
Y 2	8.90 c	7.09 e	189.17e	189.58e	44.96d	45.17 d
$LSD_{0.05}$	1.27	1.37	3.22	3.90	1.20	2.03

Table 5: Interaction between the water stress treatments and maize genotypes on grain yield,plant height and proline content during 2014seasons.

Character / genotypes	Grain yield (ard/fad)			Plant height (cm)			Proline content (mg/g)		
	10	15	20	10	15	20	10	15	20
Gm 2	6.69	4.89	4.52	161.25	111.25	101.25	43.85	58.50	61.83
Sd 7	9.67	6.75	6.01	163.75	143.75	126.25	28.45	29.63	53.33
Sd 63	8.57	5.75	4.92	127.50	107.50	97.50	34.87	45.84	52.54
Gz 612	7.40	5.06	4.26	191.25	161.25	152.50	26.65	41.34	45.73
Gz 628	7.23	5.76	4.43	152.50	132.50	117.50	33.23	40.68	51.33
Gz 639	7.29	5.45	4.08	152.50	143.75	133.75	24.16	33.66	39.21
Gz 653	8.02	7.05	5.46	197.50	182.50	167.50	34.12	45.57	60.92
Sc 10	19.59	17.19	12.94	257.50	247.50	213.75	24.34	27.57	43.06
Sc 129	14.57	13.02	11.82	213.75	208.75	193.75	35.41	44.72	49.81
Sc 162	17.25	16.16	14.93	227.50	222.50	213.75	26.63	40.08	54.72
Twc 321	17.49	16.83	13.32	221.25	213.75	202.50	38.30	54.56	58.51
W 1	10.60	7.09	6.50	170.00	158.75	148.75	24.92	27.63	43.06
W 2	10.05	7.51	6.94	196.25	186.25	176.25	28.09	46.54	61.96
Y 1	10.68	7.84	7.18	182.50	173.75	163.75	26.93	33.71	59.81
Y 2	10.03	8.77	7.89	202.50	193.75	171.25	29.98	45.53	59.35
$LSD_{0.05}$ (trt)		0.44			1.15			0.36	
$LSD_{0.05}$ (gen)		0.73			1.86			0.69	

Table 6: Interaction between the water stress treatments and maize genotypes on grain yield,plant height and proline content during 2016seasons.

Character / genotypes	Grain yield (ard/fad)			Plant height (cm)			Proline content (mg/g)		
	10	15	20	10	15	20	10	15	20
Gm 2	6.57	5.04	4.60	162.50	113.75	103.75	43.09	58.67	59.67
Sd 7	9.05	7.07	5.78	158.75	141.25	123.75	29.58	41.83	48.96
Sd 63	8.64	5.58	5.09	85.75	106.25	98.75	33.61	46.61	53.50
Gz 612	7.52	5.40	4.36	192.50	163.75	153.75	26.91	39.68	45.79
Gz 628	7.57	5.76	4.65	157.50	137.50	120.00	33.45	40.33	51.23
Gz 639	6.94	5.81	3.93	151.25	142.50	131.25	24.57	32.54	39.45
Gz 653	8.22	7.37	6.62	201.25	183.75	166.25	37.01	45.24	60.06
Sc 10	18.71	17.47	14.28	258.75	245.00	208.75	23.75	27.45	41.45
Sc 129	14.83	13.68	11.84	212.50	207.50	192.50	33.85	46.12	49.54
Sc 162	16.90	15.02	13.62	232.50	222.50	212.50	26.03	41.72	55.63
Twc 321	16.30	14.54	13.06	222.50	211.25	207.50	38.82	55.11	59.15
W 1	9.39	7.49	6.83	171.25	160.00	156.25	25.35	28.76	42.16
W 2	10.33	9.84	7.63	201.25	188.75	177.50	26.60	48.23	57.10
Y 1	10.41	9.61	8.70	183.75	175.00	170.00	26.50	32.86	59.20
Y 2	8.27	7.26	5.75	202.50	192.50	173.75	29.89	47.44	58.17
$LSD_{0.05}$ (trt)		0.51			1.39			0.69	
$LSD_{0.05}$ (gen)		0.79			2.26			1.17	

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الملخص العربي

العلاقة بين الإجهاد المائى ومحصول الحبوب، إرتفاع النبات، كمية البرولين فى الذرة الشامية

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أجريت تجربتان حقليتان بمزرعة محطة البحوث الزراعية بالنوبارية (كيلو ٤٦ طريق الاسكندرية – القاهرة الصحرواى) التابعة لمركز البحوث الزراعية خلال الموسم الصيفى لعام ٢٠١٤ و٢٠١٦ على الترتيب وذلك لدراسة تحمل بعض الهجن وهى (هـ.ف. ١٠، هـ.ف. ١٢٩، هـ.ف. ١٦٢، هـ.ث. ٣٢١) وكذلك أبائها (سدس ٧، سدس ٦٣، جيزة ٦١٢، جيزة ٦٢٨، جيزة ٦٣٩، جيزة ٦٥٣، جميزة ٢) وبعض العشائر المتحملة للجفاف (DTP-1-C$_7$-yellow, DTP-1-C$_7$-white, DTP-2-C$_5$-yellow, DTP-2-C$_5$-white) للإجهاد المائى ومدى تأثيره على محصول الحبوب وأطوال النباتات وكذلك قياس محتوى الأوراق من البرولين.

وكان التصميم الإحصائى للتجربة هو قطع عشوائية منشقة فى أربعة مكررات وكانت فترات الرى هى (١٠، ١٥، ٢٠ يوم) ويتضح من النتائج أختلاف قدرة الأصناف والسلات والعشائر المستخدمة فى البحث على تحمل نقص الماء حيث أدى الإجهاد المائى لنقص محصول الحبوب وكذلك أطوال النباتات وزيادة محتوى الأوراق من الحامض الأمينى البرولين خلال موسمى الدراسة.

وتشير النتائج في السنة الاولي الي ان هجين فردى ١٠ أعطى أعلى محصول خلال موسمى الدراسة عن باقى التراكيب الوراثية ولكن لم تكن بينة وبين هجين فردى ١٦٢ وهجين ثلاثى ٣٢١ فروق معنوية فى الموسم الاولبينما كانت هناك فروق معنوية فى السنة الثانية لنفس الهجن أماالسلالة (جميزة-٢) كانت أقل التراكيب الوراثية فى محصول خلال الموسمين ايضاً.

أما بالنسبة لأطوال النباتات فإن هجين فردى ١٠ سجل أعلى ارتفاع للنبات عن باقى التراكيب الوراثية خلال موسمى الدراسة بينما كانت السلالة (سدس ٦٣) أقل أرتفاع فى التراكيب الوراثية خلال الموسمين.

وبالنسبة لمحتوى الأوراق من البرولين فإن السلالة (جميزة-٢) احتوت أوراقها على أعلى كمية من حامض البرولين الأمينى خلال موسمى الدراسة بينما كان أقل تركيب وراثى فى محتوى أوراقة من البرولين هى السلالة (جيزة ٦٣٩).