Improving Drought Tolerance in White Maize Population

El-Shamarka S.A.[1]; Darwish I.H.[1]; Marwa M.El-Nahas[1]; Gamea H.A.[2] and El-Harany A.A.[1]

[1] Crop Science Dept., Faculty of Agriculture, Menoufia Univ., Egypt

[2] Maize Research Section, Field Crops Research Institute, ARC, Egypt

ABSTRACT

Field experiments were carried out in four successive seasons (2015 to 2018) at the experimental farm of faculty of agriculture, Menoufia University, in Shebin El-Kom, Egypt. The main objectives of this study were to study the effect of water stress on different maize traits and identify the effectiveness of S_1 recurrent selection for improving drought tolerance in Tep#5 population (white). 100 S_1's were isolated and evaluated under normal irrigation (NI) and drought stress (DS) at flowering stage. The highest yielding 10 lines (10%) selected under each environment were random mated by bulking pollen and make crosses handly. Two sub-populations were obtained (Tep#5-NI and Tep#5-DS).The population (Tep#5-NI) along with the original population (Tep#5) were evaluated for 19 traits under normal irrigation condition (NI) and the population (Tep#5-DS) along with the original population (Tep#5) were evaluated under drought stress condition (DS) in a randomized complete block design with four replications. Results indicated wide genetic variation among S_1 progenies for most studied traits under both selection environments (NI and DS). Heritability estimates were generally higher under drought stress than under normal irrigation conditions. Number of kernels/row, 100-kernels weight and ear length traits were predicted to grain yield more efficiently under drought stress than under normal irrigation conditions. One cycle of S_1 recurrent selection under water-stress caused a significant actual improvement of grain yield of the newly developed population (Tep#5-DS) over its original population (Tep#5) of 15.47%. The improved population Tep#5-NI developed by using normal irrigation as a selection environment showed significant actual improvements in grain yield under normal irrigation (12.46%) environment. Selection under water stressed and non-stressed irrigations were efficient in improving grain yield.

Key words: Maize, Populations, Recurrent selection, Drought tolerance, physiological characters, yield and its components.

INTRODUCTION

Maize (*Zea mays* L.) is the third most important cereals after wheat and rice all over the world as well as in Egypt. In Egypt, the cultivated area of maize reached 2.619 million fad with total yield and annual average production 7.10 million tones and 2.711 ton/fad, respectively (FAOSTAT, 2017). Irrigation is a major limiting factor affecting plant growth, development and yield mainly in arid and semiarid regions where plants are often exposed to periods of water stress (drought stress).

Drought is a major reason for yield loss worldwide, reducing average yields about 50% and more (Wang *et al.*2003; Cairns *et al.* (2013) and Rekaby *et al.* (2017). Breeding for drought tolerance in maize is a complex task, because, drought might affect the crop at any stage of development. Many breeders have focused emphasizing the effects of drought at flowering and grain filling, because, maize is most sensitive at these stages (Maazou *et al.*, 2016). It is well established that drought stress impairs numerous metabolic and physiological processes in plants (Efeoğlu *et al.*, 2009). The reaction of the plants to drought differs significantly at various organizational levels depending upon intensity and duration of stress, as well as, plant species and the stage of development (Chaves *et al.*, 2003).

One of the goals of the Egyptian breeders is breeding hybrids ifhigh yield under normal and stress environmental conditions, such as, drought and limited irrigation water to expand cultivation in the new lands. This might reduce the importation bill and rationalize irrigation water under limited Egyptian water resources.

Recurrent selection is population improvement that increase the frequency of favorable alleles while maintenance genetic variation (Doerksen, 2003). The S_1 recurrent selection also called endogamic selection, involves repeated regeneration of the first selfed (S_1) progenies and subsequent evaluation of the progenies to select the superior ones that can be recommended to reconstitute improved version of the parent variety. In maize, this selection scheme is considered more efficient than other selection schemes in improving broad-based populations as it conserves that, deleterious homozygous genes eliminated through selection (Leta and Jifar, 2010). S_1 recurrent selection proved to be effective in improving drought tolerance in maize (Al-Naggar *et al.*, 2004).

The main objectives of this recent study were to study the effect of water stress on different maize traits and identify the effectiveness of S_1 recurrent selection for improving drought tolerance in the two maize populations.

MATERIALS AND METHODS

This study was carried-out in four successive summer seasons (2015 to 2018) at the experimental farm of the faculty of agriculture, Menoufia University, (Shebin El-Kom, Egypt). The Tep#5 population (white) was used as a base population to practice one cycle of S_1 recurrent selection for drought tolerance.

1. Experimental site

The field experiments were conducted in northern Egypt (Shebin El-Kom)..Soil samples were taken before sowing until 40 cm depth to determine some physical and chemical properties of soil according to Jackson (1973) and Black (1982). The experimental site, classified as clay loam soil. Some physical and chemical properties of soil located in the experimental site are shown in (Table 1 a and b), respectively.

2. Experimental procedure and cultural practices:

2.1. Formation of S_1 lines

In the 2015 season, kernels of the open-pollinated population Tep#5 (white) was sown at Shebin El-Kom, on the 5th of May under normal irrigation condition (NI). More than two hundred vigorous and disease-free plants were chosen before silking, and was self-pollinated. At harvest, the best 100 selfed (S_1) ears were selected based on their ear characteristics and grain yield weight. Ears of S_1's were divided to two parts, the first were assigned for evaluation in the next season and the second parts were kept as remnant S_1's for developing the new cycle of the population.

2.2. Evaluation of the S_1 lines and Random Mating of the S_1 Lines

In 2016 season, seeds of 100 S_1 lines that were selected was sown at Shebin El-Kom farm in the 1st, May in single-ridge/plots of 2.5 m long and 0.7 m width for evaluation under two irrigation regimes:

1- Normal conditions (NI): seven irrigations were applied, the first one was applied at 21 days often sowing (DAS) and other irrigations were repeated every 12 days.

2- Drought stress (DS): five irrigations were applied, the first one was applied at 21 DAS and other irrigations were repeated every 12 days, but withholding the 3th (45 DAS) and 5th (69 DAS) irrigations.

A randomized complete block (RCBD) design with three replications was used for evaluating each group of S_1 lines for grain yield characters. Experiment of drought stress was surrounded with a wide ridge (2.1 m width) to avoid water leak between treatments. Two kernels were sown per hill at 25 cm spacing. Plants were thinned after seedling emergence to secure one plant per hill to produce 24000 plants per fad. All other agricultural practices were done according to the recommendation of ARC, Egypt. Harvesting was done after 110 days. At harvest, the highest 10 S_1's (about 10%) were selected under normal irrigation and drought stress. Selection of S_1's based mainly on grain yield per plot and short anthesis-silking interval (ASI) a secondary selection criteria. Finally, two groups of S_1's (under normal (NI) and drought stress (DS) conditions) namely, Tep#5-NI and Tep#5-DS.

2.3. Intercrossing fields

In the summer season of 2017, the ten selected S_1 lines from each group were planted in Shebin El-Kom, at1st May in ten ridges contains 25 hills/ ridge. These S_1 lines were randomly mated by bulking pollen from the S_1 plants and using hand crossing. This procedure was applied separately each group. At harvest, ears were shelled, dried and bulked for each group to form seeds of the two sub-populations as follows: (1) Sub-population I (Tep#5-NI) and (2) Sub-population II (Tep#5-DS).

2.3. Evaluation experiments

In the summer season of 2018 (1st May) were evaluated the two new sub-populations that produced from intercrossing along with original populations (Tep#5) at Shebin El-Kom in two separate experiments represented irrigation regimes, i.e.; normal irrigation and drought-stress at flowering stage. The two trials were arranged in a Randomized Complete Block Design (RCBD) with four replications. Each plot consisted of 5 ridges, 5 m long and 0.7 m width (plot area was 17.5 m^2), with plants spaced 25 cm apart within ridges.

Table 1a: Physical properties of the experimental field soil (Over years)

Soil Depth (cm)	Particles Size Distribution (%)			Bulk Density (gm cm^{-3})	Field Capacity (%)	Permanent Wilting Point (%)	Available Water (%)
	Sand	Silt	Clay				
0 – 40	21.40	30.66	47.94	1.20	34.1	17.73	16.37

Table 1b: Chemical properties of the experimental field soil (Over years)

Soil Depth (Cm)	pH	E.C. (ds m^{-1})	O. M. (%)	Soluble cations (meg l^{-1})				Soluble anions (meg l^{-1})		
				Na^+	K^+	Ca^{+2}	Mg^{+2}	Cl^-	$HCo3^{-2}$	$So4^{-2}$
0 – 40	8.67	0.30	1.8	3.3	0.07	0.25	0.15	1.1	1.55	1.12

Plants were thinned to one per hill before the first irrigation, to produce 24000 plants per fad. Other agricultural practices were done according to the recommendation of ARC, Egypt.

3. Studied characters:

3.1- Agronomic characters

Days to 50 % anthesis (DTA, days), days to 50 % silking (DTS, days), anthesis-silking interval (ASI, days), plant height (PH, cm) and ear height (EH, cm).

3.2- Water relations

Samples were taken after 75 days from sowing, to determine each of the following water relations:

1. **Relative water content (RWC, %):** determined by the method of Barrs and Weatherley (1962) as follows:

$$RWC\,\% = \frac{\text{Fresh wt.} - \text{Dry wt.}}{\text{Turgid wt.} - \text{Dry wt.}} \times 100$$

Full turgid weight were recorded after soaking leaves in distilled water for 6 hours under laboratory light and temperature condition. Leaves dried at 70° C for 72 hours to determine dry weights.

2. **Osmotic pressure (OP, bar):** The cell sap of leaves was used for measuring the TSS by the refractometer, then special tables were used to calculate the osmotic pressure as described by Gosev (1960).
3. **Transpiration rate (TR, mg/gfw.hr):** The transpirational lose water was determined using the weight method as described by Kreeb (1990).

3.3- Physio-chemical constituents

Samples were taken after 75 days from sowing, to determine each of the physio-chemical constituents as follows:

1. **Enzymes activities;** Fresh leaves were used to determine the activity of peroxidase and phenoloxidase enzymes using spectrophotometer (CT-2200 Spectrophotometer– Medline, Scientific limited). Peroxidase activity (O.D. /g F.W.) was expressed as changes in absorbance per minute per gram fresh weight (Reuveni *et al.*, 1992). The increase in absorbance density at 470 nm was recorded. Activity of phenoloxidase (O.D. /g F.W.) was expressed as the change in the absorbance of the mixture at 495 nm (Matta and Dimond, 1963).
2. **Photosynthetic pigments (SPAD):** Ear leave samples of five plants were randomly taken at 65 DAS to determine the total chlorophyll (Chl. a+b) using SPAD meter.
3. **Proline content (PC, µg/g D.W.):** It was determined in leaves at 65 DAS according to the method described by Bates *et al*. (1973).

3.4- Yield and its components:

At harvest, the following data were recorded: Number of ears / plant (EPP), ear diameter (ED, cm), ear length (EL, cm), number of rows / ear (RPE), number of kernels / row (KPR), 100-kernels weight (100 KW, g), kernels weight / ear (KWPE, g), grain yield /plot (GYPP, kg) and grain yield (GY, ton/fad).

3.5- Grain quality

1. **Protein percentage (PP, %):** Protein percentage in the dry kernels was calculated by multiplying N% by the factor of 5.75. Nitrogen % was determined using micro Kjeldahel method as outlined by AACC (2000).
2. **Protein yield (PY, kg /fad):** It was determined by multiplying kernel yield/fad by kernel protein percentage.

3.6- Genetical parameters

1. Genotypic (σ^2_g) and phenotypic (σ^2_p) variances

Analysis of variance and expected mean squares (E.M.S) of RCBD under different environments.

S.O.V	Df	MS	EMS
Replications	r-1	-	-
Genotypes	g-1	M_2	$\sigma^2_e + r\,\sigma^2_g$
Error	(r-1) (g-1)	M_1	σ^2_e

Genotypic (σ^2_g) and phenotypic (σ^2_p) variances were computed as follows:

$$\sigma^2_g = \frac{M_2 - M_1}{r}$$

$$\sigma^2_p = \sigma^2_g + \frac{\sigma^2_e}{r}$$

Where r = number of replications.

2. Heritability

Heritability (%) in the broad sense (h^2_b) for a different environments was estimated according to Hallauer and Miranda (1988) by using the following formula:

$$h^2_b\,\% = \frac{\sigma^2_g}{\sigma^2_p} \times 100$$

3. Correlations

Genotypic (r_g) correlations were calculate between each pair of studied traits under each environment according to Betran (1999) using the following formulae:

$$r_g = \frac{\sigma^2_{gxy}}{(\sigma^2_{gx} x \sigma^2_{gy})^{\frac{1}{2}}} \times 100$$

Where: σ^2_{gxy} = the phenotypic and genotypic covariance of the two traits, X and Y, respectively.

$\sigma^2_{gx}$and σ^2_{gy} =the genotypic variance of the two traits, x and y, respectively.

5- Statistical analysis

Analysis of variance was computed according to Snedecor and Cochran (1989). LSD test was used to compare the differences between means.

RESULTS AND DISCUSSION

Experiment I: Evaluation of 100 S_1 progenies of the white population (Tep#5) for drought tolerance.

a. Analysis of variance:

The analyses of variance for all studied traits of S_1 progenies (derived from Tep#5 population) evaluated under normal and drought stress conditions were presented in Table (2). Results of the analysis of variance revealed significant or highly significant differences among genotypes (S_1 progenies) for all studied traits under both normal and drought stress conditions. These differences of S_1 plants allowed the possibilities of culling by selection to normal and drought conditions.

The measured characters for evaluated S_1lines under normal irrigation were less uniform than the corresponding measurements under water-stress condition, except for, grain yield per plot, that was classified by the magnitude of recorded coefficient of variations (C.V.). In this concern, Umar *et al.* (2015) reported larger (C.V.) were for days to 50% anthesis, days to 50% silking, anthesis-silking interval and grain yield under water stress compared to non-stress conditions.

b. Performance of S_1 progenies

Values of grain yield/plot of the 100 S_1 progenies ranged from 1.45 to 2.61 kg/plot under normal condition, and from 0.35 to 1.18 kg/plot under drought stress condition, with mean values of 1.72 and 0.69 kg/plot, respectively (Table 3). A reduction of 60.05% in grain yield /plot of the 100 S_1 progenies due to drought stress was accompanied by a significant reduction in ear length (17.51%), number of kernels /row (19.67%) and 100-kernels weight (7.63%). As for yield component, number of kernels /row showed maximum reduction due to drought stress, while minimum reduction was observed for number of rows /ear. On the other hand, drought stress caused an increases days to 50 % anthesis (3.16%), days to 50 % silking (5.92%) and anthesis-silking interval (88.46%). Reductions in means of the 100 S_1 progenies due to water stress was also accompanied by reductions in ranges (more uniform) for traits; grains yield /plot, 100-kernels weight, number of kernels /row, number of rows /ear, ear diameter and ear length. Moreover, increases in means of the 100 S_1's due to drought stress were accompanied by an increases in ranges (less uniform) for traits; days to 50 % silking, days to 50 % anthesis, days to 50 % silking, anthesis-silking interval.

Means of grain yield /plot of the highest 10 S_1 progenies (selected on the basis of grain yield/plot) were 2.35 and 1.08 kg /plot) (with ranges from 2.05 to 2.61 and 1.01 to 1.18 kg /plot) under normal and drought stress conditions, respectively. The superiority of the 10 S_1's over the 100 S_1's in grain yield / plot was higher under drought stress (57.59%) and normal conditions (36.39%).Superiority of mean grain yield /plot of the 10 S_1's over the 100 S_1's was associated with superiority in number of kernels /row (11.01 and 16.31%) and days to 50 % silking (-3.62 and -3.81%) under normal and drought stress conditions, respectively. On the other hand, the best 10 S_1's in grain yield were characterized by lower means than the 100 S_1's for days to 50% anthesis (-2.48 and -1.97%), anthesis-silking interval (-37.73 and -33.92%), Ear length (13.34 and 10.38%), Ear diameter (9.49 and 3.48%), number of rows /ear(12.42 and 7.36%) and 100-kernels weight (12.57 and 10.35%) under normal and drought stress conditions, respectively (Table 3)

Table 2: Separate analysis of variance for all studied traits of 100 S_1's (derived from Tep#5) grown under normal (NI) and drought stress (DS) conditions.

S. O. V	d.f	Mean squares								
		Days to 50% anthesis (days)	Days to 50% silking (days)	Anthesis-silking interval (days)	Ear length (cm)	Ear diameter (cm)	Number of rows / ear	Number of kernels / row	100-kernels weight(g)	Grain yield /plot(kg)
Normal condition										
Replications	2	2.973	2.003	1.110	1.201	0.016	0.093	12.010	0.576	0.062
Genotypes	99	11.626**	16.402**	2.663**	4.730**	0.164**	3.320**	12.743**	13.961**	0.165**
Error	198	3.354	3.646	1.134	1.729	0.071	1.467	5.616	5.589	0.034
C.V.%		3.361	3.391	58.500	7.416	6.688	9.284	6.984	8.304	10.677
Drought stress										
Replications	2	4.120	3.270	0.070	2.323	0.080	0.520	2.582	0.666	0.021
Genotypes	99	6.099**	9.897**	2.002**	5.074**	0.157**	3.214**	27.790**	16.040**	0.131**
Error	198	1.585	1.519	0.309	0.807	0.060	0.951	2.926	1.896	0.009
C.V.%		2.240	2.067	16.208	6.142	6.216	7.478	6.276	5.237	13.772

** indicate significance at 0.01 level of probability.

Table 3: Means and ranges for all studied traits of 100 S_1's and selected 10 S_1's (based on grains yield / plot) derived from Tep#5 population evaluated under normal (NI) and drought stress (DS) conditions.

Trait	Treatment	Mean		Difference		Range				Drought effect (%)	
		100 S_1's	Best 10 S_1's	Absolute	% of 100 S_1's	100 S_1's Lowest	100 S_1's Highest	Best 10 S_1's Lowest	Best 10 S_1's Highest	100 S_1's	Best 10 S_1's
Days to 50% anthesis (days)	NI	54.49	53.13	-1.35	-2.48	50.67	60.33	51.33	54.67	-	-
	DS	56.21	55.10	-1.11	-1.97	53.00	59.67	53.33	56.33	3.16^{**}	3.70^{**}
Days to 50% silking (days)	NI	56.31	54.27	-2.04	-3.62	51.33	62.67	51.67	56.00	-	-
	DS	59.64	57.37	-2.27	-3.81	56.00	65.67	56.00	58.67	5.92^{**}	5.71^{**}
Anthesis-silking interval (days)	NI	1.82	1.13	-0.69	-37.73	-2.33	4.67	0.33	1.33	-	-
	DS	3.43	2.27	-1.16	-33.92	2.00	6.33	2.00	3.00	88.46^{**}	100.00^{**}
Ear length (cm)	NI	17.73	20.09	2.37	13.34	14.67	21.33	17.73	21.33	-	-
	DS	14.62	16.14	1.52	10.38	11.33	18.20	14.83	18.20	-17.51^{**}	-19.67^{**}
Ear diameter (cm)	NI	3.99	4.36	0.38	9.49	3.25	4.60	4.10	4.60	-	-
	DS	3.96	4.09	0.14	3.48	3.13	4.53	3.68	4.40	-0.74	-6.19^{**}
Number of rows / ear	NI	13.05	14.67	1.62	12.42	10.00	15.33	14.00	15.33	-	-
	DS	13.04	14.00	0.96	7.36	10.00	15.33	12.67	15.33	-0.05	-4.55^{*}
Number of kernels / row	NI	33.93	37.67	3.74	11.01	29.33	39.67	36.00	39.67	-	-
	DS	27.26	31.70	4.45	16.31	20.67	36.33	26.67	36.33	-19.67^{**}	-15.84^{**}
100-kernels weight (g)	NI	28.47	32.05	3.58	12.57	24.10	35.23	29.92	35.23	-	-
	DS	26.30	29.02	2.72	10.35	20.92	31.51	25.43	31.51	-7.63^{**}	-9.45^{**}
Grain yield /plot (kg)	NI	1.72	2.35	0.63	36.39	1.45	2.61	2.05	2.61	-	-
	DS	0.69	1.08	0.40	57.59	0.35	1.18	1.01	1.18	-60.05^{**}	-53.84^{**}

*and** indicate significance at 0.05 and 0.01 levels of probability, respectively.NI; normal irrigation – DS; drought stress

Significant reduction of 53.84% in grain yield /plot of the best 10 S_1's due to drought stress was accompanied by reductions in number of rows /ear (4.55 %), number of kernels /row (15.84%), 100-kernels weight (9.45%), ear diameter (6.19%) and ear length (19.67), *i.e.*; in all yield components. However, reductions due to drought stress were lower for the selected 10 S_1's than those of the 100 S_1's for all studied traits, except, days to 50 % silking, days to 50% anthesis, anthesis-silking interval, where reduction due to drought stress were higher. Similar results were obtained by Magorokosho *et al.* (2003); Moser (2004); Shaboon (2004) and Hussein *et al.* (2019).

c. Variance components and heritability

Changes in the magnitude of genotypic (σ^2_g) and phenotypic (σ^2_p) variances, as well as the estimated corresponding broad-sense heritability (h^2_b) of the studied traits of the 100 S_1 progenies from normal to drought stress experiments were presented in (Table 4).The changes in magnitude of σ^2_p from normal to drought stressed environment was in the same direction for days to 50% anthesis, days to 50% silking, anthesis-silking in terval, ear diameter, number of rows/ear and grain yield/plot traits, where, the magnitude of σ^2_p was smaller under drought stressed than normal environment. On the other hand, the magnitude of σ^2_p was larger under drought stress than normal environment for number of kernels/row, 100-kernels weight and ear length traits. While, the σ^2_gvalues of anthesis-silking interval, ear length, ear diameter, number of kernels/row, 100-kernels weight, number of rows/ear and grain yield/plot traits, were higher under drought stress than normal irrigation. On the other hand, the magnitude of σ^2_g was smaller under drought stressed than normal environment for days to 50% anthesis and days to 50% silking traits. This might indicate that, selection under drought stress is successful than normal conditions. Similar results were obtained by Cairns *et al.* (2013) and Al-Naggar *et al.* (2009).

Heritability for grain yield/plot showed a general magnitude of increase with imposing drought stress (79.54% under the normal to 93.17% under drought stress environments) (Table 8). Moreover, for all studied yield components, including number of rows/ear, number of kernels/row and 100-kernels, weight the magnitude of h^2_b was larger under drought stress than normal conditions. Broad-sense heritability (h^2_b) estimates were generally of medium magnitude for all studied traits under normal conditions, except grains yield/plot, days to 50% silking and days to 50% anthesis that showed high magnitud. This might due to the magnitude of genotypic variance (σ^2_g) for these characters (2.5 times the environmental variance (σ^2_e)).

Table 4: Genetic (σ^2_g) and phenotypic (σ^2_p) variances, and heritability in the broad sense (h^2_b) for all studied traits of 100 S_1 s(derived from Tep#5 population) evaluated under normal (NI)and drought stress (DS) conditions.

Trait	σ^2_p	$C.V_P$	σ^2_p	$C.V_P$	σ^2_g	$C.V_g$	σ^2_g	$C.V_g$	h^2_b%	
	Normal irrigation		Drought stress		Normal irrigation		Drought stress		Normal irrigation	Drought stress
Days to 50% anthesis	3.88	7.11	2.03	3.62	2.76	5.06	1.50	2.68	71.15	74.02
Days to 50% silking	5.47	9.71	3.30	5.53	4.25	7.55	2.79	4.68	77.77	84.65
Anthesis-silking interval	0.89	48.77	0.67	19.46	0.51	28.01	0.56	16.45	57.43	84.56
Ear length (cm)	1.58	8.89	1.69	11.57	1.00	5.64	1.42	9.73	63.45	84.10
Ear diameter (cm)	0.05	1.37	0.05	1.33	0.03	0.78	0.03	0.82	56.64	61.58
No. of rows / ear	1.11	8.48	1.07	8.22	0.62	4.73	0.75	5.78	55.81	70.41
No. of kernels / row	4.25	12.52	9.26	33.99	2.38	7.00	8.29	30.41	55.93	89.47
100-kernels weight(g)	4.65	16.35	5.35	20.33	2.79	9.80	4.71	17.93	59.96	88.18
Grain yield / Plot (kg)	0.06	3.20	0.04	6.36	0.04	2.54	0.04	5.93	79.54	93.17

$C.V_{P;}$ phenotypic coefficient of variation - $C.V_g$; genotypic coefficient of variation

Broad-sense heritability (h^2_b) estimates were very high for all studied traits under drought stress because the genotypic variance (σ^2_g) for these characters was 2.5 times the environmental variance (σ^2_e), except ear diameter was medium magnitude. These results confirm with those reported by Beyene *et al.* (2015) and El-Rouby *et al.* (2017).

a. Correlations between traits

Under drought experiment, data in Table (5) indicated a significant positive genetic correlation between grain yield/plot and number of kernels/row (r_g = 0.47), ear diameter (r_g = 0.41), number of rows/ear (r_g = 0.27), 100-kernels weight (r_g = 0.40) and ear length(r_g = 0.45). Results also showed a significant negative correlation between grain yield/plot and days to 50% silking (r_g = -0.67), anthesis-silking interval (r_g = -0.62) and days to 50% anthesis (r_g = -0.53) under drought stress conditions. These characters could be used for indirect selection for yield especially if they were less affected by environment. Under normal condition, grain yield/plot had a significant positive genetic association with ear length (r_g = 0.94), number of kernels /row (r_g = 0.82), row/ear (r_g = 0.81), 100-kernels weight (r_g = 0.69) and ear diameter (r_g = 0.66). On the other hand, a significant negative genetic associations was observed between grain yield/plot and anthesis-silking interval (r_g = -0.35), days to 50% silking (r_g = -0.28) and days to 50% anthesis (r_g = -0.20) under normal conditions. These results are in agreement with those reported by Al-Naggar *et al.* (2009); Cairns *et al.* (2013) and El-Rouby *et al.* (2017).

Experiment II: Evaluation of the effectiveness of S_1 recurrent selection.

a. Analysis of variance

Mean squares for physiological and biochemical traits, yield and its components and kernels quality in the cycles (C_0 and C_1) derived from Tep#5 under normal and drought stress conditions are shown in tables (6 & 7 & 8).

Table 5: Genetic correlations (r_g) between pairs of studied traits of the 100 S_1 progenies (derived from Tep#5 population) under normal (below diagonal) and drought stress (above diagonal) conditions.

Trait	Days to 50% anthesis	Days to 50% silking	Anthesis-silking interval	Ear length (cm)	Ear diameter (cm)	No. of rows / ear	No. of kernels / row	100-kernels weight (g)	Grain yield / Plot (kg)
Days to 50% anthesis		0.91	0.39	-0.38	0.10	0.12	-0.22	0.11	-0.53
Days to 50% silking	0.95		0.74	-0.35	-0.05	0.02	-0.27	-0.10	-0.67
Anthesis-silking interval	0.42	0.68		-0.16	-0.27	-0.15	-0.25	-0.40	-0.62
Ear length (cm)	-0.29	-0.29	-0.16		0.04	-0.03	0.46	0.14	0.45
Ear diameter (cm)	-0.28	-0.36	-0.41	0.58		0.36	0.09	0.47	0.41
No. of rows /ear	-0.02	-0.03	-0.04	0.72	0.57		0.22	0.17	0.27
No. of kernels / row	-0.23	-0.25	-0.20	0.67	0.70	0.69		0.12	0.47
100-kernels weight (g)	-0.16	-0.25	-0.34	0.73	0.97	0.47	0.72		0.40
Grain yield / Plot (kg)	-0.20	-0.28	-0.35	0.94	0.66	0.81	0.82	0.69	

Table 6: Mean squares of physiological and biochemical traits for the 1st cycle population (derived from Tep#5) under normal and drought stress conditions.

S. O. V	d.f	Mean squares						
		Chlorophyll (SPAD)	Relative water content (%)	Transpiration rate (mg/gfw.hr)	Osmotic pressure C.S. (bar)	Peroxidase activity (O.D. /g F.W.)	Phenoloxidase activity (O.D. /g F.W.)	Proline content (µg/g D.W.)
					Normal conditions			
Replications	3	0.163	0.014	0.415	0.042	0.0001	0.0000	69.493
Genotypes	1	7.220	3.143*	24.256	0.060	0.0006	0.0002*	131.166
Error	3	1.305	0.108	3.517	0.023	0.0001	0.0000	244.035
C.V.%		2.363	0.479	5.921	0.582	1.294	2.506	2.257
					Drought stress			
Replications	3	0.091	0.128	0.087	0.232	0.0000	0.0000	206.713
Genotypes	1	22.819**	30.254**	36.642**	3.712**	0.0011**	0.0006*	3663.965**
Error	3	0.269	0.329	0.507	0.0398	0.0000	0.0000	48.842
C.V.%		1.259	0.927	2.562	0.745	0.690	3.476	0.885

*and** indicate significance at 0.05 and 0.01 levels of probability, respectively.

Table 7: Mean squares of yield and its components for the 1st cycle population (derived from Tep#5) under normal and drought stress conditions.

S. O. V	d.f	Mean squares									
		Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	No. of ears / plant	No. of rows / ear	No. of kernels / row	100-kernels weight (g)	Weight kernels /ear (g)	Grain yield (ton/fad)
						Normal conditions					
Replications	3	52.333	52.778	0.031	0.011	0.000	0.004	0.071	0.066	5.919	0.001
Genotypes	1	2403.56**	1058.0*	0.014	0.027	0.006	0.080	21.342**	2.682**	935.31*	0.242**
Error	3	22.111	46.333	0.004	0.015	0.001	0.040	0.551	0.069	14.963	0.005
C.V.%		2.515	6.598	0.372	2.667	2.842	1.367	2.008	0.938	2.555	2.407
						Drought stress					
Replications	3	13.444	0.778	0.076	0.018	0.001	0.033	0.034	0.304	6.802	0.002
Genotypes	1	410.889*	56.889*	0.161	0.036	0.035**	0.109	15.309**	11.985**	857.36*	0.164**
Error	3	18.778	4.111	0.076	0.018	0.001	0.033	0.301	0.279	1.996	0.004
C.V.%		2.835	2.188	1.790	3.279	2.967	1.331	1.855	2.093	1.385	3.249

*and** indicate significance at 0.05 and 0.01 levels of probability, respectively.

Table 8: Mean squares of kernels quality for the 1st cycle population (derived from Tep#5) under normal and drought stress conditions.

S. O. V	d.f	Mean squares	
		Crude protein in kernels (%)	Protein yield (kg/fad)
		Normal conditions	
Replications	3	0.055	74.907
Genotypes	1	1.411*	6237.987**
Error	3	0.066	48.381
C.V.%		2.906	2.626
		Drought stress	
Replications	3	0.112	41.425
Genotypes	1	0.334*	1899.274**
Error	3	0.025	36.459
C.V.%		1.969	3.833

*and** indicate significance at 0.05 and 0.01 levels of probability, respectively.

Analysis of variance insignificant differences between Tep#5 and Tep#5-NI populations under normal conditions for all studied traits, except for, relative water content, Phenoloxidase activity, plant height, ear height, number of kernels / row, 100-kernels weight, weight kernels /ear, grain yield, crude protein in kernels and protein yield; while, a significant differences between Tep#5 and Tep#5-DS populations under drought stress conditions were noticed for all studied traits, except for, ear length, ear diameter and number of rows / ear.

b. Performance of populations

Mean of physiological and biochemical traits, yield and its components and kernels quality in the new cycle derived from Tep#5 under different environments (normal and drought stress) during 2018 season are presented in Tables (9 &10 &11).

Physiological and biochemical traits

Results in Table 9 indicated that, drought stress causes a reduction in chlorophyll, relative water content, transpiration rate, peroxidase activity and phenoloxidase activity, while it causes increase in osmotic pressure and proline content in leaves compared to normal conditions.

Under normal condition, superiority of C_1 population (Tep#5-NI) over the original population (Tep#5) in relative water content and phenoloxidase activity. The rate of increase in C_1 relative to $C_0$for relative water content and phenoloxidase activity were amounted to 1.84% and 6.25%, respectively. Meanwhile, under drought stress conditions, the superiority of C_1 population (Tep#5-DS) over the original population (Tep#5) was existed for all studied traits. The rate of increase in C_1 (tep#5-NI) relative to C_0 (tep#5) for chlorophyll, relative water content, osmotic pressure, peroxidase activity, phenoloxidase activity and proline content were amounted to8.56, 6.49, 5.25, 5, 6.67 and 5.57% respectively. However, the rate of decrease for transpiration rate was 14.30%.Water stress could restrict internode elongation and leaf expansion through inhibiting cell expansion (Namich, 2007). Relative water content has been reported as an important indicator of water stress in leaves, which is directly related to soil water content. Osmotic adjustment is an active accumulation of solutes within the plant in response to decrease in soil water potential, thus reducing the harmful effects of water deficit. Under stressed conditions, cell membranes are subject to changes often associated with the increase in the cell permeability. These results are in consistence to those reported by Efeoglu *et al*. (2009); Heidari and Moaveni (2009); Hammad and Ali (2014) and Gomaa *et al*. (2017**).**

Yield and its components

Data in Table 10 indicated that, drought stress condition affected grain yield and its components, where, grain yield was reduce from 2.81 ton/fad under normal condition to 1.81 ton/fad under drought stress for C_0 (decrease rate 35.59%). C_1yield was reduce from 3.16 ton/fad under normal condition to 2.09 ton/fad under drought stress by (33.86%).

Under normal condition, a superiority of C_1 population (Tep#5-NI) over the original population (Tep#5) in plant height, ear height, number of kernels /row, 100-kernels weight, weight kernels /ear and grain yield traits amounted to 20.43, 25.09, 2.26, 4.22, 15.38 and 12.46%, respectively. Meanwhile, under drought stress conditions, the superiority of C_1 population (Tep#5 DS) over the original population (Tep#5) existed for all studied traits, except, ear length, ear diameter and number of rows /ear traits.
The rate of increase in C_1 (tep#5-DS) relative to C_0 (tep#5) for plant height, ear height, number of ears /plant, number of kernels /row, 100-kernels weight, weight kernels /ear and grain yield amounted to 9.84, 5.92, 18.67, 9.82, 10.20, 22.59 and 15.47%, respectively. The two improved populations showed significant superiority in grain yield/fad over original population under normal and drought stress conditions. These results are in agreement with those reported by Singh *et al.* (2000); Gamea (2010); Sadalla *et al*. (2014) and Beyene *et al*. (2015).

Table 9: Mean performance of physiological traits for the 1[st] cycle population (derived from Tep#5) under normal and drought stress conditions.

Populations		Mean						
		chlorophyll	Relative water content (%)	Transpiration rate (mg/gfw.h)	Osmotic pressure C.S. (bar)	Peroxidase activity (O.D./g F.W.)	Phenoloxidase activity (O.D. /g F.W.)	Proline content (µg/g D.W.)
Normal conditions								
Tep#5	Original	47.40	67.92	33.41	25.98	0.71	0.16	688.10
	C_1	49.30	69.17	29.93	25.80	0.72	0.17	696.20
L.S.D	0.05	2.570	0.739	4.220	0.339	0.021	0.009	35.153
Drought stress								
Tep#5	Original	39.50	59.97	29.93	26.10	0.60	0.15	768.16
	C_1	42.88	63.86	25.65	27.47	0.63	0.16	810.96
L.S.D	0.05	1.167	1.291	1.602	0.449	0.010	0.012	15.727

Table 10: Mean performance of yield and its components for the 1st cycle population (derived from Tep#5) under normal and drought stress conditions.

Populations		Mean									
		Plant height (cm)	Ear height (cm)	Ear length (cm)	Ear diameter (cm)	No. of ears / plant	No. of rows / ear	No. of kernels / row	100 kernels weight(g)	Weight kernels /ear (g)	Grain yield (ton/fad)
		Normal conditions									
Tep#5	Original	169.67	91.67	16.70	4.53	1.01	14.53	35.33	27.46	140.59	2.81
	C_1	204.33	114.67	16.78	4.65	1.07	14.73	38.60	28.62	162.21	3.16
L.S.D	0.05	10.581	15.317	0.140	0.276	0.066	0.450	1.671	0.592	8.705	0.162
		Drought stress									
Tep#5	Original	145.67	90.00	15.27	4.00	0.75	13.60	28.20	24.03	91.62	1.81
	C_1	160.00	95.33	15.55	4.13	0.89	13.83	30.97	26.48	112.32	2.09
L.S.D	0.05	9.751	4.563	0.621	0.300	0.055	0.411	1.235	1.189	3.179	0.143

Table 11: Mean performance of kernels quality for the 1st cycle population (derived from Tep#5) under normal and drought stress conditions.

Populations		Mean	
		Crude protein in kernels (%)	Protein yield (kg/fad)
		Normal conditions	
Tep#5	Original	8.43	236.95
	C_1	9.27	292.80
L.S.D	0.05	0.579	15.652
		Drought stress	
Tep#5	Original	7.86	142.11
	C_1	8.27	172.93
L.S.D	0.05	0.357	13.587

Kernels quality

Results in Table 11 indicated that, drought stress causes a reduction in kernels crude protein and protein yield. The C_1 population (Tep#5-NI and Tep#5-DS) showed superiority in kernels quality traits over the original population (Tep#5) under normal and drought stress environments, respectively. These results are in agreement with those reported by Okporie *et al.* (2013).

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الملخص العربي

تحسين تحمل الجفاف في عشيرة بيضاء الحبوب من الذرة الشامية

شعبان أحمد الشمارقة[١]، إبراهيم حسيني درويش[١]، مروة محمد النحاس[١]، حمدي السيد جامع[٢]، أشرف عادل الحراني[١]

[١] قسم المحاصيل – كلية الزراعة – جامعة المنوفية

[٢] قسم بحوث الذرة الشامية – معهد بحوث المحاصيل الحقلية – مركز البحوث الزراعية

أجريت تجربة حقلية بالمزرعة البحثية بكلية الزراعة جامعة المنوفية بشبين الكوم بمصر في أربعة مواسم متتالية خلال الفترة من ٢٠١٥ – ٢٠١٨ أثناء الموسم الصيفي، حيث استخدمت عشيرة بيضاء من الذرة الشامية (Tep#5) كعشيرة أساس لهذه الدراسة وذلك لإجراء دورة واحدة من الانتخاب المتكرر لأنسال الجيل الأول من التلقيح الذاتي لتحمل ظروف الجفاف. وقد استهدفت الدراسة الحالية دراسة تأثير الاجهاد المائي على بعض صفات الذرة الشامية وتحديد أكثر الصفات المرتبطة بالإجهاد المائي مع المحصول لاستخدامها كمعيار انتخابي وكذلك تقدير كفاءة طريقة الانتخاب المتكرر لتحسين تحمل الإجهاد المائي في واحده من عشائر الذرة الشامية البيضاء. تم تكوين مجموعة تشتمل على ١٠٠ نسلا من أنسال الجيل الذاتي الأول المستمدة من عشيرة الذرة الشامية (Tep#5) في موسم ٢٠١٥، ثم قيمت هذه المجموعة من الأنسال تحت ظروف الاجهاد وعدم الاجهاد المائي في موسم ٢٠١٦ حيث تم انتخاب أفضل ١٠% من الأنسال في محصول الحبوب تحت كل بيئة من البيئتين. وفي موسم ٢٠١٧ تم عمل كل التهجينات الممكنة باليد بين أنسال كل مجموعة منتخبة على حده. وفي موسم ٢٠١٨. تم اجراء تقييم العشيرة المستنبطة Tep#5-NI مع العشيرة الأصلية (Tep#5) لـــ ١٩ صفة تحت ظروف الري العادي، وتم تقييم العشيرة المستنبطة Tep#5-DS مع العشيرة الأصلية تحت ظروف الاجهاد المائي، ونفذت كل تجربة على هيئة قطاعات كاملة العشوائية في أربعة مكررات.

أشارت النتائج إلى وجود تباعد وراثي كبير بين أنسال الجيل الذاتي الأول لمعظم الصفات المدروسة تحت كل من نظامي الري. كانت قيم معامل التوريث بمعناها العام أعلى بصفة عامة تحت ظروف الاجهاد المائي عنها تحت ظروف عدم الاجهاد. كما أوضحت النتائج أن الانتخاب لصفات عدد الحبوب/الصف، وزن الـــ ١٠٠ حبة وطول الكوز من المتوقع أن يكون أكثر فاعلية تحت ظروف الجفاف عنه تحت ظروف الري الكامل. أدت دورة واحدة من الانتخاب الدوري لأنسال الجيل الذاتي الأول لصفة محصول الحبوب تحت ظروف الاجهاد المائي كبيئة انتخابية إلى تحسين حقيقي معنوي في محصول الحبوب للعشيرة Tep#5-DS عندما قيمت تحت ظروف الاجهاد المائي حيث بلغت الزيادة ١٥,٤٧% عن العشيرة الأصلية Tep#5. كما أدت أيضاً دورة واحدة من الانتخاب الدوري لأنسال الجيل الذاتي الأول لصفة محصول الحبوب تحت ظروف الري الطبيعي كبيئة انتخابية إلى تحسين حقيقي معنوي في محصول الحبوب للعشيرة Tep#5-NI عندما قيمت تحت ظروف الري الكامل حيث بلغت الزيادة ١٢,٤٦% عن العشيرة الأصلية Tep#5. اوضحت النتائج أمكانية استخدام طريقة الانتخاب الدوري S_1 كأحد الوسائل البسيطة والفعالة في تحسين عشيرة الذرة الشامية تحت الدراسة. حيث يمكن استخدام مثل هذه العشائر المحسنة كمصادر مناسبة لعزل سلالات جديدة تدخل في انتاج الهجن المتحملة للجفاف.