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RESPONSE SELECTION FOR DROUGHT TOLERANC IN MAIZE

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ABSTRACT: The present study was carried out in 4 seasons during 4 years from 2017 to 2020 at the field of BeniSuef in. Res. Sta., Middle Egypt com. The main objectives were to develop new maize populations of increased tolerance to drought and evaluate predicted and actual gains from one cycle of S_1 recurrent selection. Two sets of 121 S_2's were developed from the local population Pop 277, the 1st set was evaluated under well water (WW) and intermediate water-stress (IWS) conditions. The highest yielding 18 lines (15%) were selected under each environment. Intercrossing of the two groups of 18 S_1's was done in separate blocks. The resulted of new 2 populations, Pop277-IWS and Pop277-WW) indicated wide genetic variation among S_1 progenies for most studied traits under all selection environments. Broad sense heritability estimates were generally higher under water-stress than under non-stress conditions. Results indicated that anthesis -silking interval, ears plant^{-1} and stay green traits could be valuable criteria in increasing the selection efficiency for drought tolerance. Actual superiority in grain yield over Pop277 due to one cycle of S_1 recurrent selection was (26.77%) by the improved populations (Pop277-IWS),

Key words: Maize, Recurrent selection, Drought tolerance, Selection, Target environment, Alternative criteria, Population improvement.

INTRODUCTION

Maize (*Zea mays* L.) is one of the most important cereal crops in Egypt. It is used in human food, animal feeding and industry. Current maize hybrids cultivated in Egypt are selected under well irrigation and therefore are subject to yield losses when grown under water deficit. Grain yield losses can even be greater if drought.

Occurs at the most drought-sensitive stages of crop growth, such as the flowering and grain filling periods (**Witt *et al.*, 2012).** Moreover, drought stress at silking, tasselling and grain filling stages has been reported to be more drastic on grain yield in maize than stress during vegetative phase **(Grant *et al.*, 1989)**. However, (**Olaoye *et al.*, 2009 and Videnovic *et al.*, 2013)** stated that the highest yield reduction 66% was recorded when plants were subjected to post anthesis moisture deficit compared to well-watered conditions,

It has been well established that the genetic improvement of maize for tolerance to drought could result in genetic gains (**Edmeades *et al.*, 1999 and Badu-Apraku *et al.*, 2021).** One important way to close the gap between potential and realized yield under DS is to adopt agronomic practices that effectively maximize water availability to the plant campos**.** Therefore, drought tolerant maize genotypes could be valuable germplasm resources in environments with the erratic occurrence of varying intensities of drought (**Akaogu *et al.*, 2017).** Drought-tolerant maize varieties offer the most economic and sustainable opportunity to stabilize maize yields (**Badu-Apraku *et al.*, 2017).**

Reduction of current water resources in Egypt will adversely affect maize production in

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the future. One of the most effective and practical strategies to reduce negative effects of drought to maize production is the development of hybrids with better tolerance to drought stress (**Rosielle and Hamblin 1981 ; Bänziger *et al.*, 2000 ; Richards *et al.*, 2010** and **Erdal *et al.*, 2015)**. reported that breeding for tolerance to drought stress is difficult because the genetic mechanism that controls the expression of such tolerance in crop plants is poorly understood and because of the polygenic nature of such a complicated character. The study of **Al-Naggar *et al.* (2016a)** mentioned that earlier anthesis and silking, shorter interval between anthesis and silking, less barren stalks and non-rolling of leaves were suitable characteristics for obtaining high maize grain yield either under water stressed at flowering, water stressed at grain filling or well watered environments.

Combining ability analysis is the most widely used biometrical tool for giving an indication of the relative magnitude of genetic variance. This also provides a guideline for selection of elite parents and desirable cross combinations to be used in formulation of a systematic breeding project for rapid improvement. In this respect, general and specific combining abilities had been estimated under drought stress conditions in maize by several in vestigators (**Aminu *et al.*, 2014; Al-Naggar *et al.*, 2016b; Saif-ul-Malook *et al.*, 2016; Ertiro *et al.*, 2017 and Murtadha *et al.*, 2018)**. Therefore, the present investigation was conducted to identify desirable parents and cross combinations as well as to gather information on the genetic behavior of grain yield and its contributing characters under water stress conditions.

MATERIALS AND METHODS

This study was carried out in 5 seasons during the years from 2017 to 2020 at Middle Egypt com. Res., Station.

Plant Material

Seeds of the yellow local cultivar of maize Pop-277 were used in this study as the base population for practicing one cycle of S_1 recurrent selection for drought tolerance.

The reason of using this population (Pop-277) as a source material of this study for improving drought tolerance *via* selection is because of its history in drought tolerance and its richness in genetic variability. So the genetic improvement *via* selection for drought tolerance in this population is expected to be achieved. The improved new populations expected to be derived after practicing one cycle of S_1 recurrent selection could be utilized directly as drought-tolerant open-pollinated cultivars or as sources for developing improved inbred lines to be used for producing drought tolerant single and three-way cross hybrids and synthetics.

Experimental Procedure

Developing the S_1's seed

In the 2017 season, seeds of the open-pollinated population Pop-277were sown under normal conditions in an isolated field at Middle Egypt com. One thousands of vigorous and disease-free plants were chosen before silking, and were self-pollinated. At harvest, 121selfed (S_1) ears were selected based on grain yield quantity and ear characteristics and were randomly divided into two groups (each group consisted of 121 S_1 progenies representing Pop-277); the first groupwas usedfor evaluation under water stress and well-water conditions. Each selected S_1 ear was separately shelled and preserved for evaluation in the next season.

S_1 Progeny evaluation and selection experiment

In 2018 season (5^{th} of June) 121 S_1 progenies of each group were separately grown at Middle Egypt com. in single row plots, 5 m length and 0.8 cm width *i.e.* the plot size was 4 m^2. For the 1^{st} group of S_1's, two irrigation regimes were used, *i.e.* well-watered (WW), and water-stress (IWS) at flowering stage by preventing the 4^{th} and 5^{th} irrigations. Irrigation interval between the 3^{rd} and the next (the 6^{th}) irrigation for the water-stress treatment was 39 days, and therefore water stress period was 26 days *i.e.* just before and during flowering stage.

Treatment A split-plot design in lattice arrangement (11 X 11) with two replicates was used for each group of S_1 lines. Main plots were devoted to irrigation regimes (for the 1^{st} group of S_1's)

At harvest, in all trials (well water and water stress), the best 15 % of the evaluated 121 S_1's (18 S_1's) were selected under each environment. Selection was mainly based on grain yield per plant under each or across environments. High number of ears per plant and short anthesis-silking interval (ASI) were taken into consideration as selection secondary criteria.Since, for the water regimes the best 18 lines selected under each environment, separately, so two groups of selected lines were obtained, *i.e.* the 1stgroup of the best 18 lines under well-water, the 2nd group of the best 18 lines under water-stress,

Selection and developing the S_2's seed

In the same season (2018) the other part of each S_1 seed of each group was sown in an isolated block at Middle Egypt com. and their plants were self-pollinated to develop the S_2 seed of each of the 121 progenies of each group Based on results of the S_1 evaluation experiments, the best 18 S_1's (15%) in grain yield plant^{-1} were determined under each selection environment (making two groups of selected S_1's; *i.e.* 18 S_1's under IWS and 18 S_1's selected under WW their S_2 versions were selected and their S_2 seeds were kept for making intercrossing (among each group of selections of S_2 lines) in the next season.

Intercrossing fields

During the 2019 season, four isolated fields were used to make intercrossing among the 18 selected S_1's of each of the two groups. For each isolated field, a mixture of seeds representing equal number of seed of each of the 18 selected S_1 lines was made and planted on the 1st of March 2019. Artificial intercrossing (sib-pollination) among all plants in each field was made. Ears harvested from each intercrossing field were shelled and their seed were blended together. Therefore we obtained two blends of seeds, the first represents the F_1 seeds resulted from intercrossing among 18 S_1 lines selected only under well-watered (or selected simultaneously under both water-stress and non-stress conditions), which hereafter was referred to as Pop277-WW, and the second represents the F_1 seed resulted from intercrossing among the 18 S_1 lines selected only under water-stress, which was referred to as Pop277-IWS.

Random-mating of experimental populations

In the late season of 2019 in August, seeds of each of the four experimental populations were planted in isolated blocks (30 rows each); pollen from different plants in 15 rows were collected and used for pollination of different plants from the other 15 rows, to achieve random mating among plants for one generation in each block in order to reach a considerable level of genetic equilibrium. Each block was harvested separately, ears were shelled and seeds from each block were blended thoroughly. Therefore, seeds of two new (improved) populations were obtained, *i.e.*Pop277- WW and pop277-IWS.

Population evaluation experiments

In the 2020 season, the two new experimental populations (Pop277- IWS and Pop277 -WW) along with the original (Pop277) population were evaluated in two separate experiments, the 1stexperiment was (well-water), and the 2nd experiment was under water-stress at flowering stage intermediate water stress (IWS), the 2nd one was water stress at both flowering and grain filling stages Irrigation regimes applications were the same like those previously mentioned and used in 2018 season when evaluating S_1 progenies, except the fourth experiment, where the irrigation was given only at 1st, 2nd and 3rd irrigations and thereafter prevented till harvest to insure severe water stress. The experimental design used for each of these four experiments was a randomized complete block design (RCBD) with 4 replications. The experimental plot consisted of 4 rows of 6 m long and 0.8 m width (*i.e.* the plot size was 19.2 m^2).

In all experiments in 2018, 2019 and 2020 seasons, sowing was done in hills spaced 25 cm along the row and plants were thinned to one plant per hill. All other recommended agricultural practices were followed.

The soil of the experimental site at fun seeds was clayey. Depth of the water Table of the experimental field at the end of the stress period was 105 and 125.5 cm for the well-watered trials and 130 and 135.4 cm for the water-stressed trials of S_1's and populations' evaluation in 2018 and 2020 seasons, respectively.

Biometrical analysis

Data on ASI, LR, LS and SG traits were normalized using the transformation formula (trait + 10)$^{-1/2}$ and those on traits measured as percentages were normalized using arcsines transformation For S_1 progeny trials. Analysis of variance of the split plot design was computed after carrying out Bartlet test according to **Snedecor and Cochran (1989)**. Moreover, each main plot in each progeny trial was analyzed as a lattice design for the propose determining genetic parameters separately under each environment, considering replicates as fixed effects, entries as random effects and incomplete blocks as random effects within replicates. Because the relative efficiency of the randomized complete block design (RCBD) was higher than that of the lattice design, expected mean squares under a separate environment were estimated from ANOVA Table of RCBD (Table 1) according to **Halluaer and Miranda (1988)**.

RESULTS AND DISCUSSION

Experiment II: Evaluation of S_1 Progenies for Drought Tolerance

Analysis of variance

Separate and combined analyses of variance for studied traits of S_1 progenies (derived from pop277 population) evaluated under well-water and water-stress just before and during flowering period at fun seeds in 2018 season are presented in Tables 1 and 2. Results of the combined analysis of variance showed that highly significant differences existed among the two irrigation regimes for all studied traits.

Combined analyses of variance across irrigations also exhibited highly significant differences among genotypes (121 S_1 progenies) for all studied traits. This result indicats that there are substantial variation among genotypes in genes controlling the traits under study.

Mean squares due to genotypes (S_1 progenies) X irrigations interaction were either significant or highly significant for all studied traits, except of rows ear^{-1}, ear height and leaf rolling. The significant genotype (progeny) X soil moisture interaction for the studied traits indicated the possibility of selection within (Pop 277) population for improved performance under a specific moisture environment.

characteristic of this experiment was the large increase in the coefficient of variation (C.V.) of the water-stressed as compared to non-stressed environment for grain yield per plant, ears per plant, rows per ear, kernels per row, kernels per plant and barren stalks, but was about the same for ASI, days to silking, 100-kernel weight and plant and ear height while the opposite was true for leaf rolling, leaf senescence and stay green traits. The small, single-row plots (chosen in part because of the restriction in seed number which would exist in a conventional testing program) may have contributed to this high variation. The problem of whether this interaction represented true genetic differences will be examined in the experimental-populations experiment (using a large plot size) and observing the effect of this large size on lowering the coefficient of variation from the non-stressed to water-stressed treatment. These results are consistent with, **Yu, *et al*.(2021)**

It helps to quantify the agronomic parameters like leaf area, yield, crop cover, biomass, etc., with evolving understanding about leaf reflectance, leaf emittance, leaf thickness, canopy shape, leaf age, nutrient status and, importantly, water status **(Dar *et al*., 2021 and Kumar *et al*., 2022**). utilized HTP technique to identify drought tolerant maize lines possessing favorable traits for drought stress tolerance. Under stress, the data revealed a robust link between canopy temperature and above-ground biomass.

In general, the magnitude of coefficient of variation was maximum (22.47, 37.59 and 26.88%) for kernels plant^{-1} followed by grain yield plant^{-1} (20.37, 37.7 and 25.31%) and minimum for days to silking (2.73, 3.96 and 3.42%) and plant height (5.8, 6.9 and 6.36%) at well-water, water-stress and combined data across stressed and unstressed environments, respectively.

Separate analysis of variance (Tables 1 and 2) revealed that significant or highly significant differences existed among genotypes (S_1 progenies) for all studied traits under both well-watered and water-stress conditions except for barrenness under well-water and rows ear^{-1}

Table 1. Separate and combined analyses of variance for yield and it's components of 121 S_1's (derived from Pop-277 grown under well-watered and inter-mediate water stress conditions at BeniSuef in 2018 season

S.O.V	d.f	GYPP	EPP	RPE	KPR	KPP	100KW
				Well-watered			
Replications	1	284.58	0.00010	4.59	197.16	23704.47	2.65
Genotypes	120	1118.63**	0.05**	1.55**	17.56*	27349.85**	10.05**
Error	120	505.00	0.02	0.79	11.94	14543.38	4.91
C.V.%		20.37	14.59	6.53	9.53	22.47	10.94
				Inter-mediate water-stressed			
Replications	1	1419.53	0.45	1.29	2.97	35222.64	16.20
Genotypes	120	458.08**	0.07**	1.93	33.66**	13913.82**	5.33*
Error	120	147.08	0.02	1.50	16.70	4421.29	3.53
C.V.%		37.47	29.65	9.57	14.45	37.59	10.37
				Combined across water regimes			
Irrigation	1	764074.8**	31.67**	116.38**	8774.65**	17299768.14**	535.09**
Reps/I	2	852.03	0.22	2.78	99.81	29254.62	9.39
Genotypes	120	866.08**	0.06**	2.34**	31.16**	23726.22**	9.58**
G X I	120	710.64**	0.06**	1.13	19.71*	17981.58**	5.80*
Error	240	325.99	0.02	1.14	14.20	9486.71	4.23
C.V.%		25.31	19.76	8.05	11.61	26.88	10.73

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

GYPP: Grain yield per plant, EPP: Ears per plant, RPE: Rows per ear, KPR: Kernels per row, KPP: Kernels per plant, 100 KW: 100 Kernel weight

Table 2. Separate and combined analyses of variance for some phenological and morphological of 121 S_1's (derived from Pop-277) grown under well-watered and inter-mediate water-stress conditions at BeniSuef in 2018 season component

S.O.V	d.f	Mean squares							
		DTS	ASI	PH	EH	BS	LR	LS	SG
					Well -watered				
Replications	1	27.66	0.01	184.62	426.34	607.92	0.15	0.040	0.01
Genotypes	120	7.29**	0.03*	521.33**	236.84**	120.97	0.11**	0.311**	0.10**
Error	120	2.77	0.020	142.55	97.02	114.65	0.05	0.070	0.04
C.V.%		2.73	12.58	5.89	9.21	13.03	17.68	9.730	10.33
					Inter-mediate water-stressed				
Replications	1	31.17	0.69	3916.80	1914.74	1594.06	0.04	0.190	0.02
Genotypes	120	23.06**	0.35**	377.70**	194.25**	278.05**	0.03*	0.056**	0.02**
Error	120	6.38	0.16	154.53	91.41	87.68	0.02	0.070	0.01
C.V.%		3.96	12.58	6.90	09.56	17.95	4.43	4.110	2.65
					Combined across water regimes				
Irrigation	1	977.36**	546.00**	64750.62**	5962.20**	136639.2**	366.48**	176.050**	44.30**
Reps/I	2	29.41	15.84	2050.50	1170.45	2042.04	0.54	5.600	0.43
Genotypes	120	17.54**	9.69**	625.26**	335.88**	391.43**	1.46**	7.840**	1.70**
G X I	120	12.82**	8.02**	273.76**	95.24	347.31**	0.88**	3.160	0.67**
Error	240	4.57	3.58	148.51	94.21	136.79	0.70	1.680	0.45
C.V.%		3.43	12.61	6.364	9.38	14.98	31.51	16.130	17.40

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

PH: Plant height, EH: Ear height, DTS: Days to silking, ASI: Anthesis silking interval, BS: Barren stalks, LS :Leaf senescence , LR :Leaf rolling, SG:Stay green under water stress environment, which showed insignificant differences among genotypes.

Performance of S_1 progenies

The mean grain yields of the 121 S1 progenies were 113.4 and 33.4g plant-1(ranging from 66.19 to 186.6 g and from 2.34 to 77.62 g plant^{-1}) under well-watered and water-stress environments, respectively (Table 3). A highly significant reduction of 70.7% in grain yield plant^{-1} of the 121 S_1 progenies due to water-stress was accompanied by a significant reduction in ears plant^{-1} (48.1%), rows ear^{-1} (7.8%), kernels row^{-1} (22.7%), kernels plant^{-1} (67.5%), 100-kernel weight (10.2%), plant height (11.4%), ear height (5.6%) and stay green (30.3%) (Table 3). As a yield component, maximum reduction due to water-stress was shown by kernels plant^{-1}, whileminimum reduction was observed for rows ear^{-1} trait. On the other hand, drought stress caused unfavorable increases in the means of the 121 S_1 progenies for barren stalks (182.17%).

Variance components and heritability

Changes in the magnitude of genetic (δ^2_g) and phenotypic (δ^2_p) variances, as well as the estimated corresponding broad-sense heritability (h^2_b) and expected genetic advance of studied traits for the 121 S_1 progenies (derived from the population 277) from well-watered to drought environments are presented in Table 5.

The changes in magnitude of δ^2_p and δ^2_g from well-watering to drought stressed environment were in the same direction and of similar magnitude for grain yield^{-1}, kernels plant^{-1}, 100-kernel weight, ASI, plant and ear height, leaf rolling and leaf senescencetraits, where the magnitude of δ^2_g and δ^2_p was considerably smaller under drought stressed than non-stressed environment. On the other hand, the magnitude of δ^2_g and δ^2_p was larger under drought stressed than well-watered environment for ears plant^{-1}, kernels row^{-1}, days to 50% silking, barrenness and stay green traits. Exceptions were rows ear^{-1} and leaf senescence traits, where, increases in δ^2_p and δ^2_g were accompanied by decrease in δ^2_g under water-stress conditions (Table 5). This indicates that selection for grain yield^{-1}, kernels plant^{-1}, 100-kernel weight, ASI, plant and ear height, leaf rolling and leaf senescence traits are predicted to be more efficient under well-watered than water-stressed environments, while using the drought stressed environment is expected to result in more efficient selection for the remaining traits as compared to using the well-watered environment, as proposed by **Al-Naggar *et al.* (2004) Okasha *et al*. (2014) and Badu-Apraku *et al.* (2023)**

Broad-sense heritability (h^2_b) estimates (Table 5) were generally of medium magnitude for all studied traits under separate environments (stressed and unstressed), except plant height and leaf senescence under well-water environment and days to silking, stay green, barren stalks, kernels plant^{-1} and grain yield plant^{-1} under water-stress conditions which were of high magnitude, while barren stalks trait exhibited very low heritability value under non-stress conditions.

The heritability for grain yield plant^{-1}showed a general tendency to increase with imposing drought stress (Table 5), from 55.94% under the well-water to 69.23% under water stress environments. Moreover, for all studied yield components, including ears plant^{-1}, kernels row^{-1} and kernels plant^{-1} the magnitude of h^2_b was larger under drought stress than non-stress conditions except for rows ear^{-1} and 100-kernel weight which exhibited decrease with imposing drought stress. Moreover, resultes indicate that the magnitude of heritability (h^2_b) for days to silking, ASI, barren stalks and stay green traits increased from well-water to water-stress. In contrast, the heritability for plant and ear height, leaf rolling and leaf senescence traits decreased with imposing moisture stress conditions. The reduction in h^2_b estimate of ear height was however very small (from 60.22% at non-stress to 53.99% at stress).

Under well-watering, the highest h2b estimates were for leaf senescence (79.33 %), plant height (74.13%) and days to silking (63.05 %), while the lowest estimates were shown by barren stalks (5.31%). Under water-stress, the highest h2b estimates were exhibited by stay green78.29%), days to silking (73.83%), barren

Table 3. Means and ranges for all studied traits of 121 S_1's and selected 18 S_1's (based on grain yield) derived from Pop-277 population evaluated under inter-mediate water-stress (IWS) and well-water (WW) conditions at BeniSuef in 2018 season

Trait	Treatment	Mean		Difference		Range				Drought effect (%)	
						121 S_1's		Best 18 S_1's			
		121 S_1's	Best 18 S_1's	Absolute	%of 121 S_1's	Lowest	highest	lowest	highest	121 S_1's	Best 18 S_1's
GYPP (g)	WW	113.628	149.022	35.394	31.722	66.198	186.66	128.214	186.66	-	-
	W S	33.354	52.734	19.380	58.650	2.346	77.622	40.902	77.622	- 70.7**	-64.6**
EPP	WW	1.122	1.224	0.102	12.546	0.714	1.5708	1.020	1.5708	-	-
	W S	0.612	0.714	0.204	29.682	0.102	1.0608	0.510	0.918	- 48.1**	-40.3**
RPE	WW	14.178	14.280	0.102	0.816	11.832	17.544	12.240	16.32	-	-
	W S	13.158	13.668	0.510	4.284	9.180	15.606	13.056	15.300	- 7.8*	- 4.1
KPR	WW	37.740	38.454	0.714	2.040	30.906	43.962	31.008	43.758	-	-
	W S	29.172	31.518	2.346	8.364	13.566	38.250	24.786	38.250	- 22.7**	-18.0**
100KW (g)	WW	20.808	21.420	0.612	3.060	14.790	26.622	19.380	26.622	-	-
	W S	18.666	19.380	0.714	3.774	14.076	22.746	16.728	22.746	- 10.2**	- 9.7*
KPP	WW	564.06	717.366	153.306	27.744	288.048	950.334	583.440	950.334	-	-
	W S	182.172	278.256	96.084	53.754	11.934	413.1	210.120	413.100	- 67.5**	- 61.2**
DTS	WW	62.730	62.628	-0.102	-0.204	58.650	70.890	63.240	66.810	-	-
	W S	65.280	63.648	-1.632	-2.448	59.670	73.440	60.690	66.810	4.1	1.8

** and** indicate to significance at 0.05 and 0.01 levels of probability, respectively.
GYPP: Grain yield per plant, EPP: Ears per plant, RPE: Rows per ear, KPR: Kernels per row, KPP: Kernels per plant, 100 KW: 100 Kernel weight , WW:Well - water ; WS: Water- steress

Table 4. Continued………

Trait	Treatment	Mean		Difference		Range				Drought effect (%)	
		121 S_1's	Best 18 S_1's	Absolute	%of 121 S_1's	121 S_1's		Best 18 S_1's			
						Lowest	highest	lowest	highest	121 S1's	Best 18 S1's
ASI	WW	2.958	0.0306	-2.856	-100.87	0	3.06	0	-1.02	-	-
	W S	3.264	2.958	-0.204	-7.038	0	18.36	2.754	3.366	11.01**	106.38*
PH (cm)	WW	208.896	218.688	9.792	4.794	163.200	248.88	183.6	243.78	-	-
	W S	184.620	187.272	2.652	1.428	146.370	214.2	159.12	204.000	11.62**	-14.68**
EH (cm)	WW	109.140	116.178	7.038	6.630	78.540	131.58	99.96	128.52	-	-
	W S	103.020	103.530	0.510	0.510	78.030	124.44	88.74	119.34	-5.71	-11.11**
BS (%)	WW	17.340	12.546	-4.794	-28.356	10.302	44.574	10.302	21.012	-	-
	W S	48.246	38.556	-9.690	-20.604	22.032	75.276	22.236	50.184	182.17**	212.16**
LR (1-5)	WW	1.326	1.224	-0.204	-0.132	1.020	1.938	1.02	1.428	-	-
	W S	3.570	3.366	-0.102	-0.020	1.530	5.100	3.264	3.672	171.560**	194.20**
LS (1-10)	WW	7.650	2.652	-0.102	-2.958	2.550	10.200	1.938	2.958	-	-
	W S	8.874	4.182	-0.031	-0.714	4.080	10.200	3.774	4.284	16.320*	55.08**
SG (1-5)	WW	1.428	1.836	0.510	32.334	2.040	5.100	3.060	3.672	-	-
	W S	0.816	1.530	0.714	-57.834	2.550	5.100	1.428	1.734	-30.80**	-8.2*

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

LS :Leaf senescence , LR:Leaf rolling, SG:Stag green , PH: Plant height , EH: Ear height
ASI: Anthesis silking interval, BS: Barren stalks

Table 5. Genetic (δ^2_g) and phenotypic (δ^2_p) variances, and heritability in the broad sense (h^2_b) for all studied traits of 121 S_1's (derived from Pop-277 evaluated under well-watered and inter-mediate water stress conditions at BeniSuef in 2018 season

Trait	δ^2_p		δ^2_g		h^2_b%	
	WW	WS	WW	WS	WW	WS
GYPP	559.320	228.990	306.816	155.448	55.947	69.238
EPP	0.030	0.035	0.0173	0.0214	61.924	62.995
RPE	0.760	0.964	0.3743	0.214	50.041	22.664
KPR	8.610	16.810	2.754	8.476	32.621	51.387
KPP	13895.46	6956.4	6619.8	4746.06	48.715	69.584
100KW	5.030	2.667	2.570	0.898	52.142	34.323
DTS	3.650	11.526	2.254	8.344	63.056	73.837
ASI	0.580	0.1785	0.194	0.099	33.997	57.120
PH	260.610	188.853	189.414	111.588	74.134	60.271
EH	118.430	97.104	69.921	51.408	60.221	53.998
BS	60.480	138.873	3.1518	95.197	5.3142	69.921
LR	0.060	0.017	0.028	0.006	52.887	35.995
LS	0.160	0.064	0.121	0.033	79.336	53.427
SG	0.020	0.155	0.011	0.121	46.747	79.856

Mainly due to high heritability for these traits observed under the respective environments (Tables 5 and 6). GYPP: Grain yield per plant, EPP: Ear per plant, RPE: Row per ear, KPR: Kernels per row, KPP: Kernels per plant, 100 KW: 100 Kernel weight , LS :Leaf senescence , LR :Leaf rolling, SG: Stag green , BS: Baren stalks

Table 6. Genetic advance from direct selection (*i.e.* selection environment same as target environment) and correlated genetic response (CR) for indirect selection (*i.e.* selection and target environments differ in irrigation regimes or selection in a secondary trait for the improvement of grain plant^{-1})

Selection environment	GYPP	EPP	KPP	ASI	LR	SG
Direct selection response (R)						
Well-water (WW)	15.23	12.73	12.96	1.46	1.81	2.61
Intermediate water-Stress (IWS)	43.09	28.25	43.72	8.39	1.40	2.07
Indirect selection response (CR)						
a. Selection environment vs target environment						
WW for use under IWS	3.99	-0.11	5.17	0.91	0.82	1.77
RE %	(26.76)	(-0.89)	(40.68)	(63.75)	(46.42)	(69.32)
WS for use under WW	0.63	-0.09	90.05	3.42	2.13	2.09
RE %	(1.49)	(-0.32)	(210.0)	(42.38)	(154.40)	(102.90)
b. Secondary traits vs grain yield/fad						
Non-stressed (WW)	-	7.55	11.96	-1.04	-0.81	0.85
RE %	-	(60.51)	(98.87)	(-72.24)	(-45.83)	(33.46)
Stressed (IWS)	-	26.77	42.52	-7.94	-0.81	-0.17
RE %	-	(96.85)	(99.19)	(-96.54)	(-59.12)	(-8.53)
WW for use under IWS	-	1.07	4.71	-0.55	-0.35	-0.24
RE %	-	(8.57)	(37.07)	(-38.25)	(20.05)	(-9.56)
WS for use under WW	-	1.53	7.88	-2.65	-0.42	-0.34
RE %	-	(5.52)	(18.39)	(-32.22)	(-31.03)	(-17.08)

Values in parentheses are the relative efficiencies (RE) = 100 (CR/R).
RE: Relative efficiency; WW: Well – water; IWS: Intermediate water-sterss

stalks (68.55%) and grain yield plant-1 (69.85%), (while the lowest ones were observed for rows ear^{-1} (22.66%). The fluctuation of heritability estimates from well- water to water stress indicates the influence of water treatments on expression of traits.

The expected genetic advance for six traits showing high heritabilities and strong genetic correlation with grain yield plant^{-1} were calculated for direct and indirect selection using 15% selection intensity (Table 6).

Direct Selection

Predicted genetic advance from direct selection in each environment reached its maximum value under drought selection environment for four traits (grain yield plant^{-1}, ears plant^{-1}, kernels plant^{-1} and ASI) and under high-N selection environment for two traits, *i.e*., leaf rolling and stay green

Indirect Selection

Selection environment *vs* target environment

Predicted genetic advance from indirect selection, which incorporates both the heritability and the genetic correlation between two different environments (well-water and water-stress) for the same trait, could be used to identify the best selection environment based on its relative efficiency (RE) in that environment (Table 6).

The expected genetic advance from direct selection in each environment was generally greater than the predicted from indirect selection at another environment, as indicated by the relative efficiency values <100% for most single environments (Table 6).

It is therefore concluded that in this study the predicted gain from direct selection especially for grain yield under a specific soil moisture environment would improve the trait under consideration in a better way than the indirect selection. The direct selection under water-stressed environment would take the advantage of high heritability.

Some exceptions are shown in the results of the present study in favor of the indirect selection. The indirect selection under water-stress for the use under well-water environment was more efficient than direct selection under water-stress for kernels plant^{-1} (RE = 210.0%), leaf rolling (RE = 154.4%) and stay green (RE = 102.9%). This may be attributed to the very low S_1 generation mean of ears plant^{-1} and stay green and to the high h^2_b estimates under drought selection as compared to well-water environment (Table 4).

The predicted results of the present study are in most traits assured that genotypes may be evaluated under the conditions in which they will ultimately be produced, namely a certain soil-moisture environment. The direct selection under water-stressed environment would ensure the preservation of alleles for drought tolerance. (**Ud-Din *et al*., 1992 and Shaboon 2004) .**

A Secondary Trait Vs Grain Yield

Responses of grain yield plant^{-1} to selection for secondary traits were calculated (Table 6) such that selection was for increased values of ears plant^{-1}, kernels plant^{-1} and stay green or a decrease in ASI and leaf rolling traits. Direct selection for grain yield was more efficient than the predicted genetic advance from indirect selection for all secondary traits in all cases of improving of grain yield. This conclusion is based on comparisons between predicted responses of improving grain yield indirectly *via* a single secondary trait and directly *via* grain yield itself by calculating the value of relative efficiency. These comparisons showed that direct selection for grain yield was significantly superior to indirect selection *via* any single secondary trait. Exceptions for the previous conclusion in this study indicated that indirect selection, *i.e.* response of grain yield to selection for secondary traits was approximately of equal efficiency to direct selection for grain yield itself for increase of ears plant^{-1} (RE=96.85%) and kernels plant^{-1} (RE =99.19%) and decrease of ASI (RE = -72.24) under well-water for use under water-stress environment and increase of kernels plant^{-1} (RE =98.87%) under non-stress conditions.

It is therefore concluded that secondary traits such as ears plant-1, kernels plant-1, ASI, leaf rolling and stay green are valuable criteria in increasing the efficiency of selection for grain yield under water-stress environment. These traits should be recommended to breeding programs for improving drought tolerance.

Selection for improved performance under drought based on grain yield alone has often been considered inefficient, but the use of secondary traits of adaptive value whose genetic variability increased increase selection efficiency. (**Bolanos and Edmeades 1996**). Physiologists and ideotype breeders have advocated the judicious incorporation of secondary traits within breeding programs (**Blum, 1988; Ludlow and Muchow 1990**). Results of the present study suggest that to maximize the genetic gain from selection, for improving grain yield, future research should focus on the incorporation of secondary traits such ears plant^{-1}, kernels plant^{-1}, ASI, leaf rolling, leaf senescence and stay green traits in the selection programs along with the grain yield trait.

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استجابة الذرة الشامية للإنتخاب لتحمل الجفاف

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أجريت هذه الدراسة فى المحطة البحثية مصر الوسطى بمحافظه بنى سويف على مدى أربعه مواسم زراعيه من عام 1917حتى عام 2020 حيث تم تكوين مجموعتين من أنسال الجيل الذاتى الأول المستمدة من العشيرة 277 وكل مجموعه تشمل 121 نسلا فى موسم 2017 ، ثم قيمت هاتين المجموعتين من الأنسال كل على حده تحت ظروف الإجهاد وعدم الإجهاد المائى فى موسم 2018 حيث تم إنتخاب أفضل 15% من الأنسال فى محصول الحبوب وفى نفس الموسم تم عمل تلقيح ذاتى لهذه الأنسال المنتخبة للحصول على أنسال الجيل الثانى. وفى الموسم المبكر لعام 2019 تم عمل كل التهجينات الممكنة بين أنسال كل مجموعه منتخبه فى حقول معزولة وفى الموسم المتأخر لنفس العام تم عمل تزاوج عشوائى بين نباتات كل عشيره جديده فى حقول معزولة للوصول لحاله الإتزان الوراثى. وفى موسم 2020 تم إجراء التقييم للعشائر الجديدة بالإضافة للعشيرة الأصلية 277 تحت ظروف الإجهاد وعدم الإجهاد المائى وذلك للصفات المحصولية والفسيولوجية. وأشارت النتائج إلى وجود تباعد وراثى كبير بين أنسال الجيل الذاتى والأول لمعظم الصفات المدروسة تحت كل البيئات الإنتخابية. وكانت قيم كفاءة التوريث بمعناها العام أعلى بصفة عامة تحت ظروف الإجهاد المائى عنها عن عدم الإجهاد المائى كما أوضحت الدراسة أن الإنتخاب لقصر الفترة بين نثر اللقاح وخروج الحريرة وطول فتره البقاء أخضر وعدد الكيزان بالنبات قد تكون معايير انتخابيه جيده لزياده كفاءه الانتخاب لتحمل ظروف الاجهاد المائى. وكان التفوق الحقيقى فى محصول الحبوب فى العشائر المستنبطة من العشيرة الأصلية 277 والراجع لتطبيق دوره واحده من الانتخاب الدورى لإنسال الجيل الذاتى الاول معنويا للعشيرة IWS- pop277 بقيمه (26.77%) تحت ظروف الاجهاد المائى.

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