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INTRA-POPULATION IMPROVEMENT OF MAIZE EARLINESS AND DROUGHT TOLERANCE

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ABSTRACT

A total of 400 S'_1s were extracted from the maize open-pollinated cultivar Giza-2 (Pop-0) in 2004 season, classified into 4 groups (each of 100 S'_1s) based on divergent selection for early (E) and late (L) silking and maturity. i.e. EE, EL, LE and LL and evaluated in 2005 season under well-watered (WW) and water-stressed (WS) environments. The highest yielding 16% of lines (16) were selected under WW and WS and 8 groups of 16 S'_1s were obtained (EEWW, EEWS, ELWW, ELWS, LEWW, LEWS, LLWW and LLWS). These 8 groups were separately (in isolation) intercrossed in 2006 early season and random mated in 2006 late season to achieve a genetic equilibrium. The resulted 8 populations (Pop-EEWW, Pop-EEWS, Pop-ELWW, Pop-ELWS, Pop-LEWW, Pop-LEWS, Pop-LLWW and Pop-LLWS) along with Pop-0 were evaluated in 2007 season under WW and WS conditions. The main objectives were to develop new population(s) of earlier maturity or silking and/or higher grain yield/fed (GYPF) than Giza-2 and to test the actual progress in earliness and GYPF under WW and WS. WS reduced means and ranges of the S'_1s for all studied traits, except for barren plants (BP) %, which was increased. Estimates of genetic variance, heritability in broad-sense and predicted genetic advance from selection were, generally higher in the 400 S'_1s than in each group of 100 S'_1s alone. This tendency was more pronounced in earliness and less pronounced in grain yield traits. Grain yield/plant, 100-kernel weight, kernels/row and barrenness showed valuable secondary traits in increasing the efficiency of selection for GYPF under WS. As a result of practicing one cycle of S_1 recurrent selection it was possible to develop new populations that achieved an actual progress in both earliness and high grain yield together which reached in Pop-LEWW to 3.2 and 3.0 days earlier in maturity than Giza-2 and 3.5 ard (22.6%) and 2.3 ard (19.5%) increase in GYPF and in Pop-LEWS to 4.9 and 5.0 days earliness in maturity and 2.0 ard (13.0%) and 1.9 ard (15.7%) increase in GYPF under WW and WS, respectively. In earliness of maturity only, progress reached in Pop-EEWW to 4.9 and 5.0 days and in Pop-EEWS to 5.9 and 6.1 days earlier in maturity than Pop-0 under WW and WS, respectively, but GYPF was reduced than Giza-2 by 7.7 and 14.9% under WW and 14.6 and 20.2% under WS for Pop-EEWW and Pop-EEWS, respectively.

Key words: ***Maize, Earliness, Maturity, Silking, Growing degree days, Drought tolerance, Divergent selection, S_1 recurrent selection, Population improvement***

INTRODUCTION

One of the drought tolerance breeding strategies in maize is developing early maturing varieties. Such varieties consume less amount of irrigation water, tolerate drought stress and contribute to multi-cropping systems in Egypt. They are also suitable for intercropping systems and under high-plant densities, since their plants are less competitors for moisture, light and nutrients than late maturing ones. A well adapted early-maturing hybrid can produce high yield as compared with late one under short season (Larson and Clegg 1999) and under water – stress conditions (Mugo *et al* 1998). Genetic variability in maize exists for vegetative phase duration (VPD), *i.e* time from planting to silk emergence (Giesbrecht 1960, Beil 1975, and Troyer and Larkins 1985) or filling period duration (FPD) *i.e* time from silk emergence to black layer maturity (Hallaur and Miranda 1988, Ottaviano and Camussi 1981, Soares *et al* 1981 and Corke and Kannenberg 1989).

To start a breeding program for developing early maturing and/or drought tolerant maize germplasm, the source population from which elite inbred lines are extracted should be improved. Population improvement in maize is practiced *via* a variety of methods; among them the S_1 recurrent selection is the most widely used for drought tolerance (Al Nagger *et al* 2004) and early maturity (Rinke and Sentz 1961, Troyer and Brown 1972 and 1976, Corke and Kannenberg 1989 and Troyer 1990). Previous studies reported that intra-population improvement based on S_1 progenies is effective in utilizing the additive genetic variance in a better way than other intra-population improvement methods and presents an opportunity for selection against major deleterious recessive genes that become homozygous with inbreeding (Genter 1971 and 1973, Hallauer and Miranda, 1988 and Tanner and Smith 1987).

Three methods of breeding for earliness were reported in the literature. The 1st called Rinke's method (Rinke and Sentz 1961) to develop earlier forms from elite, late inbred lines by backcrossing. Large one-or two-backcross populations (> 500 plants) grown at high plant density (2 X normal) with selection for early flowering among predominantly late genotypes develops earlier forms of the elite late inbreds. Results showed recovered inbreds flowering 5 to 10 days earlier than their recurrent parents. In hybrids, the recoveries averaged 13% more yield and 4% less stalk breakage than comparable-maturity recommended check hybrids (Rinke and Sentz 1961). Troyer and Brown's method (1972 and 1976) of selection (2nd method) for early flowering in a late synthetic was also used. They advocate crossing exotic late germplasm with elite Corn Belt material, sibbing within populations for several generations to increase recombination then practicing simple recurrent selection for early flowering within large populations ($\geq$1000 plants) at high plant density (2 X normal) until local adaptation is attained. This method was effective with an average reduction of 9.5 days to flower, 7.5% less grain moisture and an average yield increase of 11% after six cycles of selection. Troyer's (1978) source-sink scheme is the third method. It features selection both for early flowering, to increase grain filling period (sink), and for large plant size, to increase photosynthetic area (source). Resulting hybrids yielded well both in long and short seasons. As in the Rinke's method, early-and late–maturity inbreds are used as source materials and large populations (600-2000 plants) are grown at high plant densities (2 X normal) to select for early flowering. The source–sink method differs from the Rinke's method by including selection for more photosynthetic capacity (fast seedling and juvenile plant growth; tall, leafy mature plants; and stay green).

The objectives of this study were to develop new maize populations of early maturity and/or high yielding ability, study the genetic variability, heritability and expected genetic advance from selection in S_1 progenies extracted from the base population Giza-2 for earliness and grain yield, test the actual progress in the earliness and grain yield of the developed new populations and identify the corn secondary traits strongly associated with the grain yield and earliness under drought stress and non-stress conditions.

MATERIALS AND METHODS

The field experiments of this study were carried out in five seasons during the years 2004 through 2007 at Sids, Bany Sweif Governorate, Egypt.

Genetic material

Seeds of the white local dent corn (*Zea mays* L.) population Giza-2 were used in this study. This population is an adapted composite open pollinated cultivar in the eighth cycle of improvement (C8). This population was used in this study as a source population to practice one cycle of S_1 recurrent selection for earliness and drought tolerance. The reason of using this population is due to its wide genetic variability for such traits.

Developing the S_1 lines

In the late 2004 season, seeds of the population Giza-2 were sown under well-watered conditions in a relatively high plant density (30,000 plants/fed) in an isolated field at Sids, Bany Sweif. Based on source and sink method of selection for earliness developed by Troyer (1978), more than four thousands of vigorous and disease-free plants were used for recording data on earliness (at flowering and maturity stages) and were selfpollinated. These plants were subjected in the field to divergent selection for flowering (silking) into early (E) and late (L) and for maturity into early (E) and late (L) and therefore four groups were obtained, *i.e.*, EE, EL, LE and LL. The best 100 selfed ears from each group were chosen based on ear characteristics. Thus, four groups were made; each group consisted of 100 selfed ears as follows: Group I: It consisted of early silking - early maturing 100 EE S_1's, Group II: It consisted of early silking - late maturing 100 EL S_1's, Group III: It consisted of late silking - early maturing 100 LE S_1's and Group IV: It consisted of late silking - late maturing 100 LL S_1's. Each ear in the 4 selected groups was separately shelled and its respective seeds were preserved for progeny evaluation in the next season.

Progeny evaluation of S_1's

In the normal summer 2005 season, 100 S_1 progenies of each group were separately grown (May 11th) in single-row plots, 5 m length and 0.7 m width under two water stress environments; *i.e.* well watered (WW) under full irrigation and water stress (WS) at flowering where irrigation was prevented for the 4th and 5th irrigations. A split plot design in lattice arrangement (10 X 10) with two replications was used for each group of S_1 lines, *i.e.* four groups of S_1's (100 EE S_1's, 100 EL S_1's, 100 LE S_1's and 100 LL S_1's) were therefore included. All cultural practices were applied as recommended by ARC. Sixteen S_1 progenies in each group were selected in each trail. Selection of the families was based on high grain yield. Therefore, four groups of selected 16 S_1's (16 EE S_1's, 16 EL S_1's, 16 LE S_1's and 16 LL S_1's) were obtained under well-watering and four under water-stress, making a total of 8 groups of the best 16 S_1's (i.e.; 16 EEWW S_1's, 16 EEWS S_1's, 16 ELWW S_1's, 16 ELWS S_1's, 16 LEWW S_1's, 16 LEWS S_1's, 16 LLWW S_1's, and 16 LLWS S_1's).

Intercrossing of the selected S_1's

In the early summer season of 2006 (April, 1st), the best selected progenies in each of the 8 groups were crossed separately in all possible combinations at Sids. Eight separate (isolated) blocks were used to make intercrossing among the 16 selected progenies of each of the 8 groups. A blend of equal number of seeds of each of the 16 selected S_1's was planted in a separate (isolated) intercrossing block. Artificial intercrossing (sib-pollination) among all plants in each block was used. Ears harvested from each intercrossing block were shelled and their seed were blended separately. Therefore, eight sub-populations were obtained as follows: sub-population I (EEWW): representing an improved experimental population of early silking and early maturing under well-water conditions, sub-population II (EEWS): representing an improved experimental population of early silking and early maturing under water-stress conditions, sub-population III (ELWW): representing an improved experimental population of early silking and late maturing under well-water conditions, sub-population IV (ELWS): representing an improved experimental population of early silking and late maturing under water-stress conditions, sub-population V (LEWW): representing an improved experimental population of late silking and early maturing under well-water conditions, sub-population VI (LEWS): representing an improved experimental population of late silking and early maturing under water-stress conditions, sub-population VII (LLWW): representing an improved experimental population of late silking and late maturing under well-water conditions and sub-population VIII (LLWS): representing an improved experimental population of late silking and late maturing under water-stress conditions.

Random-mating of experimental sub-populations

In the late season of 2006 (August, 14th), seeds of each of the eight sub-populations were planted in a separate (isolated) block (20 rows each), pollen from different plants in 10 rows were collected and used for pollination of different plants from the other 10 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 eight new (improved) sub populations were obtained i.e.; Pop-EEWW, Pop-EEWS, Pop-ELWW, Pop-ELWS, Pop-LEWW, Pop-LEWS Pop-LLWW, and Pop-LLWS.

Evaluation trails

In the summer season 2007, the eight new sub populations as well as the original population Giza-2 (Pop-0), were planted on the 10th of May under two irrigation regimes. A split-plot design in randomized complete blocks arrangements was used with 4 replications. The two irrigation regimes (previously described) were devoted to the main plots and the nine populations were arranged in the sub-plots. The experimental plot consisted of 4 rows of 5 m long and 0.7 m wide, *i.e.* the plot area was 14 m^2. Sowing was done in hills spaced 25 cm along the row and plants were thinned to one plant per hill before the first irrigation. All other recommended cultural practices were followed. The soil of the experimental site at Sids was clayey.

Data recorded

The following data were recorded: (1) days to 50% silking (DTS) per plot, (2) days to 50% physiological maturity (DTM) per plot (3) growing degree days (GDD) per plot; calculated according to Muchow (1990) as follows: daily GDD = $((T_{max} + T_{min})/2) - T_{base,}$ where: T_{max} = the daily maximum air temperature, T_{min} = the daily minimum air temperature and T_{base} = the GDD base temperature; for corn (10 °C.), (4) grain moisture content (GMC) in % at harvest, (5) grain filling period (GFP) in days, (6) grain filling rate (GFR) in g/d, (7) plant height (PH), (8) barren plants (BP) in %, (9) number of kernels/row (KPR), (10) 100-kernel weight in g (100KW), (11) grain yield/plant (GYPP) in g and (12) grain yield in ardabs per feddan (GYPF), by converting the grain yield per plot in Kg (adjusted at 15.5% grain moisture) to ardabs (ard) per feddan (one ardab = 140 kg and one feddan = 4200 m^2).

Biometrical analysis

Separate and combined analysis of variance of the split-plot design was computed after carrying out Bartlet test according to Snedecor and Cochran (1989). Each main plot in each experiment was analyzed as a lattice design for the purpose of determining genetic parameters separately under each irrigation regime. Because the relative efficiency of lattice design was similar to that of the randomized complete block design (RCBD), expected mean squares, genotypic (δ^2_g), phenotypic (δ^2_p) and environmental (δ^2_p) variances under a separate environment were estimated from ANOVA table according to Hallauer and Miranda (1988). Heritability (%) in the broad sense (h^2_b) under a separate environment was estimated by using the following formula: h^2_b (%) = $100\ \delta^2_g / (\delta^2_g + \delta^2_e / r)$. The genotypic ($^r g_{xy}$) correlation coefficients were calculated between each pair of studied traits under each of the well-watered and water-stressed environments using the following formulae: $^r g_{xy} = \delta^2_{gxy} / (\delta^2_{gx} . \delta^2_{gy})^{½}$ where: δ^2_{gxy} = the genotypic covariance of the two traits, X and Y and δ^2_{gx} and δ^2_{gy} = the genotypic variance of the two traits X and Y, respectively.

Expected genetic advance from direct selection for all studied traits under each environment (stress or non-stress) was calculated according to Singh and Chaudhary (1999) as follows: GA = $100\ i\ h^2 \delta_p / X$; Where: X of the administrator of the appropriate heritability under moisture regime. h^2 = the applied heritability, i = selection differential (i =1.54 and 2.17 for 4 and 16% selection intensity, respectively used in this study). The selection intensity 4% was used here in selection for flowering and maturity and 16% in selection for grain yield/feddan. Indirect correlated response (CR) in yield (Y) from selection in a secondary trait (X) was estimated according to Falconer (1989) as follows: $CR_j = 100\ i\ H^{1/2}_x H^{1/2}_y r_{gxy}\ \delta_p / X_y$; where: $H^{1/2}_x$ and $H^{1/2}_y$ = square roots of heritability of traits X and Y respectively, CR_j = correlated response in yield trait (Y), r_{gxy} = genetic correlations among traits X and Y and X_y = general mean of yield trait (Y).

RESULTS AND DISCUSSION

Results of the combined analysis of variance (data not presented) showed that significant or highly significant differences existed among the two irrigation regimes for all studied traits except for DTS and highly significant differences among the 400 S_1 progenies for all studied traits. Genotypic differences were reported by other investigators for earliness, grain filling period and rate and grain yield and its components (Troyer and Brown 1972, Fonturbel and Ordas 1981, Moreno-Gonzalez 1986, Ordas *et al* 1996, Edmeades *et al* 1999, Niaz *et al* 2000, Perez-Colmenarez *et al* 2002, Badu-Apraku *et al* 2004, Gomes-e-Gama *et al* 2004, Shaboon 2004, Badu-Apraku *et al* 2005 and Campos *et al* 2006). Mean squares due to genotypes (400 S_1 progenies) X irrigation regimes interaction were highly significant for all studied traits, indicating the possibility of selection within Giza–2 population for earliness and lateness as well as for high grain yield under a specific moisture environment, as proposed by Fischer *et al* (1989). Separate analysis of variance (data not presented) of 400 S_1 progenies under each irrigation regime, also indicated that the 400 S_1's differed significantly ($P \leq 0.01$) for all studied traits.

Combined analysis of variance of each group of 100 S_1's, *i.e.* 100EE S_1's, 100EL S_1's, 100LE S_1's and 100 LL S_1's (date not presented), revealed that the two irrigation regimes differed significantly for all studied traits, except DTS for the 100EE S_1's, DTS, BP, 100KW, GYPP and GYPF for the 100 EL S_1's, DTM, GMC, GFP, BP, and GYPF for the 100 LE S_1's and GMC for the 100LL S_1's. Mean squares due to genotypes for each group of 100 S_1's under each environment and combined across environments were significant or highly significant for all studied traits, except for GFP under water stress in the four groups of 100 S_1's, which were not significant. Mean squares due to genotypes X irrigation regimes interaction for each group of 100 S_1's (data not presented) were significant or highly significant for all studied traits, except for DTS and DTM in the 100 EL S_1's, DTS in the 100 LE S_1's and DTS, DTM and GFP in the 100 LL S_1's group.

Performance of S_1 progenies

In general, water stress caused earliness in silking and maturity, increase in barren plants and decrease in grain yield of all studied groups of S_1's, *i.e.,* 400 S_1's,100 EE S_1's, 100 EL S_1's, 100 LE S_1's and LL S_1's (Table 1). Water stress effect was more pronounced in earliness traits of the LL S_1's. It is worthy to note that water stress effect on the mean grain yield was more pronounced in the group of LL S_1's and was less pronounced in

Table 1. Summary of means for studied traits of the 400 S_1's, 100 EE S'_1s, 100 EL S'_1s, 100 LE S'_1s and 100 LL S'_1s evaluated under water stress (WS) and non stress (WW) conditions.

Genotype	Parameter	DTS (day)		DTM (day)		GMC (%)		GFP (day)		PH (cm)	
		WW	WS	WW	WS	WW	WS	WW	WS	WW	WS
400 S_1's	Mean	62.7	61.1	118.8	110.9	25.0	22.0	56.1	49.9	206.2	193.1
	WSE%		-2.6		-6.6		-12.09*		-11.1*		-6.34*
100 EE S_1's	Mean	54.8	54.4	107.6	103.0	17.5	15.1	52.8	48.7	188.0	171.3
	Abs Diff.	-7.9	-6.7	-11.2	-7.9	-7.5	-6.8	-3.3	-1.2	-18.2	-21.8
	Rel (%) Diff.	-12.6	-10.9	-9.5	-7.1	-30.0	-31.1	-5.9	-2.4	-8.8	-11.3
	WSE%		-0.8		-4.2*		-13.5*		-7.8*		-8.8*
100 EL S_1's	Mean	55.4	54.5	114.3	107.9	31.1	27.6	58.9	53.4	193.7	178.6
	Abs Diff.	-7.4**	-6.5**	-4.6*	-3.0	6.1**	5.6**	2.8	3.5	-12.5	-14.5
	Rel (%) Diff.	-11.7	-10.7	-3.8	-2.7	24.5	25.5	5.0	7.0	-6.1	-7.5
	WSE%		-1.5*		-5.6		-11.4		-9.4		-7.8**
100 LE S_1's	Mean	70.5	67.9	121.5	110.7	17.9	14.5	51.0	42.8	213.0	205.2
	Abs Diff.	7.8**	6.8**	2.7	-0.2	-7.1**	-7.5**	-5.1	-7.0	6.8	12.1
	Rel (%) Diff.	12.4	11.2	2.2	-0.2	-28.6	-33.9	-9.1	-14.1	3.3	6.3
	WSE%		-3.7*		-8.9*		-18.7		-15.9*		-3.6*
100 LL S_1's	Mean	70.2	67.5	132.0	122.1	33.5	30.7	61.7	54.6	230.1	217.2
	Abs Diff.	7.5**	6.4**	13.2**	11.1**	8.5**	8.7**	5.7	4.7	23.9	24.1
	Rel (%) Diff.	12.0	10.5	11.1	10.0	34.1	39.6	10.1	9.5	11.6	12.5
	WSE%		-3.9*		-7.5**		-8.5		-11.6*		-5.6*
LSD $_{0.05}$		2.0	2.2	3.5	4.8	2.4	2.2	2.4	4.2	16.0	14.2
		BP (%)		KPR		100KW (g)		GYPP (g)		GYPF (ard)	
400 S_1's	Mean	0.8	20.6	34.2	26.8	18.9	15.8	82.7	53.2	11.2	6.7
	WSE%		2330.3*		-21.6*		-16.5*		-35.7**		-40.6*
100 EE S_1's	Mean	1.2	25.1	31.6	26.6	18.2	14.4	72.6	47.0	9.7	5.2
	Abs Diff.	0.4	4.5	-2.6	-0.2	-0.7	-1.4	-10.0	-6.2	-1.5	-1.5
	Rel (%) Diff.	43.3	21.6	-7.6	-0.9	-3.7	-8.7	-12.2	-11.6	-13.2	-21.9
	WSE%		1963.6		-15.9*		-20.9		-35.3		-46.5
100 EL S_1's	Mean	0.7	18.0	33.5	27.7	19.4	17.0	84.1	57.5	11.1	7.0
	Abs Diff.	-0.2	-2.6	-0.7	0.9	0.4	1.2	1.4	4.3	-0.1	0.4
	Rel (%) Diff.	-19.1	-12.7	-2.0	3.4	2.3	7.7	1.7	8.1	-0.6	5.6
	WSE%		2523.6		-17.3*		-12.1**		-31.7*		-36.9
100 LE S_1's	Mean	0.8	21.0	34.0	24.4	18.3	14.6	76.4	50.0	10.9	6.0
	Abs Diff.	0.0	0.4	-0.3	-2.5	-0.6	-1.2	-6.2	-3.2	-0.3	-0.7
	Rel (%) Diff.	-2.3	2.0	-0.7	-9.1	-3.0	-7.4	-7.5	-6.0	-2.3	-10.0
	WSE%		2436.5*		-28.3*		-20.3**		-34.6*		-45.2*
100 LL S_1's	Mean	0.7	18.4	37.8	28.6	19.8	17.1	97.5	58.2	13.0	8.4
	Abs Diff.	-0.2	-2.3	3.6	1.8	0.8	1.3	14.8	5.0	1.8	1.7
	Rel (%) Diff.	-21.9	-10.9	10.4	6.6	4.4	8.4	17.9	9.5	16.2	26.3
	WSE%		2670.0		-24.3**		-13.4*		-40.3*		-35.4
LSD $_{0.05}$		1.0	17.8	5.8	5.2	2.3	2.1	17.9	13.5	2.9	2.6

Abs Diff. = Mean of 100 S_1's - Mean of 400 S_1's and Rel (%) = Abs diff. / Mean of 400 S1's X 100, WSE% (Water stress effect) = 100 (WS-WW)/WW.

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

the group of 100 EL S_1's, suggesting that the 1st group could be considered as the most susceptible while the 2nd group as the most tolerant to drought stress. It is worthy to note that in general, the 100 EE S_1's were significantly earlier in flowering and maturity traits, but were significantly inferior than the 400 S_1's in grain yield. On the contrary, the 100 LL S_1's were significantly later in flowering and maturity and superior in grain yield as compared with the 400 S_1's. The 100 EL S_1's were significantly earlier in flowering, later in maturity and equal in grain yield as compared with the 400 S_1's. It is interesting to mention that the group of 100 LE S_1's was significantly later in flowering, but earlier in maturity and comparable in grain yield to the 400 S_1's, *i.e.* showed 7 days (in average) earlier in maturity than the 400 S_1's and kept the yield potentiality of the original population. The difference between the highest and lowest estimate (data not presented) of the 400 S_1's was generally greater than that of each group of 100 S_1's. This was more pronounced in earliness and less pronounced in grain yield traits under both stress and non stress conditions, probably due to practicing selection for earliness traits on the S_0 level and to the smaller sample size in the 100 S_1's than in the 400 S_1's for grain yield traits.

Mean grain yield/fed of the best 16 EE S_1's was significantly higher by 29.4 and 34.3% than that of the corresponding group of 100 EE S_1's and was insignificantly higher by 12.3 and 4.9% than that of the 400 S_1's (representing the whole Giza-2 population) under non-stress and water-stress, respectively (Table 2). Superiority in mean grain yield/fed of the 16 EE S_1's over the 100 EE S_1's was associated with superiority in grain yield/plant (23.0 and 19.8%), KPR (9.7 and 4.0%) and 100KW (6.9 and 10.4%) under non-stress and water-stress, respectively. On the other hand, the best 16 EE S_1's in grain yield were characterized by lower means of barrenness by 97.4 and 61.2% than the 100 EE S_1's and 0.8 and 10.9% than the 400 S_1's under non-stress and drought stress, respectively. The best 16 EE S_1's in grain yield were significantly earlier than the 400 S_1's for DTS (by 12.1 and 10.5%), DTM (by 9.2 and 6.3%) and GMC (by 30.9 and 31.7%) under well-watered and water stressed environments, respectively. The superiority of the 16 EE S_1's over the 400 S_1's was higher under well-watered for GYPF, GYPP, BP, DTS and DTM, while it was higher under stressed environment for GMC trait.

For the best 16 EL S_1's mean grain yield/fed was significantly higher by 30.5 and 27.8% than that of the corresponding group of 100 EL S_1's and by 29.8 and 34.9% than that of the 400 S_1's under well-watered and water stress environments, respectively(Table 2). Superiority in mean grain yield/fed of the 16 EL S_1's over the 100 EL S_1's was associated with superiority in grain yield / plant (22.9 and 13.9%), 100KW (8.1 and 3.0%)

Table 2. Means for studied traits of selected 16 S_1's of each group of 100 S_1's evaluated under well-watered (WW) and water-stress (WS) conditions in 2005 season and absolute (Abs) and relative (Rel) differences between them and means of the 400 S'_1s.

Trait	Treatment	16 EE S_1's Mean	Rel (%) of 400 S_1's	Rel (%) of 100 S_1's	16 EL S_1's Mean	Rel (%) of 400 S_1's	Rel (%) of 100 S_1's
DTS	WW	55.2	-12.1**	0.6	55.5	-11.6**	0.2
	WS	54.6	-10.5**	0.5	54.4	-10.9**	-0.2
DTM	WW	107.9	-9.2**	0.3	114.4	-3.7*	0.2
	WS	103.9	-6.3**	0.9	107.6	-3.0	-0.3
GMC	WW	17.3	-30.9**	-1.2	31.9	27.5**	2.4
	WS	15.0	-31.7**	-0.8	28.2	28.2**	2.2
PH	WW	188.2	-8.7*	0.1	196.7	-4.6	1.5
	WS	172.3	-10.8**	0.6	181.3	-6.1	1.5
BP	WW	0.0	-96.3	-97.4	0.0	-100.0	-100.0
	WS	9.7	-52.8	-61.2	4.7	-77.0	-73.6
KPR	WW	33.8	-1.3	6.9	37.6	9.7	12.0
	WS	29.4	9.4	10.4	29.1	8.4	4.8
100KW	WW	20.0	5.7	9.7	20.9	10.6	8.1
	WS	15.0	-5.1	4.0	17.5	11.0	3.0
GYPP	WW	89.3	8.0	23.0*	103.3	25.0*	22.9
	WS	56.3	5.9	19.8	65.4	23.1	13.9
GYPF	WW	12.6	12.3	29.4*	14.5	29.8*	30.5*
	WS	7.0	4.9	34.3	9.0	34.9	27.8
			16 LE S_1's			16 LL S_1's	
DTS	WW	70.8	12.9**	0.5	70.4	12.2**	0.2
	WS	69.0	13.1**	1.7	67.7	10.9**	0.4
DTM	WW	122.0	2.6	0.4	132.3	11.4**	0.3
	WS	111.5	0.5	0.7	122.8	10.7**	0.6
GMC	WW	18.2	-27.3**	1.8	33.2	32.9**	-0.9
	WS	14.6	-33.3**	0.9	30.9	40.8**	0.9
PH	WW	213.4	3.5	0.2	232.4	12.7**	1.0
	WS	208.1	7.8*	1.4	218.6	13.2**	0.6
BP	WW	0.0	-96.3	-96.2	0.2	-80.1	-74.6
	WS	11.9	-42.5	-43.6	11.2	-46.0	-39.3
KPR	WW	36.6	6.9	7.7	40.4	18.1*	7.0
	WS	27.3	1.7	11.9	31.7	18.3	10.9
100KW	WW	20.5	8.4	11.8*	20.4	7.9	3.4
	WS	15.2	-3.8	3.8	18.0	13.9*	5.1
GYPP	WW	92.5	11.9	20.9	115.0	39.2**	18.0*
	WS	60.1	13.0	20.2	74.1	39.3**	27.3**
GYPF	WW	14.3	28.0*	31.1	16.4	46.2**	25.8*
	WS	7.8	16.5	29.4	11.2	67.8**	32.9**

Abs Diff. = Mean of 16 S_1's - Mean of 100 S_1's or 400 S_1's , Rel (%) Diff. = Abs/ Mean of 100 S_1's or 400 S_1's X 100, WSE% (Water stress effect) = 100 (WS-WW)/WW, * and ** indicate significance at 0.05 and 0.01 levels of probability, respectively.

and KPR (12.0 and 4.8%) under well-watering and water-stress, respectively. On the contrary, the best 16 EL S_1's in grain yield showed lower means of barrenness than the 100 EL S_1's by 100.0 and 73.6% and than the 400 S_1's by 100.0 and 77.0% under non-stress and water-stress, respectively. The best 16 EL S_1's in grain yield were significantly earlier. than the 400 S_1's for DTS (11.6 and 10.9) and DTM (3.7 and 3.0%) and higher in GMC (27.5 and 28.2%) under non-stress and water-stress, respectively. The superiority of the 16 EL S_1's over the 100 EL S_1's was higher under non-stress than under stress for GYPP and KPR while it was higher under water stress than non-stress for BP, GYPF, 100KW, and GMC.

Regarding the best 16 LE S_1's mean grain yield/fed was significantly higher than that of the corresponding 100 LE S_1's by 31.1 and 29.4% and than that of the 400 S_1's by 28.0 and 16.5% under well-watering and water stress conditions, respectively (Table 2).. Superiority in mean grain yield/fed of the 16 LE S_1's over the 100 LE S_1's was associated with superiority in grain yield/plant (20.9 and 20.2%), 100KW (11.8 and 3.8%) and KPR (7.7 and 11.9%) under well-watering and drought stress, respectively. On the contrary, the best 16 LE S_1's in grain yield exhibited lower means of barrenness than the 100 EL S_1's by 96.2 and 43.6% and than the 400 S_1's for barren plants by 96.3 and 42.5%, under well-watered and water-stressed environments, respectively. The superiority of the 16 LE S_1's over the 100 LE S_1's was higher under non-stress than under water-stress for GYPF, GYPP and 100KW, and was higher under water-stress than non-stress for KPR.

Mean grain yield/fed of the best 16 LL S_1's was significantly higher than that of the corresponding 100 LL S_1's by 25.8 and 32.9% and than that of the 400 S_1's by 46.2 and 67.8% under non-stress and water-stress, respectively (Table 2). Superiority in mean grain yield/fed of the 16 LL S_1's over the 100 LL S_1's was associated with superiority in grain yield/plant (18.0 and 27.3%), 100KW (3.4 and 5.1%) and KPR (7.0 and 10.9%) under well-watering and water-stress, respectively. On the contrary, the best 16 LL S_1's in grain yield exhibited lower means of barrenness than the 100 LL S_1's by 74.6 and 39.3% and than the 400 S_1's by 80.1 and 46.0% under non-stress and water-stress, respectively. The best 16 LL S_1's in grain yield were significantly later than the 400 S_1's for DTS (12.2 and 10.9), DTM (11.4 and 10.7%) and GMC (32.9 and 40.8%) *i.e.* in all flowering and maturity traits under well-watering and water-stressed environments, respectively. The superiority of the 16 LL S_1's over the 100 LL S_1's was higher under water-stress than under non-stress for GYPF, GYPP, 100KW, and KPR.

Correlations

Genotypic correlation coefficients between GYPF, DTS and DTM and other studied traits (Table 3), in the 400 S_1's indicated a strong positive genetic correlation (r_g) between grain yield/fed and grain yield/plant (r_g = 0.94 and 0.88) and above average positive r_g values between grain yield/fed and each of 100KW (0.72 and 0.67) and number of kernels/row (0.79 and 0.69) under well-watered and water-stressed environments, respectively.

Table 3. Genetic correlation coefficients (r_g) between GYPF, DTS or DTM and each of other studied traits of the 400 S_1's and between GYPF and each of other traits of the 100 EE, 100 EL, 100 LE and 100 LL S_1's under well-watered (WW) and water-stress (WS) conditions in 2005 season.

S_1 group	Trait	Environment	GYPP	100KW	KPR	BP	PH	GFP	GMC	DTM	DTS
400 S_1's	GYPF	WW	0.94	0.72	0.79	-0.20	0.38	0.37	0.36	0.46	0.33
		WS	0.88	0.67	0.69	-0.75	0.40	0.47	0.52	0.58	0.29
	DTS	WW	0.24	0.09	0.38	-0.29	0.86	0.10	0.09	0.98	
		WS	0.09	0.05	-0.08	-0.32	0.90	-0.28	0.07	0.89	
	DTM	WW	0.43	0.24	0.49	-0.48	0.90	0.67	0.60		
		WS	0.29	0.47	0.18	-0.73	0.82	0.54	0.72		
100 EE S_1's	GYPF	WW	0.98	0.79	0.64	-0.47	-0.13	-0.06	0.01	0.03	0.07
		WS	0.84	0.64	0.76	-0.80	0.00	-0.03	0.08	-0.02	0.01
100 EL S_1's	GYPF	WW	0.86	0.67	0.67	-0.44	0.14	0.06	0.15	0.05	0.04
		WS	0.80	0.47	0.60	-0.88	0.11	0.16	0.05	0.14	0.05
100 LE S_1's	GYPF	WW	0.93	0.80	0.84	-0.14	-0.03	-0.04	0.17	-0.03	-0.01
		WS	0.96	0.71	0.79	-0.66	-0.01	-0.06	0.15	0.04	0.12
100 LL S_1's	GYPF	WW	0.90	0.61	0.68	-0.60	0.03	-0.02	0.03	-0.08	-0.09
		WS	0.86	0.54	0.69	-0.81	0.12	0.22	0.12	0.13	-0.08

N = 800 for 400 S_1's and = 200 for each 100 S_1's group.

It is worth noting that grain yield per feddan exhibited a negative genetic correlation with percentage of barren plants under water-stress conditions (r_g= -0.75). Number of days to silking exhibited high positive genetic correlation coefficients with DTM (0.98 and 0.89) and PH (0.86 and 0.90) under well-watered and water-stressed environments, respectively. Number of days to maturity in the 400 S_1's showed positive genetic associations with plant height (r_g = 0.90 and 0.82), GMC (r_g = 0.60 and 0.72) and GFP (r_g = 0.67 and 0.54) under non-stress and water-stress, respectively.

Grain yield per feddan showed a positive association with grain yield/plant (r_g = 0.98 and 0.84 for the100 EE S_1's, 0.86 and 0.80 for the 100 EL S_1's, 0.93 and 0.96 for the 100 LE S_1's and 0.90 and 0.86 for the 100 LL S_1's), kernels/row (r_g = 0.64 and 0.76 of the 100 EE S_1's, 0.76 and 0.60 for the 100 EL S_1's, 0.84 and 0.79 for 100 LE S_1's and 0.68 and 0.69 for 100

LL S_1's) and 100 kernel weight ($r_g = 0.79$ and 0.64 for 100 EE S_1's, 0.67 and 0.47 for the 100 EL S_1's, 0.80 and 0.71 for 100 LE S_1's and 0.61 and 0.54 for 100 LL S_1's) under non-stress and water-stress, respectively. In general, genetic correlations between grain yield and kernels/row were higher than the corresponding ones between grain yield and 100-kernel weight under both environments. Bolanos and Edmeades (1996) also concluded that more than 75% of the variation in grain yield under drought was accounted by variation in kernels and ears/plant. High correlations between grain yield and its components are normally found because of lack of independence among them (Blum 1988). Correlation analysis in this study confirmed that water-stress before and during flowering affected mainly number of kernels/row and to a lesser extent the size of the kernel. Similar conclusion was also reported by Hall *et al* (1981).

Variance components and heritability

Summarizing the results of δ_g^2, δ_p^2 and h_b^2 (Table 4) of the five groups of S_1's (400 S_1's, 100 EE S_1's, 100 EL S_1's, 100 LE S_1's and 100 LL S_1's) indicated that both parameters δ_g^2 and h_b^2 were considerably higher in the 400 S_1's (representing the whole population of Giza-2) than in each of the four sub-populations. The reduction in δ_g^2 from the 400 S_1's to the four sub-populations of 100 S_1's each, was more pronounced in earliness traits (DTS and DTM), while was less pronounced in grain yield traits. This could be attributed to that selection was already practiced at the S_0 level for initiating the four groups of S_1's (100 EE, 100 EL, 100 LE and 100 LL S_1's), while selection for grain yield was not yet practiced at the S_0 level. In general, the magnitude of δ_g^2, δ_p^2 and h_b^2 (Table 4) was considerably smaller under stressed than under non-stressed environment for GYPP, GYPF, 100KW, KPR, GMC, DTS and DTM for the 400 S_1's, GYPP, GYPF, and DTM for the 100 EE S_1's, GYPP, GYPF, 100KW, KPR, PH and DTM for the 100 EL S_1's, GYPP, GYPF, 100KW, KPR, DTS and DTM for the 100 LE S_1's and GYPP, GYPF, 100KW and KPR for the100 LL S_1's. On the contrary, the magnitude of δ_g^2, δ_p^2 and h_b^2 was smaller under well-watering than under drought for the remaining traits of each group of S_1's.

The highest estimate of h_b^2 were exhibited by DTS (99.1 and 98.7%), GMC (98.7 and 98.9%) and DTM (98.2 and 94.4%) in the 400 S_1's, DTS (84.9 and 87.0%), GYPP (85.9 and 79.6%) in the 100 EE S_1's, BP (98.2 and 84.6%), and GMC (89.0 and 90.5%) in the 100 EL S_1's, DTS (87.5 and 82.1%) in the the100 LE S_1's and DTS (82.7 and 80.5%) and GMC (84.2 and 87.7 %) in the 100 LL S_1's under well-watered and water stressed

Table 4. Genetic (δ^2_g) and phenotypic (δ^2_p) variances and heritability in the broad sense (h^2_b%) for studied traits of the 400, 100 EE,100 EL, 100 LE and 100 LL S'$_1$s evaluated under non-stress and water stress conditions at Sids in 2005 season.

Trait	400 S$_1$'s			100 EE S$_1$'s			100 EL S$_1$'s			100 LE S$_1$'s			100 LL S$_1$'s		
	δ^2_g	δ^2_p	h^2_b(%)	δ^2_g	δ^2_p	h^2_b(%)	δ^2_g	δ^2_p	h^2_b(%)	δ^2_g	δ^2_p	h^2_b(%)	δ^2_g	δ^2_p	h^2_b(%)
							Non-stress								
DTS	60.4	60.9	99.1	1.6	1.9	84.9	1.2	1.5	77.4	3.0	3.4	87.5	2.1	2.5	82.7
DTM	87.1	88.7	98.2	3.8	4.3	88.4	4.6	6.0	77.4	11.1	12.8	87.1	2.8	3.6	77.7
GMC	56.9	57.7	98.7	0.9	1.3	71.9	5.3	5.9	89.0	0.9	1.4	62.7	3.5	4.1	84.2
GFP	20.6	21.4	96.5	2.4	2.7	90.2	1.2	1.5	77.4	2.6	3.0	85.3	1.1	1.4	79.4
PH	351.8	385.1	91.4	53.7	91.3	58.9	118.1	147.1	80.3	38.4	75.7	50.7	92.4	120.7	76.6
BP	3.3	3.4	96.4	5.3	5.5	96.4	3.4	3.4	98.2	2.5	2.6	95.4	1.8	1.9	94.6
KPR	15.9	20.2	78.6	5.7	8.7	65.7	13.5	18.4	73.4	11.9	15.9	74.7	12.8	18.4	69.9
100KW	3.0	3.7	81.7	3.1	3.9	78.9	2.9	3.6	81.0	2.8	3.3	83.6	1.7	2.2	77.6
GYPP	283.5	324.8	87.3	166.2	193.5	85.9	169.9	219.7	77.4	197.1	240.1	82.1	182.3	210.0	86.8
GYPF	5.1	6.2	82.6	3.2	4.1	78.6	3.1	4.1	75.3	4.3	5.5	79.3	3.3	4.2	77.7
							Water-stress								
DTS	46.0	46.6	98.7	2.5	2.9	87.0	1.4	2.1	68.1	2.7	3.3	82.1	2.1	2.7	80.5
DTM	50.5	53.5	94.4	2.2	4.8	77.2	3.0	4.1	74.7	3.8	4.9	77.3	3.0	4.1	73.7
GMC	55.4	56.0	98.9	1.2	1.7	74.4	5.3	5.9	90.5	1.0	1.5	69.2	4.5	5.1	87.8
GFP	21.1	23.3	90.2	1.6	2.2	72.8	1.3	1.8	71.5	1.7	2.1	81.6	1.3	1.7	74.7
PH	464.1	490.1	94.7	121.1	146.8	82.5	43.0	84.1	51.1	123.6	143.4	86.2	158.0	175.5	90.0
BP	100.8	142.0	71.0	130.5	184.8	70.6	154.4	182.6	84.6	41.3	68.6	60.1	80.4	103.8	77.5
KPR	13.8	17.2	79.9	21.1	24.6	86.0	6.0	9.3	64.7	10.2	14.7	69.7	8.0	10.6	75.8
100KW	2.5	3.1	80.7	0.9	1.2	70.8	0.8	1.1	72.7	1.2	1.5	78.7	1.2	2.0	62.4
GYPP	93.4	117.1	79.8	73.5	92.3	79.6	58.0	80.4	72.2	70.2	92.1	76.2	41.5	56.1	74.0
GYPF	2.8	3.6	76.0	1.0	1.8	57.9	1.5	2.2	67.8	1.2	1.7	70.9	1.1	1.6	70.2

environments, respectively. The magnitude of the h_b^2 for grain yield per fed and per plant in the 400 S_1's, 100 EE S_1's, 100 EL S_1's, 100 LE S_1's and 100 LL S_1's was above average (82.0, 85.0, 77.4, 79.3 and 77.0, respectively) under non-stress and (76.0, 57.0, 72.2, 76.0 and 70.0 %, respectively) under water stress. Empig *et al* (1972) suggested that the expected values of δ_g^2 would be equal to additive genetic variance (δ_A^2) if dominance and/or epistasis were lacking in the population or when gene frequency for the segregating loci is equal 0.5. High heritability estimates for the studied traits indicated that selection based on the mean performance of S_1 families would be a successful tool in improving population (Giza-2) for earliness as well as for grain yield under both well-watering and water-stress conditions. Similar conclusion was supported by Dudlel and Moll (1969), Darrah *et al* (1972), Sadek *et al* (1988), Walen *et al* (1991), Barakat (2003) and Shaboon (2004).

Expected gain from selection

In general, estimates of expected genetic advance (GA %) were higher under well-watered than under water-stressed environment in the four groups of 100 S_1's as well as in the 400 S_1's (Table 5). On the contrary, the GA percentages were higher under water-stress than under non-stress in the 4 groups of 100 S_1's and in the 400 S_1's for grain moisture content. Moreover, GA percentages were greater under non-stress than under stress for DTS in the 3 groups 100 EE S_1's, 100 EL S_1's and 100 LL S_1's, DTM in the 2 groups 100 EL S_1's and 100 LL S_1's, PH and KPR in the 3 groups 100 EE S_1's, 100 LE S_1's and 100 LL S_1's as well as in the 400 S_1's. Moreover, GA estimates were higher under non-stress than under water-stress for GFP and 100KW in the four groups of 100 S_1's, but not in the 400 S_1's and GYPF in 100 EE S_1's, 100 LE S_1's and 100 LL S_1's.

In general, the percentages of GA were higher for all studied traits in the 400 S_1's than in the four groups of 100 S_1's (100 EE S_1's, 100 EL S_1's, 100 LE S_1's and 100 LL S_1's). This tendency was more pronounced in earliness and grain filling period traits (DTS, DTM, GMC and GFP) and less pronounced in grain yield and its components. This could be attributed to that selection for earliness was practiced in the whole population of Giza-2 (represented by the 400 S_1's), but selection for grain yield was not yet practiced in the 400 S_1's, since it was practiced in each group of 100 S_1's (EE, EL, LE and LL), separately.

The highest GA percentages were exhibited by the traits BP, GYPP and GYPF in all the four groups of 100 S_1's as well as in the 400 S_1's. On the contrary, the lowest GA percentages were exhibited by the traits DTS, DTM, GFP and PH in the four groups of 100 S_1's and DTM, GFP and

Table 5. Predicted genetic advance from direct selection for the improvement of studied traits of the 4 groups of 100 S_1's and the 400 S_1's using a selection intensity of 4% and 16 %.

Trait	Environment	400 S_1's		100 EE S_1's		100 EL S_1's		100 LE S_1's		100 LL S_1's	
		4%	16%	4%	16%	4%	16%	4%	16%	4%	16%
DTS	WW	26.8	19.0	4.7	3.3	3.7	2.6	5.0	3.5	4.1	2.9
	WS	23.9	17.0	5.9	4.2	3.9	2.8	4.8	3.4	4.2	3.0
DTM	WW	16.9	12.0	3.7	2.6	3.6	2.6	5.6	4.0	2.4	1.7
	WS	13.5	9.6	3.6	2.5	3.0	2.2	3.4	2.4	2.7	1.9
GMC	WW	65.1	46.3	10.1	7.2	15.1	10.7	9.1	6.4	11.1	7.9
	WS	73.1	52.0	13.8	9.8	17.3	12.3	12.7	9.0	14.0	10.0
GFP	WW	17.3	12.3	6.1	4.3	3.5	2.5	6.3	4.5	3.3	2.3
	WS	19.0	13.5	4.8	3.4	3.9	2.7	6.0	4.3	3.9	2.8
PH	WW	18.9	13.4	6.5	4.6	10.9	7.8	4.5	3.2	7.9	5.6
	WS	23.6	16.8	12.7	9.0	5.7	4.1	10.9	7.8	11.9	8.5
BP	WW	454	323	404	288	576	410	403	287	424	302
	WS	88.9	63.3	83.0	59.0	137.6	97.9	51.4	36.6	93.2	66.3
KPR	WW	22.4	15.9	13.3	9.5	20.4	14.5	19.0	13.5	17.2	12.2
	WS	26.8	19.1	34.8	24.8	15.5	11.0	23.7	16.9	18.7	13.3
100KW	WW	17.9	12.8	18.5	13.2	17.2	12.3	18.0	12.8	12.7	9.1
	WS	19.4	13.8	11.9	8.4	9.8	7.0	14.2	10.1	11.1	7.9
GYPP	WW	41.3	29.4	35.7	25.4	29.6	21.1	36.1	25.7	28.0	19.9
	WS	35.2	25.1	35.3	25.1	24.4	17.4	31.7	22.6	20.7	14.7
GYPF	WW	39.9	28.4	35.4	25.2	29.6	21.1	36.8	26.2	26.7	19.0
	WS	47.2	33.6	32.1	22.9	30.8	21.9	33.5	23.9	22.6	16.1

100KW in the group of 400 S_1's. In other words, it could be noted that grain yield per plant and per feddan were among the traits showing the highest percentages of expected gain from selection. In contrast, earliness attributes were amongst those traits showing the lowest predicted gain from selection in the four groups of 100 S_1's, which could be attributed to the low magnitudes of δ_g^2 and heritability in these groups of 100 S_1's, since they were already selected from the original population (400 S_1's) for earliness in flowering and maturity. For earliness characteristics, expected genetic advance from selection using 4% selection intensity in the original population (400 S_1's) was 26.8 and 23.9% for DTS, 16.9 and 13.5% for DTM, 65.1 and 73.1% for GMC and 17.3 and 19.0% for GFP under well-watered and water-stressed environments, respectively. For grain yield per feddan, predicted genetic gain from selection using 16% selection intensity was 25.2 and 22.9% for the 100 EE S_1's, 21.1 and 21.9% for the 100 EL

S_1's, 26.2 and 23.9% for the 100 LE S_1's, 19.0 and 16.1% for the 100 LL S_1's and 28.4 and 33.6% for the 400 S_1's under well-watering and water-stress conditions, respectively.

Indirect selection (a secondary trait *vs* grain yield)

Responses of grain yield/fed to selection for secondary traits were calculated for each group of 100 S_1's (Table 6) such that selection was for either increased values of GYPP, KPR and 100KW or a decrease in barren stalks, DTS, DTM, GMC and GFP traits. In general direct selection for grain yield/fed was more efficient in predicted genetic advance from indirect selection for all secondary traits. This conclusion is based on comparisons between predicted responses of improving grain yield indirectly *via* a single secondary trait and directly *via* grain yield *per se* by calculating the value of relative efficiency (RE) which was <100%. These comparisons showed that direct selection for grain yield was significantly superior to indirect selection *via* any single secondary trait. Responses to selection for single secondary traits in all studied groups of 100 S_1's were higher under well-watered than under water-stressed environments. The reason for that could be attributed to the low heritability under water-stress conditions (Shabana *et al* 1980 and Shaboon 2004).

When responses of grain yield to selection for single secondary traits were compared under any selection environment, responses of grain yield per fedden to selection for high grain yield/plant was predicted to be the largest, followed by 100KW and KPR under both environments and for low percentage of barren plants under water-stress conditions. It is therefore concluded that secondary traits such as grain yield/plant, 100-kernel weight, number of kernels/row and barrenness are valuable criteria in increasing the efficiency of selection for grain yield under water stress conditions. These traits could be used in water deficit breeding programs. They are related to genetic water-stress tolerance. Other secondary traits which were not considered in this study may deserve further attention regarding their value in water deficit breeding programs. Selection for improved performance under drought based on grain yield alone has often been considered inefficient, but the use of a secondary trait of adaptive value whose genetic variability increased under drought can increase selection efficiency (Bolanos and Edmeades 1996). Physiologists and ideotype breeders have advocated the judicious incorporation of secondary traits within breeding programs (Blum 1988 and 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 as barren stalks, 100KW and KPR traits in the selection programs along with the grain yield trait.

Table 6. Predicted correlated genetic response from indirect selection (selection in a secondary trait for the improvement of grain yield/fed) of the 4 groups of 100 S_1's and the 400 S_1's.

S_1 group	DTS				DTM				GMC				GFP			
	WW	RE%	WS	RE%	WW	RE%	WS	RE%	WW	RE%	WS	RE%	WW	RE%	WS	RE%
400 S_1's	14.5	36.2	15.4	32.7	19.9	49.8	30.4	64.5	15.6	39.1	28.2	59.7	16.0	40.1	24.1	51.1
100 EE S_1's	2.6	7.5	0.3	0.9	1.1	3.2	-0.6	-1.8	0.4	1.2	3.0	9.3	-2.4	-6.8	-0.2	-0.8
100 EL S_1's	1.3	4.3	1.4	4.6	1.5	5.0	4.7	15.2	4.9	16.6	1.7	5.6	1.7	5.7	2.2	7.0
100 LE S_1's	-0.6	-1.5	4.3	13.0	-1.1	-2.9	1.5	4.5	5.5	15.0	5.0	15.0	-1.6	-4.3	-0.1	-0.4
100 LL S_1's	-2.1	-8.0	2.9	12.9	0.9	3.4	3.1	13.7	-0.5	-1.7	5.2	23.2	0.8	3.1	3.1	13.6
	BP				KPR				100KW				GYPP			
400 S_1's	-8.8	-22.1	-34.2	-72.5	30.8	77.3	33.6	71.1	28.8	72.1	32.6	69.0	38.7	97.0	42.6	90.3
100 EE S_1's	-18.2	-51.5	-28.3	-88.2	20.5	58.0	29.6	92.1	28.0	79.1	22.7	70.8	36.3	102.7	31.6	98.3
100 EL S_1's	-15.0	-50.6	-30.3	-98.2	19.5	65.7	18.2	59.0	20.6	69.5	15.0	48.7	25.7	86.7	25.3	82.2
100 LE S_1's	-5.6	-15.1	-20.4	-60.7	29.8	81.1	26.1	78.0	30.2	82.2	25.1	74.8	34.7	94.4	33.4	99.6
100 LL S_1's	-17.6	-66.1	-19.1	-84.6	17.3	64.9	16.2	71.4	16.3	61.0	11.5	50.9	25.3	94.8	19.9	88.0

Relative efficiencies (RE%) = 100 (CR/R).

Experimental population evaluation trial

Analysis of variance

Results of the combined analysis of variance (data not presented) showed that highly significant differences existed among the two irrigation regimes for all studied characters, except for BP trait. Combined analysis of variance also showed significant or highly significant differences among the nine populations for all studied traits, except for BP trait. Mean squares due to populations X irrigation regimes interaction were significant or highly significant for 7 out of 12 studied traits, *i.e.* DTS, DTM, GDD, GMC, GFP, GFR and GYPP. For these traits, populations performed differently under different irrigation regimes. Separate analysis of variance revealed significant or highly significant differences among populations either under well-watered or water-stressed environments for all studied traits, except for percentage of barren stalks under water stressed environment.

Performance of populations

The mean grain yields of the Pop-O, Pop-EEWW, Pop-EEWS, Pop-ELWW, Pop-ELWS, Pop-LEWW, Pop-LEWS, Pop-LLWW and Pop-LLWS were 15.6, 14.4, 13.3, 16.4, 14.8, 19.1, 17.6, 16.6 and 15.9 ard/fed under well-watered and 11.8, 10.1, 9.4, 11.6, 10.6, 14.1, 13.7, 12.6 and 11.2 ard/fed under water-stressed environment, respectively (Table 7).

Pop-LEWW showed the best grain yield per fed and per plant and was significantly superior to all other studied populations, including Pop-0 either under water-stressed or non-stressed environments. The second best population in grain yield per fed after Pop-LEWW was the new population Pop-LEWS, which was significantly superior over all other populations under both environments. In the third rank for grain yield/fed came the new populations Pop-LLWW and Pop-ELWW under both water-stress and non-stress conditions which was significantly superior in grain yield/fed over Pop-0, Pop-EEWW, Pop-EEWS, Pop-ELWS and Pop-LLWS.

The new populations Pop-LEWS and Pop-LEWW showed the lowest reduction in grain yield due to water deficit and therefore could be considered the most drought tolerant population in this study. Superiority of Pop-LEWW, Pop-LEWS, Pop-LLWW and Pop-ELWW over Pop-0 and other new populations in grain yield/fed was also exhibited in grain yield per plant under both irrigation regimes. Pop-LEWW exhibited the largest means of grain yield/plant (108.6 and 94.4 g), 100 kernels weight (20.6 and 17.8 g), number of kernels / row (43.3 and 34.2) and grain filling rate (2.0 and 1.8 g/day) under well – watered and water-stressed environments,

Table 7. Means of all studied traits for the 9 populations (8 improved and one original) evaluated under well-watered and water-stress conditions at Sids in 2007.

Trait	Pop-0	Pop-EEWW	Pop-EEWS	Pop-ELWW	Pop-ELWS	Pop-LEWW	Pop-LEWS	Pop-LLWW	Pop-LLWS	LSD (0.05)
Well-water conditions										
DTS	62.7	59.5	59.8	59.1	59.2	65.6	64.9	64.2	65.0	1.5
DTM	123	118	117	121	120	120	118	126	126	3
GDD	1856	1772	1754	1827	1815	1811	1772	1899	1905	39
GMC	27.1	17.0	15.9	32.0	30.1	18.0	17.0	34.2	32.1	1.4
GFP	60.5	58.8	57.5	62.2	61.0	54.4	53.4	61.7	61.3	3.0
GFR	1.5	1.6	1.6	1.6	1.6	2.0	1.8	1.7	1.6	0.1
PH	222	184	178	196	190	208	202	230	223	9
BP	1.5	0.4	0.6	0.8	0.4	0.2	0.6	0.7	1.4	0.5
KPR	37.0	35.4	33.0	38.1	35.8	43.3	40.7	39.4	36.3	3.6
100KW	18.3	21.1	19.3	20.6	19.1	20.6	19.3	22.0	21.1	2.6
GYPP	92.5	95.8	93.6	99.5	95.7	108.6	97.2	104.9	96.8	7.0
GYPF	15.6	14.4	13.3	16.4	14.8	19.1	17.6	16.6	15.9	1.0
Water-stress conditions										
DTS	61.2	58.8	58.1	56.4	57.4	62.7	62.0	63.8	63.1	2.2
DTM	117	112	111	116	114	114	112	121	120	4
GDD	1754	1683	1661	1723	1705	1708	1683	1823	1815	66
GMC	24.8	17.2	15.2	28.5	27.7	18.2	16.2	30.6	28.6	1.4
GFP	56.1	53.6	53.2	59.1	56.8	51.6	50.3	57.2	57.2	2.0
GFR	1.5	1.5	1.5	1.5	1.5	1.8	1.7	1.6	1.5	0.2
PH	217	167	175	192	174	200	200	221	217	9
BP	4.9	3.1	2.9	1.2	2.4	1.1	2.1	3.2	2.7	2.6
KPR	33.6	35.9	31.7	36.8	32.0	34.2	29.7	35.3	29.9	3.8
100KW	15.2	18.5	16.0	21.2	18.6	17.8	15.8	21.1	18.1	2.6
GYPP	82.7	81.5	80.3	91.1	84.1	94.4	86.3	93.7	85.2	5.4
GYPF	11.8	10.1	9.4	11.6	10.6	14.1	13.7	12.6	11.2	0.8
Water stress effect (WSE%)										
DTS	-2.4	-1.2	-2.9	-4.6	-3.0	-4.4	-4.5	-0.6	-2.9	
DTM	-4.8	-5.0	-5.1	-4.8	-5.0	-4.8	-5.1	-3.9	-4.8	
GDU	-5.5	-5.0	-5.3	-5.7	-6.1	-5.7	-5.0	-4.0	-4.7	
GMC	-8.5	1.1	-4.8	-11.0	-8.1	0.8	-4.8	-10.6	-11.0	
GFP	-7.2	-8.8	-7.4	-4.9	-6.9	-5.2	-5.8	-7.3	-6.7	
GFR	-3.7	-6.7	-7.3	-3.8	-5.7	-8.3	-5.7	-3.7	-5.7	
PH	-2.3	-9.4	-1.7	-2.2	-8.5	-3.8	-1.1	-3.9	-2.8	
BP	228	676	375	47	500	450	257	343	89	
KPR	-9.1	1.7	-4.2	-3.5	-10.7	-21.1	-27.1	-10.5	-17.6	
100KW	-17.1	-12.5	-17.3	3.2	-2.3	-13.3	-17.8	-3.8	-14.0	
GYPP	-10.6	-15.0	-14.2	-8.5	-12.1	-13.0	-11.2	-10.7	-12.0	
GYPF	-24.4	-30.0	-29.1	-29.2	-28.5	-26.3	-22.6	-24.3	-29.4	

WSE% (Water stress effect) = 100 (WS-WW)/WW.

respectively. Reduction in grain yield/fed due to water stress in all studied populations was mainly attributed to reduction in grain yield/plant followed by reduction in 100KW, KPR. This indicates that drought just before and during flowering affects mainly the number of kernels/row. The earliest populations in maturity (DTM) were Pop-EEWS (117.3 and 111.3 days), Pop-EEWW (118.3 and 112.4 days), Pop-ELWW (121.3 and 115.5 days and Pop-ELWS (120.2 and 114.3 days) as compared with Pop-0 (123.2 and 117.3 days) under well-watering and water-stress, respectively. On the other hand, the latest populations in DTM were Pop-LLWW (125.9 and 126.3 days) and Pop-LLWS (126.3 and 120.2 days). The earliest populations in flowering (DTS) were Pop-EEWS, Pop-EEWW and Pop-ELWS under both water-stressed and non-stressed environments. On the contrary, the populations Pop-LLWW and Pop-LLWS were the latest in DTS under both environments.

In general, the highest estimates of GDD, GMC and GFP traits were shown by Pop-LLWW and Pop-LLWS, while the lowest estimates were exhibited by the populations Pop-EEWW and pop-EEWS under both irrigation regimes. It is interesting to mention that the populations Pop-LEWW and Pop-LEWS were earlier in maturity and at the same time gave higher grain yield/fed as compared with Pop-0 (Giza-2). The increase of these two new populations in yield over Giza-2 could be attributed to the elongation in vegetative growth period (source) and thus accumulation of more photosynthetic assimilates as well as to the high rates of grain filling shown by these populations. Corke and Kannenberg (1989) found that increased vegetative phase duration (VAD) had positive significant effect on grain yield and that increased actual filling period duration (AFPD) had positive slightly effects on grain yield, but these were generally not significant. They reported that differences in kernel number per plant contributed most to grain yield variation within any environment, whereas 1000 kernel weight contributed most to grain yield difference across environments. Their results indicated a vegetative size limitation for grain yield of short season maize in the material studied. They stated that this should not be interpreted strictly as a source (supply of photoassimilate) limitation during the grain filling period, because preanthesis source size may partly determine kernel number per plant and thus affect sink size.

Change due to selection

a. Change in selected traits

One cycle of S_1 recurrent selection for high grain yield, late flowering and early maturity using the well-watered as a selection environment caused a significant improvement of the Pop-LEWW over its

Table 8. Change in selected traits due to one cycle of S_1 recurrent selection in the eight improved populations in absolute units (AC) and relative (RC%) values as compared to the original population (Pop-0) evaluated under well watered and water stress conditions at Sids 2007.

Population		Well-water			Water-stress		
		DTS (d)	DTM (d)	GYPF (ard/fed)	DTS (d)	DTM (d)	GYPF (ard/fed)
Pop-EEWW	AC	-3.2*	-4.9*	-1.2*	-2.4*	-5.0*	-1.7*
	RC(%)	-5.1	-4.0	-7.7	-4.0	-4.2	-14.6
Pop-EEWS	AC	-2.9*	-5.9*	-2.3*	-3.1*	-6.1*	-2.4*
	RC(%)	-4.7	-4.8	-14.9	-5.1	-5.2	-20.2
Pop-ELWW	AC	-3.6*	-1.9	0.7	-4.8*	-1.8	-0.2
	RC(%)	-5.8	-1.5	4.8	-7.9	-1.5	-1.9*
Pop-ELWS	AC	-3.5*	-3.0*	-0.8	-3.8*	-3.1	-1.2
	RC(%)	-5.6	-2.4	-4.9	-6.2	-2.6	-10.1
Pop-LEWW	AC	2.9*	-3.2*	3.5*	1.5	-3.0	2.3*
	RC(%)	4.6	-2.6	22.6	2.4	-2.6	19.5
Pop-LEWS	AC	2.2*	-4.9*	2.0*	0.8	-5.0*	1.9*
	RC(%)	3.5	-4.0	13.0	1.3	-4.3	15.7
Pop-LLWW	AC	1.4	2.7*	1.0*	2.6*	3.7	0.8*
	RC(%)	2.3	2.2	6.3	4.2	3.1	6.5
Pop-LLWS	AC	2.2*	3.1*	0.3	1.9	2.9	-0.6
	RC(%)	3.6	2.5	1.9	3.0	2.5	-4.8

AC; Absolute change = New Pop – Pop-0 and RC(%), Relative change = 100 (New Pop – Pop-0)/Pop-0.
* indicates significance at 0.05 level of probability.

original population (Pop-O) in grain yield/fed by 3.5 and 2.3 ard (22.6 and 19.5%), significant lateness in silking by 2.9 and 1.5 days (4.6 and 2.4%) and significant earliness in maturity by 3.2 and 3.0 days (2.6 and 2.6 %) under well-watered and water-stressed environments, respectively (Table 8).

The improved Pop-LEWS developed by using the soil moisture deficits as a selection environment came in the second place with regard the improvements over Pop-O in grain yield and earliness traits. This new population (Pop-LEWS) showed superiority over Pop-O in grain yield/fed by 2.0 and 1.9 ard (13.0 and 15.7%), and was later than Pop-O in maturity by 4.9 and 5.0 days (4.0 and 4.3%) under non-stress and water-stress, respectively.

Selection for high grain yield, late flowering and late maturity under well-watering caused significant improvements in grain yield/fed for the new population Pop-LLWW by 1.0 and 0.8 ard (6.3 and 6.5%) over its original population (Pop-O) under well-watered and water-stressed environments, respectively. However, this new population Pop-LLWW showed a delay in silking of 1.4 and 2.6 days (2.3 and 4.2%) and in maturity of 2.7 and 3.7 days (2.2 and 3.1%) as compared with the original population Pop-O, under well-watered and water-stressed environments, respectively.

Selection for grain yield under stressful conditions is often considered less efficient because of the commonly observed decline in heritability (Blum 1988) and several reports of selections made in maize appear to confirm this (Arboleda-Rivera and Compton 1974, Johnson and Geadelmann 1989 and Bolanos and Edmeades 1993). Our results also confirm that gains when selecting for improved yield under adequate soil moisture conditions that coincide with flowering of maize are clearly obtainable under both environments (stressed and unstressed) and even are more pronounced under water-stress conditions. One cycle of S_1 recurrent selection for early silking, early maturity and high grain yield under water-stress environment in the Pop-EEWS caused a direct significant improvement in earliness of silking of 2.9 and 3.1 days (4.7 and 5.1%) and in earliness of maturity of 5.9 and 6.1 days (4.8 and 5.2%) and significant reduction in grain yield/fed of 14.9 and 20.2% under well-watering and water-stress conditions, respectively. Moreover, the new experimental population (Pop-EEWW) developed by one cycle of S_1-recurrent selection for early silking, early maturity and high yield under a well-watering selection environment was significantly earlier than the original Giza-2 population (Pop-0) in silking by 3.2 and 2.4 days (5.1 and 4.0%) and in maturity by 4.9 and 5.0 days (4.0 and 5.2%), but was significantly lower in grain yield/fed by 1.2 and 1.7 ard (7.7 and 14.6%) under well-watered and water-stressed environments, respectively.

b. Change in unselected traits

Selection improvement in earliness of silking, earliness of maturity and high grain yield/fed over Pop-0 under the moisture deficit target environment was associated with a significant decrease in growing degree units (GDD) of 71.0 and 93.0 unit (4.0 and 5.3%), decrease in grain moisture content (GMC) of 7.6 and 9.6% (30.8 and 38.7%), shortening in grain filling period (GFP) of 2.5 and 2.9 days (4.5 and 5.2%), decrease in plant height (pH) of 49.7 and 42.0 cm (22.9 and 19.4%) for Pop-EEWW and Pop-EEWS, respectively (Table 9). Under the well-watered target environment, selection improvement in earliness of silking, earliness of maturity and high grain yield over Pop-0 was attributed to significant

Table 9. Change in unselected traits due to one cycle of S_1 recurrent selection in the eight improved populations in absolute units (AC) and relative (RC%) values as compared to the original population (Pop-0) evaluated under well watered and water-stress conditions at Sids 2007.

Population	Change	GDD	GMC (%)	GFP (d)	PH (cm)	BP (%)	GFR (g/d)	KPR	100KW (g)	GYPP (g)
					Well- watering					
Pop-EEWW	AC	-83.8*	-10.1*	-1.7	-37.6*	-1.4	0.1*	-1.7	2.8	3.3
	RC(%)	-4.5	-37.3	-2.8	-16.9	-91.7	6.5	-4.5	15.2	3.6
Pop-EEWS	AC	-102.0*	-11.1*	-3.0*	-44.0*	-1.2	0.1*	-4.0*	1.0	1.1
	RC(%)	-5.5	-41.1	-5.0	-19.9	-80.0	6.5	-10.7	5.4	1.2
Pop-ELWW	AC	-29.0	5.0*	1.7	-25.7*	-1.5	0.1*	1.1	2.3	7.0*
	RC(%)	-1.6	18.3	2.9	-11.6	-96.7	4.6	3.0	12.3	7.6
Pop-ELWS	AC	-41.0*	3.0*	0.5	-31.8*	-1.1	0.0	-1.2	0.8	3.2
	RC(%)	-2.2	11.2	0.8	-14.4	-73.3	2.6	-3.4	4.3	3.4
Pop-LEWW	AC	-45.0*	-9.0*	-6.1*	-13.7*	-1.3	0.5*	6.3*	2.3	16.1*
	RC(%)	-2.4	-33.3	-10.0	-6.2	-86.7	30.4	17.0	12.5	17.4
Pop-LEWS	AC	-83.8*	-10.1*	-7.1*	-19.6*	-0.9	0.3*	3.7*	1.0	4.7
	RC(%)	-4.5	-37.3	-11.7	-8.8	-60.8	18.9	10.0	5.3	5.0
Pop-LLWW	AC	43.0*	7.1*	1.2	7.9*	-0.8	0.2*	2.4	3.7	12.4*
	RC(%)	2.3	26.4	2.0	3.6	-51.7	11.1	6.4	20.0	13.4
Pop-LLWS	AC	49.0*	5.1*	0.8	1.1	-0.1	0.1*	-0.7	2.8	4.3
	RC(%)	2.6	18.8	1.4	0.5	-6.7	3.3	-2.0	15.3	4.7
					Water stress					
Pop-EEWW	AC	-71.0*	-7.6*	-2.5*	-49.7*	-1.8	0.0	2.3	3.3	-1.3
	RC(%)	-4.0	-30.8	-4.5	-22.9	-37.0	3.1	6.8	21.7	-1.5
Pop-EEWS	AC	-93.0*	-9.6*	-2.9*	-42.0*	-2.1	0.0	-2.0	0.8	-2.4
	RC(%)	-5.3	-38.7	-5.2	-19.4	-42.1	2.4	-5.9	5.2	-2.9
Pop-ELWW	AC	-31.0	3.7*	3.0*	-24.9*	-3.8*	0.1	3.2	6.0	8.4*
	RC(%)	-1.8	15.0	5.4	-11.5	-76.1	4.5	9.4	39.9	10.1
Pop-ELWS	AC	-49.0	2.9*	0.7	-42.9*	-2.5	0.0	-1.7	3.5	1.4
	RC(%)	-2.8	11.7	1.2	-19.8	-51.3	0.4	-5.0	22.9	1.6
Pop-LEWW	AC	-46.0	-6.6*	-4.5*	-16.5*	-3.8*	0.4*	0.5	2.7	11.7*
	RC(%)	-2.6	-26.6	-8.1	-7.6	-77.7	24.2	1.6	17.7	14.1
Pop-LEWS	AC	-71.0*	-8.6*	-5.8*	-16.6*	-2.8*	0.2*	-4.0*	0.7	3.6
	RC(%)	-4.0	-34.7	-10.4	-7.7	-57.4	16.5	-11.8	4.5	4.4
Pop-LLWW	AC	69.0*	5.8*	1.1	4.2	-1.7	0.2*	1.6	6.0	11.0*
	RC(%)	3.9	23.4	2.0	1.9	-34.8	11.1	4.8	39.2	13.3
Pop-LLWS	AC	61.0	3.8*	1.0	-0.1	-2.3	0.0	-3.7	3.0	2.5
	RC(%)	3.5	15.5	1.9	0.0	-46.2	1.1	-11.1	19.6	3.0

AC; Absolute change = New Pop – Pop-0 and RC%; Relative change = 100 (New Pop – Pop-0)/Pop-0. , * indicates significance at 0.05 level of probability.

improvements in other traits, namely decrease in GDD by 83.8 and 102.0 units (4.5 and 5.5%), decrease in GMC by 10.1 and 11.1% (37.3 and 41.1%), shortening in GFP by 1.7 and 3.0 days (2.8 and 5.0%), decrease in PH by 37.6 and 44.0 cm (16.9 and 19.9%) for Pop-EEWW and Pop-EEWS, respectively.

Selection for early silking, late maturity and high grain yield was associated with significant decrease in GDD by 31.0 and 49.0 units (1.8 and 2.8%), increase in GMC by 3.7 and 2.9 (15.0 and 11.7%), increase in GFP by 3.0 and 0.7 days (5.4 and 1.2%), decrease in PH by 24.9 and 42.9 (11.5 and 19.8%) and increase in 100KW by 6.1 and 3.5 g (39.9 and 22.9%) for Pop-ELWW and Pop-ELWS, respectively under moisture deficit target environment. Under well-watered target environment, significant changes in the unselected traits included a reduction in GDD by 29.0 and 41.0 (1.6 and 2.2%), an increase in GMC by 5.0 and 3.0% (18.3 and 11.2%), an increase in GFP by 1.7 and 0.5 days (2.9 and 0.8%), a decrease in PH by 25.7 and 31.8 cm (11.6 and 14.4%), an increase in 100KW by 2.3 and 0.8 g (12.3 and 4.3%), and an increase in GFR by 0.07 and 0.04 g/day (4.6 and 2.6%) for Pop-ELWW and Pop-ELWS, respectively.

Under water stressed target environment, selection improvement in lateness of silking, earliness of maturity and high grain yield over the original population Pop-0 was associated with significant decrease in GDD by 46.0 and 71.0 (2.6 and 4.0%), decrease in GMC by 6.6 and 8.6% (26.6 and 34.7%), decrease in GFP by 4.5 and 5.8 days (8.1 and 10.4%), decrease in PH by 16.5 and 16.6 cm (7.6 and 7.7%), increase in GFR by 0.5 and 0.3 g/day (30.4 and 18.9%) and increase in 100KW by 2.7 and 0.7 g (17.7 and 4.5%) for Pop-LEWW and Pop-LEWS, respectively. Under non-stress target environment, significant changes in the unselected traits included decrease in GDD of 45.0 and 83.8 units (2.4 and 4.5%), decrease in GMC of 9.9 and 10.1% (33.3 and 37.3%), decrease in GFP of 6.1 and 7.1 days (10.0 and 11.7%), decrease in PH of 13.7 and 19.6 cm (6.2 and 8.8%), increase in GFR of 0.2 and 0.1 g/day (11.1 and 3.3%) and increase in 100KW of 2.3 and 1.0 g (12.5 and 5.3%) for the same populations (Pop-LEWW and Pop-LEWS), respectively. Selection for late silking, late maturity and high yield caused a significant increase in GMC by 2.3 and 2.6% and increase in 100KW by 3.7 and 2.8 g (20.0 and 15.3%), for Pop-LLWW and Pop-LLWS, respectively evaluated under well watered-target environment. Significant changes in the unselected traits as compared to Pop-0 included increase in GDD by 69.0 and 61.0 units, (3.9 and 3.5%), increase in GMC by 5.8 and 3.8% (23.4 and 15.5%), increase in GFR by 0.2 and 0.02 g/day (11.1 and 1.1%), and increase in 100KW by 6.0 and 3.0 g (39.2 and 19.6%)

for the same populations Pop-LLWW and Pop-LLWS, respectively when were evaluated under water-stress conditions.

Actual *vs* predicted progress

In general, estimates of actual progress in grain yield/ fed as a result of practicing one cycle of S_1 recurrent selection shown in only three of the new populations, *i.e* Pop-LEWW (22.6 and 19.5%), Pop-LEWS (13.0 and 15.7) and Pop-LLWW (6.3 and 6.5), were much lower than those of predicted progress, under well-watered and water-stressed environments, respectively. This could be due to the overestimation of the heritability based on the total genetic variance (in the broad sense). It is believed that a considerable amount of non-heritable genetic variance (dominance and epitasis) is included in such total genetic variance. Failure in achieving actual progress in grain yield/fed in some of the newly-developed populations could be attributed to the negative correlation between grain yield and earliness of DTS and DTM, especially for Pop-EEWW and Pop-EEWS and high percentage of lodging (data not presented) and barrenness for Pop-LLWS. Furthermore, Al-Naggar *et al* (2004) reported that one cycle of S_1 recurrent selection using the well-watered as a selection environment cause a significant improvement in GYPF of Pop-1 over DTP-1 under water deficits by 30.8% and under well-watered conditions by 16.0%.

The higher gains in grain yield/fed from selection per cycle achieved in the present study in some newly-developed populations (especially Pop-LEWW and Pop-LEWS) as compared to those reported by other investigators might be attributed to the richness of the original population (Giza-2) in genetic variability and to using the S_1 progeny method which utilizes the additive genetic variance in a better way than other methods and presents an opportunity for selection against major deleterious recessive genes that become homozygous with inbreeding (Genter 1971 and 1973, Tanner and Smith 1987 and Hallauer and Miranda 1988). Actual progress in earliness either for silking or maturity as a result of practicing one cycle of S_1 recurrent selection was much lower than those of the calculated predicted progress. This also could be due to overestimation of the heritabilities for these earliness traits based on the total rather than on the additive genetic variance. The actual significant gain *via* one cycle of S_1 recurrent selection for earliness of maturity achieved in this study was 5.9 and 6.1 days for Pop-EEWS, 4.9 and 5.0 days for Pop-EEWW, 3.0 and 3.1 days for Pop-ELWS, 3.2 and 3.0 days for Pop-LEWW and 4.9 and 5.0 days for Pop-LEWS under WW and WS, respectively. This gain in earliness of maturity is much greater than that reported by previous investigators (Subandi 1985, Troyer and Larkins 1985, Troyer 1988 and 1990, Ordas 1988 and Ordas *et al* 1996). The reason for obtaining such higher gains in earliness of maturity than those reported by other researchers might be attributed to the following: (1) the better effectiveness of S_1 recurrent selection as compared with other selection methods used in other studies, (2) the richness of Giza-2 in genetic variability concerning days to flowering and to maturity, which was not previously utilized in selection programs and (3) practicing selection for earliness in this study under water stress conditions which gave better gains for earliness than under non-stress conditions.

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التحسين داخل العشيره للتبكير في النضج وتحمل الجفاف في الذرة الشامية

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تم إجراء التجارب الحقلية لهذه الدراسة في سدس لمدة خمس مواسم من عام ٢٠٠٤ حتى ٢٠٠٧ ، حيث تم تكوين ٤٠٠ نسل من أنسال الجيل الذاتي الأول المستمدة من عشيرة الصنف مفتوح التلقيح من الذرة جيزة-٢ وذلك في موسم ٢٠٠٤ ثم قسمت هذه الأنسال إلى أربعة مجاميع (كل مجموعة ١٠٠ سلالة) بالاعتماد على الانتخاب المتعاكس (التبكير والتأخير) لصفتى ٥٠% خروج حريرة و ٥٠% نضج فسيولوجى (مبكرة الحريرة ، مبكرة النضج ومبكرة الحريرة متأخرة النضج، متأخرة الحريرة مبكرة النضج، متأخرة الحريرة متأخرة النضج)، وتم التقييم في موسم ٢٠٠٥ تحت ظروف الجفاف (في مرحلة التزهير) وظروف الري الكامل وبناء على

ذلك تم انتخاب أفضل ١٦% من هذه الأنسال (على أساس المحصول) تحت ظروف الجفاف أو ظروف الري الكامل على حده فكان لدينا ثمانية مجموعات من السلالات المنتخبة كل منها ١٦ سلالة. وفي الموسم المبكر لعام ٢٠٠٦ تم زراعة هذه المجاميع الثمانية من الأنسال في حقول منفصلة، وتم عمل كل التهجينات الممكنة بينها وفي الموسم الصيفى المتأخر لعام ٢٠٠٦ ثم عمل التزاوج العشوائي بين نباتات كل مجموعة في حقول منفصلة للوصول إلى الاتزان الوراثي. ثم في موسم ٢٠٠٧ تم تقييم العشائر الثمانية (Pop-EEWW, Pop-EEWS, Pop-ELWW, Pop-ELWS Pop-LEWW, Pop-LEWS, Pop-LLWW, Pop-LLWS) مقارنة بالعشيرة الأصلية Pop-0 تحت ظروف كلا البيئتين. كانت أهداف الدراسة هي استنباط عشائر جديدة ذات حريرة أو نضج مبكرين و/أو ذات محصول حبوب بالفدان عالي عن جيزة-٢ واختبار التقدم الحقيقي في التبكير ومحصول حبوب الفدان تحت كلا من ظروف الإجهاد وعدم الإجهاد المائي. تسبب الإجهاد المائي في نقص المتوسط والمدى لسلالات الجيل الذاتي الأول بالنسبة لكل الصفات تحت الدراسة، ماعدا صفة نسبة النباتات الذكر التي زادت فيها هذه القيم نتيجة الجفاف. كانت قيم التباين الوراثي وكفاءة التوريث العامة والتحسين المتوقع بالانتخاب أعلي بصفة عامة في العشيرة الكلية (٤٠٠ سلالة S_1) عنها في كل مجموعة من ١٠٠ سلالة S_1 على حدة، وكان هذا الاتجاه أكثر وضوحاً في صفات التبكير وأقل وضوحاً في صفات محصول الحبوب. أظهرت صفات محصول حبوب النبات ووزن الـ ١٠٠ حبة وعدد حبوب الصف والتدكير أنها صفات ثانوية ذات قيمة في زيادة كفاءة الانتخاب لمحصول حبوب الفدان تحت ظروف الجفاف. أمكن من هذه الدراسة استنباط عشائر جديدة حققت تقدماً حقيقياً عن الصنف جيزة-٢ نتيجة إجراء دورة واحدة من الانتخاب الدوري لأنسال الجيل الذاتي الأول في التبكير في النضج والمحصول العالي معاً وصل في العشيرة Pop-LEWW إلى ٣,٢ ، ٣,٠ يوم تبكير في النضج و ٣,٥ أردب (٢٢,٦%)، ٢,٣ أردب (١٩,٥%) زيادة في محصول حبوب الفدان وفي العشيرة Pop-LEWS وصل إلى ٤,٩ ، ٥,٠ يوم تبكير فى النضج و٢,٠ أردب (١٣,٠%)، ١,٩ أردب (١٥,٧%) زيادة في محصول الفدان تحت ظروف الري الكامل والجفاف على التوالي، وفي التبكير فى النضج فقط وصل في العشيرتين Pop-EEWS, Pop-EEWW ٤,٩ ، ٥,٩ يوم تبكير فى النضج تحت الري الكامل ٥,٠ ، ٦,١ يوم تحت ظروف الإجهاد، بينما نقص محصول حبوب الفدان للعشيرتين بنسب تتراوح بين ٧,٧ ، ١٤,٩% تحت ظروف الري، ١٤,٦ ، ٢٠,٢% تحت ظروف الجفاف للعشيرتين على التوالي.