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GENETIC PARAMETERS OF DROUGHT TOLERANCE IN MAIZE S'_1s AND THEIR TESTCROSSES

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ABSTRACT

Seventy one testcrosses were developed in 1997 by crossing 71 S_1 lines of maize derived from the maize drought tolerant populations DTP-1 (36 S_1' s) and DTP-2 (35 S_1' s) to a common inbred tester (S_1 family) derived from Cairo-1 (a drought susceptible population). In 1998, the S_1' s, testcrosses and the inbred tester were grown in the field at the Res. Sta. of Fac. of Agric, Cairo Univ., Giza to evaluate performance and estimate combining ability, heterosis, heritability and predicted selection gain in lines and testcrosses under water-stressed and non-stressed environments. Heterobeltiosis was generally greater under stress than non-stress conditions. Significant positive heterobeltiosis was found under water stress for grain yield (19.99% in DTP-1 and 19.0% in DTP-2). Wider ranges and higher favorable frequency (%) of heterobeltiosis were found in grain yield than other traits and in DTP-2 than DTP-1 under stress. Combining ability analysis indicated that selection of superior inbred lines of high general combining ability from both DTP-1 or DTP-2 and of high specific combining ability with the S_1 inbred tester may be effective. Broad-sense heritability was higher under stress than under full irrigation for all studied traits, with the highest value for grain yield/plant in both populations. Predicted genetic advance from direct selection under water stress conditions was higher than that under non-stress conditions for grain yield and its components in both populations. Estimated expected gain in grain yield was 54.3 and 60.8 % under stress and 26.6 and 32.4 % under control for DTP-1 and DTP-2, respectively.

Key words: ***Drought tolerance, Combining ability, Heterosis, Expected selection gain, Maize, S_1, Testcrosses, Population improvement***

INTRODUCTION

Maize (*Zea mays* L.) is susceptible to drought especially during the flowering stage (Chapman *et al* 1996). Losses in grain yield are particularly severe when drought stress occurs at this stage (Classen and Shaw 1970 and Grant *et al* 1989).

Expansion of growing maize in the newly-reclaimed lands of Egypt where soils are characterized by low-water-holding capacity and irrigation water is limited necessitates the development of drought tolerant maize cultivars for such areas. The problem have been the adoption of an efficient breeding program to such a complicated character (Edmeades *et al* 1992). This requires understanding the genetic and breeding parameters of yield characters affecting drought tolerance.

The estimation of combining ability and type of gene action for a certain trait is very important to design an appropriate breeding program for improving such trait. Cockerham (1961) concluded that if the estimate of general combining ability (GCA) or additive genetic variance is of major importance, the most effective breeding procedure would be the intrapopulation selection, while, hybrid program may be the appropriate choice, if the specific combining ability (SCA) or non-additive variance is the major component. Sprague and Tatum (1942) concluded that GCA could be determined from single cross combinations, and could be more effectively determined from top-cross test, particularly if preliminary information are required for screening a large number of lines. Their conclusions are valid in current breeding programs because of the increased interest in developing and growing single crosses. The literature on the combining ability and heterosis of traits related to drought tolerance in maize is very scarce.

The role of heterosis for manifesting drought tolerance in maize was studied by few investigators (Younis *et al* 1988, Sharma and Bhalla 1991). They found that heterosis increased under drought stress, and suggested that some crosses could be exploited directly as hybrid cultivars or their inbreds could be used to produce drought tolerant composites.

Different opinions were reported in the literature regarding the best environment for enhancing predicted selection gain. Frey (1964) and Allen *et al* (1978) concluded that selection without stress would optimize gain, since heritabilities were greater under those conditions than under stress. On the contrary, some researchers found that heritability and consequently selection gain increased in stressful environments (Russell 1969, Stuper and Moll 1977 and Troyer and Rosenbrook 1983).

The objectives of the present investigation were to study performance, combining ability, heterosis, type of gene action and heritability for maize traits related to drought tolerance in S_1 families and their testcrosses and estimate the predicted gain from direct selection for maize traits under optimum and drought stress environments.

MATERIALS AND METHODS

In 1997 season, 71 testcrosses were developed by crossing 71 S_1 lines derived from the drought tolerant populations DTP-1 (36 S_1's) and DTP-2 (35 S_1's) as females with a common inbred tester. The inbred tester was an S_1 family derived from the local open-pollinated population Cairo-1, which proved in a previous work (El-Sayed 1998) as a drought susceptible population. DTP-1 and DTP-2 were developed at CIMMYT, Mexico.

In 1998 season, the parental S_1 families, their testcrosses and the tester (143 entries) were evaluated under drought stress and non-stress environments in the field at the Agricultural Research Station, Faculty of Agriculture, Cairo University, Giza. The experimental design was a split-plot design with two replications. The main plots involved two soil moisture regimes, i.e. non-stress (control) and water-stress at flowering stage. Water stress at flowering was induced by withholding the 4^{th} and 5^{th} irrigations. Genotypes occupied the sub plots. Sowing date was June 1, 1998. Each sub-plot consisted of one row, 6 m long and 70 cm wide. Seeds were over-sown in hills 25 cm apart and were later thinned to one plant/hill. All recommended practices for optimum maize production were used.

The following traits were recorded: number of ears/plant, number of rows/ear, number of kernels/row, 100-kernel weight and grain yield/plant adjusted at 15.5 % grain moisture. All data were measured on 5 guarded plants/plot. Ordinary analysis of variance of a split-plot design was computed according to Steel and Torrie (1980). The sum of squares for genotypes under each irrigation treatment were partitioned into testcrosses (within DTP-1 group, within DTP-2 group and group 1 vs group 2), parents and parents vs testcrosses; and estimates of expected mean squares (E.M.S) for each treatment were computed.

Estimates of better parent heterosis (heterobeltiosis) under drought stress and non-stress environments were determined by using the following equation: $(F_1 - BP)/BP \times 100$, where, F_1 = mean of the F_1 and BP = mean of the better parent. Test of significance for heterobeltiosis was made by using LSD at 0.05 probability level. The standard error (S.E) for the LSD was calculated as follows: $S.E. = (2MSe/r)^{0.5}$, where, MSe = error mean square for genotypes and r = number of replications.

Specific combining ability effects for all studied traits were calculated for testcrosses from each population as a deviation of the mean performance of each testcross from the mean performance of all crosses for such population (Singh and Narayanan, 2000).

Genetic variance (σ^2_G) and heritability (h^2) in the broad sense of testcross means in each population and over populations under drought stress and non-stress environments was computed as $h^2 = \sigma^2_G/(\sigma^2_G + \sigma^2_E/r)$. Genetic advance (GA) from direct selection for all studied traits was calculated according to Becker (1984).

RESULTS AND DISCUSSION

Analysis of variance

Analysis of variance among genotypes, S_1's and testcrosses derived from DTP-1 and DTP-2 populations and the S_1 inbred tester derived from Cairo-1 population evaluated under two soil-moisture regimes (Table 1) showed highly significant differences due to genotypes for all studied traits. Significant differences were observed between moisture regimes only for kernels/row, 100-kernel weight and grain yield/plant. Genotypes x moisture regimes exhibited highly significant differences for all studied traits.

Mean squares due to all testcrosses, DTP-1 testcrosses (group-1), DTP-2 testcrosses (group-2), group-1 vs. group-2, parental S_1's and parental S_1's vs. crosses were significant or highly significant for all studied traits, except group-1 vs. group-2 for ears/plant, rows/ear and kernels/row, and parents for kernels/row (Table 1).

Table 1. Analysis of variance of traits of maize S_1 testcrosses and their S_1 parents evaluated under two moisture regimes in 1998.

S.O.V	M.S.				
	Ears/ plant	Rows/ ear	Kernels/ row	100-Kernel weight	Grain yield/plant
Moisture regimes (M)	7.754	62.39	5340.079**	4071.112*	252352.64*
Genotypes (G)	0.097**	7.39**	121.836**	61.797**	4580.028**
Test crosses (C)	0.076**	3.15**	34.94**	43.38**	2186.23**
DTP-1 (crosses) -G 1	0.073**	3.14**	32.75**	45.69**	1312.60**
DTP-2 (crosses) -G 2	0.083**	3.26**	38.08**	39.80**	2960.36**
G 1 vs. G 2	0.02	0.23	4.84	84.19**	6442.45**
Parents (P)	0.109**	9.52**	155.39	61.69**	5257.22**
P vs. C	0.597**	152.86**	3822.28**	1358.25**	124065.43**
G x M	0.038**	1.363**	23.212**	19.489**	861.218**

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

Mean performance

Average grain yield/plant was significantly decreased under water stress by 37.3, 35.7 and 53.6 %, of the to full irrigation for S_1's of DTP-1, DTP-2 and Cairo-1, respectively (Table 2). Maximum reduction of yield from drought stress reached in S_1 lines was 69.8 and 83.7 % for DTP-1 and DTP-2 groups, respectively. However, some S_1 families exhibited

Table 2. Mean performance, lower and higher limits of the range and drought tolerance index (TI) of parental S_1 maize lines and tester for studied traits in 1998 season.

Trait		Parental S_1 lines						$LSD_{0.05}$		
		DTP-1 (36 S_1's)			DTP-2 (35 S_1's)			Cairo-1 (S_1Tester)		
		Control	Stress	TI	Control	Stress	TI*	Control	Stress	TI
Ears/ plant	Mean	1.30	1.1	83.97	1.30	1.10	85.90	1.30	1.10	84.60
	Low	1.00	1.0	66.70	1.00	1.00	62.50	M**	G**	G x M*
	High	2.00	1.5	110.00	1.60	1.40	120.00	-	0.25	0.35
Rows/ ear	Mean	12.70	12.10	95.40	12.80	11.50	89.70	13.40	13.50	100.60
	Low	10.50	6.00	57.10	9.20	6.00	57.10	M	G	G x M
	High	15.50	14.80	108.70	15.00	15.00	115.80	-	1.61	2.25
Kernels/ row	Mean	26.80	21.50	79.90	27.40	21.30	77.50	32.50	24.80	76.10
	Low	15.80	6.50	41.10	15.50	6.00	38.10	M	G	G x M
	High	40.20	31.20	118.2	36.80	36.30	99.45	1.52	4.53	6.41
100-Kernels wt. (g)	Mean	40.30	27.40	68.10	33.50	27.40	81.60	40.00	28.50	71.30
	Low	25.00	16.50	50.80	21.00	17.00	43.00	M	G	G x M
	High	40.50	36.00	98.30	39.50	36.50	107.00	3.30	3.82	5.41
Grain yield/ plant (g)	Mean	94.50	59.20	62.70	107.20	68.90	64.30	141.60	65.70	46.40
	Low	33.20	12.20	30.20	43.20	9.30	16.30	M	G	G x M
	High	193.2	121.40	95.80	220.80	147.30	95.60	32.91	19.23	27.19

** M, G and G x M indicate moisture regimes, genotypes and genotypes x moisture regimes interaction, respectively.

* TI = drought tolerance index = (Absolute value under stress/ Absolute value under control) X 100

minimal reduction in grain yield under water stress of only 4.2 and 4.4 % for DTP-1 and DTP-2, respectively.

Average ears/plant was insignificantly decreased because of water stress to 83.97, 85.9 and 84.6 % of the control for S_1's of DTP-1, DTP-2 and tester, respectively. Maximum reductions in ears/plant reached in some S_1's of DTP-1 and DTP-2 to 33.3 and 37.5 %, respectively. On the other hand, ears/plant in some S_1's was insignificantly increased due to water stress by 10 and 20 % for some S_1's DTP-1 and DTP-2 groups, respectively.

On average, insignificant reduction in rows/ear because of drought stress was 4.6 and 10.3 % for S_1's of DTP-1 and DTP-2, respectively. While the S_1 inbred of Cairo-1 did not exhibit any change for rows/ear due to water stress. Maximum reduction in rows/ear because of drought reached in some S_1's to 42.9 % for both DTP-1 and DTP-2 groups. On the other hand, some S_1's of DTP-1 and DTP-2 exhibited increases in rows/ear due to water stress of 8.7 and 15.8 %, respectively.

Average kernels/row was significantly reduced under water stress by 20.1, 22.5 and 23.9 % for S_1's of DTP-1, DTP-2 and Cairo-1, respectively as compared to control. Some S_1's of DTP-1 and DTP-2 showed maximum reduction in kernels/row of 58.9 and 61.9 %, respectively. On the other hand, few S_1 families from DTP-1 alone exhibited increases in kernels/row of up to 18.2%.

Average 100-kernel weight was significantly reduced under water stress by 31.9, 18.4 and 28.7 % from control for S_1's of DTP-1, DTP-2 and Cairo-1, respectively. Maximum reduction in 100-kernel weight for some S_1's of DTP-1 and DTP-2 reached 49.2 and 57.0 %, respectively. Some S_1 families in DTP-2 showed a slight increase of 7.0 % in 100-kernel weight.

The previous results indicate that reduction in yield of S_1 lines due to water stress was generally accompanied by losses in yield components i.e.in ears/plant, rows/ear, kernels/row and 100-kernel weight, but significant losses were only observed in kernels/row and 100-kernel weight. Reduction in each yield component, separately, was not as high as reduction in grain yield/plant. Our results are consistent with those reported by France and Turelle (1953), Classen and Shaw (1970), Kaul *et al* (1972), El-Yazal (1976), El-Zeiny and Kortam (1983) and El-Sayed (1988).

On average, a significant reduction of 35.3 and 35.5 % in grain yield/plant was observed for DTP-1 and DTP-2 testcrosses, respectively due to water stress (Table 3). Some testcrosses of DTP-1 and DTP-2 groups showed maximum reduction in grain yield of 71.9 and 70.4 %, respectively due to drought stress conditions. On the other hand, some testcrosses showed minimum reductions in grain yield of only 2.7 and 7.9 % due to stress for DTP-1 and DTP-2 groups, respectively.

Average kernels/row, was significantly decreased under stress by 19.2 and 23.8 % from the control for DTP-1 and DTP-2 testcrosses, respectively. Some DTP-1 and DTP-2 testcrosses exhibited maximum reductions in kernels/row of 43.8 and 51.9 % due to water stress. In contrast, some other testcrosses exhibited increases in kernels/row under stress conditions than in control of 12.3 and 3.9 % for DTP-1 and DTP-2, respectively.

Average significant reductions of 15.5 and 17.6 % in 100-kernel weight occurred due to water stress in DTP-1 and DTP-2 testcrosses, respectively. Some testcrosses of DTP-1 and DTP-2 exhibited maximum reduction in 100-kernel weight of 42.1 and 47.4 %, respectively due to water stress as compared to non-stress conditions. In contrast, some

Table 3. Mean performance, lower and upper range limits and drought tolerance index (TI) of DTP-1 and DTP-2 testcrosses for all studied traits in 1998 season.

Traits		Testcrosses						L.S.D (0.05)		
		DTP-1 x Cairo-1			DTP-2 x Cairo-1					
		Control	Stress	TI	Control	Stress	TI	M	G	G x M*
Ears/ plant	Mean	1.4	1.1	82.6	1.4	1.1	79.7			
	Low	1.0	1.0	63.7	1.0	1.0	68.6			
	High	1.7	1.6	114.2	1.9	1.3	121.3	-	0.25	0.35
Rows/ ear	Mean	13.6	13.2	97.1	13.4	12.7	94.8			
	Low	12.0	11.0	82.6	12.0	10.3	83.3			
	High	14.9	15.6	113.9	16.3	14.7	107.7	-	1.61	2.25
Kernels/ row	Mean	32.6	26.4	80.8	33.3	25.4	76.2			
	Low	24.9	20.0	56.2	25.9	18.5	48.1			
	High	38.5	36.3	112.3	38.9	35.0	103.9	1.52	4.53	6.41
100-Kernels wt. (g)	Mean	35.6	30.1	84.5	36.7	30.3	82.4			
	Low	29.0	21.0	57.9	31.0	20.5	52.6			
	High	42.0	38.0	103.0	43.5	39.0	100.0	3.30	3.82	5.41
Grain yield/ plant (g)	Mean	132.8	86.0	64.7	142.8	92.3	64.5			
	Low	97.4	43.2	28.1	112.7	34.4	29.6			
	High	185.4	132.4	97.3	210.6	194.0	92.1	32.91	19.23	27.19

* M, G and G x M indicates moisture regimes, genotypes and genotypes x moisture regimes interaction, respectively.

testcrosses in DTP-1 groups exhibited an increase of 3.0 % in 100-kernel weight due to water stress treatment.

Average reduction in yield in both groups of testcrosses due to water stress conditions was accompanied by average reductions in all yield components i.e. ears/plant, rows/ear, kernels/row and 100-kernel weight, although average reduction in each yield component was not as much as reduction in grain yield. Highest reductions occurred in kernels/row and lowest reductions in rows/ear. These results are consistent with several authors (France and Turrelle 1953, Classen and Shaw 1970, Kaul *et al* 1972, El-Yazal 1976, El-Zeiny and Kortam 1983 and El-Sayed 1998), who found that water stress at flowering stage caused significant reductions in yield and its components, with a higher reduction in yield than in each yield component separately.

Heterobeltiosis

Average estimates of heterobeltiosis % (% heterosis over the better *parent) of testcrosses of* S_1 *lines to the Cairo-1 inbred tester are presented in* Table (4).

Table 4. Average, range and % of significant positive cases (SPC) of heterobeltiosis in testcrosses of S_1 lines of DTP-1 and DTP-2 populations.

Traits		DTP-1 testcrosses		DTP-2 testcrosses	
		Non-stressed Control	Stressed	Non-stressed Control	Stressed
Ears/plant	Average	0.32	-0.34	2.14	-3.60
	Range	(-30.0)**-30.8**	(-16.7)-45.5**	(-12.7)-35.2**	(-16.7)-16.2
	SPC %	9.1	5.0	4.5	0.0
Rows/ear	Average	-1.01	-3.2*	0.89	-0.59
	Range	(-19.5)*-14.2	(-18.5)*-7.4	(-11.8)-14.9	(-23.5)**-8.6
	SPC %	0.0	0.0	0.0	0.0
Kernels/row	Average	-0.54	3.54	0.35	-2.72
	Range	(-32.8)**-18.3	(-19.2)-46.6**	(-25.2)**-19.8*	(-40.0)**-38.2**
	SPC %	0.0	9.1	5.0	14.3
100-Kernels wt.	Average	-10.97**	3.68	-8.10**	2.86
	Range	(-23.8)**-5.0	(-27.5)**-26.3**	(-22.5)**-8.8	(-28.1)**-28.8**
	SPC %	0.0	33.3	0.0	25.0
Grain yield	Average	-7.6**	19.99**	-2.3	19.00**
	Range	(-46.3)**-21.6*	(-45.7)**-101.4**	(-99.2)**-63.1**	(-74.0)**-78.1**
	SPC %	8.3	27.8	14.3	40.0

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

Under water stress conditions, significant estimates of positive heterobeltiosis were observed for grain yield/plant (19.99 %) for DTP-1 testcrosses. In contrast, significant negative heterobeltiosis (unfavorable) was observed for rows/ear (-3.2 %). On the other hand, DTP-2 testcrosses under stress showed, on average, significant positive heterobeltiosis estimate for grain yield/plant (19.0 %). In general, there was a directional increase in the magnitude of heterobeltiosis estimates due to water stress as compared to control conditions. This observation was shown in both DTP-1 and DTP-2 testcrosses. Our results are consistent with those reported by Younis *et al* (1988) who found that heterosis increased under drought stress. Average heterobeltiosis in yield the present experiment considerably increased from control to stress conditions (from –7.6 to 19.99 % for DTP-1 testcrosses and from –2.3 to 19.0 % for DTP-2 testcrosses, respectively).

Variation in heterotic response in crosses among S_1 testecrosses as measured by the magnitude of the range in heterobeltiosis estimates and the relative frequency of testcrosses showing significantly favorable positive or negative estimates is presented in Table (4). Under control treatment DTP-1 testcrosses exhibited wider heterobeltiosis ranges than under stress for rows/ear trait. On the other hand, DTP-1 testcrosses showed wider heterobeltiosis ranges under stress than under non-stress conditions for ears/plant, kernels/row, 100-kernel weight and grain yield/plant traits, with the widest ranges for grain yield/plant. For DTP-2 testcrosses, wider heterobeltiosis ranges were recorded for ears/plant and grain yield/plant under control than those under stress and for rows/ear, kernels/row and 100-kernel weight under stress than under control conditions, with the widest ranges observed for grain yield. Comparing DTP-1 with DTP-2 groups of testcrosses for their heterobeltiosis ranges, indicate that under control conditions DTP-1 had wider ranges of heterobeltiosis than DTP-2 group for ears/plant, rows/ear and kernels/row, while for DTP-2 the opposite was true for 100-kernel weight and grain yield/plant. Under water stress conditions, DTP-1 testcrosses showed wider heterobeltiosis ranges than DTP-2 for ears/plant, while DTP-2 testcrosses exhibited wider heterobeltiosis ranges than DTP-1 crosses for the remaining tested traits.

Relative frequencies (%) of testcrosses showing significant favorable heterobeltiosis estimates (Table 4) were generally higher under stressed than non-stressed conditions for all traits in both DTP-1 and DTP-2 groups of testcrosses, except for ears/plant, where the opposite was true. Under stressed conditions, the frequency (%) of favorable heterobeltiosis estimates was higher in DTP-2 than in DTP-1 for kernels/row and grain yield/plant, while these estimates were higher in DTP-1 than in DTP-2 for ears/plant and 100-kernel weight. Our results suggested that frequency of favorable heterobeltiosis estimates for grain yield/plant and its components increased under water stress than those under non-stress conditions. Similar results were observed by Younis *et al* (1988).

The presence of positive and negative heterobeltiosis estimates suggests that both DTP-1 and DTP-2 populations accumulated more favorable genes for productivity under water stress and indicate that these populations (DTP-1 and DTP-2) are genetically diverse from Cairo-1 tester. Falconer (1981) pointed out that if crossed populations do not differ in gene frequencies there will be no heterosis. Hallauer and Miranda (1988), also stated that abundant heterosis manifested in a cross of two populations leads to the conclusion that the parental varieties are more genetically diverse than varieties that manifested little or no heterosis. Sharma and Bhalla (1991) suggested that crosses among inbred lines which performed well and showed high heterosis for grain yield could be exploited directly as hybrid cultivars or their inbreds could be used to produce drought tolerant composites.

Combining ability effects

Specific combining ability (SCA) effects were calculated as the deviation of the mean performance of each testcross from the mean performance of all testcrosses which belong to a certain population (Singh and Narayanan 2000), in our case either DTP-1 or DTP-2 populations. The tester used in this study is an S_1 inbred derived from the local open-pollinated cultivar Cairo-1. This population was found, in a previous study (El-Sayed 1998) to be susceptible to drought stress. Using susceptible testers is desirable for determining combining ability for tolerance to respective stress (Russell 1961, El-Itriby *et al* 1990 and Al-Naggar *et al* 1997). Therefore, in this study the S_1 inbred of Cairo-1 which is susceptible to drought stress was used to differentiate among S_1's of DTP-1 and DTP-2 populations (drought tolerant populations) in their combining ability for drought tolerance. The S_1 inbred tester is also believed to be able to determine both specific (SCA) and general (GCA) combining abilities of the S_1 families of DTP-1 and DTP-2. This belief is based on the fact that the S_1 inbred has only 0.5 inbreeding coefficient and on the general consensus that an inbred tester has the ability to disclose the general (GCA) as well as specific (SCA) combining ability of a group of genotypes (Horner *et al* 1973, Walejko and Russell 1977, Zambezi *et al* 1986 and Al-Naggar *et al* 1997).

Data on combining ability effects of testcrosses between S_1's (of DTP-1 and DTP-2 populations) and the S_1 inbred tester of Cairo-1 are summarized in Table (5). Ranges of combining ability effects differed among the studied traits, among the two moisture regimes and among the two groups of S_1's (i.e. among DTP-1 and DTP-2 groups of testcrosses). Widest ranges of combining ability effects were shown by grain yield/plant. In contrast, narrowest range of combining ability effects were exhibited by ears/plant followed by rows/ear. In general, grain yield and most yield components showed wider ranges of combining ability effects under water stress than under non-stress conditions. This effect on combining ability ranges was more pronounced in the grain yield of DTP-2 testcrosses under stress than under non-stress conditions.

Table 5. Combining ability effects of testcrosses of maize S_1 lines of DTP-1 and DTP-2 populations and the S_1 inbred tester from Cairo-1 in 1998 season.

Traits		DTP-1 testcrosses		DTP-2 testcrosses	
		Non-stressed Control	Stressed	Non-stressed Control	Stressed
Ears/plant	Range	(-0.4)-0.3	(-0.1)-0.5	(-0.4)-0.5	(-0.1)-0.2
	% Pos. effects*	8.33	8.33	8.57	0.00
	% Neg. effects	11.11	0.00	17.14	0.00
Rows/ear	Range	(-1.6)-1.3	(-2.2)-2.4	(-1.4)-2.9	(-2.4)-2.0
	% Pos. effects	2.80	2.80	11.43	8.57
	% Neg. effects	5.60	5.60	0.00	5.71
Kernels/row	Range	(-7.7)-5.7	(-6.4)-9.9	(-7.4)-5.6	(-6.9)-9.6
	% Pos. effects	8.33	8.33	5.71	20.00
	% Neg. effects	5.60	19.44	5.71	17.14
100-Kernels wt.	Range	(-6.6)-7.4	(-9.1)-7.9	(-5.7)-6.8	(-9.8)-8.7
	% Pos. effects	13.90	25.00	8.57	28.57
	% Neg. effects	11.11	22.22	5.71	14.29
Grain yield	Range	(-35.4)-52.6	(-42.8)-46.4	(-30.1)-67.8	(-57.9)-101.7
	% Pos. effects	11.1	22.20	22.9	25.7
	% Neg. effects	25.0	22.20	28.6	22.9

* indicates relative frequencies of testcrosses showing significant positive and negative combining ability effects.

The frequency (%) of significantly positive (favorable) combining ability effects (Table 5) for grain yield was 11.1 % and 22.9 % under control, and increased to 22.2 % and 25.7 % under stress for S_1's of DTP-1 and DTP-2 populations, respectively. This indicates that selection of superior lines with high general combining ability for grain yield under stress (for drought tolerance) may be effective in DTP-1 and DTP-2 populations. Selection of superior hybrid combinations between some superior S_1's of either DTP-1 or DTP-2 origin of high specific combining ability for drought tolerance and the S_1 inbred of Cairo-1 origin may also be effective. The high estimates of heterosis previously reported (Table 4) between S_1's from DTP-1 or DTP-2 and S_1 inbred from Cairo-1 for grain yield under water stress conditions also confirms the genetic divergence between Cairo-1 and each of DTP-1 and DTP-2. A reciprocal recurrent selection program may also be effective using these populations in order to isolate superior inbred lines with superior specific combining ability for productivity under water stress conditions.

Heritability

Broad-sense heritability estimates (Table 6) under control ranged from 14.1 % for rows/ear to 80.3 % for grain yield in the DTP-1, from 17.0 % for rows/ear to 85.0 % for grain yield in the DTP-2 and from 16.8 % for rows/ear to 83.5 % for grain yield when data were combined over populations.

Table 6. Estimates of heritability (%) in the broad sense for studied traits under control and drought stress for S_1 testcrosses of DTP-1 and DTP-2 populations in 1998 season.

Trait	DTP-1 testcross		DTP-2 testcross		All testcross	
	Control	Stress	Control	Stress	Control	Stress
Ears/plant	33.3	50.0	40.0	50.0	35.0	50.0
Rows/ear	14.1	54.0	17.0	57.0	16.8	55.5
Kernels/row	51.0	65.2	36.4	76.8	45.0	71.5
100-Kernel wt.	69.0	81.5	62.3	80.1	67.0	81.0
Grain yield/plant	80.3	84.8	85.0	92.0	83.5	89.6

Under water stress, heritability ranged from 50.0 % (ears/plant) to 84.8 % (grain yield), from 0.0 % (ears/plant) to 92.0 % (grain yield) and from 25.0 % (ears/plant) to 89.6 % (grain yield/plant) for DTP-1, DTP-2 and overall populations, respectively. The largest heritability estimates under stress were reported by grain yield /plant followed by 100-kernel weight and then kernels/row in DTP-1, DTP-2 and overall populations.

All studied traits showed larger heritability estimates under stress than their respective estimates under control in DTP-1, DTP-2 and over populations. Similar to our results, some investigators found that the component of genetic variance and consequently heritability estimates were increased in stress environments (Russell 1969, Stuber and Moll 1997, Troyer and Rosenbrook 1983 and Bolanos and Edmeades 1996). In contrast, other researchers reported decreases in the magnitude of genetic variance and heritabilities under stressed environments (Frey 1964, Subandi and Copton 1974, Blum 1988 and Asay and Johnson 1990).

Predicted selection gain

In the present study the expected genetic advance was calculated for direct selection using a 10 % selection intensity (Table 7).

Table 7. Genetic advance (%) from direct selection under stress and non-stress conditions for DTP-1, DTP-2 and overall populations, 1998 season.

Genotypes	Ears/ plant	Rows/ ear	Kernels/ row	1000-kernel wt.	Grain yield/ plant
		Control			
All populations	12.46	7.22	11.79	14.43	32.03
DTP-1	11.73	6.51	12.49	14.61	26.63
DTP-2	13.65	7.22	10.60	13.90	32.38
		Stress			
All testcrosses	17.32	13.02	29.57	23.76	54.60
DTP-1	16.94	12.85	21.38	25.63	45.34
DTP-2	18.43	13.20	30.98	23.49	60.83

Under water stress conditions predicted genetic advance from direct selection was higher than that under non-stress conditions in ears/plant , rows/ear, kernels/row, 100-kernel weight and grain yield overall populations; in ears/plant, rows/ear, kernels/row, 100-kernel weight and grain yield for DTP-1 and in ears/plant, rows/ear, kernels/row, 100-kernel weight and grain yield for DTP-2 population. Selection gain under stress was approximately three fold greater for kernels/row and two folds greater for grain yield/plant than non-stress environment. Maximum selection gain was predicted to occur in grain yield and in the DTP-2 population. The reason for that could be ascribed to the higher heritability estimates under stressed environment than heritability under optimum environment (Table 6), resulting in higher predicted gain from selection under stressfull than under optimal conditions.

Different opinions were reported in the literature regarding the best environment for enhancing predicted selection gain. Frey (1964) and Allen *et al* (1978) concluded that selection without stress would optimize gain, since heritabilities were greater under those conditions than under stress. On the contrary, some researchers found that heritability and consequently selection gain increased in stressful environments (Russell 1969, Stuper and Moll 1977 and Troyer and Rosenbrook 1983). Our results are in favor of the second strategy.

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مدلولات وراثية لتحمل الجفاف فى سلالات الذرة فى جيل الإخصاب الذاتى الأول وهجنها القمية

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تم فى عام ١٩٩٧ تركيب ٧١ هجين قمى بين ٧١ سلالة جيل اول ذاتى (S_1) من الذرة الشامية المستنبطة من عشيرتين متحملتين للجفاف مع سلالة جيل ذاتى اول مستنبطة من العشيرة المحلية "قاهرة-١" الحساسة للجفاف. وفى موسم ١٩٩٨ تم تقييم السلالة الذاتية والهجن والمختبر فى حقل محطة التجارب الزراعية بكلية الزراعة-جامعة القاهرة بالجيزة. كان الهدف هو دراسة الأداء، والقدرة على الائتلاف وقوة الهجين ودرجة التوريث والعائد المتوقع من الانتخاب فى سلالات الـ (S_1) والهجن الاختبارية تحت ظروف الجفاف (أثناء فترة التزهير) وظروف الرى الكامل (الكنترول).

بصفة عامة كانت قوة الهجين بالنسبة للأب الأحسن تحت ظروف التقسية أعلى منها تحت ظروف الكنترول. وبالنسبة لمحصول الحبوب للنبات تم الحصول على أعلى متوسط لقوة الهجين الموجبة والمعنوية بالنسبة للأب الأحسن (٢٠ % فى العشيرة DTP-1 و ١٩,٠ % فى العشيرة DTP-2). وتحت ظروف الجفاف تميزت صفة المحصول كما تميزت العشيرة DTP-2 عن العشيرة DTP-1 من حيث إظهار أوسع مدى وأعلى تكرار للهجن الاختبارية التى بها قوة هجين بالنسبة للأب الأحسن. أشار تحليل القدرة على الائتلاف الى أنه من الممكن انتخاب سلالات تربية داخلية متفوقة فى قدرتها الائتلافية العامة والخاصة مع المختبر . كانت درجة التوريث بمعناها العام تحت ظروف الجفاف أعلى منها تحت ظروف الرى الكامل بالنسبة لكل الصفات المدروسة حيث سجلت أعلى قيمة بالنسبة لمحصول الحبوب فى كلا العشيرتين (٨٤,٨ % فى الـ DTP-1 و ٩٢ % فى الـ DTP-2).

كان التحسين الوراثى المتوقع من الانتخاب المباشر تحت ظروف الجفاف أعلى منه تحت ظروف الرى الكامل فى محصول الحبوب ومكوناته لكلا العشيرتين. فقد وصل هذا التحسين المتوقع فى المحصول إلى ٥٤,٣ و ٦٠,٨ % تحت ظروف الجفاف بينما كان ٢٦,٦ و ٣٢,٤ % تحت ظروف الرى الكامل بالنسبة للعشيرة DTP-1 والعشيرة DTP-2، على التوالى. تم الحصول على أعلى تحسين وراثى متوقع فى صفة المحصول عند مقارنته بالتحسين المتوقع فى مكونات المحصول كما أن العشيرة DTP-2 أعطت أعلى قيم تحسين متوقع مقارنة بالعشيرة DTP-1.

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