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DIRECT AND INDIRECT SELECTION UNDER SOME DROUGHT STRESS ENVIRONMENTS IN CORN (*Zea mays* L.)

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ABSTRACT

Sixteen white open pollinated populations of maize were evaluated in 1995 and 1996 season at Sids Agric. Res. Station of the ARC, Egypt under 5 soil moisture regimes (4 stressed and one non-stressed environments). The objectives were to: 1- identify maize traits strongly associated with yield under water stress to be used as selection criteria for reliable screening drought tolerant genotypes; 2- to estimate the heritability under different soil moisture regimes and 3- to compare these moisture regimes as evaluation environments based on expected genetic advance from direct and indirect selection.

Results suggested that the strogest association with absolute yield under drought stress environments was negative for days to 50% silking, anthesis to silking interval (ASI), leaf/air temperature and barren stalks (%). Moreover, such association was positive for ears/plant and kernels/row. Thus, these triats were considered as useful selection criteria for screening maize genotypes for their drought tolerance if phenotypic correlation reflects positive relationships at the genetic level.

Heritability estimates under drought stress environments for grain yield, number of kernels/row, leaf/air temperature and leaf rolling were lower but those for ASI, ears/plant and stay green traits were higher than those estimates under non-stressed environment.

The prediction gain from direct selection in either stress or non-stress environments was greater than that from indirect selection in either stress or non-stress environments for all studied traits (ASI, leaf rolling, leaf temperature, stay green, ears/plant and grain yield). Maximum genetic advance from direct selection for grain yield was obtained from the stressed environments at flowering stage.

Key words: Maize, corn, drought tolerance, selection criteria, moisture regimes, correlation, heritability, selection gain.

INTRODUCTION

In Egypt, irrigation water deficit is one of the most important problems facing the horizontal expansion of growing maize and other crops in the newly reclaimed lands, mostly exist in the desert. Growing maize under such sandy soil conditions, which normally has a low moisture helding capacity would expose the maize plants to drought stress. Maize breeders are therefore deeply involved during the last years, in attempts to improve high yielding cultures under drought stress environments (Edmeades *et al*., 1992). The problems have been the adoption of proper technique of selecting resistant genotypes to soil water stress and conducting an efficient breeding program to such a complicated character. This also requires determining which trait and which selection environment should be recommended to the maize breeder as most suitable for breeding for drought tolerance.

Many investigators studied the correlations between yield and other plant attributes under soil moisture stress in order to determine rapid and accurate indirect slection criteria for drought tolerance. A strong negative association was reported under drought stress between grain yield and each of anthesis-silking inverval (Bolanos and Edmeades, 1993) barren stalks(Edmeades *et al*., 1993) leaf temperature (Fischer *et al*., 1989) and leaf rolling (Saneoka *et al*.,1996). While strong positive association was found between grain yield and each of the number of ears/plant (Guei and Wassom, 1992, Terrazas *et al*., 1995 and Ribaut *et al*., 1997) and number of kernels/row (Weerathaworn *et al*., 1992) and Ribaut *et al*. (1997). These investigators suggested that mentioned traits could be used as indicators of drought tolerance in a population.

Choosing the optimal environment in which to achieve maximum genetic gain is an important factor for crop breaders. Falconer (1989) and Allen *et al*. (1978) concluded that the heritability of yield and the genetic correlation between the yield in the selection and target environments could be used to identify the best environment that would optimize correlated response. Some researchers found that genetic variance components and heritability were increased in drought stressed environment (Troyer and Rosenbrook, 1983, Bolanos and Edmeades, 1996 and Ribaut *et al*., 1997). In contrast, Blum (1988) and Asay and Johnson (1990) reported decreases in genetic variance magnitudes and heritabilities under stress environments.

Two contrasting strategies in the literature for identifying genotypes that will be of high yielding under drought: (1) Genotypes may be evaluated under the conditions they will ultimately produced namely, a certain type of drought stress. (2) Genotypes may be evaluated under optimum conditions maximizing heritability. Johnson and Geadelmann (1989) reported that gain from selection was superior when evaluated in favorable conditions. However, Arboleda-Rivera and Compton (1974) and Martinez-Barajas *et al*. (1992), found that progress from selection for high yield under well-watered conditions was greatly reduced under crop water deficit.

The objectives of the present study were: 1- to identify the maize characters strongly associated with yield under water stress in order to be used as relation criteria for a reliable selection for drought tolerance; 2- to estimate heritability under different soil moisture regimes and 3- to compare these moisture regimes as evaluation environments based on expected genetic advance from direct and indirect selection.

MATERIALS AND METHODS

Two field experiments were carried out at Sids Agricultural Research Station, Agric. Res. Center (ARC), Egypt, during 1995 and 1996 seasons.

A total of 16 white maize populations (15 exotics and 3 locals) were chosen to represent wide differences in their genetic background,characteristics related to drought tolerance and origin (Table 1).

Table (1): Name, Symbol and origin of the 16 populations used.

Name	Symbol	Origin	Name	Symbol	Origin
1- Weekley Prolific	WP	USA	9- Mexican Junes	MJ	India
2-American ite Flint	AWF	Spain	10- White Dwarf Compositi	WDC	India
3- Maiskaning	Mai	Germany	11- Adramet Skaja Beloja	ASB	Russia
4- Bianca Peria	BP	Italy	12- Pirsabak	Pir	Pakistan
5- South Africa	SA	South Africa	13- Giza -2	G2	Egypt
6- Missouri	Mis	USA	14-American Early Dent	AED	Egypt
7- Kitale Synthetic	KS	Kenya	15- Tepalcinqo-5	TPS	Mexico
8- Synthetic La Posta	SLP	Mexico	16- Cairo -1	C-1	Egypt

In both seasons, the preceding crop was wheat and the kernels were planted in hills spacied 25 cm. on the 15th of June. The soil of the experimental field was clay which contained about 46% clay, 32% silt, 21% fine sand and 1% corse sand (according to the analysis done by Soil and Water Res. Inst. ARC, Egypt). Average temperature at Sids Station in July, August, September and October was 30.7, 29.8 , 29.0 and 25.2 in 1995 and 30.3, 30.5, 29.8 and 24.8 in 1996, respectively (according to Meteorology and Climate Res. Sec., Soil and Water Res. Inst., ARC, Egypt).

A split plot design with three replications was used, where main plots were devoted to the 5 water stress treatments (Table 2), meanwhile the 18 populations were randomly distributed at the sub ones. Each sub-plot consisted of 4 ridges, 6 m long and 70 cm apart. Ten guarded plants grown in the two inner rides were used for collecting data. All agricultural practices were carried out as recommended.

Ten guarded plants from the two inner ridges of each plot were used for data collection. The measured fourteen traits were:

1- Days to 50% silking.
2- Anthesis to silking interval (ASI)
3- Plant height,(P.H.), cm.
4- Ear height (E.H.), cm.
5- Leaf area (L.A.), cm, according to Francis *et al*., (1969).
6- Leaf rolling (L.R.), scores according to O'Toole and Maya (1978).
7- Leaf/air temperature ratio (LAT) by using infrared thermometer.
8- Percentage of barren plants (B/P %).
9- Stay green (SG) soon after physiological maturity, using a scale from 1 to 5, where 5 is completely green and 1 is completely dry.
10- Number of ears per 100 plant, (E/100P).
11- Number of rows/ear (R/E).
12- Number of kernels/rows (K/R).

13- Weight of 100 kernels, gm. (100-KW).
14- Grain yield per plant percentages was estimated by converting grain yield per plot adjusted to 15.5%.

Table (2) : Soil moisture regimes, symbol, skipped irrigation stage of irrigation prevention and days of irrigation prevention.

Soil moisture regime	Symbol	Skipped irrigation	Stage of irrigation prevention	Days of prevention
1- Well watering	WW	None	None	36
2- Before flowering	BF	The 3rd and 4^{th}	Late vegetative growth & early Flowering	36
3- At flowering	FS	The 4th and 5^{th}	Flowering	36
4- After flowering	AF	The 6th and after to harvest	Grain filling	51
5- Severe stress	SS	The 5th and after to harvest	Flowering and grain filling	63

Statistical analysis:

Separate analysis of variance of split-plot design for each season were carried out for all studied traits according to Snedecor and Cochran (1981).

I- Correlations:

Simple correlation coefficients (r) were calculated between GY/P and each of the other studied characters.

II- Heritability:

The expected mean squares (EMS) shown in Table (3) were used to estimate the genetic (σ^2_g) and genetic x year interaction (σ^2_{gy}) variances as follows:

$$\sigma^2_g = \frac{M3-M2}{ry}$$

$$\sigma^2_{gy} = \frac{M2-M1}{r}$$

where, r = number of replicates and y = number of years

The phenotypic variance (σ_{ph}) was estimated as follows :

$$\sigma^2_{ph} = (\sigma^2_g/ + \frac{\sigma^2_{gy}}{r} + \frac{\sigma^2_e}{ry}$$

Heritability in the broad sense (h^2_b) was estimated using the following formula:

$$h^2_p = (\sigma^2_g/\sigma^2_{ph}) \times 100$$

Table (3) : Expected mean squares (E.M.S) of the combined analysis of variance accross 2 years.

S.O.V.	D.F.	M.S.	E.M.S.
Years (Y)	y-1 = 1		
Years/rep's	Y(r-1) = 4		
Population (P)	(p-1) = 15	M_3	$\sigma^2_e + r\sigma^2_{gy} + ry\sigma^2_g$
P x Y	(p-1) (y-1) = 15	M_2	$\sigma^2_e + r\sigma^2_{gy}$
Pooled error	Y(r-1)(p-1) = 60	M_1	σ^2_e

III- Genetic advance (GA):

a- For direct selection:

Genetic advance (GA) for direct selection for anthesis silking interval, leaf rolling, leaf to ear temperature ratio, stay green and grain yield was calculated according to Becker (1984) as follows:

$GA = 100\ iH^{1/2}\ \sigma^2_{ph}/x$, where

x = general mean of the appropriate moisture regime.

σ_{ph} = square root of the denominator of the appropriate heritability under moisture regime.

$H^{1/2}$ = square root of the applied heritability

i = selection intensity (K value corresponding to the percentage selected, 10%) = 1.76.

b-For indirect selection :

Genetic correlations (r_g) among moisture regimes for each trait were first calculated from variances and covariance as follows:

$r_g = \sigma_{jk} / (\sigma_j\ \sigma_k)$

where σ_{jk} is the genetic covariance between moisture regimes j and k σ_j and σ_k are the genetic standard deviations of moisture regimes j and k, respectively.

Correlated response (CR) in moisture regime j from selection in moisture regime k was then estimated according to Falconer (1981) as follows:

$CR_j = 100\ H_i^{1/2}\ H_k^{1/2}\ r_{gik}\ \sigma_{ph}/x_j$, where

$H^{1/2}{}_j$ and $H^{1/5}{}_k$ = square roots of heritabilities of moisture regimes j and k, respectively.

r_{gjk} = genetic correlations among moisture regimes j and k,respectively.

CR_j = correlated response in moisture regime j.

X_j = general mean of moisture regime j.

RESULTS AND DISCUSSION

Combined analysis of variance over years showed that highly significant differences existed among the 16 populations and the 5 soil moisture regimes for all studied 14 traits.

Population x years, populations x moisture regimes, moisture regimes x years and populations x moisture regimes x years interactions were significant or highly significant for all studied traits, except moisture regimens x years interaction for ear height, ears/plant, rows/ear and 100-kernel weight, population x years interaction for days to 50% silking, ASI, ear height and leaf temperature , population x moisture regimes interaction for leaf temperature and population x moisture regimes x yers interaction for days to 50% silking ASI, plant and ear height and leaf area, which were insignificant.

Correlations :

Estimates of simple correlation coefficients between studied traits and yield across all genotypes and averaged over locations are given in Table (4). In general, grain yield/plant was negatively associated with number of days to 50% silking, anthesis-silking interval (ASI), percentage of barren stalks, leaf rolling and leaf air temperature and positively associated with plant and ear heights, leaf area, stay green, ears/plant rows/ear and 100-kernel weight under all soil moisture regimes.

It is obvious that though the signs of correlation under stress conditions remained as they were in WW, the values of WW were less in magnitude than those under stressed environments in most cases. Number of significant (r) values increased from 7 under WW to 10, 8, 10 and 10 in BF, FS, AF and SS treatments, respectively. These results are consistent with those reported by Ribaut *et al*. (1997).

Yield under water stressed conditions at BF, FS, AF and SS treatments was negatively correlated with the number of days to 50% silking (r=-0.281, -0.495, -0.603 and - 0.447, respectively). These negative relationships between grain yield and growth duration to 50% silking was also reported by other researchers (Blum *et al*., 1989 and Guei and Wassom, 1992). Blum *et al*., (1989) added that growth duration, as expressed by the number of days to flowering was well associated with plant production under drought stress (r=0.89). Early flowering genotypes had a pronounced advantage in grain yield as already established previously (Blum, 1970). The disadvantage of late flowering genotypes was in their greater stover production and presumably their large leaf area and water requirement (Blum and Arkin, 1984).

Significant netagive correlation coefficients were alo obtained between grain yield and the length of ASI under drought conditions at BF, FS, AF and SS moisture regimes (r=-0.365, -0.369, -0.406 and -0.242, respectively). Delayed silking due to drought stress which coincides with flowering, results in an increase in length of the ASI, (Bolanos and Edmeades, 1993). An increased ASI (or asynchrony) has usually been associated with reduction in grain yield (Classen and Show, 1970, Westgate and Boyer, 1986, Bolanos and Edmeades, 1993, Edmeades et al. 1993, Bolanos and Edmeades 1996). This is not surprising, since the establishment of final kernel number occurs in a 2 weeks period following flowering (Claassen and Shaw, 1970). Terrazas et al. (1995) suggested that ASI and prolificacy index could be used as indicators of drought tolerance in a population.

Table (4): Simple correlation coefficients between GY/P (gm) and each of the studied traits under the 5 soil moisture regimes (data are combined over 1995 and 1996 seasons).

Traits	Unstressed	Stressed at			
	WW	BF	FS	AF	SS
1- Days to 50%	-0.468**	-0.281**	-0.495**	-0.603**	-0.447**
	-0.126	-0.365**	-0.369**	-0.406**	-0.242*
2- ASI, days	0.337**	0.350**	0.316**	0.033	0.321**
3- Plant	0.006	0.206*	0.179	0.246*	0.109
n	0.151	0.598**	0.55	0.129	0.258*
4- Ear	-0.100	-0.349**	-0.331**	-0.261*	-0.170
n	-0.233*	-0.326**	-0.365**	-0.234*	-0.267**
5- Leaf	-0.473**	-0.513**	-0.518**	-0.331**	-0.681**
	0.297**	0.035	0.170	-0.267**	-0.162
6- Leaf rolling	0.627**	0.660**	0.869**	0.074**	0.818**
7- Leaf/air	0.062	0.287**	0.100	0.029	0.334*
	0.408**	0.417**	0.396**	0.526**	0.420**
8- Barren	0.169	0.133	0.196	0.310**	0.240*
9- Stay green					
10- Ears/100					
11- Rose/ear					
12- Kernels/row					
13- 100-kernel weight,gm					

N = 96 * and ** indicate significance at 0.05 and 0.01 levels of probability, respectively

Under stress correlations between plant height and grain yield were positive and significant (r = 0.350, 0.316 and 0.321 at BF, FS and SS conditions, respectively). Final plant height may be taken as a simple integrated measure of growth response to stress. Blum et al (1989) also reported that plant height under drought stress was found to be well associated with grain yield under stress. Growth response to stress in terms of plant height was also found to serve well as one component of multiple selection index for drought resistance in maize (Fischer et al., 1989). It is therefore probably that plant height as observed under stress conditions may serve as an additional criterion for stress response.

Correlation between grain yield and the degree of leaf rolling under water deficit was significant and negative at BF, FS and AF stress conditions (with r = -0.349, -0.331 and -0.261, respectively). Similar observations had been reported by Saneoka et al., (1996). They mentioned that degree of leaf rolling was smaller in drought tolerant cultivars which maintained a higher somatic adjustment under moderate and severe water stress treatments.

Leaf temperature under stress at BF, FS, AF and SS conditions exhibited significant negative association with grain yield (r = -0.326, -0.365, -0.234 and -0.267, respectively). Fischer et al. (1989) also reported highly significant negative correlation (r = -0.73) between canopy temperature and yield under severe moisture-deficits and suggested that leaf temperature might be used as important element in screening for drought resistance in a number of genotypes.

Percentage of barren stalks was negatively associated with grain yield under water deficit at BF, FS, AS and SS conditons with (r) values equal -0.513,-0.518, -0.331 and -0.681, respectively. High yield under stress of the drought tolerant population of maize “Tuxpeno Sequia” was associated with reduced barrenness (Edmeades et al. 1993).

Yield under drought stress conditions at BF, FS, AF and SS treatments was strongly and positively correlated with the number of ears/plant (r = 0.660, 0.869, 0.742 and 0.818, respectively). Similar positive correlation were reported by Biasutti and Peiretti (1992), Guei and Wassom (1992) , Terrazas et al. (1995) and Ribaut et al. (1997).

The association between grain yield and number of kernels/row under stress is significant and positive (r = 0.417, 0.396, 0.526 and 0.420 at BF, FS, AF and SS conditions, respectively). Number of rows/ear showed weak positive association with grain yield under stress at BF (r = 0.287) and SS (r =0.234) conditions only. Similar weak positive association was exhibited between grain yield and 100-kernel weight only under stress at AF (r = 0.310) and SS (r = 0.240).

Weerathaworn et al. (1992) reported also that reduction in grain yield resulted from pre-flowering water stress was associated by lowering in grain number and/or 1000/grain weight, but post-flowering stress mainly reduced 1000-grain weight. Also, results of Ribaut et al. (1997) confirmed that water stress before and during flowering affected mainly the kernel number and to a lesser extent the size of the kernels.

The present correlation studies indicated that under water stress the strongest association of grain yeild was with each of number of ears/plant, barren stalks and kernels/row (as yield component traits), days to 50 % silking, ASI (as phenological traits) and leaf temperature (as a physiological trait). It is therefore suggested that number of ears/plant, barren stalks, kernels/row, days to 50% silking, ASI and leaf temperature could be recommended as selection criteria for screening maize genotypes for their drought tolerance, if phenotypic correlations reflect similar trends at the genetic level. Fischer et al. (1989) used ASI, rate of leaf and stem extension as selection indices along with yield to improve drought tolerance in maize. The resulting drought tolerant population developed by them outyielded all others by 500 kg/ha under the severe treatment. Biasutti and Peiretti (1992) concluded that drought tolerance could be improved by selecting prolific genotypes with a lesser gap between pollen shade and silking, more grains/row and reduced ear leaf sensences. Moreover, Terrazas et al. (1995) suggested that ASI and the prolificacy index could be used as indicators of drought tolerance in a population.

Genetic variance and heritability:

Genetic variance (Table 5) for grain yield, 100 kernel weight and ear height decreased with increasing water stress, i.e. under all stressed environments, while that for ASI, ears/plant and percentage of barren stalks increased. Maximum values of genetic variance for days to 50% silking, ASI, leaf rolling, rows/ear and kernels/row were exhibited under severe stress, for plant height, leaf temperature and barren stalks under post-flowering stress, for stay green trait and ears/plant under flowering stress and for only leaf area under pre-flowering stress. However, maximum estimates of genetic variance for ear height, 100-kernel weight and grain yield were shown under optimum environment (control).

Broad-sense heritability estimates (Table 5) ranged from 13.8% for stay green trait to 98.5% for ear height under full irrigation (WW), from 5.8% for leaf temperature to 94.3% for ear height under stress at BF stage, from 6.7% for leaf rolling to 96.8% for ear height under stress at FS, from 7.3% for number of rows/ear to 96.9% for ear height under stress at AF stage and from 1.7 % for leaf temperature to 97.7% for ear height under severe stress (SS) conditions.

Table (5): Estimates of genetic variance (G.V.) and broad-sense heritability h^2_b % for studied traits at moisture regimes.

Traits	Genetic variance					Heritability (%)				
	Unstressed WW (control)	Stressed at				Unstressed WW (control)	Stressed at			
		F	FS	AF	SS		BF	FS	AF	SS
1- D-50%S	17.32	11.33	40.57	21.69	44.71	94.6	83.2	95.7	94.4	94.9
2-ASI	0.200	8.46	8.49	0.423	9.414	64.0	75.3	73.9	39.0	88.4
3-P.H.	650.15	444.46	520.69	819.44	689.40	96.6	94.3	96.8	96.6	97.7
4-E.H.	633.69	275.17	365.90	624.17	523.65	98.5	92.1	92.4	91.6	93.3
5-L.A.	938.24	1703.88	856.62	1686.43	630.80	45.7	44.1	61.4	84.1	54.2
6- L.R.	0.017	0.019	0.002	0.019	0.021	85.3	22.7	6.7	51.0	22.5
7-L.A.T.	0.204	0.118	0.497	0.910	0.050	40.4	5.8	15.9	32.2	1.7
8- B/P %	0.870	16.25	13.30	35.11	2.51	17.8	20.5	10.9	29.1	4.9
9-S.G.	0.010	0.01	0.02	0.001	0.002	13.8	12.1	58.7	14.2	58.8
10- E/100 P	22.07	136.28	137.73	109.13	71.08	50.7	72.4	68.1	41.0	70.0
11- R/E	1.960	0.28	0.96	0.16	2.09	81.1	12.5	55.9	7.3	82.7
12- K/R	3.190	1.77	3.99	0.66	11.64	71.4	16.3	42.9	11.7	43.5
13-100 KW	22.8	14.08	22.71	8.56	18.55	79.3	75.9	88.9	64.3	75.8
14-GY/fed.	13.27	6.32	4.91	2.92	2.46	89.9	78.8	84.2	44.0	85.6

Out of the 14 studied traits, broad-sense heritability estimates for 3, 7, 3, and 7 traits showed larger heritability estimates under stress at BF, FS, AF and SS, respectively than their respective estimates under control. Those traits were : ASI, barren stalks and ears/plant at BF, days to 50% silking, ASI, leaf area, stay green, ears/plant and 100-kernel weight at FS, leaf area, barren stalks and stay green at AF and days to 50% silking, ASI, plant height, leaf area, stray green, , ears/plant and rows/ear at SS conditions.

Maximum heritability estimates in the broad-sense were exhibited for ear height (98.5%), leaf rolling (85.3%), leaf temperature (40.4), kernels/row (71.4%) and grain yield (89.9%) under non-stressed conditions (WW), for only ears/plant (72.4%) under water stress at BF, for days to 50% silking (95.7%) and 100 kernels weight (88.9%) under stress at FS, for leaf area (84.1%) and barren stalks (29.1%) under stress at AF stage and for ASI (82.%) under severe water deficit. This would be helping in choosing the suitable environment for practicing selection programs to improve traits for better expression under a specific environment, especially those related to drought tolerance. For example, the best environment for maximizing the heritability of anthesis-silking interval would be under severe stress and that for maximizing heritability of ears/plant would be under stress at pre-flowering stage.

Heritability in broad-sense for grain yield, number of kernels/row, leaf temperature, leaf rolling decreased with increasing drought, but those for ASI, of ears/plant and stay green trait increased. Broad-sense heritability for grain yield was 89.9% at WW but fell to 78.8, 84.2, 44.0 and 85.6% under stress at BF, FS, AF and SS, respectively. Heritability for ASI was 64.0% at WW, but approached 75.3, 73.9 and 88.4% under moistrue stress at BF, FS and SS, respectively.

Similar to our results, some researchers found that the component of genetic variance and consequently heritability were increased in stressful environments. (Troyer and Rosenbrook, 1983), Ribaut et al. 1997, and Bolanos and Edmeades, 1996). In contrast, other investigators reported decreases in genetic variance magnitudes and heritabilities under stressed environments (Blum, 1988 and Asay and Johnson, 1990).

Predicted selection gain under different soil moisture environments:

The expected genetic advance for ASI, leaf rolling, leaf temperature, stay green, number of ears/plant and grain yield were calculated for direct and indirect selection using a 10% selection intensity (Table 6).

Genetic advance from direct selection in each moisture regime reached its maximum values under stressed environment at flowering stage (FS) for ASI (67.49%) stay green (18.09%), earl/plant (49.00%) and grain yield (76.02%), under stressed environment (control) did not exhibit any one of these maximum values of genetic advance from direct selection (Table 6). Predicted gain from indirect selection which incorporates both the heritability and the genetic correlation between the trait in different environments, could be used to identify the best selection environment based on its relative efficiency in that environment (Table 6). For all traits, the predicted gain from selection in each environment was greater than the predicted gain from indirect selection in another environment, as indicated by the relative efficiency values < 100% for all single environment in Table (6). It is therefore concluded that for all studied traits, the predicted gain from direct selection under stressed or non-stressed environment would improve the trait under consideration in a way better than the indirect selection. The direct selection under water stress environment would ensure the preservation of alleles for drought tolerance (Langer *et al*., 1979) and the direct selection under full irrigation regime would improve the maximum potential for a trait and would take advantage of the high heritability (Allen et al., 1978, Blum, 1988 and Braun *et al*., 1992).

Literature includes two contrasting strategies for identifying genotypes that will be high yielding under drought:

i- Genotypes may be evaluated under the conditions they will ultimately be produced, namely, a certain type of drought, to minimize the genotype x environment interaction.A drawback of this approach is that some traits that lower productivity under favorable conditions (Blum, 1988 and Ludlow and Muchow, 1990). Another potential limitation is that heritability of grain yield and thus the effectiveness of selection, is often reduced under moisture stress (Blum, 1988). Edmeades *et al*. (1992) reported that in maize this was not the case until yield fell below about 20% of its level under unstressed conditions.

ii- Genotypes may be evaluated under optimum conditions maximizing heritability. Johnson and Geadelmann (1989) reported that yield gains from selection under irrigation were equal to those from selection under drought stress when evaluated in stress conditions and that such gains were superior when evaluated in favorable conditions. Martinez-Barajas *et al*., (1992), however, found that progress from selection for high yield under well-watered conditions was greatly reduced under crop water deficit.

Table (6): Genetic advance from direct selection (i.e. selection environment same as response environment) and correlated genetic response for indirect selection (i.e. selection and responseenvironment differ) in some studied traits.Selection and response environment were different moisture regimes.

Treatment	ASI	Leaf rolling	Leaf temp.	Stage green	Ears/100 plants	Grain yield
Direct selection (R)						
WW	35.71	5.21	0.95	10.06	29.62	41.10
PF	67.40	6.66	0.63	9.45	34.70	67.78
FS	67.49	2.06	1.31	18.09	49.00	76.02
AF	45.81	8.99	1.71	3.19	25.70	36.07
SS	66.66	10.01	0.41	7.46	37.60	70.01
Indirect selection (CR)						
WW vs. BF	16.50	0.51	0.07	0.28	42.84	15.17
R.E.	(46.20)	(9.80)	(7.40)	(2.80)	(69.14)	(36.90)
BF vs.	28.70	1.26	0.13	0.27	43.25	26.73
WW	(42.60)	(18.90)	(20.60)	(2.90)	(80.23)	(39.40)
R.E.	22.10	1.13	0.34	1.08	41.53	6.94
WW vs. FS	(61.90)	(21.70)	(35.90)	(10.70)	(71.32)	(16.90)
R.E.	38.80	1.59	0.75	0.94	76.68	13.25
FS vs. WW	(57.50)	(77.20)	(57.30)	(5.20)	(63.90)	(17.40)
R.E.	14.70	1.30	0.22	0.54	32.22	17.78
WW vs.AF	(40.20)	(24.90)	(23.30)	(5.40)	(91.93)	(43.30)
R.E.	24.13	2.89	0.45	0.17	36.57	22.30
AF vs. WW	(52.70)	(32.20)	(26.30)	(5.30)	(70.28)	(61.80)
R.E.	1.79	1.30	0.04	0.81	42.13	21.68
WW vs. SS	(5.00)	(24.90)	(4.20)	(8.00)	(70.31)	(52.70)
R.E.	2.84	4.86	0.09	0.29	57.55	37.75
SS vs. WW	(4.30)	(48.50)	(22.10)	(3.90)	(65.33)	(53.90)
R.E.	24.08	1.12	0.03	2.72	50.12	9.93
BF vs. FS	(35.70)	(16.80)	(4.80)	(28.80)	(69.23)	(14.70)
R.E.	22.74	0.64	0.03	2.36	91.65	10.77
FS vs. BF	(33.70)	(31.10)	(2.30)	(13.00)	(53.46)	(14.20)
R.E.	5.44	0.70	0.10	1.09	38.88	27.11
BF vs. AF	(8.10)	(10.50)	(15.80)	(11.50)	(89.25)	(40.00)
R.E.	5.14	0.63	0.12	0.34	43.71	19.31
AF vs. BF	(11.20)	(7.00)	(7.00)	(10.70)	(58.80)	(53.60)
R.E.	10.88	2.45	0.03	6.52	50.85	12.98
BF vs. SS	(16.10)	(36.70)	(4.80)	(69.00)	(68.24)	(19.10)
R.E.	9.93	3.70	0.03	2.33	68.78	12.83
SS vs BF	(14.90)	(36.90)	(7.40)	(31.30)	(54.67)	(18.30)
R.E.	24.37	0.24	0.72	0.24	68.92	26.51
FS vs. AF	(36.10)	(11.70)	(55.00)	(1.30)	(71.10)	(34.90)
R.E.	22.77	0.38	0.66	0.08	42.37	17.40
AF vs. FS	(49.70)	(4.20)	(38.60)	(2.50)	(60.66)	(48.20)
R.E.	62.02	0.16	0.07	11.57	90.14	39.40
FS vs. SS	(91.90)	(7.90)	(5.40)	(64.00)	(54.36)	(51.80)

R.E.	56.01	0.42	0.06	4.76	66.68	35.90
SS vs. FS	(84.20)	(4.20)	(14.70)	(63.80)	(56.39)	(51.20)
R.E.	21.27	1.51	0.12	1.18	42.99	1.09
AF vs. SS	(46.40)	(16.80)	(7.00)	(37.00)	(59.78)	(3.00)
R.E.	20.56	2.53	0.12	1.36	51.73	1.51
SS vs. AF	(30.80)	(25.30)	(29.50)	(18.20)	(72.69)	(2.20)
R.E.						

Values in parentheses are the relative efficiencies (R.E) = R/CR x 100.

Our results are in favor of the first strategy in all cases. However, a third strategy, currently used at CIMMYT, which is simultaneous evaluation under near-optimum and drought condition, with selection of those genotypes that perform will in both environments (Calhoun *et al*., 1994 and Byrne *et al*., 1995). However, ultimate evaluation must be performed in the target environment prior to recommendation of a cultivar for commercial production.

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الانتخاب المباشر وغير المباشر تحت بيئات جفاف مختلفة فى الذرة الشامية

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أجريت تجربتان حقليتان بمحطة البحوث الزراعية ، مركز البحوث الزراعية, بناحية سدس ، خلال موسمى ١٩٩٥، ١٩٩٦ ، وذلك لدراسة المقاومة للجفاف على محصول الذرة الشامية ، حيث أختبرت ستة عشرة عشيرة نباتية (٣ محلية و١٣ مستوردة) تحت خمس معاملات من الاجهاد المائى : ١) الرى الكامل . ٢) الإجهاد المائى قبل التزهير. ٣) الإجهاد المائى أثناء التزهير. ٤) الإجهاد المائى بعد التزهير(.٥) الإجهاد الشديد فى مرحلتى التزهير وامتلاء الحبوب معا .

وأجريت التجارب فى تصميم القطع المنشقة بثلاث مكررات ، حيث خصصت القطع الرئيسية لمعاملات الاجهاد المائى ، فى حين وزعت العشائر عشوائيا فى القطع الفرعية. وفى الموسمين كان المحصول السابق قمحا ، وكانت الزراعة فى ١٥ يونية ، حيث نفذت جميع المعاملات الزراعية طبقا للتوصيات وتم قياس أربعة عشرة صفة وهى :

١- عدد الأيام من الزراعة وحتى ظهور ٥٠% من الحراير. ٢-عدد الأيام بين انتشار حبوب اللقاح وظهور الحراير.٣- إرتفاع النبات (سم) . ٤-إرتفاع الكوز (سم) . ٥- مساحة الورقة (سم٢). ٦- درجة التفاف الورقة ٧- درجة حرارة الورقة ٨-النسبة المئوية للنباتات الذكر ٩- البقاء أخضرا. ١٠- عدد الكيزان على النبات. ١١- عدد صفوف الكوز . ١٢- عدد حبوب الصف . ١٣ - وزن المائة حبة.

١٤- محصول الحبوب بالجرام للنبات وبالاردب للفدان.

وتم عمل التحليل الاحصائى فى كل موسم على حدة وعمل تحليل الاختلاف المجمع للموسمين وتم حساب معاملات الارتباط البسيط بين محصول النبات وبقية الصفات المدروسة وحساب التباين الوراثى ونسبة التوريث بمعناها العام ولجميع الصفات وحساب التقدم المتوقع من الانتخاب المباشر وغير المباشر تحت ظروف التقسية المختلفة للجفاف .

وفيما يلى ملخص لأهم النتائج :

١- كان الارتباط بين محصول النبات وكل من تاريخ خروج ٥٠% من الحراير والفترة بين انتشار حبوب اللقاح وخروج الحراير (ASI) والتفاف الاوراق ودرجة حرارة الورقة معنويا وسالبا فى جميع معاملات الاجهاد المائى الخمس . الا أن إرتباط المحصول مع باقى الصفات المدروسة كان معنويا وموجبا – ولقد ثبت أن إشارة معامل الارتباط (r) ظلت كما هى بصرف النظر عن معاملة الاجهاد المائى . كذلك إتضح أن الارتباط غير المعنوى للمحصول مع ASI فى الرى الكامل قد تحولت الى إرتباط معنوى مع معاملات التقسية المائية الأربع ولوحظت نفس الظاهرة مع صفة التفاف الاوراق فى كل معاملات التقسية ماعدا تحت ظروف التقسية الشديدة .

٢- أظهرت الدراســة أن معامـلات الأرتبـاط البسـيط بين المحصول وكل من عدد كيزان النبات ونسبة النبات الذكر وعدد حبوب الصف وعدد الايام حتى خروج ٥٠% من الحراير وال ASI وإرتفاع النبات(باعتبارها صفات فينولوجية) أهم مكونات المحصول (باعتبارها صفات فينولوجية) وصفة درجة حرارة الورقة (كصفة فسيولوجية) يمكن إستخدامها كدلائل إنتخابية لغربلة وتمييز العشائر طبقا لمقاومتها للجفاف .

٣- نقصت قيم التباين الوراثى ونسب التوريث بمعناها العام تحت ظروف الاجهاد المائى عنها تحت ظروف الرى الكامل بالنسبة لصفات محصول الحبوب وعدد حبوب الصف وحرارة الورقة والتفاف الاوراق ، بينما زادت

هذه القيم تحت ظروف الاجهاد المائى مقارنة بظروف الرى الكامل فى صفات ASI و عدد كيزان النبات والبقاء الاخضر .

٤- أثبتت الدراسة أنه بالنسبة لجميع الصفات المدروسة فأن التحسين المتوقع من الانتخاب المباشر قد تفوق على التحسين من الانتخاب غير المباشر تحت أى من ظروف الرى الكامل أو الاجهاد المائى . وأن أقصى تحسين وراثى لصفة مقاومة الجفاف معبرة فى صفة محصول الحبوب يمكن الحصول عليه لو أجرى الانتخاب المباشر فى البيئات المجهدة مائيا فى مرحلة التزهير .